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Preface

Application Developer's Guide - Fundamentals describes features of application development for the Oracle Server, Release 8.1.5. Information in this guide applies to versions of the Oracle Server that run on all platforms, and does not include system-specific information.

The Preface includes the following sections:

Information in This Guide

As an application developer, you should learn about the many Oracle Server features that can ease application development and improve performance. This Guide describes Oracle Server features that relate to application development. It does not cover the PL/SQL language, nor does it directly discuss application development on the client side. The table of contents and the "How This Book Is Organized" section has more information about the material covered. The "Other Guides" section points to other Oracle documentation that contains related information.

Audience

The *Application Developer's Guide - Fundamentals* is intended for programmers developing new applications or converting existing applications to run in the Oracle environment. This Guide will also be valuable to systems analysts, project managers, and others interested in the development of database applications.

This guide assumes that you have a working knowledge of application programming, and that you are familiar with the use of Structured Query Language (SQL) to access information in relational database systems.

Certain sections of this Guide also assume a knowledge of the basic concepts of object oriented programming.

Feature Coverage and Availability

The *Application Developer's Guide - Fundamentals* contains information that describes the features and functionality of the Oracle8*i* and the Oracle8*i* Enterprise Edition products. Oracle8*i* and Oracle8*i* Enterprise Edition have the same basic features. However, several advanced features are available only with the Enterprise Edition, and some of these are optional. For example, to use object functionality, you must have the Enterprise Edition and the Objects Option.

For information about the differences between Oracle8*i* and the Oracle8*i* Enterprise Edition and the features and options that are available to you, see *Getting to Know Oracle8i*.

Other Guides

Use the *PL/SQL User's Guide and Reference* to learn PL/SQL and to get a complete description of this high-level programming language, which is Oracle Corporation's procedural extension to SQL.

The Oracle Call Interface (OCI) is described in *Oracle Call Interface Programmer's Guide*

You can use the OCI to build third-generation language (3GL) applications that access the Oracle Server.

Oracle Corporation also provides the Pro* series of precompilers, which allow you to embed SQL and PL/SQL in your application programs. If you write 3GL application programs in Ada, C, C++, COBOL, or FORTRAN that incorporate embedded SQL, then refer to the corresponding precompiler manual. For example, if you program in C or C++, then refer to the *Pro*C/C++ Precompiler Programmer's Guide.*

Oracle Developer/2000 is a cooperative development environment that provides several tools including a form builder, reporting tools, and a debugging environment for PL/SQL. If you use Developer/2000, then refer to the appropriate Oracle Tools documentation.

For SQL information, see the *Oracle8i SQL Reference* and *Oracle8i Administrator's Guide*. For basic Oracle concepts, see *Oracle8i Concepts*.

How This Book Is Organized

The *Application Developer's Guide - Fundamentals* contains the following chapters. This section includes a brief summary of what you will find in each chapter.

Part I: Introduction

Chapter 1, "Programmatic Environments"

This chapter presents brief introductions to these application development systems.

Chapter 2, "Visual Modelling for Software Development"

This chapter provides an overview of the Oracle Server application development process.

Part II: Designing the Database

Chapter 3, "Managing Schema Objects"

This chapter explains the steps that the Oracle Server performs to process the various types of SQL commands and PL/SQL statements.

Chapter 4, "Selecting a Datatype"

This chapter describes how to manage the objects that can be created in the database domain of a specific user (schema), including tables, views, numeric sequences, and synonyms. It also discusses performance enhancements to data retrieval through the use of indexes and clusters.

Chapter 5, "Maintaining Data Integrity"

This chapter describes how to choose the correct Oracle datatype. The datatypes described include fixed- and variable-length character strings, numeric data, dates, raw binary data, and row identifiers (`ROWIDs`).

Chapter 6, "Selecting an Index Strategy"

This chapter describes the extended SQL commands and PL/SQL interface for the `LOB` datatypes, which include `BLOBs` for unstructured binary data, `CLOBs` and `NCLOBs` for character data, and `BFILEs` for data stored in an external file.

Chapter 7, "Managing Index-Organized Tables"

This chapter describes index-organized tables, including features of index-organized tables, and when to use them.

Chapter 8, "Processing SQL Statements"

This chapter describes how Oracle processes Structured Query Language (SQL) statements.

Chapter 9, "Dynamic SQL"

This chapter describes dynamic SQL, native dynamic SQL vs. the DBMS_SQL package, when to use dynamic SQL.

Chapter 10, "Using Procedures and Packages"

This chapter explains how to define and use object views.

Chapter 11, "External Routines"

This chapter describes how to use declarative integrity constraints to provide data integrity within an Oracle database.

Chapter 12, "Establishing Security Policies"

This chapter describes how to create procedures that can be stored in the database for continued use. Grouping these procedures into packages is also described in this chapter.

Part III: The Active Database

Chapter 13, "Using Triggers"

This chapter describes how to use public and private pipes to allow sessions in the same Oracle Server instance to communicate with one another or with a disk file.

Chapter 14, "Working With System Events"

This chapter describes how to use advanced queuing to defer or regulate the execution of work in a client/server environment.

Chapter 15, "Using Publish-Subscribe"

This chapter describes how to create and debug database triggers. Numerous examples are included.

Part IV: The Object-Relational Database Management System

Chapter 16, "User-Defined Datatypes"

This chapter describes how you can write stored procedures and anonymous PL/SQL blocks using dynamic SQL.

Chapter 17, "Objects in Views"

This chapter contains an extended example of how to use object views.

Chapter 18, "Design Considerations for Oracle Objects"

This chapter explains the implementation and performance characteristics of Oracle's object-relational model.

Chapter 19, "Programmatic Environments for Oracle Objects"

This chapter covers Oracle Call Interface (OCI); Pro*C / C++; Oracle Objects For OLE; and Java, JDBC, and Oracle SQLJ.

Part V: CUBE and ROLLUP Extensions to SQL

Chapter 20, "Analyzing Data with ROLLUP, CUBE, AND TOP-N QUERIES"

This chapter explains using CUBE, ROLLUP, and Top-N Queries.

Appendix

Appendix A, "Oracle XA"

The appendix describes how to use the Oracle XA library.

Conventions Used in This Guide

The following notational and text formatting conventions are used in this guide:

[ ]
Square brackets indicate that the enclosed item is optional. Do not type the brackets.

{ }
Braces enclose items of which only one is required.

|
A vertical bar separates items within braces, and may also be used to indicate that multiple values are passed to a function parameter.

...
In code fragments, an ellipsis means that code not relevant to the discussion has been omitted.

`font change`
SQL or C code examples are shown in monospaced font.

italics
Italics are used for OCI parameters, OCI routines names, file names, and data fields.

UPPERCASE
Uppercase is used for SQL keywords, like SELECT or UPDATE.

This guide uses special text formatting to draw the reader's attention to some information. A paragraph that is indented and begins with a bold text label may have special meaning. The following paragraphs describe the different types of information that are flagged this way.

> **Note:** The "Note" flag indicates that you should pay particular attention to the information to avoid a common problem or to increase understanding of a concept.
>
> **Warning:** An item marked as "Warning" indicates something that an OCI programmer must be careful to do, or not do, in order for an application to work correctly.
>
> **See Also:** Text marked "See Also" points you to another section of this guide, or to other documentation, for additional information about the topic being discussed.

Your Comments Are Welcome

We value and appreciate your comment as an Oracle user and reader of our manuals. As we write, revise, and evaluate our documentation, your opinions are the most important feedback we receive.

You can send comments and suggestions about this manual to the following e-mail address:

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If you prefer, then you can send letters or faxes containing your comments to the following address:

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Part I

Introduction To Working With The Server

Part I contains the following chapters:

1

Programmatic Environments

This chapter presents brief introductions to these application development systems:

- What Can PL/SQL Do?
- Overview of OCI
- Overview of Oracle Objects for OLE
- Pro*C/C++
- Pro*COBOL
- Oracle JDBC
- Oracle SQLJ

What Can PL/SQL Do?

PL/SQL is Oracle's procedural extension to SQL, the standard database access language. An advanced 4GL (fourth-generation programming language), PL/SQL offers seamless SQL access, tight integration with the Oracle server and tools, portability, security, and modern software engineering features such as data encapsulation, overloading, exception handling, and information hiding.

With PL/SQL, you can use SQL statements to manipulate Oracle data and flow-of-control statements to process the data. Moreover, you can declare constants and variables, define procedures and functions, use collections and object types, and trap run-time errors. Thus, PL/SQL combines the data manipulating power of SQL with the data processing power of procedural languages.

Applications written using any of the Oracle programmatic interfaces (Oracle Call Interface, Java, Pro*C/C++, or COBOL) can call PL/SQL stored procedures and send anonymous blocks of PL/SQL code to the server for execution. 3GL applications have full access to PL/SQL scalar and composite datatypes via host variables and implicit datatype conversion.

PL/SQL's tight integration with Oracle Developer lets you use one language to develop the client and server components of your application, which can be partitioned to achieve optimum performance and scalability. Also, Oracle's Web Forms allows you to deploy your applications in a multi-tier Internet or intranet environment without modifying a single line of code.

How Does PL/SQL Work?

A good way to get acquainted with PL/SQL is to look at a sample program. Consider the procedure below, which debits a bank account. When called, procedure `debit_account` accepts an account number and a debit amount. It uses the account number to select the account balance from the database table. Then, it uses the debit amount to compute a new balance. If the new balance is less than zero, an exception is raised; otherwise, the bank account is updated.

```
PROCEDURE debit_account (acct_id INTEGER, amount REAL) IS
   old_balance REAL;
   new_balance REAL;
   overdrawn   EXCEPTION;
BEGIN
   SELECT bal INTO old_balance FROM accts
      WHERE acct_no = acct_id;
   new_balance := old_balance - amount;
```

```
   IF new_balance < 0 THEN
      RAISE overdrawn;
   ELSE
      UPDATE accts SET bal = new_balance
         WHERE acct_no = acct_id;
   END IF;
   COMMIT;
EXCEPTION
   WHEN overdrawn THEN
      -- handle the error
END debit_account;
```

What Advantages Does PL/SQL Offer?

PL/SQL is a completely portable, high-performance transaction processing language that offers the following advantages:

Full Support for SQL

PL/SQL lets you use all the SQL data manipulation, cursor control, and transaction control commands, as well as all the SQL functions, operators, and pseudocolumns. So, you can manipulate Oracle data flexibly and safely. Moreover, PL/SQL fully supports SQL datatypes. That reduces the need to convert data passed between your applications and the database.

PL/SQL also supports dynamic SQL, an advanced programming technique that makes your applications more flexible and versatile. Your programs can build and process SQL data definition, data control, and session control statements "on the fly" at run time.

Tight Integration with Oracle

Both PL/SQL and Oracle are based on SQL. Moreover, PL/SQL supports all the SQL datatypes. Combined with the direct access that SQL provides, these shared datatypes integrate PL/SQL with the Oracle data dictionary.

The %TYPE and %ROWTYPE attributes further integrate PL/SQL with the data dictionary. For example, you can use the %TYPE attribute to declare variables, basing the declarations on the definitions of database columns. If a definition changes, the variable declaration changes accordingly at run time. This provides data independence, reduces maintenance costs, and allows programs to adapt as the database changes to meet new business needs.

Better Performance

Without PL/SQL, Oracle must process SQL statements one at a time. Each SQL statement results in another call to Oracle and higher performance overhead. In a networked environment, the overhead can become significant. Every time a SQL statement is issued, it must be sent over the network, creating more traffic.

However, with PL/SQL, an entire block of statements can be sent to Oracle at one time. This can drastically reduce communication between your application and Oracle. If your application is database intensive, you can use PL/SQL blocks to group SQL statements before sending them to Oracle for execution.

PL/SQL stored procedures are compiled once and stored in executable form, so procedure calls are quick and efficient. Also, stored procedures, which execute in the server, can be invoked over slow network connections with a single call. This reduces network traffic and improves round-trip response times. Executable code is automatically cached and shared among users. That lowers memory requirements and invocation overhead.

Higher Productivity

PL/SQL adds functionality to non-procedural tools such as Oracle Forms and Oracle Reports. With PL/SQL in these tools, you can use familiar procedural constructs to build applications. For example, you can use an entire PL/SQL block in an Oracle Forms trigger. You need not use multiple trigger steps, macros, or user exits. Thus, PL/SQL increases productivity by putting better tools in your hands.

Moreover, PL/SQL is the same in all environments. As soon as you master PL/SQL with one Oracle tool, you can transfer your knowledge to other tools, and so multiply the productivity gains. For example, scripts written with one tool can be used by other tools.

Scalability

PL/SQL stored procedures increase scalability by isolating application processing on the server. Also, automatic dependency tracking for stored procedures aids the development of scalable applications.

The shared memory facilities of the Multithreaded Server (MTS) enable Oracle to support 10,000+ concurrent users on a single node. For more scalability, you can use the Net8 Connection Manager to multiplex Net8 connections.

Maintainability

Once validated, a PL/SQL stored procedure can be used with confidence in any number of applications. If its definition changes, only the procedure is affected, not the applications that call it. This simplifies maintenance and enhancement. Also, maintaining a procedure on the server is easier than maintaining copies on various client machines.

Support for Object-Oriented Programming

Object Types An object type is a user-defined composite datatype that encapsulates a data structure along with the functions and procedures needed to manipulate the data. The variables that form the data structure are called attributes. The functions and procedures that characterize the behavior of the object type are called methods, which you can implement in PL/SQL.

Object types are an ideal object-oriented modeling tool, which you can use to reduce the cost and time required to build complex applications. Besides allowing you to create software components that are modular, maintainable, and reusable, object types allow different teams of programmers to develop software components concurrently.

Collections A collection is an ordered group of elements, all of the same type (for example, the grades for a class of students). Each element has a unique subscript that determines its position in the collection. PL/SQL offers two kinds of collections: nested tables and VARRAYs (short for variable-size arrays).

Collections, which work like the arrays found in most third-generation programming languages, can store instances of an object type and, conversely, can be attributes of an object type. Also, collections can be passed as parameters. So, you can use them to move columns of data into and out of database tables or between client-side applications and stored subprograms. Furthermore, you can define collection types in a PL/SQL package, then use them programmatically in your applications.

Portability

Applications written in PL/SQL are portable to any operating system and platform on which Oracle runs. In other words, PL/SQL programs can run anywhere Oracle can run. You need not tailor them to each new environment. That means you can write portable program libraries, which can be reused in different environments.

Security

PL/SQL stored procedures enable you to partition application logic between the client and server. That way, you can prevent client applications from manipulating sensitive Oracle data. Database triggers written in PL/SQL can disable application updates selectively and do content-based auditing of user queries.

Furthermore, you can restrict access to Oracle data by allowing users to manipulate it only through stored procedures that execute with their definer's privileges. For example, you can grant users access to a procedure that updates a table, but not grant them access to the table itself.

Overview of OCI

The Oracle Call Interface (OCI) is an application programming interface (API) that allows you to create applications that use a third-generation language's native procedures or function calls to access an Oracle database server and control all phases of SQL statement execution. OCI provides:

- Improved performance and scalability through the efficient use of system memory and network connectivity
- Consistent interfaces for dynamic session and transaction management in a two-tier client-server or multi-tier environment
- N-tiered authentication
- Comprehensive support for application development using Oracle objects
- Access to external databases
- Ability to develop applications that service an increasing number of users and requests without additional hardware investments

OCI allows you to manipulate data and schemas in an Oracle database using a host programming language, such as C. It provides a library of standard database access and retrieval functions in the form of a dynamic runtime library (OCILIB) that can be linked in an application at runtime. This eliminates the need to embed SQL or PL/SQL within 3GL programs.

OCI supports the datatypes, calling conventions, syntax, and semantics of a number of third-generation languages including C, C++, COBOL and FORTRAN. Oracle is also planning to provide support for Java.

Advantages of OCI

OCI provides significant advantages over other methods of accessing an Oracle database:

- More fine-grained control over all aspects of the application design
- High degree of control over program execution
- Use of familiar 3GL programming techniques and application development tools such as browsers and debuggers
- Support of dynamic SQL (method 4)
- Availability on the broadest range of platforms of all the Oracle Programmatic Interfaces
- Dynamic bind and define using callbacks
- Describe functionality to expose layers of server metadata
- Asynchronous event notification for registered client applications
- Enhanced array data manipulation language (DML) capability for array `INSERT`s, `UPDATE`s, and `DELETE`s
- Ability to associate a commit request with an execute to reduce roundtrips
- Optimization for queries using transparent prefetch buffers to reduce roundtrips
- Thread safety so you do not have to use mutual exclusive locks (mutex) on OCI handles

Parts of the OCI

The OCI encompasses four main sets of functionality:

- OCI *relational functions*, for managing database access and processing SQL statements
- OCI *navigational functions*, for manipulating objects retrieved from an Oracle database server
- OCI *datatype mapping and manipulation functions*, for manipulating data attributes of Oracle types
- OCI *external procedure functions*, for writing C callbacks from PL/SQL

Procedural and Non-Procedural Elements

The Oracle Call Interface (OCI) allows you to develop applications that combine the non-procedural data access power of Structured Query Language (SQL) with the procedural capabilities of most programming languages, such as C and C++.

- In a non-procedural language program, the set of data to be operated on is specified, but what operations will be performed, or how the operations are to be carried out is not specified. The non-procedural nature of SQL makes it an easy language to learn and to use to perform database transactions. It is also the standard language used to access and manipulate data in modern relational and object-relational database systems.
- In a procedural language program, the execution of most statements depends on previous or subsequent statements and on control structures, such as loops or conditional branches, which are not available in SQL. The procedural nature of these languages makes them more complex than SQL, but it also makes them very flexible and powerful.

The combination of both non-procedural and procedural language elements in an OCI program provides easy access to an Oracle database in a structured programming environment.

The OCI supports all SQL data definition, data manipulation, query, and transaction control facilities that are available through an Oracle database server. For example, an OCI program can run a query against an Oracle database. The queries can require the program to supply data to the database using input (bind) variables, as follows:

```
SELECT name FROM employees WHERE empno = :empnumber
```

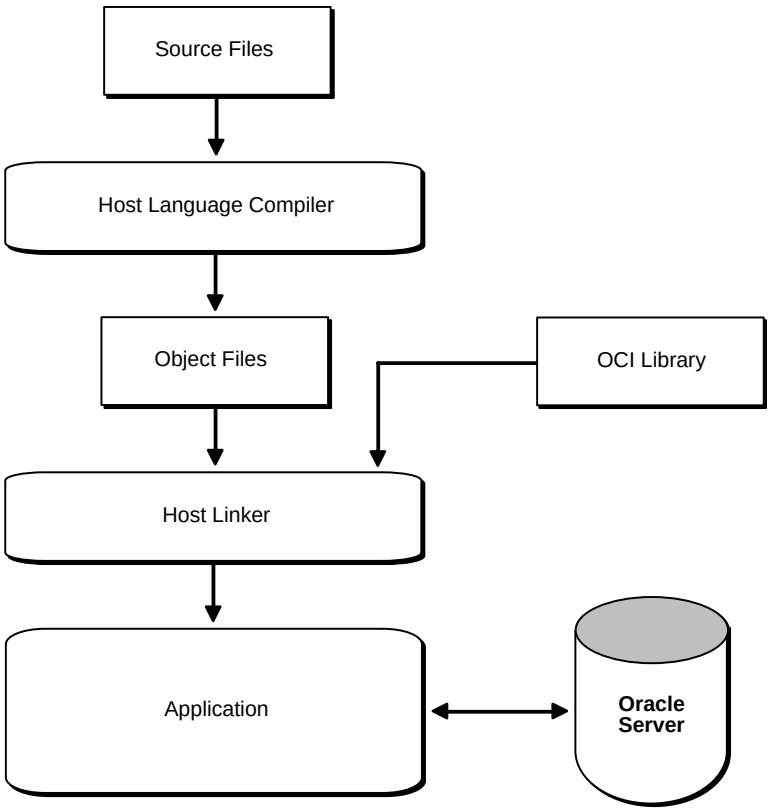
In the above SQL statement, `:empnumber` is a placeholder for a value that will be supplied by the application.

You can also use PL/SQL, Oracle's procedural extension to SQL. The applications you develop can be more powerful and flexible than applications written in SQL alone. The OCI also provides facilities for accessing and manipulating objects in an Oracle database server.

Building an OCI Application

As Figure 1–1 shows, you compile and link an OCI program in the same way that you compile and link a non-database application. There is no need for a separate preprocessing or precompilation step.

Figure 1–1 The OCI Development Process



Note: On some platforms, it may be necessary to include other libraries, in addition to the OCI library, to properly link your OCI programs. Check your Oracle system-specific documentation for further information about extra libraries that may be required.

Overview of Oracle Objects for OLE

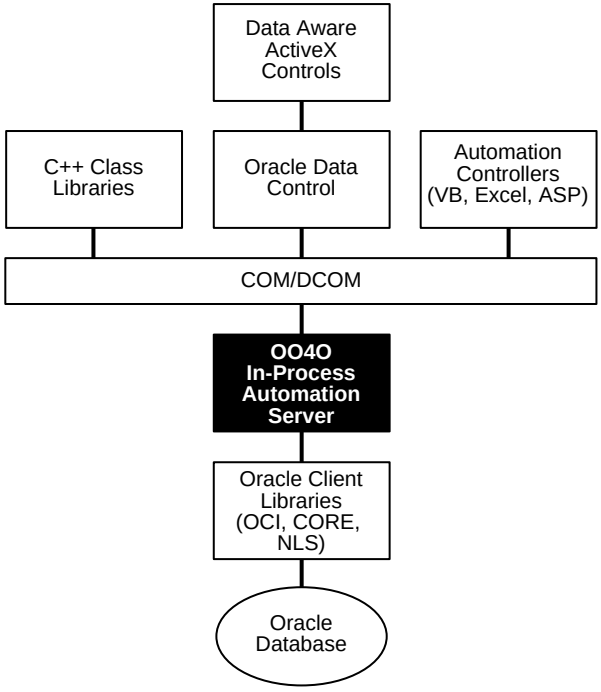
Oracle Objects for OLE (OO4O) is a product designed to allow easy access to data stored in Oracle databases with any programming or scripting language that supports the Microsoft COM Automation and ActiveX technology. This includes Visual Basic, Visual C++, Visual Basic For Applications (VBA), IIS Active Server Pages (VBScript and JavaScript), and others.

OO4O consists of the following software layers:

- OO4O "In-Process" Automation Server
- Oracle Data Control
- Oracle Objects for OLE C++ Class Library

Figure 1–2, "Software Layers" illustrates the OO4O software components.

Figure 1–2 Software Layers



Note: See the OO4O online help for detailed information about using OO4O.

The OO4O Automation Server

The OO4O Automation Server is a set of COM Automation objects for connecting to Oracle database servers, executing SQL statements and PL/SQL blocks, and accessing the results.

Unlike other COM-based database connectivity APIs, such as Microsoft ADO, the OO4O Automation Server has been developed and evolved specifically for use with Oracle database servers.

It provides an optimized API for accessing features that are unique to Oracle and are otherwise cumbersome or inefficient to use from ODBC or OLE database-specific components.

OO4O provides key features for accessing Oracle databases efficiently and easily in environments ranging from the typical two-tier client/server applications, such as those developed in Visual Basic or Excel, to application servers deployed in multi-tiered application server environments such as web server applications in Microsoft Internet Information Server (IIS) or Microsoft Transaction Server (MTS).

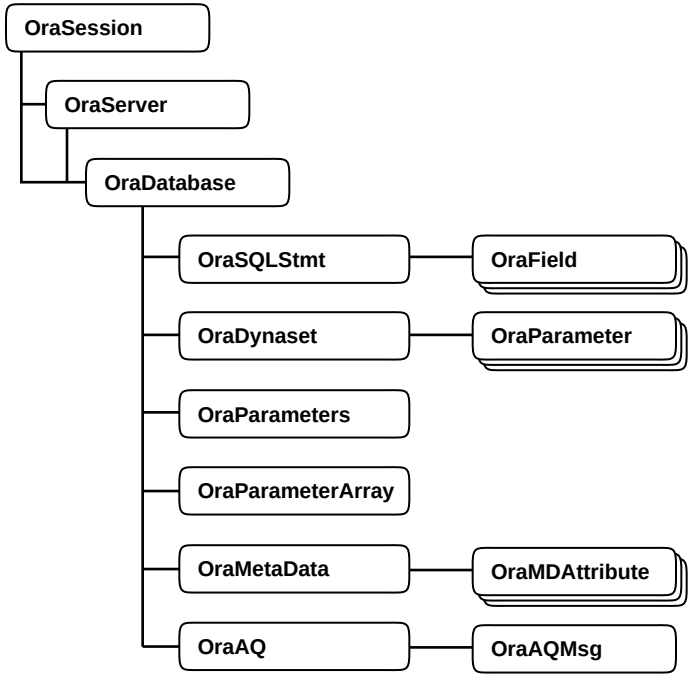
Features include:

- Support for execution of PL/SQL anonymous blocks and stored procedures. This includes support for Oracle datatypes allowed for input/output parameters of PL/SQL stored procedures including PL/SQL cursors. See "Support for Oracle LOB and Object Datatypes" on page 1-17.
- Support for scrollable and updateable cursors for easy and efficient access to result sets of queries.
- Thread-safe objects and Connection Pool Management Facility for developing efficient web server applications.
- Full support for Oracle8*i* Object-Relational and LOB datatypes.
- Full support for Advanced Queuing in Oracle8*i*
- Support for array inserts and updates.
- Support for Microsoft Transaction Server (MTS).

OO4O Object Model

The Oracle Objects for OLE object model is illustrated in Figure 1–3, "Objects and Their Relation".

Figure 1–3 Objects and Their Relation



OraSession

An OraSession object manages collections of OraDatabase, OraConnection, and OraDynaset objects used within an application.

Typically, a single OraSession object is created for each application, but you can create named OraSession objects for shared use within and between applications.

The OraSession object is the top-most level object for an application. It is the only object created by the CreateObject VB/VBA API and not by an Oracle Objects for OLE method. The following code fragment shows how to create an OraSession object:

```
Dim OraSession as Object
```

```
Set OraSession = CreateObject("OracleInProcServer.XOraSession")
```

OraServer

OraServer represents a physical network connection to an Oracle database server.

The OraServer interface is introduced to expose the connection multiplexing feature provided in the Oracle Call Interface. After an OraServer object is created, multiple user sessions (OraDatabase) can be attached to it by invoking the OpenDatabase method. This feature is particularly useful for application components, such as Internet Information Server (IIS), that use Oracle Objects for OLE in an n-tier distributed environments.

The use of connection multiplexing when accessing Oracle severs with a large number of user sessions active can help reduce server processing and resource requirements while improving the server scalability.

OraDatabase

An OraDatabase interface in the Oracle8i release adds additional methods for controlling transactions and creating interfaces representing of Oracle object types. Attributes of schema objects can be retrieved using the Describe method of the OraDatabase interface.

In previous releases, an OraDatabase object is created by invoking the OpenDatabase method of an OraSession interface. The Net8 alias, user name, and password are passed as arguments to this method. In the Oracle8i release, invocation of this method results in implicit creation of an OraServer object.

As described in the OraServer interface description, an OraDatabase object can also be created using the OpenDatabase method of the OraServer interface.

Transaction control methods are available at the OraDatabase (user session) level. Transactions may be started as Read-Write (default), Serializable, or Read-only. These include:

- BeginTrans
- CommitTrans
- RollbackTrans

For example:

```
UserSession.BeginTrans(OO4O_TXN_READ_WRITE)
UserSession.ExecuteSQL("delete emp where empno = 1234")
UserSession.CommitTrans
```

OraDynaset

An OraDynaset object permits browsing and updating of data created from a SQL SELECT statement.

The OraDynaset object can be thought of as a cursor, although in actuality several real cursors may be used to implement the OraDynaset's semantics. An OraDynaset automatically maintains a local cache of data fetched from the server and transparently implements scrollable cursors within the browse data. Large queries may require significant local disk space; application implementers are encouraged to refine queries to limit disk usage.

OraField

An OraField object represents a single column or data item within a row of a dynaset.

If the current row is being updated, then the OraField object represents the currently updated value, although the value may not yet have been committed to the database.

Assignment to the Value property of a field is permitted only if a record is being edited (using Edit) or a new record is being added (using AddNew). Other attempts to assign data to a field's Value property results in an error.

OraMetaData

An OraMetaData object is a collection of OraMDAttribute objects that represent the description information about a particular schema object in the database.

The OraMetaData object can be visualized as a table with three columns:

- Metadata Attribute Name
- Metadata Attribute Value
- Flag specifying whether the Value is another OraMetaData Object

The OraMDAttribute objects contained in the OraMetaData object can be accessed by subscripting using ordinal integers or by using the name of the property. Referencing a subscript that is not in the collection (0 to Count-1) results in the return of a NULL OraMDAttribute object.

OraParameter

An OraParameter object represents a bind variable in a SQL statement or PL/SQL block.

OraParameter objects are created, accessed, and removed indirectly through the OraParameters collection of an OraDatabase object. Each parameter has an identifying name and an associated value. You can automatically bind a parameter to SQL and PL/SQL statements of other objects (as noted in the objects' descriptions), by using the parameter's name as a placeholder in the SQL or PL/SQL statement. Such use of parameters can simplify dynamic queries and increase program performance.

OraParamArray

An OraParamArray object represents an "array" type bind variable in a SQL statement or PL/SQL block as opposed to a "scalar" type bind variable represented by the OraParameter object.

OraParamArray objects are created, accessed, and removed indirectly through the OraParameters collection of an OraDatabase object. Each parameter has an identifying name and an associated value.

OraSQLStmt

An OraSQLStmt Object represents a single SQL statement. Use the CreateSQL method to create the OraSQLStmt object from an OraDatabase.

During create and refresh, OraSQLStmt objects automatically bind all relevant, enabled input parameters to the specified SQL statement, using the parameter names as placeholders in the SQL statement. This can improve the performance of SQL statement execution without re-parsing the SQL statement.

SQLStmt

The SQLStmt object (updateStmt) can be later used to execute the same query using a different value for the :SALARY placeholder. This is done as follows:

```
OraDatabase.Parameters("SALARY").value = 200000
updateStmt.Parameters("ENAME").value = "KING"
updateStmt.Refresh
```

OraAQ

An OraAQ object is instantiated by invoking the CreateAQ method of the OraDatabase interface. It represents a queue that is present in the database.

Oracle Objects for OLE provides interfaces for accessing Oracle's Advanced Queuing (AQ) Feature. It makes AQ accessible from popular COM-based

development environments such as Visual Basic. For a detailed description of Oracle AQ, please refer to *Oracle8i Application Developer's Guide - Advanced Queuing*.

OraAQMsg

The OraAQMsg object encapsulates the message to be enqueued or dequeued. The message can be of any user-defined or raw type.

For a detailed description of Oracle AQ, please refer to *Oracle8i Application Developer's Guide - Advanced Queuing*.

OraAQAgent

The OraAQAgent object represents a message recipient and is only valid for queues which allow multiple consumers.

The OraAQAgent object represents a message recipient and is only valid for queues which allow multiple consumers.

An OraAQAgent object can be instantiated by invoking the AQAgent method. For example:

```
Set agent = qMsg.AQAgent(name)
```

An OraAQAgent object can also be instantiated by invoking the AddRecipient method. For example:

```
Set agent = qMsg.AddRecipient(name, address, protocol).
```

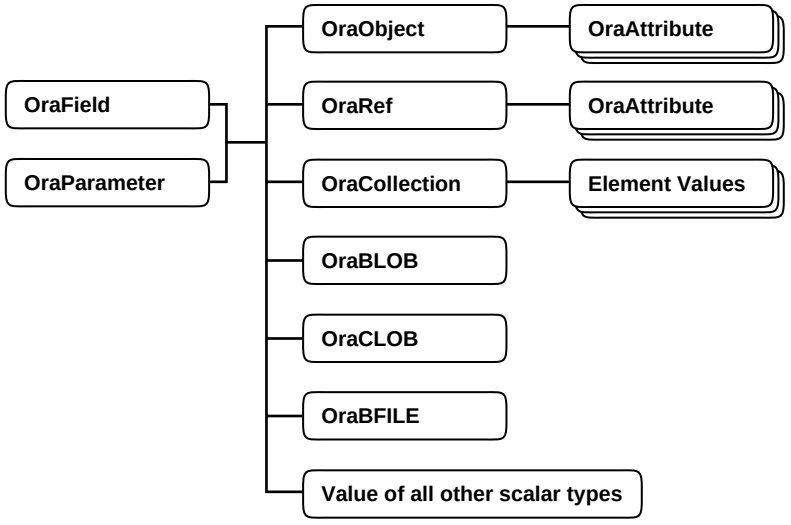
Support for Oracle LOB and Object Datatypes

Oracle Objects for OLE provides full support for accessing and manipulating instances of object datatypes and LOBs in an Oracle database server. Figure 1–4, "Supported Oracle Datatypes" illustrates the datatypes supported by OO4O.

For a discussion of support for object datatypes, see "Oracle Objects For OLE" on page 19-16.

Instances of these types can be fetched from the database or passed as input or output variables to SQL statements and PL/SQL blocks, including stored procedures and functions. All instances are mapped to COM Automation Interfaces that provide methods for dynamic attribute access and manipulation. These interfaces may be obtained from:

Figure 1–4 Supported Oracle Datatypes



OraBLOB and OraCLOB

The OraBlob and OraClob interfaces in OO4O provide methods for performing operations on large objects in the database of data types BLOB, CLOB, and NCLOB. In this help file BLOB, CLOB, and NCLOB datatypes are also referred to as LOB datatypes.

LOB data is accessed using Read and the CopyToFile methods.

LOB data is modified using Write, Append, Erase, Trim, Copy, CopyFromFile, and CopyFromBFile methods. Before modifying the content of a LOB column in a row, a row lock must be obtained. If the LOB column is a field of an OraDynaset, then the lock is obtained by invoking the Edit method.

OraBFILE

The OraBFile interface in OO4O provides methods for performing operations on large objects BFILE data type in the database.

The BFILEs are large binary data objects stored in operating system files (external) outside of the database tablespaces.

The Oracle Data Control

The Oracle Data Control (ODC) is an ActiveX Control that is designed to simplify the exchange of data between an Oracle database and visual controls such edit, text, list, and grid controls in Visual Basic and other development tools that support custom controls.

ODC acts an agent to handle the flow of information from an Oracle database and a visual data-aware control, such as a grid control, that is bound to it. The data control manages various user interface (UI) tasks such as displaying and editing data. It also executes and manages the results of database queries.

The Oracle Data Control is compatible with the Microsoft data control included with Visual Basic. If you are familiar with the Visual Basic data control, learning to use the Oracle Data Control is quick and easy. Communication between data-aware controls and a Data Control is governed by a protocol that has been specified by Microsoft.

The Oracle Objects for OLE C++ Class Library

The Oracle Objects for OLE C++ Class Library is a collection of C++ classes that provide programmatic access to the Oracle Object Server. Although the class library is implemented using OLE Automation, neither the OLE development kit nor any OLE development knowledge is necessary to use it. This library helps C++ developers avoid the chore of writing COM client code for accessing the OO4O interfaces.

Additional Sources of Information

For detailed information about Oracle Objects for OLE refer to the online help that is provided with the OO4O product:

- Oracle Objects for OLE Help
- Oracle Objects for OLE C++ Class Library Help

To view examples of the use of Oracle Object for OLE, see the samples located in the ORACLE_HOME\OO4O directory of the Oracle installation. Additional OO4O examples can be found in the following Oracle publications, including:

- *Oracle8i Application Developer's Guide - Large Objects (LOBs)*
- *Oracle8i Application Developer's Guide - Advanced Queuing*
- *Oracle8i Supplied Packages Reference*

Pro*C/C++

The Pro*C / C++ precompiler is a software tool that allows the programmer to embed SQL statements in a C or C++ source file. Pro*C / C++ reads the source file as input and outputs a C or C++ source file that replaces the embedded SQL statements with Oracle runtime library calls, and is then compiled by the C or C++ compiler.

When there are errors found during the precompilation or the subsequent compilation, modify your precompiler input file and re-run the two steps.

How You Implement a Pro*C/C++ Application

Here is a simple code fragment from a C source file that queries the table EMP which is in the schema SCOTT:

```
...
#define  UNAME_LEN   10
...
int   emp_number;
/* Define a host structure for the output values of a SELECT statement. */
/* No declare section needed if precompiler option MODE=ORACLE          */
struct {
    VARCHAR  emp_name[UNAME_LEN];
    float    salary;
    float    commission;
} emprec;
/* Define an indicator structure to correspond to the host output structure. */
struct {
    short emp_name_ind;
    short sal_ind;
    short comm_ind;
} emprec_ind;
...
/* Select columns ename, sal, and comm given the user's input for empno. */
    EXEC SQL SELECT ename, sal, comm
        INTO :emprec INDICATOR :emprec_ind
        FROM emp
        WHERE empno = :emp_number;
...
```

The embedded SELECT statement is only slightly different from an interactive (SQL*Plus) version. Every embedded SQL statement begins with EXEC SQL. The colon, ":", precedes every host (C) variable. The returned values of data and indicators (set when the data value is NULL or character columns have been

truncated) can be stored in structs (such as in the above code fragment), in arrays, or in arrays of structs. Multiple result set values are handled very simply in a manner that resembles the case shown, where there is only one result, because of the unique employee number. You use the actual names of columns and tables in embedded SQL.

Use the default precompiler option values, or you can enter values which give you control over the use of resources, how errors are reported, the formatting of output, and how cursors (which correspond to a particular connection, a SQL statement, etc.) are managed. Cursors are used when there are multiple result set values.

Enter the options either in a configuration file, on the command line, or inline inside your source code with a special statement that begins with EXEC ORACLE. If there are no errors found, you can then compile, link, and execute the output source file, like any other C program that you write.

Use the precompiler to create server database access from clients that can be on many different platforms. Pro*C/C++ allows you the freedom to design your own user interfaces and to add database access to existing applications.

Before writing your embedded SQL statements, you may want to test interactive versions of the SQL in SQL*Plus. You then make only minor changes to start testing your embedded SQL application.

Highlights of Pro*C/C++ Features

The following is a short subset of the capabilities of Pro*C/C++. For complete details, see the *Pro*C/C++ Precompiler Programmer's Guide*.

You can write your application in either C or C++.

You can write multi-threaded programs if your platform supports a threads package. Concurrent connections are supported in either single-threaded or multi-threaded applications.

You can improve performance by embedding PL/SQL blocks. These blocks can call functions or procedures written by you or provided in Oracle packages, in either Java or PL/SQL.

Using precompiler options, you can check the syntax and semantics of your SQL or PL/SQL statements during precompilation, as well as at runtime.

You can call stored PL/SQL and Java subprograms. Modules written in COBOL or in C can be called from Pro*C/C++. External C procedures in shared libraries are callable by your program.

You can conditionally precompile sections of your code so that they can execute in different environments.

Use arrays, or structures, or arrays of structures as host and indicator variables in your code to improve performance.

You can deal with errors and warnings so that data integrity is guaranteed. As a programmer, you control how errors are handled.

Your program can convert between internal datatypes and C language datatypes.

The Oracle Call Interface (OCI), a lower-level C interface, is available for use in your precompiler source.

Pro*C/C++ supports dynamic SQL, a technique that allows users to input variable values and statement syntax.

New Oracle8*i* Features Supported

Pro*C/C++ can use special SQL statements to manipulate tables containing user-defined object types. An Object Type Translator (OTT) will map the object types and named collection types in your database to structures and headers that you will then include in your source.

Two kinds of collection types, nested tables and VARRAYs, are supported with a set of SQL statements that allow a high degree of control over data.

Large Objects (LOBs, CLOBs, NCLOBs, and external files known as BFILEs) are accessed by another set of SQL statements.

A new ANSI SQL standard for dynamic SQL is supported for new applications, so that you can execute SQL statements with a varying number of host variables. An older technique for dynamic SQL is still usable by pre-existing applications.

National Language Support for multi-byte characters and UCS2 Unicode support are provided.

Pro*COBOL

The Pro*COBOL precompiler is a software tool that allows the programmer to embed SQL statements in a COBOL source code file. Pro*COBOL reads the source file as input and outputs a COBOL source file that replaces the embedded SQL statements with Oracle runtime library calls, and is then compiled by the COBOL compiler.

When there are errors found during the precompilation or the subsequent compilation, modify your precompiler input file and re-run the two steps.

How You Implement a Pro*COBOL Application

Here is a simple code fragment from a source file that queries the table EMP which is in the schema SCOTT:

```
...
 WORKING-STORAGE SECTION.
*
* DEFINE HOST INPUT AND OUTPUT HOST AND INDICATOR VARIABLES.
* NO DECLARE SECTION NEEDED IF MODE=ORACLE.
*
 01  EMP-REC-VARS.
     05  EMP-NAME    PIC X(10) VARYING.
     05  EMP-NUMBER  PIC S9(4) COMP VALUE ZERO.
     05  SALARY      PIC S9(5)V99 COMP-3 VALUE ZERO.
     05  COMMISSION  PIC S9(5)V99 COMP-3 VALUE ZERO.
     05  COMM-IND    PIC S9(4) COMP VALUE ZERO.
...
 PROCEDURE DIVISION.
...
     EXEC SQL
         SELECT ENAME, SAL, COMM
         INTO :EMP-NAME, :SALARY, :COMMISSION:COMM-IND
         FROM EMP
         WHERE EMPNO = :EMP_NUMBE
     END-EXEC.
...
```

The embedded SELECT statement is only slightly different from an interactive (SQL*Plus) version. Every embedded SQL statement begins with EXEC SQL. The colon, ":", precedes every host (COBOL) variable. The SQL statement is terminated by END-EXEC. The returned values of data and indicators (set when the data value is NULL or character columns have been truncated) can be stored in group items

(such as in the above code fragment), in tables, or in tables of group items. Multiple result set values are handled very simply in a manner that resembles the case shown, where there is only one result, given the unique employee number. You use the actual names of columns and tables in embedded SQL.

Use the default precompiler option values, or you can enter values which give you control over the use of resources, how errors are reported, the formatting of output, and how cursors (which correspond to a particular connection, a SQL statement, etc.) are managed.

Enter the options either in a configuration file, on the command line, or inline inside your source code with a special statement that begins with EXEC ORACLE. If there are no errors found, you can then compile, link, and execute the output source file, like any other COBOL program that you write.

Use the precompiler to create server database access from clients that can be on many different platforms. Pro*COBOL allows you the freedom to design your own user interfaces and to add database access to existing COBOL applications.

The embedded SQL statements available conform to an ANSI standard, so that you can access data from many databases in a program, including remote servers, networked through Net8.

Before writing your embedded SQL statements, you may want to test interactive versions of the SQL in SQL*Plus. You then make only minor changes to start testing your embedded SQL application.

Highlights of Pro*COBOL Features

The following is a short subset of the capabilities of Pro*COBOL. For complete details, see the *Pro*COBOL Precompiler Programmer's Guide.*

You can call stored PL/SQL or Java subprograms. You can improve performance by embedding PL/SQL blocks. These blocks can call PL/SQL functions or procedures written by you or provided in Oracle packages.

Precompiler options allow you to define how cursors, errors, syntax-checking, file formats, etc., are handled.

Using precompiler options, you can check the syntax and semantics of your SQL or PL/SQL statements during precompilation, as well as at runtime.

You can conditionally precompile sections of your code so that they can execute in different environments.

Use tables, or group items, or tables of group items as host and indicator variables in your code to improve performance.

You can program how errors and warnings are handled, so that data integrity is guaranteed.

Pro*COBOL supports dynamic SQL, a technique that allows users to input variable values and statement syntax.

New Oracle8*i* Features Supported

Large Objects (LOBs, CLOBs, NCLOBs, and external files known as BFILEs) are accessed by another set of SQL statements.

A new ANSI SQL standard for dynamic SQL is supported for new applications, so that you can execute SQL statements with a varying number of host variables. An older technique for dynamic SQL is still usable by pre-existing applications.

Pro*COBOL has many features that are compatible with DB2, for easier migration.

Oracle JDBC

JDBC (Java Database Connectivity) is an API (Applications Programming Interface) which allows Java to send SQL statements to an object-relational database such as Oracle8*i*.

The JDBC standard defines four types of JDBC drivers:

- Type 1. A JDBC-ODBC bridge. Software must be installed on client systems.
- Type 2. Has Native methods (calls C or C++) and Java methods. Software must be installed on the client.
- Type 3. Pure Java. The client uses sockets to call middleware on the server.
- Type 4. The most pure Java solution. Talks directly to the database using Java sockets.

JDBC is based on the X/Open SQL Call Level Interface, and complies with the SQL92 Entry Level standard.

Use JDBC to do dynamic SQL. Dynamic SQL means that the embedded SQL statement to be executed is not known before the application is run, and requires input to build the statement.

The drivers that are implemented by Oracle have extensions to the capabilities in the JDBC standard that was defined by Sun Microsystems. Oracle's implementations of JDBC drivers are described next:

JDBC Thin Driver

The JDBC Thin driver is a Type 4 (100% pure Java) driver that uses Java sockets to connect directly to a database server. It has its own implementation of a TTC, a lightweight implementation of a TCP/IP version of Oracle's Net8. It is written entirely in Java and is therefore platform-independent.

The Thin driver does not require Oracle software on the client side. It does need a TCP/IP listener on the server side. Use this driver in Java applets that are downloaded into a Web browser. The Thin driver is self-contained, but it opens a Java socket, and thus can only run in a browser that supports sockets.

JDBC OCI Driver

The OCI driver is a Type 2 JDBC driver. It makes calls to the OCI (Oracle Call Interface) which is written in C, to interact with an Oracle database server, thus using native and Java methods.

Because it uses native methods (a combination of Java and C) the OCI driver is platform-specific. It requires a client Oracle8*i* installation including Net8, OCI libraries, CORE libraries, and all other dependent files. The OCI driver usually executes faster than the thin driver.

The OCI driver is not appropriate for Java applets, because it uses a C library that is platform-specific and cannot be downloaded into a Web browser. It is usable in the Oracle Web Application Server which is a collection of middleware services and tools that supports access from and to applications from browsers and CORBA (Common Object Request Broker Architecture) clients.

The JDBC Server Driver

The JDBC server driver is a Type 2 driver that runs inside the database server and therefore reduces the number of round-trips needed to access large amounts of data. The driver, the Java server VM, the database, the NCOMP native compiler which speeds execution by as much as 10 times, and the SQL engine all run within the same address space.

This driver provides server-side support for any Java program used in the database: SQLJ stored procedures, functions, and triggers, Java stored procedures, CORBA objects, and EJB (Enterprise Java Beans). You can also call PL/SQL stored procedures, functions, and triggers.

The server driver fully supports the same features and extensions as the client-side drivers.

Extensions of JDBC

Among the Oracle extensions to the JDBC 1.22 standard are:

- Support for Oracle datatypes
- Performance enhancement by row prefetching
- Performance enhancement by execution batching
- Specification of query column types to save round-trips
- Control of DatabaseMetaData calls

Sample Program for the JDBC Thin Driver

The following source code registers an Oracle JDBC Thin driver, connects to the database, creates a `Statement` object, executes a query, and processes the result set.

The SELECT statement retrieves and lists the contents of the ENAME column of the EMP table.

```
import java.sql.*
import java.math.*
import java.io.*
import java.awt.*

class JdbcTest {
  public static void main (String args []) throws SQLException {
    // Load Oracle driver
    DriverManager.registerDriver (new oracle.jdbc.dnlddriver.OracleDriver());

    // Connect to the local database
    Connection conn =
      DriverManager.getConnection ("jdbc:oracle:dnldthin:@myhost:1521:orcl",
                                   "scott", "tiger");

    // Query the employee names
    Statement stmt = conn.createStatement ();
    ResultSet rset = stmt.executeQuery ("SELECT ENAME FROM EMP");

    // Print the name out
    while (rset.next ())
      System.out.println (rset.getString (1));
    // Close the result set, statement, and the connection
    rset.close();
    stmt.close();
    conn.close();
  }
}
```

An Oracle extension to the JDBC drivers is a form of the `getConnection()` method that uses a `Properties` object. The `Properties` object lets you specify user, password, and database information as well as row prefetching and execution batching.

To use the OCI driver in this code, replace the `Connection` statement with:

```
Connection conn = DriverManager.getConnection ("jdbc:oracle:oci8:@MyHostString",
    "scott", "tiger");
```

where `MyHostString` is an entry in the TNSNAMES.ORA file.

If you are creating an applet, the `getConnection()` and `registerDriver()` strings will be different.

Java in the RDBMS

The Oracle Database Server stores Java classes as well as PL/SQL subprograms. Except for GUI methods, any Java method can run in the RDBMS as a stored procedure. The following database constructs are supported:

Functions and Procedures

You write these named blocks and then define them using the loadjava, SQL CREATE FUNCTION, CREATE PROCEDURE, and/or CREATE PACKAGE statements. These Java methods can accept arguments and are callable from:

- SQL CALL statements.
- Embedded SQL CALL statements.
- PL/SQL blocks, subprograms and packages.
- DML statements (INSERT, UPDATE, DELETE, and SELECT).
- Oracle development tools such as OCI, Pro*C/C++ and Oracle Developer.
- Oracle Java interfaces such as JDBC, SQLJ statements, CORBA, and Enterprise Java Beans.

Database Triggers

A database trigger is a stored procedure that Oracle invokes ("fires") automatically whenever a given DML operation modifies the trigger's table or schema. Triggers allow you to enforce business rules, prevent invalid values from being stored, and take many other actions without the need for you to explicitly call them.

Why Use Stored Procedures?

- Stored procedures are compiled once, are easy to use and maintain, and require less memory and computing overhead.
- Network bottlenecks are avoided, and response time is improved. Distributed applications are easier to build and use.
- Computation-bound procedures run faster in the server.
- Data access can be controlled by letting users only have stored procedures that execute with their definer's privileges instead of invoker's rights.
- PL/SQL and Java stored procedures can call each other.

- Java in the server follows the Java language specification and can use the SQLJ standard, so that non-Oracle databases are also supported.
- Stored procedures can be reused in different applications as well as different geographic sites.

JDBC in SQLJ Applications

JDBC code and SQLJ code (see "Oracle SQLJ" on page 1-31) interoperates, allowing dynamic SQL statements in JDBC to be used with static SQL statements in SQLJ. A SQLJ iterator class corresponds to the JDBC result set. For more information on JDBC, see *Oracle8i JDBC Developer's Guide and Reference.*

Oracle SQLJ

SQLJ is:

- A language specification for embedding static SQL statements in Java source code which has been agreed to by a consortium of database companies, including Oracle, and by Sun, author of Java. The specification has been accepted by ANSI as a software standard.
- A software tool developed by Oracle to the standard, with extensions to the standard to support Oracle8*i* features. That tool is the subject of this brief overview.

SQLJ Tool

The Oracle software tool SQLJ has two parts: a translator and a runtime. You execute on any Java VM with a JDBC driver and a SQLJ runtime library.

A SQLJ source file is a Java source file containing embedded static SQL statements. The SQLJ translator is 100% Pure Java and is portable to any standard JDK 1.1 or higher VM.

The Oracle8*i* SQLJ implementation runs in three steps:

- Translates SQLJ source to Java code with calls to the SQLJ runtime. The SQLJ translator converts the source code to pure Java source code, and can check the syntax and semantics of static SQL statements against a database schema and verify the type compatibility of host variables with SQL types.
- Compiles using the Java compiler.
- Customizes for the target database. SQLJ generates "profile" files with Oracle-specific customizing.

Oracle8*i* supports SQLJ stored procedures, functions, and triggers which execute in a Java VM integrated with the data server. SQLJ is integrated with Oracle's JDeveloper. Source-level debugging support is available in JDeveloper.

Here is an example of the simplest SQLJ executable statement, which returns one value because `empno` is unique in the `emp` table:

```
String name;
#sql  { SELECT ename INTO :name FROM emp WHERE empno=67890 };
System.out.println("Name is " + name + ", employee number = " + empno);
```

Each host variable (or qualified name or complex Java host expression) is preceded by a colon (:). Other SQLJ statements are declarative (declares Java types) and allow

you to declare an iterator (a construct related to a database cursor) for queries that retrieve many values:

```
#sql iterator EmpIter (String EmpNam, int EmpNumb);
```

SQLJ Design Goals

The primary goal is to provide simple extensions to Java to allow rapid development and easy maintenance of Java applications that use embedded SQL to interact with databases.

Specific goals in support of the primary goal are:

- Provide a concise, legible mechanism for database access via static SQL. Most SQL in applications is static. SQLJ provides more concise and less error-prone static SQL constructs than JDBC does.
- Check static SQL at translate time.
- Provide flexible deployment configurations. This makes it possible to implement SQLJ on the client or database side or in the middle tier.
- Support a software standard. SQLJ is an effort of a group of vendors and will be supported by all of them. Applications can access multiple database vendors.
- Provide source code portability. Executables can be used with all of the vendors' DBMSs presuming the code does not rely on any vendor-specific features.

Strengths of Oracle's SQLJ Implementation

- Uniform programming style for the clients and the servers.
- Integration of the SQLJ translator with JDeveloper, a graphical IDE that provides SQLJ translation, Java compilation, profile customizing, and debugging at the source code level, all in one step.
- SQL Checker module for verification of syntax and semantics at translate-time.
- Oracle type extensions. Datatypes supported are LOBs, ROWIDs, REF CURSORs, VARRAYs, nested tables, user-defined object types, as well as other datatypes such as RAW and NUMBER.

Comparison of SQLJ with JDBC

JDBC provides a complete dynamic SQL interface from Java to databases. SQLJ fills a complementary role.

JDBC provides fine-grained control of the execution of dynamic SQL from Java, while SQLJ provides a higher level static binding to SQL operations in a specific database schema. Here are some differences:

- SQLJ source code is more concise than equivalent JDBC source code.
- SQLJ uses database connections to type-check static SQL code. JDBC, being a completely dynamic API, does not.
- SQLJ programs allow direct embedding of Java bind expressions within SQL statements. JDBC requires a separate get and/or set call statement for each bind variable and specifies the binding by position number.
- SQLJ provides strong typing of query outputs and return parameters and allows type-checking on calls. JDBC passes values to and from SQL without compile-time type checking.
- SQLJ provides simplified rules for calling SQL stored procedures and functions. The JDBC specification requires a generic call to a stored procedure (or function), *fun*, to have the following syntax (we show SQL92 and Oracle escape syntaxes, which are both allowed):

```
prepStmt.prepareCall("{call fun(?,?)}"); //stored procedure SQL92

prepStmt.prepareCall("{? = call fun(?,?)}"); //stored function SQL92

prepStmt.prepareCall("begin fun(:1,:2);end;"); //stored procedure Oracle

prepStmt.prepareCall("begin :1 := fun(:2,:3);end;");//stored func Oracle
```

SQLJ provides simplified notations:

```
#sql {call fun(param_list) };  //Stored procedure

// Declare x
...
#sql x = {VALUES(fun(param_list)) };  // Stored function
// where VALUES is the SQL construct
```

Here are similarities:

- SQLJ source files can contain JDBC calls. SQLJ and JDBC are interoperable.
- Oracle's JPublisher tool generates custom Java classes to be used in your SQLJ or JDBC application for mappings to Oracle object types and collections.
- Java and PL/SQL stored procedures can be used interchangeably.

SQLJ Example for Object Types

Here is a simple use of user-defined objects and object refs taken from *Oracle8i SQLJ Developer's Guide and Reference* , where more information on SQLJ is available:

The following items are created using the SQL script below:

- Two object types, PERSON and ADDRESS
- A typed table for PERSON objects
- An EMPLOYEE table that includes an ADDRESS column and two columns of PERSON references

```
SET ECHO ON;
/
/*** Clean up in preparation ***/
DROP TABLE EMPLOYEES
/
DROP TABLE PERSONS
/
DROP TYPE PERSON FORCE
/
DROP TYPE ADDRESS FORCE
/
/*** Create address UDT ***/
CREATE TYPE address AS OBJECT
(
  street        VARCHAR(60),
  city          VARCHAR(30),
  state         CHAR(2),
  zip_code      CHAR(5)
)
/
/*** Create person UDT containing an embedded address UDT ***/
CREATE TYPE person AS OBJECT
(
  name    VARCHAR(30),
  ssn     NUMBER,
  addr    address
)
/
/*** Create a typed table for person objects ***/
CREATE TABLE persons OF person
/
/*** Create a relational table with two columns that are REFs
     to person objects, as well as a column which is an Address ADT. ***/
```

```
CREATE TABLE  employees
(
  empnumber            INTEGER PRIMARY KEY,
  person_data     REF  person,
  manager         REF  person,
  office_addr          address,
  salary               NUMBER
)
/*** Insert some data--2 objects into the persons typed table ***/
INSERT INTO persons VALUES (
            person('Wolfgang Amadeus Mozart', 123456,
               address('Am Berg 100', 'Salzburg', 'AT','10424')))
/
INSERT INTO persons VALUES (
            person('Ludwig van Beethoven', 234567,
               address('Rheinallee', 'Bonn', 'DE', '69234')))
/
/** Put a row in the employees table **/
INSERT INTO employees (empnumber, office_addr, salary) VALUES (
            1001,
            address('500 Oracle Parkway', 'Redwood Shores', 'CA', '94065'),
            50000)
/
/** Set the manager and person REFs for the employee **/
UPDATE employees
   SET manager =
       (SELECT REF(p) FROM persons p WHERE p.name = 'Wolfgang Amadeus Mozart')
/
UPDATE employees
   SET person_data =
       (SELECT REF(p) FROM persons p WHERE p.name = 'Ludwig van Beethoven')
/
COMMIT
/
QUIT
```

Next, JPublisher is used to generate the `Address` class for mapping to Oracle `ADDRESS` objects. We omit the details.

The following SQLJ sample declares and sets an input host variable of Java type `Address` to update an `ADDRESS` object in a column of the `employees` table. Both before and after the update, the office address is selected into an output host variable of type `Address` and printed for verification.

```
...
```

```
// Updating an object

static void updateObject()
{

   Address addr;
   Address new_addr;
   int empno = 1001;

   try {
      #sql {
         SELECT office_addr
         INTO :addr
         FROM employees
         WHERE empnumber = :empno };
      System.out.println("Current office address of employee 1001:");

      printAddressDetails(addr);

      /* Now update the street of address */

      String street ="100 Oracle Parkway";
      addr.setStreet(street);

      /* Put updated object back into the database */

      try {
         #sql {
            UPDATE employees
            SET office_addr = :addr
            WHERE empnumber = :empno };
         System.out.println
            ("Updated employee 1001 to new address at Oracle Parkway.");

         /* Select new address to verify update */

         try {
            #sql {
               SELECT office_addr
               INTO :new_addr
               FROM employees
               WHERE empnumber = :empno };

            System.out.println("New office address of employee 1001:");
            printAddressDetails(new_addr);
```

```
            } catch (SQLException exn) {
            System.out.println("Verification SELECT failed with "+exn); }

         } catch (SQLException exn) {
         System.out.println("UPDATE failed with "+exn); }

      } catch (SQLException exn) {
      System.out.println("SELECT failed with "+exn); }
}
...
```

Note the use of the `setStreet()` accessor method of the `Address` instance. Remember that JPublisher provides such accessor methods for all attributes in any custom Java class that it produces.

SQLJ Stored Procedures in the Server

SQLJ applications can be stored and run in the server. You have the option of translating, compiling, and customizing SQLJ source on a client and loading the generated classes and resources into the server with the `loadjava` utility, typically using a Java archive (`.jar`) file.

Or, you have a second option of loading SQLJ source code into the server, also using `loadjava`, and having it translated and compiled by the server's embedded translator.

2

Visual Modelling for Software Development

This chapter contains information on Unified Modelling Language notation and diagrams. The topics include:

Why Employ Visual Modelling?

When application developers gather together to discuss a project, it is only a matter of minutes before someone starts sketching on a white board or pad in order to describe the problems and outline solutions. They do so because they instinctively recognize that a mixture of graphics and text is the fastest way to delineate the complex relationships entailed in software development. Participants in these meetings often end up copying down these sketches as a basis for later code development.

Unified Modelling Language

One problem with this process is that whoever creates the diagrams has to invent a notation to adequately represent the issues under discussion. Fortunately, many of the types of problems are familiar, and everyone who is in the room can ask questions about what is meant by the lines and edges. But this raises further problems: What about members of a development team who are not present? Indeed, even people who were there may later lose track of the logic underlying their notes.

To counter these difficulties, this Application Developer's documentation set uses a graphic notation defined by the Unified Modelling Language (UML), an industry-wide standard specifically created for modelling software systems. Describing the UML in its entirety is beyond the scope of the book. However, we do explain the small subset of the UML notation that we employ.

Illustrations and Diagrams

Software documentation has always contained figures. What, then, is the difference between UML-based diagrams used for modelling software development and the figures that have traditionally been used to illustrate different topics? We make a distinction between two kinds of figures in this book:

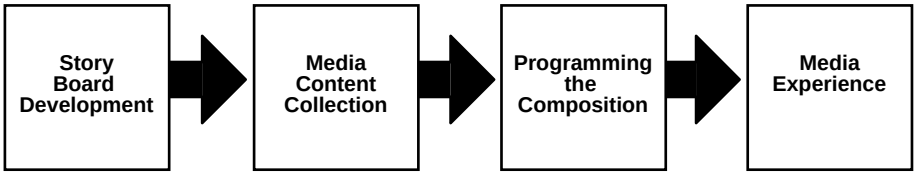
- *Illustrations* — used to describe technology to make it more understandable.
- *Diagrams* — used for actual software modelling.

The two different types are always distinguished in the figure title. The term *diagram* is always used for the following examples:

Example of an Illustration

Figure 2–1 illustrates the macro-steps entailed in creating a multimedia application. While it may be useful in planning software development from an organizational standpoint, it does not provide any help for the actual coding.

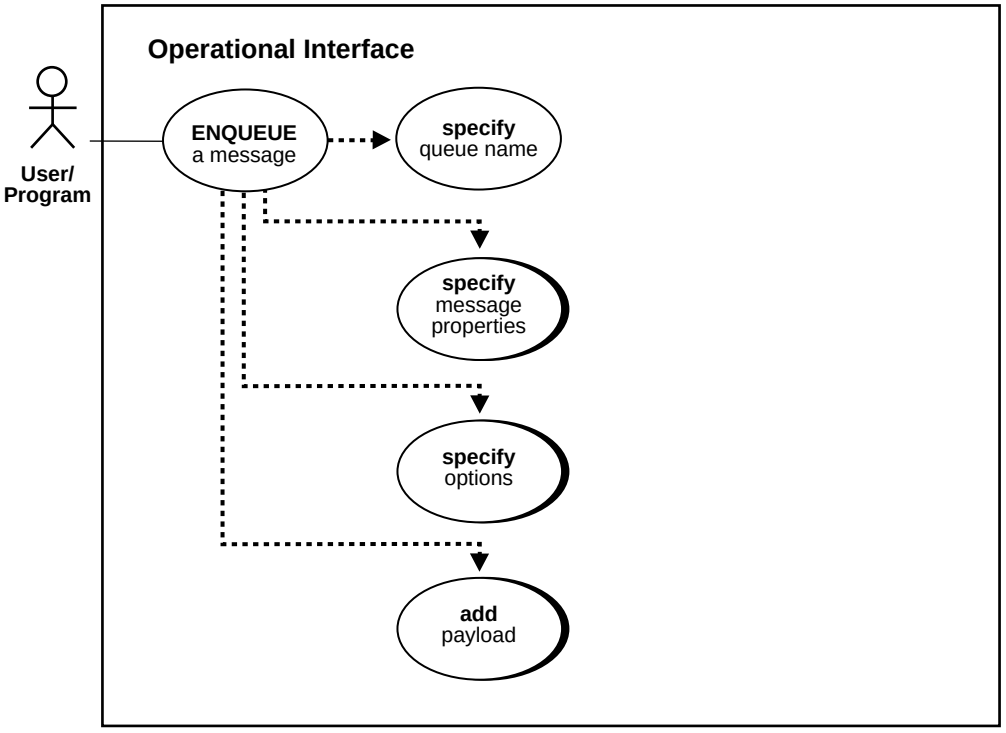
Figure 2–1 Example of an Illustration: The Multimedia Authoring Process



Example of A Diagram

In contrast to Figure 2–1, Figure 2–2 describes what you must do to enqueue a message using Oracle Advanced Queuing: You must specify a queue name, specify the message properties, specify from among various options, and add the message payload. This diagram is then complemented by further diagrams, as indicated by the drop shadows around the latter three ellipses.

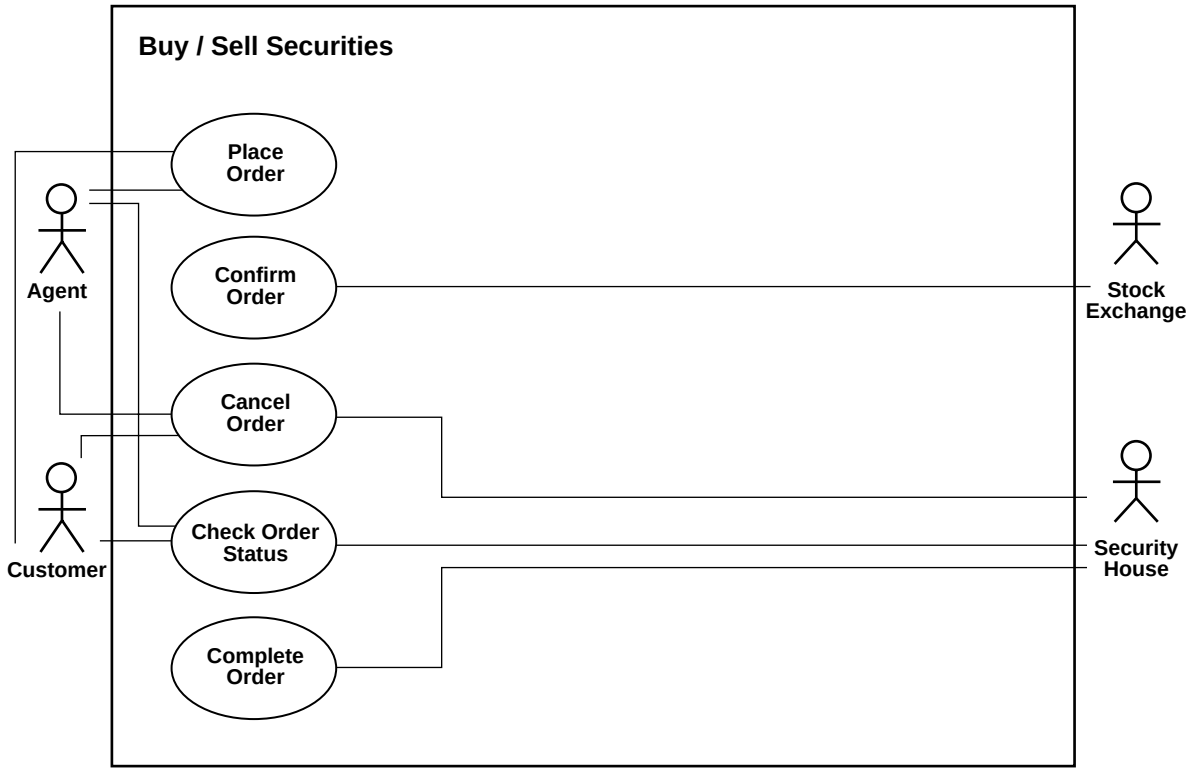
Figure 2–2 Use Case Diagram: Enqueue a Message



Use Cases

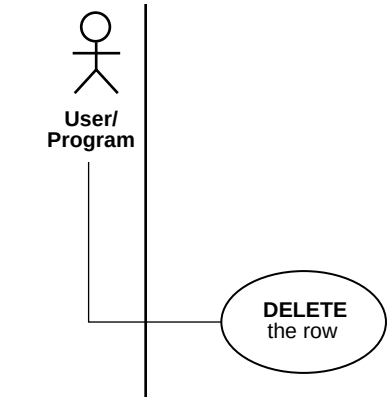
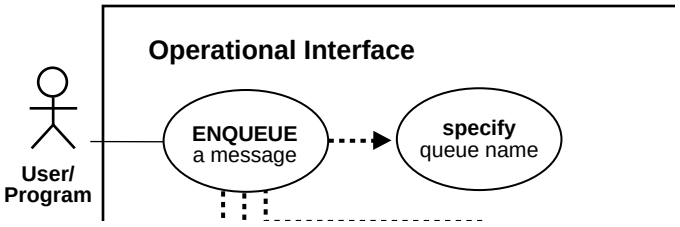
The UML contains a number of different kinds of diagrams.This release of the Application Developer's documentation set introduces the UML into documentation principally by way of *use cases*. Use cases are generally employed to describe the set of activities that comprise the sum of the application scenarios.

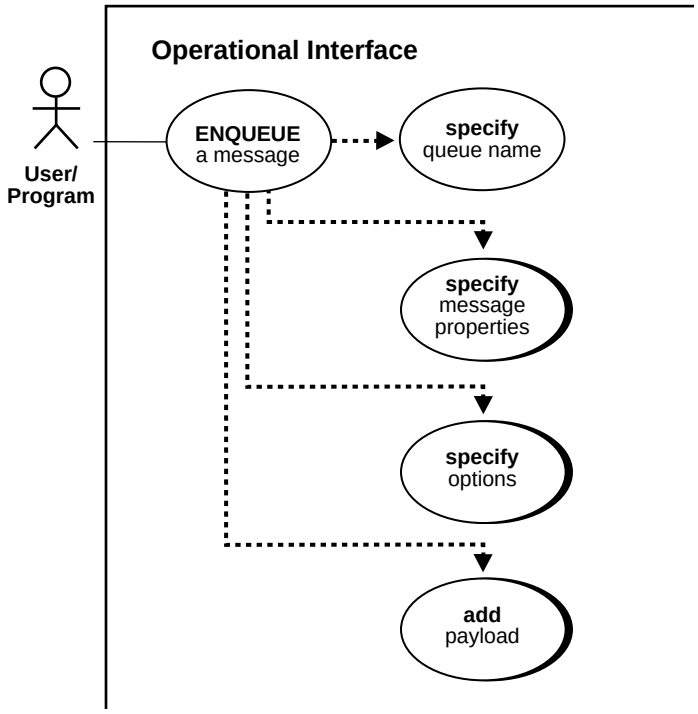
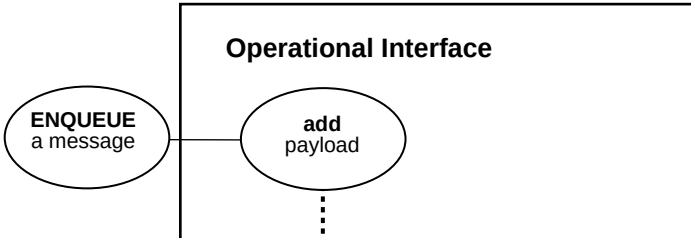
Figure 2–3 Use Cases

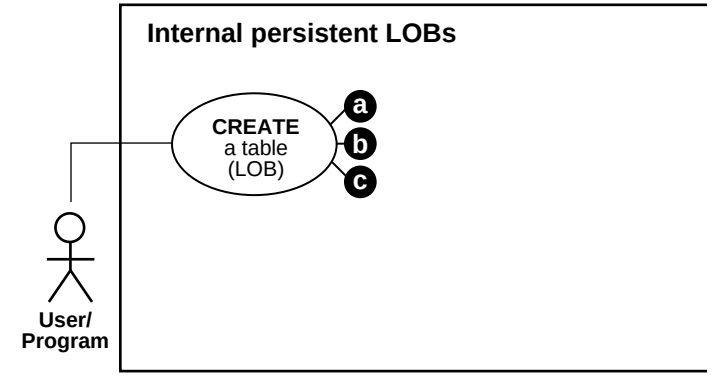


The following section is a selection of UML elements that are used in this book.

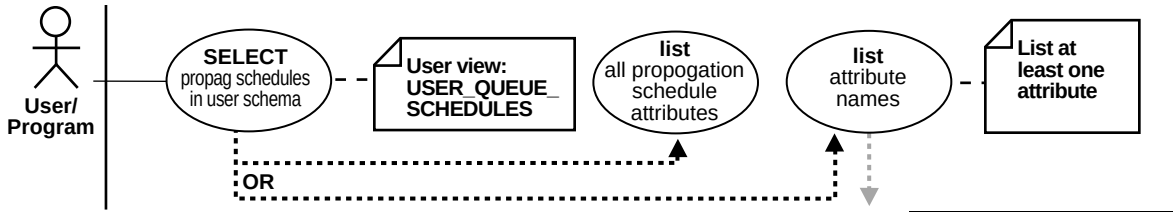
Use Case Diagrams

Graphic Element	Description
	This release of the documentation introduces and makes heavy use of the *Use Case Diagram*. Each primary use case is instigated by an *actor* ('stickman') that could be a human user, an application, or a sub-program. The actor is connected to the primary use case which is depicted as an oval (bubble) enclosing the use case action. The totality of primary use cases is described by means of a *Use Case Model Diagram*.
	Primary use cases may require other operations to complete them. In this diagram fragment: ■ specify queue name Is one of the sub-operations, or secondary use cases, necessary to complete ■ ENQUEUE a message Has the downward lines from the primary use case that lead to the other required operations (not shown)

Graphic Element	Description
	Secondary use cases that have drop shadows expand (they are described by means of their own use case diagrams). There are two reasons for this: (a) It makes it easier to understand the logic of the operation. (b) It would not have been possible to place all the operations and sub-operations on the same page. In this example, specify message properties, specify options, and add payload are all expanded in separate use case diagrams.
	This diagram fragment shows the use case diagram expanded. While the standard diagram has the actor as the initiator), here the use case itself is the point of departure for the sub-operation. In this example, the expanded view of add payload represents a constituent operation of ENQUEUE a message.

Graphic Element	Description
	This convention (a, b, c) shows that there are three different ways of creating a table that contains LOBs.
	This fragment shows use of a NOTE box, here distinguishing which of the three ways of creating a table containing LOBs.

Graphic Element



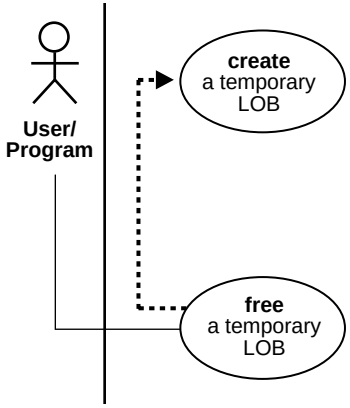
Description

This drawing shows two other common sees of NOTE boxes:

(a) A way of presenting an alternative name, as in this case the action SELECT propagation schedules in the user schema is represented by the view USER_QUEUE_SCHEDULES

(b) The action list attribute names is qualified by the note to the user that you must list at least one attribute if you elect not to list all the propagation schedule attributes.

Graphic Element

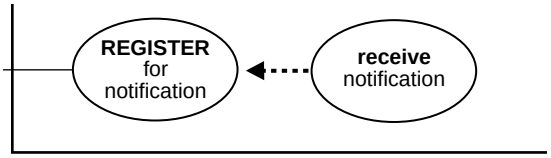


Description

The dotted arrow in the use case diagram indicates dependency. In this example, free a temporary LOB requires that you first create a temporary LOB.

This means that you should not execute the free operation on a LOB that is not temporary.

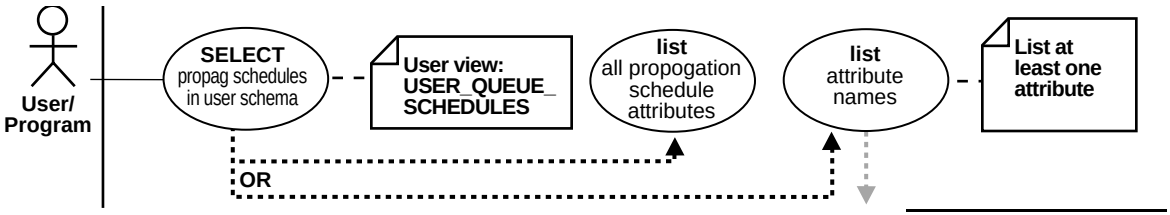
What you need to remember is that the target of the arrow shows the operation that must be performed first.



Use cases and their sub-operations can be linked in complex relationships.

In this example of a callback, you must first `REGISTER` for notification in order to later receive a notification.

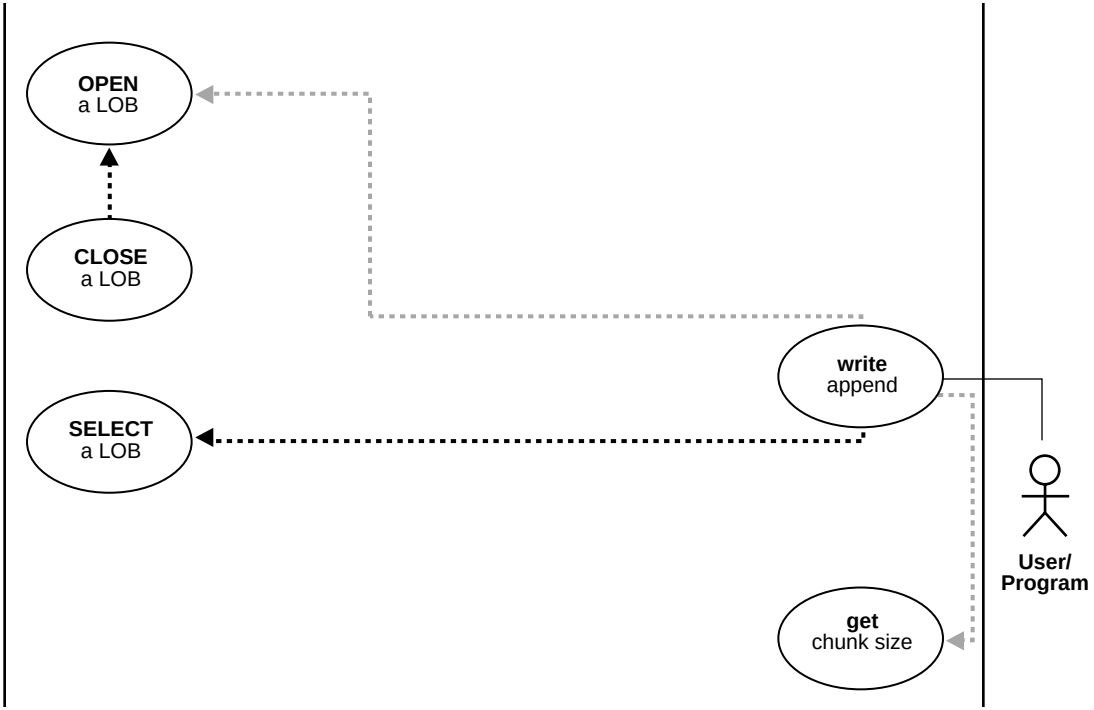
Graphic Element



Description

In this case, the branching paths of an OR condition are shown. In invoking the view, you may either choose to list all the attributes or to view one or more attributes. The fact that you can stipulate which of the attributes you want made visible is indicated by the grayed arrow.

Graphic Element



Description

Not all lined operations are mandatory. While the black dashed-line and arrow indicate that you must perform the targeted operation to complete the use case, actions that are optional are shown by the grey dashed-line and arrow.

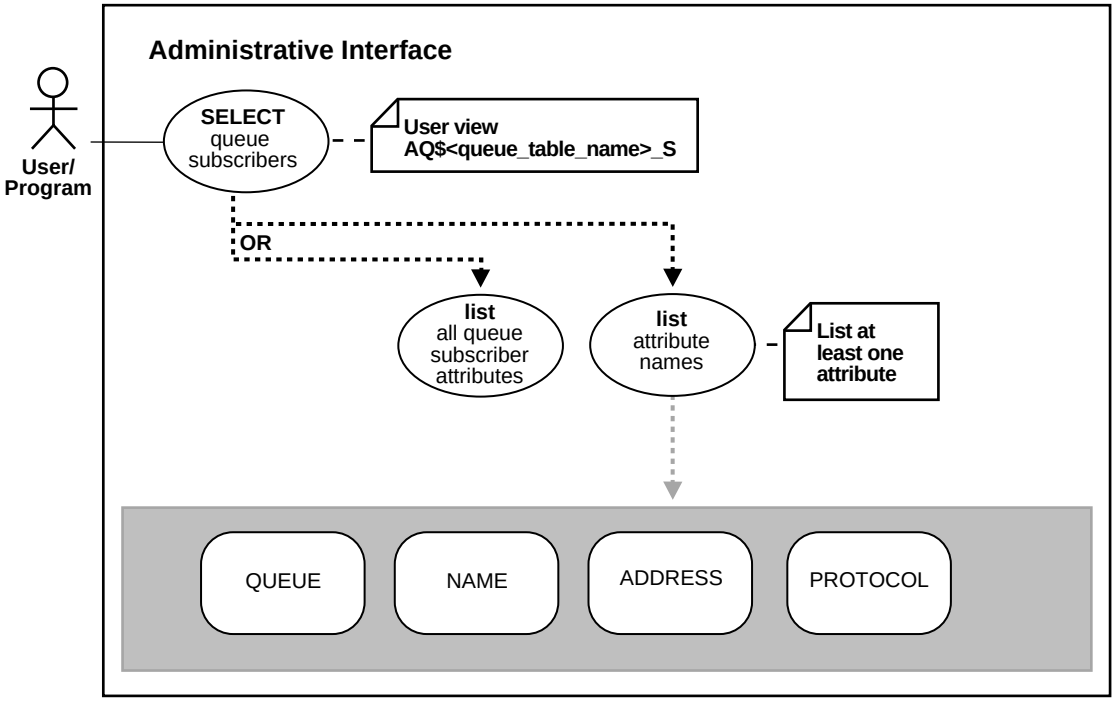
In this example, executing `WRITEAPPEND` on a `LOB` requires that you first `SELECT` a `LOB`.

As a facilitating operations, you may choose to `OPEN` a `LOB` and / or `GETCHUNKSIZE`.

However, note that if you `OPEN` a `LOB`, you will later have to `CLOSE` it.

State Diagrams

Graphic Element



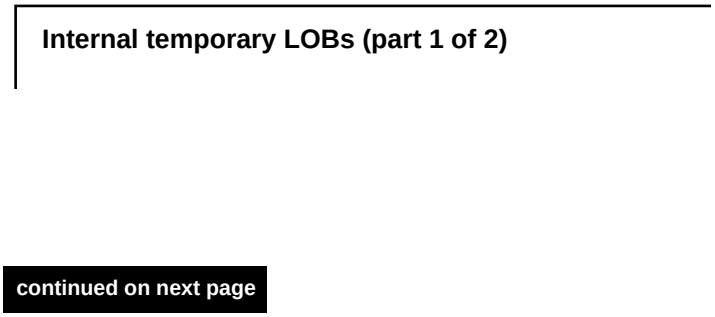
Description

All the previous notes have dealt with *use case diagrams*. Here we introduce the very basic application of a *state diagram* that we utilize in this book to present the attributes of a view. In fact, attributes of a view have only two states — visible or invisible.

We attempt to show what you might make visible in invoking the view. Accordingly, we have extended the UML to join a partial state diagram onto a use case diagram to show the totality of attributes, and thereby all the view sub-states of the view that you can see. We have demarcated the use case from the view state by coloring the background of the state diagram grey.

In this example, the view `AQ$<queue_table_name>_S` allows you to query queue subscribers. You can stipulate one, some combination, or all of the four attributes.

Graphic Element



Description

Use Case Model Diagrams summarize all the use cases in a particular domain, such as `Internal temporary LOBs`. Often, these diagrams are too complex to contain within a single page.

When that happens we resort to dividing the diagram into two parts. Please note that there is no sequence implied in this division.

In some cases, we have had to split a diagram simply because it is too long for the page. In such cases, we have included this marker.

Part II

Designing the Database

Part II contains the following chapters:

3

Managing Schema Objects

This chapter discusses the procedures necessary to create and manage the different types of objects contained in a user's schema. The topics include:

- Managing Tables
- Managing Temporary Tables
- Managing Views
- Modifying a Join View
- Managing Sequences
- Managing Synonyms
- Miscellaneous Management Topics for Schema Objects

See Also: Other information about managing schema objects can be found in the following locations:

- Indexes, clusters, and materialized views — Chapter 6
- Procedures, functions, and packages — Chapter 10
- Object types — Chapter 17
- Dependency information — Chapter 10
- If you use symmetric replication, then see *Oracle8i Replication* for information on managing schema objects, such as snapshots.
- If you use Trusted Oracle, then there are additional privileges required and issues to consider when managing schema objects; see the *Trusted Oracle* documentation.

Managing Tables

A table is the data structure that holds data in a relational database. A table is composed of rows and columns.

A table can represent a single entity that you want to track within your system. This type of a table could represent a list of the employees within your organization, or the orders placed for your company's products.

A table can also represent a relationship between two entities. This type of a table could portray the association between employees and their job skills, or the relationship of products to orders. Within the tables, foreign keys are used to represent relationships.

Although some well designed tables could represent both an entity and describe the relationship between that entity and another entity, most tables should represent either an entity or a relationship. For example, the `EMP_TAB` table describes the employees in a firm, but this table also includes a foreign key column, `DEPTNO`, which represents the relationships of employees to departments.

The following sections explain how to create, alter, and drop tables. Some simple guidelines to follow when managing tables in your database are included.

> **See Also:** The *Oracle8i Administrator's Guide* has more suggestions. You should also refer to a text on relational database or table design.

Designing Tables

Consider the following guidelines when designing your tables:

- Use descriptive names for tables, columns, indexes, and clusters.
- Be consistent in abbreviations and in the use of singular and plural forms of table names and columns.
- Document the meaning of each table and its columns with the `COMMENT` command.
- Normalize each table.
- Select the appropriate datatype for each column.
- Define columns that allow nulls last, to conserve storage space.
- Cluster tables whenever appropriate, to conserve storage space and optimize performance of SQL statements.

Before creating a table, you should also determine whether to use integrity constraints. Integrity constraints can be defined on the columns of a table to enforce the business rules of your database automatically.

> **See Also:** See Chapter 5, "Maintaining Data Integrity" for guidelines.

Creating Tables

To create a table, use the SQL command CREATE TABLE. For example, if the user SCOTT issues the following statement, he creates a non-clustered table named Emp_tab in his schema that is physically stored in the USERS tablespace. Notice that integrity constraints are defined on several columns of the table.

```
CREATE TABLE Emp_tab (
   Empno      NUMBER(5) PRIMARY KEY,
   Ename      VARCHAR2(15) NOT NULL,
   Job        VARCHAR2(10),
   Mgr        NUMBER(5),
   Hiredate   DATE DEFAULT (sysdate),
   Sal        NUMBER(7,2),
   Comm       NUMBER(7,2),
   Deptno     NUMBER(3) NOT NULL,
              CONSTRAINT dept_afkey REFERENCES Dept_tab(Deptno))
   PCTFREE 10
   PCTUSED 40
   TABLESPACE users
   STORAGE (  INITIAL 50K
              NEXT 50K
              MAXEXTENTS 10
              PCTINCREASE 25 );
```

Managing the Space Usage of Data Blocks

The following sections explain how to use the PCTFREE and PCTUSED parameters to do the following:

- Increase the performance of writing and retrieving a data or index segment
- Decrease the amount of unused space in data blocks
- Decrease the amount of row chaining between data blocks

Specifying PCTFREE

The PCTFREE default is 10 percent; any integer from 0 to 99 is acceptable, as long as the sum of PCTFREE and PCTUSED does not exceed 100. (If PCTFREE is set to 99, then Oracle puts at least one row in each block, regardless of row size. If the rows are very small and blocks very large, then even more than one row might fit.)

A lower PCTFREE:

- Reserves less room for updates to existing table rows

- Allows inserts to fill the block more completely
- Might save space, because the total data for a table or index is stored in fewer blocks (more rows or entries per block)
- Increases processing costs because blocks frequently need to be reorganized as their free space area becomes filled with new or updated data
- Potentially increases processing costs and space required if updates to rows or index entries cause rows to grow and span blocks (because UPDATE, DELETE, and SELECT statements might need to read more blocks for a given row and because chained row pieces contain references to other pieces)

A higher PCTFREE:

- Reserves more room for future updates to existing table rows
- Might require more blocks for the same amount of inserted data (inserting fewer rows per block)
- Lessens processing costs, because blocks infrequently need reorganization of their free space area
- Might improve update performance, because Oracle must chain row pieces less frequently, if ever

In setting PCTFREE, you should understand the nature of the table or index data. Updates can cause rows to grow. When using NUMBER, VARCHAR2, LONG, or LONG RAW, new values might not be the same size as values they replace. If there are many updates in which data values get longer, then increase PCTFREE; if updates to rows do not affect the total row width, then PCTFREE can be low.

Your goal is to find a satisfactory trade-off between densely packed data (low PCTFREE, full blocks) and good update performance (high PCTFREE, less-full blocks).

PCTFREE also affects the performance of a given user's queries on tables with uncommitted transactions belonging to other users. Assuring read consistency might cause frequent reorganization of data in blocks that have little free space.

PCTFREE for Non-Clustered Tables If the data in the rows of a non-clustered table is likely to increase in size over time, then reserve space for these updates. If you do not reserve room for updates, then updated rows are likely to be chained between blocks, reducing I/O performance associated with these rows.

PCTFREE for Clustered Tables The discussion for non-clustered tables also applies to clustered tables. However, if PCTFREE is reached, then new rows from *any* table

contained in the same cluster key go into a new data block chained to the existing cluster key.

PCTFREE for Indexes Indexes infrequently require the use of free space for updates to index data. Therefore, the PCTFREE value for index segment data blocks is normally very low (for example, 5 or less).

Specifying PCTUSED

Once the percentage of free space in a data block reaches PCTFREE, no new rows are inserted in that block until the percentage of space used falls below PCTUSED. Oracle tries to keep a data block at least PCTUSED full. The percent is of block space available for data after overhead is subtracted from total space.

The default for PCTUSED is 40 percent; any integer between 0 and 99, inclusive, is acceptable as long as the sum of PCTUSED and PCTFREE does not exceed 100.

A lower PCTUSED:

- Usually keeps blocks less full than a higher PCTUSED
- Reduces processing costs incurred during UPDATE and DELETE statements for moving a block to the free list when the block has fallen below that percentage of usage
- Increases the unused space in a database

A higher PCTUSED:

- Usually keeps blocks fuller than a lower PCTUSED
- Improves space efficiency
- Increases processing cost during INSERTs and UPDATEs

Choosing Associated PCTUSED and PCTFREE Values

If you decide not to use the default values for PCTFREE and PCTUSED, then use the following guidelines.

- The sum of PCTFREE and PCTUSED must be equal to or less than 100.
- If the sum is less than 100, then the ideal compromise of space utilization and I/O performance is a sum of PCTFREE and PCTUSED that differs from 100 by the percentage of space in the available block that an average row occupies. For example, assume that the data block size is 2048 bytes, minus 100 bytes of overhead, leaving 1948 bytes available for data. If an average row requires 195

bytes, or 10% of 1948, then an appropriate combination of PCTUSED and PCTFREE that sums to 90% would make the best use of database space.

- If the sum equals 100, then Oracle attempts to keep no more than PCTFREE free space, and the processing costs are highest.
- Fixed block overhead is not included in the computation of PCTUSED or PCTFREE.
- The smaller the difference between 100 and the sum of PCTFREE and PCTUSED (as in PCTUSED of 75, PCTFREE of 20), the more efficient space usage is at some performance cost.

Examples of Choosing PCTFREE and PCTUSED Values

The following examples illustrate correctly specifying values for PCTFREE and PCTUSED in given scenarios.

Example1

Scenario:	Common activity includes UPDATE statements that increase the size of the rows. Performance is important.
Settings:	PCTFREE = 20 PCTUSED = 40
Explanation:	PCTFREE is set to 20 to allow enough room for rows that increase in size as a result of updates. PCTUSED is set to 40 so that less processing is done during high update activity, thus improving performance.

Example2

Scenario:	Most activity includes INSERT and DELETE statements, and UPDATE statements that do not increase the size of affected rows. Performance is important.
Settings:	PCTFREE = 5 PCTUSED = 60
Explanation:	PCTFREE is set to 5 because most UPDATE statements do not increase row sizes. PCTUSED is set to 60 so that space freed by DELETE statements is used relatively soon, yet the amount of processing is minimized.

Example3

Scenario:	The table is very large; therefore, storage is a primary concern. Most activity includes read-only transactions; therefore, query performance is important.
Settings:	PCTFREE = 5 PCTUSED = 90
Explanation:	PCTFREE is set to 5, because UPDATE statements are rarely issued. PCTUSED is set to 90, so that more space per block is used to store table data. This setting for PCTUSED reduces the number of data blocks required to store the table's data and decreases the average number of data blocks to scan for queries, thereby increasing the performance of queries.

Privileges Required to Create a Table

To create a new table in your schema, you must have the CREATE TABLE system privilege. To create a table in another user's schema, you must have the CREATE ANY TABLE system privilege. Additionally, the owner of the table must have a quota for the tablespace that contains the table, or the UNLIMITED TABLESPACE system privilege.

Altering Tables

Alter a table in an Oracle database for any of the following reasons:

- To add one or more new columns to the table
- To add one or more integrity constraints to a table
- To modify an existing column's definition (datatype, length, default value, and NOT NULL integrity constraint)
- To modify data block space usage parameters (PCTFREE, PCTUSED)
- To modify transaction entry settings (INITRANS, MAXTRANS)
- To modify storage parameters (NEXT, PCTINCREASE, etc.)
- To enable or disable integrity constraints associated with the table
- To drop integrity constraints associated with the table

When altering the column definitions of a table, you can only increase the length of an existing column, unless the table has no records. You can also decrease the length of a column in an empty table. For columns of datatype CHAR, increasing the length of a column might be a time consuming operation that requires substantial additional storage, especially if the table contains many rows. This is because the CHAR value in each row must be blank-padded to satisfy the new column length.

If you change the datatype (for example, from VARCHAR2 to CHAR), then the data in the column does not change. However, the length of new CHAR columns might change, due to blank-padding requirements.

Use the SQL command ALTER TABLE to alter a table. For example:

```
ALTER TABLE Emp_tab
    PCTFREE 30
    PCTUSED 60;
```

Altering a table has the following implications:

- If a new column is added to a table, then the column is initially null. You can add a column with a NOT NULL constraint to a table only if the table does not contain any rows.
- If a view or PL/SQL program unit depends on a base table, then the alteration of the base table might affect the dependent object, and always invalidates the dependent object.

Privileges Required to Alter a Table

To alter a table, the table must be contained in your schema, or you must have either the ALTER object privilege for the table or the ALTER ANY TABLE system privilege.

Dropping Tables

Use the SQL command DROP TABLE to drop a table. For example, the following statement drops the EMP_TAB table:

```
DROP TABLE Emp_tab;
```

If the table that you are dropping contains any primary or unique keys referenced by foreign keys of other tables, and if you intend to drop the FOREIGN KEY constraints of the child tables, then include the CASCADE option in the DROP TABLE command. For example:

```
DROP TABLE Emp_tab CASCADE CONSTRAINTS;
```

Dropping a table has the following effects:

- The table definition is removed from the data dictionary. All rows of the table are then inaccessible.
- All indexes and triggers associated with the table are dropped.
- All views and PL/SQL program units that depend on a dropped table remain, but become invalid (not usable).
- All synonyms for a dropped table remain, but return an error when used.
- All extents allocated for a non-clustered table that is dropped are returned to the free space of the tablespace and can be used by any other object requiring new extents.
- All rows corresponding to a clustered table are deleted from the blocks of the cluster.
- If the table is a master table for snapshots, then Oracle does not drop the snapshots, but does drop the snapshot log. The snapshots can still be used, but they cannot be refreshed unless the table is re-created.

If you want to delete all of the rows of a table, but keep the table definition, then you should use the TRUNCATE TABLE command.

See Also: *Oracle8i Administrator's Guide.*

Privileges Required to Drop a Table

To drop a table, the table must be contained in your schema or you must have the DROP ANY TABLE system privilege.

Managing Temporary Tables

A temporary table has a definition or structure that persists like that of a regular table, but the data it contains exists only for the duration of a transaction or session. Oracle8*i* allows you to create temporary tables to hold session-private data. You specify whether the data is specific to a session or to a transaction.

Here are a few examples of when temporary tables can be useful:

- A Web-based airlines reservations application allows you, as a customer, to create several optional itineraries. As you develop each itinerary, the application places the data in a row of a single temporary table. As you modify each itinerary, the application updates that row accordingly. When you ultimately decide which itinerary you want to use, the application moves the row for that itinerary to a persistent table.

  During your session, the data you enter is private. When you end your session, the optional itineraries you developed are dropped.

- Several sales agents for a large bookseller use a single temporary table concurrently while taking customer orders over the phone. To enter and modify customer orders, each agent accesses the table in a session that is unavailable to the other agents. When the agent closes a session, the data from that session is automatically dropped, but the table structure persists for the other agents to use.

- An administrator uses temporary tables to improve performance when running an otherwise complex and expensive query. To do this, the administrator caches the values from a more complex query in temporary tables, then runs SQL statements, such as joins, against those temporary tables. For a thorough explanation of how this can be done, see "Example 2: Using Temporary Tables to Improve Performance" on page 3-14.

Creating Temporary Tables

You create a temporary table by using special ANSI keywords. You specify the data as *session*-specific by using the `ON COMMIT PRESERVE ROWS` keywords. You specify the data as *transaction*-specific by using the `ON COMMIT DELETE ROWS` keywords.

Example 3–1 Creating a Session-Specific Temporary Table

```
CREATE GLOBAL TEMPORARY TABLE ...
     [ON COMMIT PRESERVE ROWS ]
```

Example 3–2 Creating a Transaction-Specific Temporary Table

```
CREATE GLOBAL TEMPORARY TABLE ...
     [ON COMMIT DELETE ROWS ]
```

Using Temporary Tables

You can create indexes on temporary tables as you would on permanent tables.

For a *session*-specific temporary table, a session gets bound to the temporary table with the first insert in the table in the session. This binding goes away at the end of the session or by issuing a TRUNCATE of the table in the session.

For a *transaction*-specific temporary table, a session gets bound to the temporary table with the first insert in the table in the transaction. The binding goes away at the end of the transaction.

DDL operations (except TRUNCATE) are allowed on an existing temporary table only if no session is currently bound to that temporary table.

Unlike permanent tables, temporary tables and their indexes do not automatically allocate a segment when they are created. Instead, segments are allocated when the first INSERT (or CREATE TABLE AS SELECT) is performed. This means that if a SELECT, UPDATE, or DELETE is performed before the first INSERT, the table appears to be empty.

Temporary segments are deallocated at the end of the transaction for transaction-specific temporary tables and at the end of the session for session-specific temporary tables.

If you rollback a transaction, the data you entered is lost, although the table definition persists.

You cannot create a table that is simultaneously both transaction- and session-specific.

A transaction-specific temporary table allows only one transaction at a time. If there are several autonomous transactions in a single transaction scope, each autonomous transaction can use the table only as soon as the previous one commits.

Because the data in a temporary table is, by definition, temporary, backup and recovery of a temporary table's data is not available in the event of a system failure. To prepare for such a failure, you should develop alternative methods for preserving temporary table data.

Examples: Using Temporary Tables

Example 1: A Session-specific Temporary Table

The following statement creates a session-specific temporary table, FLIGHT_SCHEDULE, for use in an automated airline reservation scheduling system. Each client has its own session and can store temporary schedules. The temporary schedules are deleted at the end of the session.

```
CREATE GLOBAL TEMPORARY TABLE flight_schedule (
   startdate DATE,
   enddate DATE,
   cost NUMBER)
ON COMMIT PRESERVE ROWS;
```

Example 2: Using Temporary Tables to Improve Performance

This example shows how you can use temporary tables to improve performance when you run complex queries. In this example, you create four conventional tables, then run SQL statements against them. The example compares the way you would conventionally run SQL statements on those tables with the way you could run them using temporary tables. In the former case, the performance is relatively slow because the process requires hitting the table multiple times for each row returned. In the latter case, efficiency increases because you use temporary tables to cache the values from a more complex query, then run SQL statements against those temporary tables.

Create PROFILE_DEPARTMENTS table

```
CREATE TABLE Profile_departments
            (
            Department_id         NUMBER(4)     not null,
            Department_name       VARCHAR2(20)  not null,
            CONSTRAINT            profile_departments_pk
            PRIMARY KEY           (department_id)
            );
CREATE UNIQUE INDEX Profile_departments_u1
    ON Profile_departments (Department_name);

INSERT INTO Profile_departments (Department_id, Department_name)
     VALUES (3001, 'Accounting');
INSERT INTO Profile_departments (Department_id, Department_name)
     VALUES (3002, 'Marketing');
COMMIT;
```

The above script yields the following:

```
DEPARTMENT_ID          DEPARTMENT_NAME
3001                   Accounting
3002                   Marketing
```

Create PROFILE_USERS table

```
CREATE TABLE Profile_users
             (
             User_id               NUMBER(4)     not null,
             User_name             VARCHAR2(20)  not null,
             Department_id         NUMBER(4)     not null,
             CONSTRAINT            Profile_users_pk
             PRIMARY KEY           (User_id)
             );
CREATE UNIQUE INDEX Profile_users_u1
    ON Profile_users (User_name);

INSERT INTO Profile_users (User_id, User_name, Department_id)
     VALUES (2001, 'John Doe', 3001);
INSERT INTO Profile_users (User_id, User_name, Department_id)
     VALUES (2002, 'Jane Doe', 3002);
INSERT INTO Profile_users (User_id, User_name, Department_id)
     VALUES (2003, 'Bill Smith', 3002);
COMMIT;
```

The above script yields the following:

```
User ID        Name           Department
2001           John Doe       3001 (Accounting)
2002           Jane Doe       3002 (Marketing)
2003           Bill Smith     3002 (Marketing)
```

Create PROFILE_DEFINITIONS table

```
CREATE TABLE Profile_definitions
             (
             Profile_option_id     NUMBER(4)     Not Null,
             Profile_option_name   VARCHAR2(20)  not null,
             CONSTRAINT            Profile_definitions_pk
             PRIMARY KEY           (Profile_option_id)
             );
```

```
CREATE UNIQUE INDEX Profile_definitions_u1
    ON Profile_definitions (Profile_option_name);

INSERT INTO Profile_definitions (Profile_option_id, Profile_option_name)
     VALUES (1001, 'Printer');
INSERT INTO Profile_definitions (Profile_option_id, Profile_option_name)
     VALUES (1002, 'Mail Database');
COMMIT;
```

The above script yields the following:

```
Profile Option Id    Profile Option Name

1001                 Printer

1002                 Mail Database
```

Create PROFILE_VALUES table

```
CREATE TABLE Profile_values
            (
            Profile_option_id     NUMBER(4)     not null,
            Level_code            VARCHAR2(10)  not null,
            Level_id              NUMBER(4)     not null,
            Profile_option_value  VARCHAR2(20)  not null,
            CONSTRAINT            profile_values_pk
            PRIMARY KEY           (Profile_option_id,level_code,level_id),
            CONSTRAINT            Profile_values_c1
            CHECK (Level_code IN ('USER','DEPARTMENT','SITE'))
            ) ORGANIZATION INDEX;

INSERT INTO Profile_values
            (Profile_option_id, Level_code, Level_id, Profile_option_value)
     VALUES (1001, 'DEPARTMENT', 3001, 'ACCT-LPT');
INSERT INTO Profile_values
            (Profile_option_id, Level_code, Level_id, Profile_option_value)
     VALUES (1001, 'DEPARTMENT', 3002, 'MKTG-LPT');
INSERT INTO Profile_values
            (Profile_option_id, Level_code, Level_id, Profile_option_value)
     VALUES (1001, 'USER', 2003, 'SMITH-LPT');
INSERT INTO Profile_values
            (Profile_option_id, Level_code, Level_id, Profile_option_value)
     VALUES (1002, 'SITE', 0, 'mail0');
INSERT INTO Profile_values
            (Profile_option_id, Level_code, Level_id, Profile_option_value)
     VALUES (1002, 'DEPARTMENT', 3001, 'mail1');
```

```
INSERT INTO Profile_values
            (Profile_option_id, Level_code, Level_id, Profile_option_value)
     VALUES (1002, 'USER', 2002, 'mail2');

COMMIT;
```

The above script creates the following table:

PROFILE_OPTION_ID	LEVEL_CODE	LEVEL_ID	PROFILE_OPTION VALUE	
1001	DEPARTMENT	3001	ACCT-LPT	(Printer for Accounting is "ACCT-LPT")
1001	DEPARTMENT	3002	MKTG-LPT	(Printer for Marketing is "ACCT-LPT")
1001	USER	2003	SMITH-LPT	(Printer for Bill Smith is "SMITH-LPT")
1002	SITE		mail0	(Site-level mail database is "mail0")
1002	DEPARTMENT	3001	mail1	(Mail database for Accounting is "mail1")
1002	USER	2002	mail2	(Mail database for Jane Doe is "mail2")

Query for Parameter Settings for John Doe, Jane Doe, and Bill Smith

```
SELECT d.Profile_option_name, Profile_option_value, Level_id, Level_code
  FROM Profile_definitions d, Profile_values v, Profile_users u
 WHERE d.Profile_option_id = v.Profile_option_id
   AND u.User_name = 'John Doe'
   AND ((Level_code = 'USER' and level_id = U.User_id) OR
        (Level_code = 'DEPARTMENT' and Level_id = U.Department_id) OR
        (Level_code = 'SITE'))
 ORDER BY D.Profile_option_name, INSTR('USERDEPARTMENTSITE', Level_code);
```

The above script yields the following table. Note that there are multiple possible settings for the mail database, at different levels of the hierarchy.

PROFILE_OPTION_NAME	PROFILE_OPTION_VALUE	LEVEL_ID	LEVEL_CODE
Mail Database	mail1	3001	DEPARTMENT
Mail Database	mail0	0	SITE

```
PROFILE_OPTION_NAME  PROFILE_OPTION_VALUE   LEVEL_ID    LEVEL_CODE
Printer              ACCT-LPT               3001        DEPARTMENT
```

Similar queries (shown below) for Jane Doe and Bill Smith, respectively:

```
PROFILE_OPTION_NAME  PROFILE_OPTION_VALUE   LEVEL_ID     LEVEL_CODE
Mail Database        mail2                  2002 USER    USER
Mail Database        mail0                  0            SITE
Printer              MKTG-LPT               3002         DEPARTMENT
```

```
PROFILE_OPTION_NAME  PROFILE_OPTION_VALUE   LEVEL_ID     LEVEL_CODE
Mail Database        mail0                  0            SITE
Printer              SMITH-LPT              2003         USER
Printer              MKTG-LPT               3002         DEPARTMENT
```

Each shows multiple possible values for any particular parameter at different hierarchical levels.

```
SELECT d.Profile_option_name, Profile_option_value, Level_id, Level_code
  FROM Profile_definitions d, Profile_values v, Profile_users u
 WHERE d.Profile_option_id = v.Profile_option_id
   AND u.User_name = 'Jane Doe'
   AND ((Level_code = 'USER' and Level_id = u.User_id) OR
        (Level_code = 'DEPARTMENT' and Level_id = u.Department_id) OR
        (Level_code = 'SITE'))
 ORDER BY d.Profile_option_name, INSTR('USERDEPARTMENTSITE', Level_code);

SELECT d.Profile_option_name, Profile_option_value, Level_id, Level_code
  FROM PROFILE_DEFINITIONS D, PROFILE_VALUES V, PROFILE_USERS U
 WHERE D.PROFILE_OPTION_ID = V.PROFILE_OPTION_ID
   AND U.USER_NAME = 'Bill Smith'
   AND ((Level_code = 'USER' AND Level_id = u.User_id) OR
        (Level_code = 'DEPARTMENT' AND Level_id = u.Department_id) OR
        (Level_code = 'SITE'))
 ORDER BY D.Profile_option_name, instr('USERDEPARTMENTSITE', Level_code);
```

Run a Conventional Query

To produce a query that shows only the relevant (lowest-level) setting requires a complex sub-query. This sub-query reduces performance because it hits the table multiple times for each row produced.

The following script creates a view that produces the correct output:

```
CREATE OR REPLACE VIEW Profile_values_view AS
SELECT d.Profile_option_name, d.Profile_option_id, Profile_option_value,
       u.User_name, Level_id, Level_code
  FROM Profile_definitions d, Profile_values v, Profile_users u
 WHERE d.Profile_option_id = v.Profile_option_id
   AND ((Level_code = 'USER' AND Level_id = U.User_id) OR
        (Level_code = 'DEPARTMENT' AND Level_id = U.Department_id) OR
        (Level_code = 'SITE'))
   AND NOT EXISTS (SELECT 1 FROM PROFILE_VALUES P
                   WHERE P.PROFILE_OPTION_ID = V.PROFILE_OPTION_ID
                     AND ((Level_code = 'USER' AND
                           level_id = u.User_id) OR
                          (Level_code = 'DEPARTMENT' AND
                           level_id = u.Department_id) OR
                          (Level_code = 'SITE'))
                     AND INSTR('USERDEPARTMENTSITE', v.Level_code) >
                         INSTR('USERDEPARTMENTSITE', p.Level_code));
```

You can see from the following query that the values for each parameter are found at different levels of the hierarchy:

```
SELECT v.User_name, p.Profile_option_name,
       v.Profile_option_value, v.Level_code
  FROM Profile_definitions p, Profile_values_view v
 WHERE p.Profile_option_id = v.Profile_option_id
 ORDER BY v.User_name, p.Profile_option_name;
```

The above script yields the following:

```
USER_NAME      PROFILE_OPTION_NAME  PROFILE_OPTION_VALUE  LEVEL_CODE

Bill Smith     Mail Database        mail0                 SITE

Bill Smith     Printer              SMITH-LPT             USER

Jane Doe       Mail Database        mail2                 USER

Jane Doe       Printer              MKTG-LPT              DEPARTMENT

John Doe       Mail Database        mail1                 DEPARTMENT
```

```
USER_NAME      PROFILE_OPTION_NAME  PROFILE_OPTION_VALUE  LEVEL_CODE
John Doe       Printer              ACCT-LPT              DEPARTMENT
```

This view can be queried to find the values for a user, as in:

```
SELECT Profile_option_name, Profile_option_value
  FROM Profile_values_view
 WHERE User_name = 'John Doe'
 ORDER BY Profile_option_name;
```

The above query yields the following:

```
PROFILE_OPTION_NAME          PROFILE_OPTION_VALUE
Mail Database                mail1
Printer                      ACCT-LPT
```

This would be inefficient and complex to use if, for example, the parameters are used in other SQL statements; in effect, the data is re-calculated repeatedly rather than being calculated once and cached.

Enhance Performance by Using Temporary Tables

A temporary table would allow us to run the computation once, and still use the result in later SQL joins. For example:

```
DROP TABLE Profile_values_temp;
CREATE TABLE Profile_values_temp
            (
            Profile_option_id     NUMBER(4)     NOT NULL,
            Profile_option_value  VARCHAR2(20)  NOT NULL,
            Level_code            VARCHAR2(10)          ,
            Level_id              NUMBER(4)             ,
            CONSTRAINT Profile_values_temp_pk
               PRIMARY KEY (Profile_option_id)
            ) ORGANIZATION INDEX;

INSERT INTO Profile_values_temp
       (Profile_option_id, Profile_option_value, Level_code, Level_id)
SELECT Profile_option_id, Profile_option_value, Level_code, Level_id
  FROM Profile_values_view
 WHERE User_name = 'John Doe';
COMMIT;
```

By doing this, the application has computed and cached the results of the complex query into the temporary table.

Now the temporary table can be used in another SQL statement with high performance, and the application programmer can be certain that the results cached in the temporary table are freed automatically by the database when the session ends.

```
SELECT p.Profile_option_name, t.Profile_option_value, t.Level_code,
       NVL(u.User_name,NVL(d.Department_name,'site')) Level_value
  FROM Profile_definitions p, Profile_values_temp t,
       Profile_departments d, Profile_users u
 WHERE P.PROFILE_OPTION_ID = T.PROFILE_OPTION_ID
   AND T.Level_id = d.Department_id(+)
   AND T.Level_id = u.User_id(+)
 ORDER BY Profile_option_name;
```

Managing Views

A *view* is a logical representation of another table or combination of tables. A view derives its data from the tables on which it is based. These tables are called *base tables*. Base tables might in turn be actual tables or might be views themselves.

All operations performed on a view actually affect the base table of the view. You can use views in almost the same way as tables. You can query, update, insert into, and delete from views, just as you can standard tables.

Views can provide a different representation (such as subsets or supersets) of the data that resides within other tables and views. Views are very powerful because they allow you to tailor the presentation of data to different types of users.

The following sections explain how to create, replace, and drop views using SQL commands.

Creating Views

Use the SQL command CREATE VIEW to create a view. You can define views with any query that references tables, snapshots, or other views; however, the query that defines a view cannot contain the ORDER BY or FOR UPDATE clauses. For example, the following statement creates a view on a subset of data in the EMP_TAB table:

```
CREATE VIEW Sales_staff AS
    SELECT Empno, Ename, Deptno
    FROM Emp_tab
    WHERE Deptno = 10
    WITH CHECK OPTION CONSTRAINT Sales_staff_cnst;
```

The query that defines the SALES_STAFF view references only rows in department 10. Furthermore, WITH CHECK OPTION creates the view with the constraint that INSERT and UPDATE statements issued against the view are not allowed to create or result in rows that the view cannot select.

Considering the example above, the following INSERT statement successfully inserts a row into the EMP_TAB table via the SALES_STAFF view:

```
INSERT INTO Sales_staff VALUES (7584, 'OSTER', 10);
```

However, the following INSERT statement is rolled back and returns an error because it attempts to insert a row for department number 30, which could not be selected using the SALES_STAFF view:

```
INSERT INTO Sales_staff VALUES (7591, 'WILLIAMS', 30);
```

The following statement creates a view that joins data from the Emp_tab and Dept_tab tables:

```
CREATE VIEW Division1_staff AS
    SELECT Ename, Empno, Job, Dname
    FROM Emp_tab, Dept_tab
    WHERE Emp_tab.Deptno IN (10, 30)
    AND Emp_tab.Deptno = Dept_tab.Deptno;
```

The Division1_staff view is defined by a query that joins information from the Emp_tab and Dept_tab tables. The WITH CHECK OPTION is not specified in the CREATE VIEW statement because rows cannot be inserted into or updated in a view defined with a query that contains a join that uses the WITH CHECK OPTION.

Expansion of Defining Queries at View Creation Time

In accordance with the ANSI/ISO standard, Oracle expands any wildcard in a top-level view query into a column list when a view is created and stores the resulting query in the data dictionary; any subqueries are left intact. The column names in an expanded column list are enclosed in quote marks to account for the possibility that the columns of the base object were originally entered with quotes and require them for the query to be syntactically correct.

As an example, assume that the Dept_view view is created as follows:

```
CREATE VIEW Dept_view AS SELECT * FROM scott.Dept_tab;
```

Oracle stores the defining query of the Dept_view view as

```
SELECT "DEPTNO", "DNAME", "LOC" FROM scott.Dept_tab;
```

Views created with errors do not have wildcards expanded. However, if the view is eventually compiled without errors, then wildcards in the defining query are expanded.

Creating Views with Errors

Assuming no syntax errors, a view can be created (with errors) even if the defining query of the view cannot be executed. For example, if a view is created that refers to a non-existent table or an invalid column of an existing table, or if the owner of the view does not have the required privileges, then the view can still be created and entered into the data dictionary.

You can only create a view with errors by using the FORCE option of the CREATE VIEW command:

```
CREATE FORCE VIEW AS ...;
```

When a view is created with errors, Oracle returns a message that indicates the view was created with errors. The status of such a view is left as INVALID. If conditions later change so that the query of an invalid view can be executed, then the view can be recompiled and become valid. Oracle dynamically compiles the invalid view if you attempt to use it.

Privileges Required to Create a View

To create a view, you must have been granted the following privileges:

- You must have the CREATE VIEW system privilege to create a view in your schema, or the CREATE ANY VIEW system privilege to create a view in another user's schema. These privileges can be acquired explicitly or via a role.
- The **owner** of the view must be explicitly granted the necessary privileges to access all objects referenced within the definition of the view; the owner cannot obtain the required privileges through roles. Also, the functionality of the view is dependent on the privileges of the view's owner. For example, if you (the view owner) are granted only the INSERT privilege for Scott's EMP_TAB table, then you can create a view on his EMP_TAB table, but you can only use this view to insert new rows into the EMP_TAB table.
- If the view owner intends to grant access to the view to other users, then the owner must receive the object privileges to the base objects with the GRANT OPTION or the system privileges with the ADMIN OPTION; if not, then the view owner has insufficient privileges to grant access to the view to other users.

Replacing Views

To alter the definition of a view, you must replace the view using one of the following methods:

- A view can be dropped and then re-created. When a view is dropped, all grants of corresponding view privileges are revoked from roles and users. After the view is re-created, necessary privileges must be regranted.
- A view can be replaced by redefining it with a CREATE VIEW statement that contains the OR REPLACE option. This option replaces the current definition of a view, but preserves the present security authorizations.

For example, assume that you create the SALES_STAFF view, as given in a previous example. You also grant several object privileges to roles and other users. However, now you realize that you must redefine the SALES_STAFF view to correct the department number specified in the WHERE clause of the defining query, because it should have been 30. To preserve the grants of object privileges that you have made, you can replace the current version of the SALES_STAFF view with the following statement:

```
CREATE OR REPLACE VIEW Sales_staff AS
    SELECT Empno, Ename, Deptno
    FROM Emp_tab
    WHERE Deptno = 30
    WITH CHECK OPTION CONSTRAINT Sales_staff_cnst;
```

Replacing a view has the following effects:

- Replacing a view replaces the view's definition in the data dictionary. All underlying objects referenced by the view are not affected.
- If previously defined but not included in the new view definition, then the constraint associated with the WITH CHECK OPTION for a view's definition is dropped.
- All views and PL/SQL program units dependent on a replaced view become invalid.

Privileges Required to Replace a View

To replace a view, you must have all of the privileges necessary to drop the view, as well as all of those required to create the view.

Using Views

Views can be queried in the same manner as tables. For example, to query the Division1_staff view, enter a valid SELECT statement that references the view:

```
SELECT * FROM Division1_staff;

ENAME        EMPNO       JOB             DNAME
-----------------------------------------------------
CLARK         7782       MANAGER         ACCOUNTING
KING          7839       PRESIDENT       ACCOUNTING
MILLER        7934       CLERK           ACCOUNTING
ALLEN         7499       SALESMAN        SALES
WARD          7521       SALESMAN        SALES
```

```
JAMES          7900       CLERK          SALES
TURNER         7844       SALESMAN       SALES
MARTIN         7654       SALESMAN       SALES
BLAKE          7698       MANAGER        SALES
```

With some restrictions, rows can be inserted into, updated in, or deleted from a base table using a view. The following statement inserts a new row into the EMP_TAB table using the SALES_STAFF view:

```
INSERT INTO Sales_staff
    VALUES (7954, 'OSTER', 30);
```

Restrictions on DML operations for views use the following criteria in the order listed:

1. If a view is defined by a query that contains SET or DISTINCT operators, a GROUP BY clause, or a group function, then rows cannot be inserted into, updated in, or deleted from the base tables using the view.
2. If a view is defined with WITH CHECK OPTION, then a row cannot be inserted into, or updated in, the base table (using the view), if the view cannot select the row from the base table.
3. If a NOT NULL column that does not have a DEFAULT clause is omitted from the view, then a row cannot be inserted into the base table using the view.
4. If the view was created by using an expression, such as DECODE(deptno, 10, "SALES", ...), then rows cannot be inserted into or updated in the base table using the view.

The constraint created by WITH CHECK OPTION of the SALES_STAFF view only allows rows that have a department number of 10 to be inserted into, or updated in, the EMP_TAB table. Alternatively, assume that the SALES_STAFF view is defined by the following statement (that is, excluding the DEPTNO column):

```
CREATE VIEW Sales_staff AS
    SELECT Empno, Ename
    FROM Emp_tab
    WHERE Deptno = 10
    WITH CHECK OPTION CONSTRAINT Sales_staff_cnst;
```

Considering this view definition, you can update the EMPNO or ENAME fields of existing records, but you cannot insert rows into the EMP_TAB table via the SALES_STAFF view because the view does not let you alter the DEPTNO field. If you had defined a DEFAULT value of 10 on the DEPTNO field, then you could perform inserts.

Referencing Invalid Views When a user attempts to reference an invalid view, Oracle returns an error message to the user:

```
ORA-04063: view 'view_name' has errors
```

This error message is returned when a view exists but is unusable due to errors in its query (whether it had errors when originally created or it was created successfully but became unusable later because underlying objects were altered or dropped).

Privileges Required to Use a View

To issue a query or an INSERT, UPDATE, or DELETE statement against a view, you must have the SELECT, INSERT, UPDATE, or DELETE object privilege for the view, respectively, either explicitly or via a role.

Dropping Views

Use the SQL command DROP VIEW to drop a view. For example:

```
DROP VIEW Sales_staff;
```

Privileges Required to Drop a View

You can drop any view contained in your schema. To drop a view in another user's schema, you must have the DROP ANY VIEW system privilege.

Modifying a Join View

The Oracle Server allows you, with some restrictions, to modify views that involve joins. Consider the following simple view:

```
CREATE VIEW Emp_view AS
    SELECT Ename, Empno, deptno FROM Emp_tab;
```

This view does not involve a join operation. If you issue the SQL statement:

```
UPDATE Emp_view SET Ename = 'CAESAR' WHERE Empno = 7839;
```

then the EMP_TAB base table that underlies the view changes, and employee 7839's name changes from KING to CAESAR in the EMP_TAB table.

However, if you create a view that involves a join operation, such as:

```
CREATE VIEW Emp_dept_view AS
  SELECT e.Empno, e.Ename, e.Deptno, e.Sal, d.Dname, d.Loc
    FROM Emp_tab e, Dept_tab d    /* JOIN operation */
     WHERE e.Deptno = d.Deptno
       AND d.Loc IN ('DALLAS', 'NEW YORK', 'BOSTON');
```

then there are restrictions on modifying either the EMP_TAB or the DEPT_TAB base table through this view, for example, using a statement such as:

```
UPDATE Emp_dept_view SET Ename = 'JOHNSON'
    WHERE Ename = 'SMITH';
```

A *modifiable join view* is a view that contains more than one table in the top-level FROM clause of the SELECT statement, and that does *not* contain any of the following:

- DISTINCT operator
- Aggregate functions: AVG, COUNT, GLB, MAX, MIN, STDDEV, SUM, or VARIANCE
- Set operations: UNION, UNION ALL, INTERSECT, MINUS
- GROUP BY or HAVING clauses
- START WITH or CONNECT BY clauses
- ROWNUM pseudocolumn

A further restriction on which join views are modifiable is that if a view is a join on other nested views, then the other nested views must be mergeable into the top level view.

See Also: See *Oracle8i Concepts* for more information about mergeable views.

Example Tables

The examples in this section use the EMP_TAB and DEPT_TAB tables. However, the examples work only if you explicitly define the primary and foreign keys in these tables, or define unique indexes. Here are the appropriately constrained table definitions for EMP_TAB and DEPT_TAB:

```
CREATE TABLE Dept_tab (
        Deptno   NUMBER(4) PRIMARY KEY,
        Dname    VARCHAR2(14),
        Loc      VARCHAR2(13));

CREATE TABLE Emp_tab (
        Empno    NUMBER(4) PRIMARY KEY,
        Ename    VARCHAR2(10),
        Job      varchar2(9),
        Mgr      NUMBER(4),
        Hiredate DATE,
        Sal      NUMBER(7,2),
        Comm     NUMBER(7,2),
        Deptno   NUMBER(2),
FOREIGN KEY (Deptno) REFERENCES Dept_tab(Deptno));
```

You could also omit the primary and foreign key constraints listed above, and create a UNIQUE INDEX on DEPT_TAB (DEPTNO) to make the following examples work.

Key-Preserved Tables

The concept of a *key-preserved table* is fundamental to understanding the restrictions on modifying join views. A table is key preserved if every key of the table can also be a key of the result of the join. So, a key-preserved table has its keys preserved through a join.

Note:

- It is not necessary that the key or keys of a table be selected for it to be key preserved. It is sufficient that if the key or keys were selected, then they would also be key(s) of the result of the join.
- The key-preserving property of a table does not depend on the actual data in the table. It is, rather, a property of its schema and not of the data in the table. For example, if in the EMP_TAB table there was at most one employee in each department, then DEPT_TAB.DEPTNO would be unique in the result of a join of EMP_TAB and DEPT_TAB, but DEPT_TAB would still not be a key-preserved table.

If you SELECT all rows from EMP_DEPT_VIEW defined in the "Modifying a Join View" section, then the results are:

```
EMPNO      ENAME      DEPTNO     DNAME          LOC
---------------------------------------------------------
7782       CLARK      10         ACCOUNTING     NEW YORK
7839       KING       10         ACCOUNTING     NEW YORK
7934       MILLER     10         ACCOUNTING     NEW YORK
7369       SMITH      20         RESEARCH       DALLAS
7876       ADAMS      20         RESEARCH       DALLAS
7902       FORD       20         RESEARCH       DALLAS
7788       SCOTT      20         RESEARCH       DALLAS
7566       JONES      20         RESEARCH       DALLAS
8 rows selected.
```

In this view, EMP_TAB is a key-preserved table, because EMPNO is a key of the EMP_TAB table, and also a key of the result of the join. DEPT_TAB is *not* a key-preserved table, because although DEPTNO is a key of the DEPT_TAB table, it is not a key of the join.

Rule for DML Statements on Join Views

Any UPDATE, INSERT, or DELETE statement on a join view can modify *only one underlying base table.*

UPDATE Statements

The following example shows an UPDATE statement that successfully modifies the EMP_DEPT_VIEW view:

```
UPDATE Emp_dept_view
  SET Sal = Sal * 1.10
    WHERE Deptno = 10;
```

The following UPDATE statement would be disallowed on the EMP_DEPT view:

```
UPDATE Emp_dept_view
  SET Loc = 'BOSTON'
    WHERE Ename = 'SMITH';
```

This statement fails with an ORA-01779 error ("cannot modify a column which maps to a non key-preserved table"), because it attempts to modify the underlying DEPT_TAB table, and the DEPT_TAB table is not key preserved in the EMP_DEPT view.

In general, all modifiable columns of a join view must map to columns of a key-preserved table. If the view is defined using the WITH CHECK OPTION clause, then all join columns and all columns of repeated tables are not modifiable.

So, for example, if the EMP_DEPT view were defined using WITH CHECK OPTION, then the following UPDATE statement would fail:

```
UPDATE Emp_dept_view
    SET Deptno = 10
        WHERE Ename = 'SMITH';
```

The statement fails because it is trying to update a join column.

DELETE Statements

You can delete from a join view provided there is *one and only one* key-preserved table in the join.

The following DELETE statement works on the EMP_DEPT view:

```
DELETE FROM Emp_dept_view
    WHERE Ename = 'SMITH';
```

This DELETE statement on the EMP_DEPT view is legal because it can be translated to a DELETE operation on the base EMP_TAB table, and because the EMP_TAB table is the only key-preserved table in the join.

In the following view, a DELETE operation cannot be performed on the view because both E1 and E2 are key-preserved tables:

```
CREATE VIEW emp_emp AS
    SELECT e1.Ename, e2.Empno, e1.Deptno
```

```
        FROM Emp_tab e1, Emp_tab e2
        WHERE e1.Empno = e2.Empno;
        WHERE e1.Empno = e2.Empno;
```

If a view is defined using the WITH CHECK OPTION clause and the key-preserved table is repeated, then rows cannot be deleted from such a view. For example:

```
CREATE VIEW Emp_mgr AS
    SELECT e1.Ename, e2.Ename Mname
       FROM Emp_tab e1, Emp_tab e2
            WHERE e1.mgr = e2.Empno
            WITH CHECK OPTION;
```

No deletion can be performed on this view because the view involves a self-join of the table that is key preserved.

INSERT Statements

The following INSERT statement on the EMP_DEPT view succeeds, because only one key-preserved base table is being modified (EMP_TAB), and 40 is a valid DEPTNO in the DEPT_TAB table (thus satisfying the FOREIGN KEY integrity constraint on the EMP_TAB table).

```
INSERT INTO Emp_dept (Ename, Empno, Deptno)
    VALUES ('KURODA', 9010, 40);
```

The following INSERT statement fails for the same reason: This UPDATE on the base EMP_TAB table would fail: the FOREIGN KEY integrity constraint on the EMP_TAB table is violated.

```
INSERT INTO Emp_dept (Ename, Empno, Deptno)
    VALUES ('KURODA', 9010, 77);
```

The following INSERT statement fails with an ORA-01776 error ("cannot modify more than one base table through a view").

```
INSERT INTO Emp_dept (Ename, Empno, Deptno)
    VALUES (9010, 'KURODA', 'BOSTON');
```

An INSERT cannot, implicitly or explicitly, refer to columns of a non-key-preserved table. If the join view is defined using the WITH CHECK OPTION clause, then you cannot perform an INSERT to it.

Using the UPDATABLE_COLUMNS Views

Three views you can use for modifying join views are shown in Table 3–1.

Table 3–1 UPDATABLE_COLUMNS Views

View Name	Description
USER_UPDATABLE_COLUMNS	Shows all columns in all tables and views in the user's schema that are modifiable
DBA_UPDATABLE_COLUMNS	Shows all columns in all tables and views in the DBA schema that are modifiable
ALL_UPDATABLE_VIEWS	Shows all columns in all tables and views that are modifiable

Outer Joins

Views that involve outer joins are modifiable in some cases. For example:

```
CREATE VIEW Emp_dept_oj1 AS
    SELECT Empno, Ename, e.Deptno, Dname, Loc
    FROM Emp_tab e, Dept_tab d
    WHERE e.Deptno = d.Deptno (+);
```

The statement:

```
SELECT * FROM Emp_dept_oj1;
```

Results in:

```
EMPNO   ENAME      DEPTNO  DNAME          LOC
------- ---------- ------- -------------- -------------
7369    SMITH      40      OPERATIONS     BOSTON
7499    ALLEN      30      SALES          CHICAGO
7566    JONES      20      RESEARCH       DALLAS
7654    MARTIN     30      SALES          CHICAGO
7698    BLAKE      30      SALES          CHICAGO
7782    CLARK      10      ACCOUNTING     NEW YORK
7788    SCOTT      20      RESEARCH       DALLAS
7839    KING       10      ACCOUNTING     NEW YORK
7844    TURNER     30      SALES          CHICAGO
7876    ADAMS      20      RESEARCH       DALLAS
7900    JAMES      30      SALES          CHICAGO
7902    FORD       20      RESEARCH       DALLAS
7934    MILLER     10      ACCOUNTING     NEW YORK
7521    WARD       30      SALES          CHICAGO
```

```
14 rows selected.
```

Columns in the base EMP_TAB table of EMP_DEPT_OJ1 are modifiable through the view, because EMP_TAB is a key-preserved table in the join.

The following view also contains an outer join:

```
CREATE VIEW Emp_dept_oj2 AS
SELECT e.Empno, e.Ename, e.Deptno, d.Dname, d.Loc
FROM Emp_tab e, Dept_tab d
WHERE e.Deptno (+) = d.Deptno;
```

The statement:

```
SELECT * FROM Emp_dept_oj2;
```

Results in:

```
EMPNO      ENAME      DEPTNO     DNAME          LOC
---------- ---------- --------- -------------- ----
7782       CLARK      10         ACCOUNTING     NEW YORK
7839       KING       10         ACCOUNTING     NEW YORK
7934       MILLER     10         ACCOUNTING     NEW YORK
7369       SMITH      20         RESEARCH       DALLAS
7876       ADAMS      20         RESEARCH       DALLAS
7902       FORD       20         RESEARCH       DALLAS
7788       SCOTT      20         RESEARCH       DALLAS
7566       JONES      20         RESEARCH       DALLAS
7499       ALLEN      30         SALES          CHICAGO
7698       BLAKE      30         SALES          CHICAGO
7654       MARTIN     30         SALES          CHICAGO
7900       JAMES      30         SALES          CHICAGO
7844       TURNER     30         SALES          CHICAGO
7521       WARD       30         SALES          CHICAGO
                                  OPERATIONS     BOSTON
15 rows selected.
```

In this view, EMP_TAB is no longer a key-preserved table, because the EMPNO column in the result of the join can have nulls (the last row in the SELECT above). So, UPDATE, DELETE, and INSERT operations cannot be performed on this view.

In the case of views containing an outer join on other nested views, a table is key preserved if the view or views containing the table are merged into their outer views, all the way to the top. A view which is being outer-joined is currently merged only if it is "simple." For example:

```
SELECT Col1, Col2, ... FROM T;
```

The select list of the view has no expressions, and there is no WHERE clause.

Consider the following set of views:

```
CREATE VIEW Emp_v AS
    SELECT Empno, Ename, Deptno
        FROM Emp_tab;
CREATE VIEW Emp_dept_oj1 AS
    SELECT e.*, Loc, d.Dname
        FROM Emp_v e, Dept_tab d
            WHERE e.Deptno = d.Deptno (+);
```

In these examples, EMP_V is merged into EMP_DEPT_OJ1 because EMP_V is a simple view, and so EMP_TAB is a key-preserved table. But if EMP_V is changed as follows:

```
CREATE VIEW Emp_v_2 AS
    SELECT Empno, Ename, Deptno
        FROM Emp_tab
            WHERE Sal > 1000;
```

Then, because of the presence of the WHERE clause, EMP_V_2 cannot be merged into EMP_DEPT_OJ1, and hence EMP_TAB is no longer a key-preserved table.

If you are in doubt whether a view is modifiable, then you can SELECT from the view USER_UPDATABLE_COLUMNS to see if it is. For example:

```
SELECT * FROM USER_UPDATABLE_COLUMNS WHERE TABLE_NAME = 'EMP_DEPT_VIEW';
```

This might return:

```
OWNER       TABLE_NAME      COLUMN_NAM      UPD
----------  ----------      ----------      ---
SCOTT       EMP_DEPT_V      EMPNO           NO
SCOTT       EMP_DEPT_V      ENAME           NO
SCOTT       EMP_DEPT_V      DEPTNO          NO
SCOTT       EMP_DEPT_V      DNAME           NO
SCOTT       EMP_DEPT_V      LOC             NO
5 rows selected.
```

Managing Sequences

The sequence generator generates sequential numbers. Sequence number generation is useful to generate unique primary keys for your data automatically, and to coordinate keys across multiple rows or tables.

Without sequences, sequential values can only be produced programmatically. A new primary key value can be obtained by selecting the most recently produced value and incrementing it. This method requires a lock during the transaction and causes multiple users to wait for the next value of the primary key; this waiting is known as *serialization*. If you have such constructs in your applications, then you should replace them with access to sequences. Sequences eliminate serialization and improve the concurrency of your application.

The following sections explain how to create, alter, use, and drop sequences using SQL commands.

Creating Sequences

Use the SQL command CREATE SEQUENCE to create a sequence. The following statement creates a sequence used to generate employee numbers for the EMPNO column of the EMP_TAB table:

```
CREATE SEQUENCE Emp_sequence
    INCREMENT BY 1
    START WITH 1
    NOMAXVALUE
    NOCYCLE
    CACHE 10;
```

Notice that several parameters can be specified to control the function of sequences. You can use these parameters to indicate whether the sequence is ascending or descending, the starting point of the sequence, the minimum and maximum values, and the interval between sequence values. The NOCYCLE option indicates that the sequence cannot generate more values after reaching its maximum or minimum value.

The CACHE option of the CREATE SEQUENCE command pre-allocates a set of sequence numbers and keeps them in memory so that they can be accessed faster. When the last of the sequence numbers in the cache have been used, another set of numbers is read into the cache.

See Also: For additional implications for caching sequence numbers when using the Oracle Parallel Server, see *Oracle8i Parallel Server Concepts and Administration*.

General information about caching sequence numbers is included in "Caching Sequence Numbers" on page 3-40.

Privileges Required to Create a Sequence

To create a sequence in your schema, you must have the CREATE SEQUENCE system privilege. To create a sequence in another user's schema, you must have the CREATE ANY SEQUENCE privilege.

Altering Sequences

You can change any of the parameters that define how corresponding sequence numbers are generated; however, you cannot alter a sequence to change the starting number of a sequence. To do this, the sequence must be dropped and re-created.

Use the SQL command ALTER SEQUENCE to alter a sequence. For example:

```
ALTER SEQUENCE Emp_sequence
    INCREMENT BY 10
    MAXVALUE 10000
    CYCLE
    CACHE 20;
```

Privileges Required to Alter a Sequence

To alter a sequence, your schema must contain the sequence, or you must have the ALTER ANY SEQUENCE system privilege.

Using Sequences

The following sections provide some information on how to use a sequence once it has been defined. Once defined, a sequence can be made available to many users. A sequence can be accessed and incremented by multiple users with no waiting. Oracle does not wait for a transaction that has incremented a sequence to complete before that sequence can be incremented again.

The examples outlined in the following sections show how sequences can be used in master/detail table relationships. Assume an order entry system is partially comprised of two tables, ORDERS_TAB (master table) and LINE_ITEMS_TAB (detail

table), that hold information about customer orders. A sequence named ORDER_SEQ is defined by the following statement:

```
CREATE SEQUENCE Order_seq
    START WITH 1
    INCREMENT BY 1
    NOMAXVALUE
    NOCYCLE
    CACHE 20;
```

Referencing a Sequence

A sequence is referenced in SQL statements with the NEXTVAL and CURRVAL pseudocolumns; each new sequence number is generated by a reference to the sequence's pseudocolumn NEXTVAL, while the current sequence number can be repeatedly referenced using the pseudo-column CURRVAL.

NEXTVAL and CURRVAL are not reserved words or keywords and can be used as pseudo-column names in SQL statements such as SELECTs, INSERTs, or UPDATEs.

Generating Sequence Numbers with NEXTVAL To generate and use a sequence number, reference *seq_name*.NEXTVAL. For example, assume a customer places an order. The sequence number can be referenced in a values list. For example:

```
INSERT INTO Orders_tab (Orderno, Custno)
    VALUES (Order_seq.NEXTVAL, 1032);
```

Or, the sequence number can be referenced in the SET clause of an UPDATE statement. For example:

```
UPDATE Orders_tab
    SET Orderno = Order_seq.NEXTVAL
    WHERE Orderno = 10112;
```

The sequence number can also be referenced outermost SELECT of a query or subquery. For example:

```
SELECT Order_seq.NEXTVAL FROM dual;
```

As defined, the first reference to ORDER_SEQ.NEXTVAL returns the value 1. Each subsequent statement that references ORDER_SEQ.NEXTVAL generates the next sequence number (2, 3, 4,. . .). The pseudo-column NEXTVAL can be used to generate as many new sequence numbers as necessary. However, only a single sequence number can be generated per row. In other words, if NEXTVAL is referenced more

than once in a single statement, then the first reference generates the next number, and all subsequent references in the statement return the same number.

Once a sequence number is generated, the sequence number is available only to the session that generated the number. Independent of transactions committing or rolling back, other users referencing ORDER_SEQ.NEXTVAL obtain unique values. If two users are accessing the same sequence concurrently, then the sequence numbers each user receives might have gaps because sequence numbers are also being generated by the other user.

Using Sequence Numbers with CURRVAL To use or refer to the current sequence value of your session, reference *seq_name*.CURRVAL. CURRVAL can only be used if *seq_name*.NEXTVAL has been referenced in the current user session (in the current or a previous transaction). CURRVAL can be referenced as many times as necessary, including multiple times within the same statement. The next sequence number is not generated until NEXTVAL is referenced. Continuing with the previous example, you would finish placing the customer's order by inserting the line items for the order:

```
INSERT INTO Line_items_tab (Orderno, Partno, Quantity)
    VALUES (Order_seq.CURRVAL, 20321, 3);

INSERT INTO Line_items_tab (Orderno, Partno, Quantity)
    VALUES (Order_seq.CURRVAL, 29374, 1);
```

Assuming the INSERT statement given in the previous section generated a new sequence number of 347, both rows inserted by the statements in this section insert rows with order numbers of 347.

Uses and Restrictions of NEXTVAL and CURRVAL CURRVAL and NEXTVAL can be used in the following places:

- VALUES clause of INSERT statements
- The SELECT list of a SELECT statement
- The SET clause of an UPDATE statement

CURRVAL and NEXTVAL cannot be used in these places:

- A subquery
- A view's query or snapshot's query
- A SELECT statement with the DISTINCT operator
- A SELECT statement with a GROUP BY or ORDER BY clause

- A SELECT statement that is combined with another SELECT statement with the UNION, INTERSECT, or MINUS set operator
- The WHERE clause of a SELECT statement
- DEFAULT value of a column in a CREATE TABLE or ALTER TABLE statement
- The condition of a CHECK constraint

Caching Sequence Numbers

Sequence numbers can be kept in the sequence cache in the System Global Area (SGA). Sequence numbers can be accessed more quickly in the sequence cache than they can be read from disk.

The sequence cache consists of entries. Each entry can hold many sequence numbers for a single sequence.

Follow these guidelines for fast access to all sequence numbers:

- Be sure the sequence cache can hold all the sequences used concurrently by your applications.
- Increase the number of values for each sequence held in the sequence cache.

The Number of Entries in the Sequence Cache When an application accesses a sequence in the sequence cache, the sequence numbers are read quickly. However, if an application accesses a sequence that is not in the cache, then the sequence must be read from disk to the cache before the sequence numbers are used.

If your applications use many sequences concurrently, then your sequence cache might not be large enough to hold all the sequences. In this case, access to sequence numbers might often require disk reads. For fast access to all sequences, be sure your cache has enough entries to hold all the sequences used concurrently by your applications.

The number of entries in the sequence cache is determined by the initialization parameter SEQUENCE_CACHE_ENTRIES. The default value for this parameter is 10 entries. Oracle creates and uses sequences internally for auditing, grants of system privileges, grants of object privileges, profiles, debugging stored procedures, and labels. Be sure your sequence cache has enough entries to hold these sequences as well as sequences used by your applications.

If the value for your SEQUENCE_CACHE_ENTRIES parameter is too low, then it is possible to skip sequence values. For example, assume that this parameter is set to 4, and that you currently have four cached sequences. If you create a fifth sequence, then it will replace the least recently used sequence in the cache. All of the

remaining values in this displaced sequence are lost. In other words, if the displaced sequence originally held 10 cached sequence values, and only one had been used, then nine would be lost when the sequence was displaced.

The Number of Values in Each Sequence Cache Entry When a sequence is read into the sequence cache, sequence values are generated and stored in a cache entry. These values can then be accessed quickly. The number of sequence values stored in the cache is determined by the CACHE parameter in the CREATE SEQUENCE statement. The default value for this parameter is 20.

This CREATE SEQUENCE statement creates the SEQ2 sequence so that 50 values of the sequence are stored in the SEQUENCE cache:

```
CREATE SEQUENCE Seq2
    CACHE 50;
```

The first 50 values of SEQ2 can then be read from the cache. When the 51st value is accessed, the next 50 values will be read from disk.

Choosing a high value for CACHE allows you to access more successive sequence numbers with fewer reads from disk to the sequence cache. However, if there is an instance failure, then all sequence values in the cache are lost. Cached sequence numbers also could be skipped after an export and import if transactions continue to access the sequence numbers while the export is running.

If you use the NOCACHE option in the CREATE SEQUENCE statement, then the values of the sequence are not stored in the sequence cache. In this case, every access to the sequence requires a disk read. Such disk reads slow access to the sequence. This CREATE SEQUENCE statement creates the SEQ3 sequence so that its values are never stored in the cache:

```
CREATE SEQUENCE Seq3
    NOCACHE;
```

Privileges Required to Use a Sequence

To use a sequence, your schema must contain the sequence or you must have been granted the SELECT object privilege for another user's sequence.

Dropping Sequences

To drop a sequence, use the SQL command DROP SEQUENCE. For example, the following statement drops the ORDER_SEQ sequence:

```
DROP SEQUENCE Order_seq;
```

When you drop a sequence, its definition is removed from the data dictionary. Any synonyms for the sequence remain, but return an error when referenced.

Privileges Required to Drop a Sequence

You can drop any sequence in your schema. To drop a sequence in another schema, you must have the DROP ANY SEQUENCE system privilege.

Managing Synonyms

A synonym is an alias for a table, view, snapshot, sequence, procedure, function, or package. The following sections explain how to create, use, and drop synonyms using SQL commands.

Creating Synonyms

Use the SQL command CREATE SYNONYM to create a synonym. The following statement creates a public synonym named PUBLIC_EMP on the EMP_TAB table contained in the schema of JWARD:

```
CREATE PUBLIC SYNONYM Public_emp FOR jward.Emp_tab;
```

Privileges Required to Create a Synonym

You must have the CREATE SYNONYM system privilege to create a private synonym in your schema, or the CREATE ANY SYNONYM system privilege to create a private synonym in another user's schema. To create a public synonym, you must have the CREATE PUBLIC SYNONYM system privilege.

Using Synonyms

A synonym can be referenced in a SQL statement the same way that the underlying object of the synonym can be referenced. For example, if a synonym named EMP_TAB refers to a table or view, then the following statement is valid:

```
INSERT INTO Emp_tab (Empno, Ename, Job)
    VALUES (Emp_sequence.NEXTVAL, 'SMITH', 'CLERK');
```

If the synonym named FIRE_EMP refers to a stand-alone procedure or package procedure, then you could execute it in SQL*Plus or Enterprise Manager with the command

```
EXECUTE Fire_emp(7344);
```

Privileges Required to Use a Synonym

You can successfully use any private synonym contained in your schema or any public synonym, assuming that you have the necessary privileges to access the underlying object, either explicitly, from an enabled role, or from PUBLIC. You can also reference any private synonym contained in another schema if you have been granted the necessary object privileges for the private synonym. You can only reference another user's synonym using the object privileges that you have been

granted. For example, if you have the SELECT privilege for the JWARD.EMP_TAB synonym, then you can query the JWARD.EMP_TAB synonym, but you cannot insert rows using the synonym for JWARD.EMP_TAB.

Dropping Synonyms

To drop a synonym, use the SQL command DROP SYNONYM. To drop a private synonym, omit the PUBLIC keyword; to drop a public synonym, include the PUBLIC keyword. The following statement drops the private synonym named EMP_TAB:

```
DROP SYNONYM Emp_tab;
```

The following statement drops the public synonym named PUBLIC_EMP:

```
DROP PUBLIC SYNONYM Public_emp;
```

When you drop a synonym, its definition is removed from the data dictionary. All objects that reference a dropped synonym remain (for example, views and procedures) but become invalid.

Privileges Required to Drop a Synonym

You can drop any private synonym in your own schema. To drop a private synonym in another user's schema, you must have the DROP ANY SYNONYM system privilege. To drop a public synonym, you must have the DROP PUBLIC SYNONYM system privilege.

Miscellaneous Management Topics for Schema Objects

The following sections explain miscellaneous topics regarding the management of the various schema objects discussed in this chapter.

Creating Multiple Tables and Views in One Operation

You can create several tables and views and grant privileges in one operation using the SQL command CREATE SCHEMA. The CREATE SCHEMA command is useful if you want to guarantee the creation of several tables and views and grants in one operation; if an individual table or view creation fails or a grant fails, then the entire statement is rolled back, and none of the objects are created or the privileges granted.

For example, the following statement creates two tables and a view that joins data from the two tables:

```
CREATE SCHEMA AUTHORIZATION scott
    CREATE VIEW Sales_staff AS
        SELECT Empno, Ename, Sal, Comm
        FROM Emp_tab
        WHERE Deptno = 30  WITH CHECK OPTION CONSTRAINT
                           Sales_staff_cnst

CREATE TABLE Dept_tab (
    Deptno      NUMBER(3) PRIMARY KEY,
    Dname       VARCHAR2(15),
    Loc         VARCHAR2(25))
CREATE TABLE Emp_tab (
    Empno       NUMBER(5) PRIMARY KEY,
    Ename       VARCHAR2(15) NOT NULL,
    Job         VARCHAR2(10),
    Mgr         NUMBER(5),
    Hiredate    DATE DEFAULT (sysdate),
    Sal         NUMBER(7,2),
    Comm        NUMBER(7,2),
```

```
    Deptno      NUMBER(3) NOT NULL
                CONSTRAINT Dept_fkey REFERENCES Dept_tab(Deptno))

GRANT SELECT ON Sales_staff TO human_resources;
```

The CREATE SCHEMA command does not support Oracle extensions to the ANSI CREATE TABLE and CREATE VIEW commands (for example, the STORAGE clause).

Privileges Required to Create Multiple Schema Objects

To create schema objects, such as multiple tables, using the CREATE SCHEMA command, you must have the required privileges for any included operation.

Naming Schema Objects

You should decide when you want to use partial and complete global object names in the definition of views, synonyms, and procedures. Keep in mind that database names should be stable, and databases should not be unnecessarily moved within a network.

In a distributed database system, each database should have a unique global name. The global name is composed of the database name and the network domain that contains the database. Each schema object in the database then has a global object name consisting of the schema object name and the global database name.

Because Oracle ensures that the schema object name is unique within a database, you can ensure that it is unique across all databases by assigning unique global database names. You should coordinate with your database administrator on this task, because it is usually the DBA who is responsible for assigning database names.

Name Resolution in SQL Statements

An object name takes the following form:

[*schema*.]*name*[@*database*]

Some examples include:

```
Emp_tab
Scott.Emp_tab
Scott.Emp_tab@Personnel
```

A session is established when a user logs onto a database. Object names are resolved relative to the current user session. The username of the current user is the

default schema. The database to which the user has directly logged-on is the default database.

Oracle has separate namespaces for different classes of objects. All objects in the same namespace must have distinct names, but two objects in different namespaces can have the same name. Tables, views, snapshots, sequences, synonyms, procedures, functions, and packages are in a single namespace. Triggers, indexes, and clusters each have their own individual namespace. For example, there can be a table, trigger, and index all named SCOTT.EMP_TAB.

Based on the context of an object name, Oracle searches the appropriate namespace when resolving the name to an object. For example, in the following statement:

```
DROP CLUSTER Test
```

Oracle looks up TEST in the cluster namespace.

Rather than supplying an object name directly, you can also refer to an object using a synonym. A private synonym name has the same syntax as an ordinary object name. A public synonym is implicitly in the PUBLIC schema, but users cannot explicitly qualify a synonym with the schema PUBLIC.

Synonyms can only be used to reference objects in the same namespace as tables. Due to the possibility of synonyms, the following rules are used to resolve a name in a context that requires an object in the table namespace:

1. Look up the name in the table namespace.
2. If the name resolves to an object that is not a synonym, then no further work is necessary.
3. If the name resolves to a private synonym, then replace the name with the definition of the synonym and return to step 1.
4. If the name was originally qualified with a schema, then return an error; otherwise, check if the name is a public synonym.
5. If the name is not a public synonym, return an error; otherwise, then replace the name with the definition of the public synonym and return to step 1.

When global object names are used in a distributed database (either explicitly or indirectly within a synonym), the local Oracle session resolves the reference as is locally required (for example, resolving a synonym to a remote table's global object name). After the partially resolved statement is shipped to the remote database, the remote Oracle session completes the resolution of the object as above.

See Also: See *Oracle8i Concepts* for more information about name resolution in a distributed database.

Renaming Schema Objects

If necessary, you can rename some schema objects using two different methods: drop and re-create the object, or rename the object using the SQL command RENAME.

Note: If you drop an object and re-create it, then all privilege grants for the object are lost when the object is dropped. Privileges must be granted again when the object is re-created.

If you use the RENAME command to rename a table, view, sequence, or a private synonym of a table, view, or sequence, then grants made for the object are carried forward for the new name, and the next statement renames the SALES_STAFF view:

```
RENAME Sales_staff TO Dept_30;
```

You cannot rename a stored PL/SQL program unit, public synonym, index, or cluster. To rename such an object, you must drop and re-create it.

Renaming a schema object has the following effects:

- All views and PL/SQL program units dependent on a renamed object become invalid (must be recompiled before next use).
- All synonyms for a renamed object return an error when used.

Privileges Required to Rename an Object

To rename an object, you must be the owner of the object.

Renaming the Schema

The following statement sets the current schema of the session to the schema name given in the statement.

```
ALTER SESSION SET CURRENT_SCHEMA = <schema name>
```

Any subsequent SQL statements will use this schema name for the schema qualifier when the qualifier is missing. Note that the session still has only the privileges of

the current user and does not acquire any extra privileges by the above ALTER SESSION statement.

For example:

```
CONNECT scott/tiger
ALTER SESSION SET CURRENT_SCHEMA = joe;
SELECT * FROM emp_tab;
```

Since emp_tab is not schema-qualified, the table name is resolved under schema joe. But if scott does not have select privilege on table joe.emp_tab, then scott cannot execute the SELECT statement.

Listing Information about Schema Objects

The data dictionary provides many views that provide information about schema objects. The following is a summary of the views associated with schema objects:

- ALL_OBJECTS, USER_OBJECTS
- ALL_CATALOG, USER_CATALOG
- ALL_TABLES, USER_TABLES
- ALL_TAB_COLUMNS, USER_TAB_COLUMNS
- ALL_TAB_COMMENTS, USER_TAB_COMMENTS
- ALL_COL_COMMENTS, USER_COL_COMMENTS
- ALL VIEWS, USER_VIEWS
- ALL_INDEXES, USER_INDEXES
- ALL_IND_COLUMNS, USER_IND_COLUMNS
- USER_CLUSTERS
- USER_CLU_COLUMNS
- ALL_SEQUENCES, USER_SEQUENCES
- ALL_SYNONYMS, USER_SYNONYMS
- ALL_DEPENDENCIES, USER_DEPENDENCIES

Example 1: Listing Different Schema Objects by Type The following query lists all of the objects owned by the user issuing the query:

```
SELECT Object_name, Object_type FROM User_objects;
```

The query above might return results similar to the following:

```
OBJECT_NAME                    OBJECT_TYPE
------------------------------ ------------------
EMP_DEPT                       CLUSTER
EMP_TAB                        TABLE
DEPT_TAB                       TABLE
EMP_DEPT_INDEX                 INDEX
PUBLIC_EMP                     SYNONYM
EMP_MGR                        VIEW
```

Example 2: Listing Column Information Column information, such as name, datatype, length, precision, scale, and default data values, can be listed using one of the views ending with the _COLUMNS suffix. For example, the following query lists all of the default column values for the EMP_TAB and DEPT_TAB tables:

```
SELECT Table_name, Column_name, Data_default
    FROM User_tab_columns
    WHERE Table_name = 'DEPT_TAB' OR Table_name = 'EMP_TAB';
```

Considering the example statements at the beginning of this section, a display similar to the one below is displayed:

```
TABLE_NAME  COLUMN_NAME     DATA_DEFAULT
----------  --------------- --------------------
DEPT_TAB    DEPTNO
DEPT_TAB    DNAME
DEPT_TAB    LOC             ('NEW YORK')
EMP_TAB     EMPNO
EMP_TAB     ENAME
EMP_TAB     JOB
EMP_TAB     MGR
EMP_TAB     HIREDATE        (sysdate)
EMP_TAB     SAL
EMP_TAB     COMM
EMP_TAB     DEPTNO
```

Note: Not all columns have a user-specified default. These columns assume NULL when rows that do not specify values for these columns are inserted.

Example 3: Listing Dependencies of Views and Synonyms When you create a view or a synonym, the view or synonym is based on its underlying base object. The _DEPENDENCIES data dictionary views can be used to reveal the dependencies for a view and the _SYNONYMS data dictionary views can be used to list the base object of a synonym. For example, the following query lists the base objects for the synonyms created by the user JWARD:

```
SELECT Table_owner, Table_name
    FROM All_synonyms
    WHERE Owner = 'JWARD';
```

This query could return information similar to the following:

```
TABLE_OWNER                    TABLE_NAME
------------------------------ ------------
SCOTT                          DEPT_TAB
SCOTT                          EMP_TAB
```

4

Selecting a Datatype

This chapter discusses how to use Oracle *built-in* datatypes in applications. Topics include:

- Oracle Built-In Datatypes
- Trusted Oracle MLSLABEL Datatype
- ANSI/ISO, DB2, and SQL/DS Datatypes
- Data Conversion

> **See Also:** For information about *user-defined* datatypes, refer to *Oracle8i Concepts* and to Chapter 16, "User-Defined Datatypes" in this manual.

Oracle Built-In Datatypes

A datatype associates a fixed set of properties with the values that can be used in a column of a table or in an argument of a procedure or function. These properties cause Oracle to treat values of one datatype differently from values of another datatype. For example, Oracle can add values of NUMBER datatype, but not values of RAW datatype.

Oracle supplies the following built-in datatypes:

- Character datatypes
  - CHAR
  - NCHAR
  - VARCHAR2 and VARCHAR
  - NVARCHAR2
  - CLOB
  - NCLOB
  - LONG
- NUMBER datatype
- DATE datatype
- Binary datatypes
  - BLOB
  - BFILE
  - RAW
  - LONG RAW

Another datatype, ROWID, is used for values in the ROWID pseudocolumn, which represents the unique address of each row in a table.

> **See Also:** See *Oracle Call Interface Programmer's Guide* for general descriptions of these datatypes, and see *Oracle8i Application Developer's Guide - Large Objects (LOBs)* for information about the LOB datatypes.

Table 4–1 summarizes the information about each Oracle built-in datatype.

Table 4–1 Summary of Oracle Built-In Datatypes

Datatype	Description	Column Length and Default
CHAR (*size*)	Fixed-length character data of length *size* bytes	Fixed for every row in the table (with trailing blanks); maximum size is 2000 bytes per row, default size is 1 byte per row. Consider the character set (one-byte or multibyte) before setting *size.*
VARCHAR2 (*size*)	Variable-length character data	Variable for each row, up to 4000 bytes per row: Consider the character set (one-byte or multibyte) before setting *size:* A maximum *size* must be specified.
NCHAR (*size*)	Fixed-length character data of length *size* characters or bytes, depending on the national character set	Fixed for every row in the table (with trailing blanks). Column *size* is the number of characters for a fixed-width national character set or the number of bytes for a varying-width national character set. Maximum *size* is determined by the number of bytes required to store one character, with an upper limit of 2000 bytes per row. Default is 1 character or 1 byte, depending on the character set.
NVARCHAR2 (*size*)	Variable-length character data of length *size* characters or bytes, depending on national character set: A maximum *size* must be specified	Variable for each row. Column *size* is the number of characters for a fixed-width national character set or the number of bytes for a varying-width national character set. Maximum *size* is determined by the number of bytes required to store one character, with an upper limit of 4000 bytes per row. Default is 1 character or 1 byte, depending on the character set.
CLOB	Single-byte character data	Up to 2^32 - 1 bytes, or 4 gigabytes.

Table 4–1 Summary of Oracle Built-In Datatypes (Cont.)

NCLOB	Single-byte or fixed-length multibyte national character set (NCHAR) data	Up to 2^32 - 1 bytes, or 4 gigabytes.
LONG	Variable-length character data	Variable for each row in the table, up to 2^31 - 1 bytes, or 2 gigabytes, per row. Provided for backward compatibility.
NUMBER (p, s)	Variable-length numeric data.: Maximum precision *p* and / or scale *s* is 38	Variable for each row. The maximum space required for a given column is 21 bytes per row.
DATE	Fixed-length date and time data, ranging from Jan. 1, 4712 B.C.E. to Dec. 31, 4712 C.E.	Fixed at 7 bytes for each row in the table. Default format is a string (such as DD-MON-YY) specified by NLS_DATE_FORMAT parameter.
BLOB	Unstructured binary data	Up to 2^32 - 1 bytes, or 4 gigabytes.
BFILE	Binary data stored in an external file	Up to 2^32 - 1 bytes, or 4 gigabytes.
RAW (size)	Variable-length raw binary data	Variable for each row in the table, up to 2000 bytes per row. A maximum *size* must be specified. Provided for backward compatibility.
LONG RAW	Variable-length raw binary data	Variable for each row in the table, up to 2^31 - 1 bytes, or 2 gigabytes, per row. Provided for backward compatibility.
ROWID	Binary data representing row addresses	Fixed at 10 bytes (extended ROWID) or 6 bytes (restricted ROWID) for each row in the table.
MLSLABEL	Trusted Oracle datatype	See the *Trusted Oracle* documentation.

Using Character Datatypes

Use the character datatypes to store alphanumeric data.

- CHAR and NCHAR datatypes store fixed-length character strings.
- VARCHAR2 and NVARCHAR2 datatypes store variable-length character strings. (The VARCHAR datatype is synonymous with the VARCHAR2 datatype.)
- CLOB and NCLOB datatypes store single-byte and multibyte character strings of up to four gigabytes.

  See Also: *Oracle8i Application Developer's Guide - Large Objects (LOBs)*

- The LONG datatype stores variable-length character strings containing up to two gigabytes, but with many restrictions.

  See Also: "Restrictions on LONG and LONG RAW Data"

  This datatype is provided for backward compatibility with existing applications; in general, new applications should use CLOB and NCLOB datatypes to store large amounts of character data.

When deciding which datatype to use for a column that will store alphanumeric data in a table, consider the following points of distinction:

Space Usage

- To store data more efficiently, use the VARCHAR2 datatype. The CHAR datatype blank-pads and stores trailing blanks up to a fixed column length for all column values, while the VARCHAR2 datatype does not blank-pad or store trailing blanks for column values.

Comparison Semantics

- Use the CHAR datatype when you require ANSI compatibility in comparison semantics (when trailing blanks are not important in string comparisons). Use the VARCHAR2 when trailing blanks are important in string comparisons.

Future Compatibility

- The CHAR and VARCHAR2 datatypes are and will always be fully supported. At this time, the VARCHAR datatype automatically corresponds to the VARCHAR2 datatype and is reserved for future use.

CHAR, VARCHAR2, and LONG data is automatically converted from the database character set to the character set defined for the user session by the NLS_LANGUAGE parameter, where these are different.

Column Lengths for Single-Byte and Multibyte Character Sets

The lengths of CHAR and VARCHAR2 columns are specified in bytes rather than characters, and are constrained as such. The lengths of NCHAR and NVARCHAR2 columns are specified either in bytes or in characters, depending on the national character set being used.

When using a multibyte database character encoding scheme, consider carefully the space required for tables with character columns. If the database character encoding scheme is single-byte, then the number of bytes and the number of characters in a column is the same. If it is multibyte, then there generally is no such correspondence. A character might consist of one or more bytes depending upon the specific multibyte encoding scheme, and whether shift-in/shift-out control codes are present.

> **See Also:** *Oracle8i Reference* for information about National Language Support features of Oracle and support for different character encoding schemes.

Comparison Semantics

Oracle compares CHAR and NCHAR values using *blank-padded comparison semantics*. If two values have different lengths, then Oracle adds blanks at the end of the shorter value, until the two values are the same length. Oracle then compares the values character-by-character up to the first character that differs. The value with the greater character in the first differing position is considered greater. Two values that differ only in the number of trailing blanks are considered equal.

Oracle compares VARCHAR2 and NVARCHAR2 values using *non-padded comparison semantics*. Two values are considered equal only if they have the same characters and are of equal length. Oracle compares the values character-by-character up to the first character that differs. The value with the greater character in that position is considered greater.

Because Oracle blank-pads values stored in CHAR columns but not in VARCHAR2 columns, a value stored in a VARCHAR2 column may take up less space than if it were stored in a CHAR column. For this reason, a full table scan on a large table containing VARCHAR2 columns may read fewer data blocks than a full table scan on a table containing the same data stored in CHAR columns. If your application often performs full table scans on large tables containing character data, then you might

be able to improve performance by storing this data in VARCHAR2 columns rather than in CHAR columns.

However, performance is not the only factor to consider when deciding which of these datatypes to use. Oracle uses different semantics to compare values of each datatype. You might choose one datatype over the other if your application is sensitive to the differences between these semantics. For example, if you want Oracle to ignore trailing blanks when comparing character values, then you must store these values in CHAR columns.

> **See Also:** For more information on comparison semantics for these datatypes, see the *Oracle8i Reference*.

Using the NUMBER Datatype

Use the NUMBER datatype to store real numbers in a fixed-point or floating-point format. Numbers using this datatype are guaranteed to be portable among different Oracle platforms, and offer up to 38 decimal digits of precision. You can store positive and negative numbers of magnitude 1 x 10^-130 to 9.99...x10^125, as well as zero, in a NUMBER column.

For numeric columns you can specify the column as a floating-point number:

```
Column_name NUMBER
```

Or, you can specify a precision (total number of digits) and scale (number of digits to right of decimal point):

```
Column_name NUMBER (<precision>, <scale>)
```

Although not required, specifying the precision and scale for numeric fields provides extra integrity checking on input. If a precision is not specified, then the column stores values as given. Table 3–2 shows examples of how data would be stored using different scale factors.

Table 4–2 How Scale Factors Affect Numeric Data Storage

Input Data	Stored As	Specified As
7,456,123.89	NUMBER	7456123.89
7,456,123.89	NUMBER (9)	7456124
7,456,123.89	NUMBER (9,2)	7456123.89
7,456,123.89	NUMBER (9,1)	7456123.9

Table 4–2 How Scale Factors Affect Numeric Data Storage

Input Data	Stored As	Specified As
7,456,123.89	NUMBER (6)	(not accepted, exceeds precision)
7,456,123.89	NUMBER (7, -2)	7456100

> **See Also:** For information about the internal format for the NUMBER datatype, see *Oracle8i Concepts*.

Using the DATE Datatype

Use the DATE datatype to store point-in-time values (dates and times) in a table. The DATE datatype stores the century, year, month, day, hours, minutes, and seconds.

Oracle uses its own internal format to store dates. Date data is stored in fixed-length fields of seven bytes each, corresponding to century, year, month, day, hour, minute, and second.

> **See Also:** See the *Oracle Call Interface Programmer's Guide* for a complete description of the Oracle internal date format.

Date Format

For input and output of dates, the standard Oracle default date format is DD-MON-YY. For example:

```
'13-NOV-92'
```

To change this default date format on an instance-wide basis, use the NLS_DATE_FORMAT parameter. To change the format during a session, use the ALTER SESSION statement. To enter dates that are not in the current default date format, use the TO_DATE function with a format mask. For example:

```
TO_DATE ('November 13, 1992', 'MONTH DD, YYYY')
```

> **See Also:** Oracle Julian dates might not be compatible with Julian dates generated by other date algorithms. For information about Julian dates, see *Oracle8i Concepts*.

If the date format DD-MON-YY is used, then YY indicates the year in the 20th century (for example, 31-DEC-92 is December 31, 1992). If you want to indicate years in any

century other than the 20th century, then use a different format mask, as shown above.

Time Format

Time is stored in 24-hour format#HH:MM:SS. By default, the time in a date field is 12:00:00 A.M. (midnight) if no time portion is entered. In a time-only entry, the date portion defaults to the first day of the current month. To enter the time portion of a date, use the TO_DATE function with a format mask indicating the time portion, as in:

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE TABLE Birthdays_tab (Bname VARCHAR2(20),Bday DATE)
```

```
INSERT INTO Birthdays_tab (bname, bday) VALUES
    ('ANNIE',TO_DATE('13-NOV-92 10:56 A.M.','DD-MON-YY HH:MI A.M.'));
```

To compare dates that have time data, use the SQL function TRUNC if you want to ignore the time component. Use the SQL function SYSDATE to return the system date and time. The FIXED_DATE initialization parameter allows you to set SYSDATE to a constant; this can be useful for testing.

Establishing Year 2000 Compliance

An application must satisfy the following criteria to meet the requirements for Year 2000 (Y2K) compliance:

- Process date information before, during, and after 1st January 2000 without error. This entails accepting date input, providing date output, storing date information and performing calculation on dates or portions of dates.
- Provide services as published in its documentation before, during and after 1st January 2000 without changes in operation resulting from the advent of the new century.
- Respond to two digit date input in a way that resolves ambiguity as to the century in a clearly defined manner.
- Manage the leap year occurring in the year 2000 according to the quad-centennial rule.

These criteria are a superset of the Year 2000 conformance requirements set out by the British Standards Institute in DISC PD-2000-1 A Definition of Year 2000 Conformity Requirements.

You can warrant your application as Y2K compliant only if you have validated its conformance at all three of the following system levels:

- Hardware
- System software, including databases, transaction processors and operating systems
- Application software, from third parties or developed in-house

Oracle Server Year 2000 Compliance

The Oracle Server is Year 2000 compliant. No operational problems are expected with the Oracle Server, networking and system management products. Oracle's Development Organization has conducted tests of various Year 2000 operational scenarios to verify that there is no impact to users at the turn of the century. These scenarios included tests of replication, point-in-time recovery, distributed transactions. System management and networking features across time zones / datelines / centuries have also been tested.

Please note that Oracle's Year 2000 product compliance does not eliminate the need for you to test your own applications. Most importantly, your application software has to be tested on the Oracle Server to ensure that operations having to do with the year 2000 perform as promised. This test is critical even if the application software is certified to be Year 2000 compliant because there are no universal protocol definitions that can guarantee conformance without such testing.

Centuries and the Year 2000

Oracle stores year data with the century information. For example, the Oracle database stores 1996 or 2001, and not just 96 or 01. The DATE datatype always stores a four-digit year internally, and all other dates stored internally in the database have four digit years. Oracle utilities such as import, export, and recovery also deal properly with four-digit years.

Applications that use the Oracle RDBMS (Oracle7 and Oracle8 Server) and exploit the DATE data type (for date and/or date with time values) need have no concerns about their stored data when the year 2000 approaches. The Oracle7 and Oracle8 Server DATE data type stores date and time data to a precision that includes a four digit year and a time component down to seconds (typically 'YYYY:MM:DD:HH24:MI:SS')

However, some applications might be written with an assumption about the year (such as assuming that everything is 19xx). The application might hand over a two-digit year to the database, and the procedures that Oracle uses for determining the century could be different from what the programmer expects (see "Programming Hints and Tips" on page 4-14). For this reason, you should review and test your code with regard to the Year 2000.

The 'RR' Date Format

The RR date format element of the TO_DATE and TO_CHAR functions allows a database site to default the century to different values depending on the two-digit year, so that years 50 to 99 default to 19*xx* and years 00 to 49 default to 20*xx*. Therefore, regardless of the current century at the time the data is entered, the 'RR' format will ensure that the year stored in the database is as follows:

- If the current year is in the second half of the century (50 - 99), and a two-digit year between '00' and '49' is entered, this will be stored as a 'next century' year. For example, '02' entered in 1996 will be stored as '2002'.
- If the current year is in the second half of the century (50 - 99), and a two-digit year between '50' and '99' is entered, this will be stored as a 'current century' year. For example, '97' entered in 1996 will be stored as '1997'.
- If the current year is in the first half of the century (00 - 49), and a two-digit year between '00' and '49' is entered, this will be stored as a 'current century' year. For example, '02' entered in 2001 will be stored as '2002'.
- If the current year is in the first half of the century (00 - 49), and a two-digit year between '50' and '99' is entered, this will be stored as a 'previous century' year. For example, '97' entered in 2001 will be stored as '1997'.

The 'RR' date format is available for inserting and updating DATE data in the database. It is not required for retrieval or query of data already stored in the database as Oracle has always stored the YEAR component of a date in its four-digit form.

Here is an example of the RR usage:

```
INSERT INTO emp (empno, deptno,hiredate) VALUES
   (9999, 20, TO_DATE('01-jan-03', 'DD-MON-RR'));

 INSERT INTO emp (empno, deptno,hiredate) VALUES
    (8888, 20, TO_DATE('01-jan-67',  'DD-MON-RR'));

SELECT empno, deptno,
   TO_CHAR(hiredate, 'DD-MON-YYYY') hiredate
```

```
FROM emp;
```

This produces the following data:

```
EMPNO      DEPTNO     HIREDATE
---------  ---------  -----------------
8888             20       01-JAN-1967
9999             20       01-JAN-2003
```

The 'CC' Date Format

The CC date format element of the TO_CHAR function sets the century value to one greater than the first two digits of a four-digit year (for example, '20' from '1900'). For years that are a multiple of 100, this is not the true century. Strictly speaking, the century of '1900' is not the twentieth century (which began in 1901) but rather the nineteenth century.

The following workaround computes the correct century for any Common Era (CE, formerly known as AD) date. If *userdate* is a CE date for which you want the true century, use the following expression:

```
SELECT DECODE (TO_CHAR (Hiredate, 'YY'),
    '00', TO_CHAR (Hiredate - 366, 'CC'),
    TO_CHAR (Hiredate, 'CC'))  FROM Emp_tab;
```

This expression works as follows: Get the last two digits of the year. If it is '00', then it is a year in which the Oracle century is one year too large, and compute a date in the preceding year (whose Oracle century is the desired true century). Otherwise, use the Oracle century.

> **See Also:** For more information about date format codes, see *Oracle8 SQL Reference*.

Storing Dates in Character Data Types

Where applications store date values in CHAR or VARCHAR2 datatypes, and the century information is not maintained, you will need to modify the application to include routines which ensure that such dates are treated appropriately when affected by the change in century. You can do this by changing the strings to maintain century information or, with certain constraints, by using the 'RR' date format when interpreting the string as a date.

If you are creating a new application, or if you are modifying an application to ensure that dates stored as character strings are Year 2000 compliant, we advise that

you convert dates to use the Oracle DATE data type. If this is not feasible, store the dates in a form which is language and format independent, and which handles full years. For example, utilize 'SYYYY/MM/DD' plus the time element as 'HH24:MI:SS' if necessary. Note that dates stored in this form must be converted to the correct external format whenever they are displayed or received from users or other programs.

The format 'SYYYY/MM/DD HH24:MI:SS' has the following advantages:

- It is language-independent in that the months are numeric.
- It contains the full four-digit year so centuries are unambiguous.
- The time is represented fully. Since the most significant elements occur first, character-based sort operations will process the dates correctly.

The "S" format element prefixes BC dates with "-".

Viewing Date Settings

The following views will enable you to verify what your settings are:

- V$NLS_DATABASE_PARAMETERS — shows instance wide NLS parameters whether explicitly declared in the INIT.ORA or defaulting.
- NLS_SESSION_PARAMETERS — shows current session values which may have been been changed by means of ALTER SESSION

A format model is a character that describes the format of DATE or NUMBER data stored in a character string. You may use the format model as an argument of the TO_CHAR or TO_DATE function for one of the following:

- To specify the format for Oracle to use in returning a value from the database.
- To specify the format for a value you have specified for Oracle to store in the database.

Please note that the format does not change the internal representation of the value in the database.

Altering Date Settings

You may set the date format in your environment or as the default for the entire database. If you set this in your environment it will override the setting in the initialization parameter.

- To change the default date format for the entire database, change INIT.ORA to include the following

  ```
  NLS_DATE_FORMAT = DD-MON-RR
  ```

- To change the date format for the session, issue the following SQL command:

  ```
  ALTER SESSION SET NLS_DATE_FORMAT = 'DD-MON-RR'
  ```

  Caution: Note that changing this parameter at the database level will change all existing date fields as described above. We suggest you make changes at the session level unless all the users and all currently running applications process dates in the range 1950-2049.

Programming Hints and Tips

In this section we describe some common programming problems around Y2K compliance. These problems may seem to derive from incorrect Year 2000 processing by the database engine, but on closer inspection are seen to arise from incorrect use of Oracle technology.

Example 1

Your application may have defined the year of a date using a column of CHAR(2) or NUMBER(2) in order to save disk space. This can lead to unpredictable results when 20xx dates are mixed with 19xx dates. To resolve this, modify your application to use the full 4-digit year.

Example 2

You application may be designed to store a 4-digit year, but the code may allow for the incorrect storage of 2-digit year rows with the 4-digit year rows. This will lead to unpredictable results for queries by date if the date columns contains dates earlier than 1900. To deal with this problem, have your application check for rows which contain dates earlier than 1900, and then adjust for this.

Example 3

Examine your applications to determine if it processes dates prior to 1950 or later than 2049, and store the year as 2-digits. If both conditions are met, your application should not use the 'RR' format but should instead expand the 2 digit year 'YY ' into a for digit year 'YYYY', and store the 4 digit number in the database.

Example 4

The following unusual error helps illuminate the interaction between NLS_DATE_FORMAT and the Oracle 'RR' format mask. The following is a syntactically correct statement but contains a logical flaw:

```
SELECT TO_CHAR(TO_DATE(LAST_DAY('01-FEB-00'),'DD-MON-RR'),'MM/DD/RRRR')
FROM DUAL;
```

The above query will return 02/28/2000. This is consistent with the defined behavior of the 'RR' format element. However, since the year 2000 is a leap year, this is incorrect.

The problems is that the operation is using the default NLS_DATE_FORMAT, which is 'DD-MON-YY'. If the NLS_DATE_FORMAT is changed to 'DD-MON-RR', then the same select returns 02/29/2000, which is the correct value.

Let us evaluate the query as the Oracle Server engine does. The first function processed is the innermost function, LAST_DAY. Because NLS_DATE_FORMAT is YY, this correctly returns 2/28, because it is using the year 1900 to evaluate the expression. The value 2/28 is then returned to the next outer function. So, the TO_DATE and TO_CHAR functions format the value 02/28/00 using the 'RR' format mask and display the result as 02/28/2000.

If SELECT LAST_DAY('01-FEB-00') FROM DUAL is issued, the result will change depending on the NLS_DATE_FORMAT. With 'YY', the LAST_DAY returned is 28-Feb-00 because the year is interpreted as 1900. With 'RR', the LAST_DAY returned is 29-Feb-00 because the year is interpreted as 2000. The year 1900 is not a leap year whereas the year 2000 is a leap year.

Using the LONG Datatype

Note: The LONG datatype is provided for backward compatibility with existing applications. For new applications, you should use the CLOB and NCLOB datatypes for large amounts of character data. See *Oracle8i Application Developer's Guide - Large Objects (LOBs)* for information about the CLOB and NCLOB datatypes.

The LONG datatype can store variable-length character data containing up to two gigabytes of information. The length of LONG values might be limited by the memory available on your computer.

You can use columns defined as LONG in SELECT lists, SET clauses of UPDATE statements, and VALUES clauses of INSERT statements. LONG columns have many of the characteristics of VARCHAR2 columns.

Restrictions on LONG and LONG RAW Data

Although LONG (and LONG RAW; see below) columns have many uses, their use has some restrictions:

- Only one LONG column is allowed per table.
- LONG columns cannot be indexed.
- LONG columns cannot appear in integrity constraints.
- LONG columns cannot be used in WHERE, GROUP BY, ORDER BY, or CONNECT BY clauses or with the DISTINCT operator in SELECT statements.
- LONG columns cannot be referenced by SQL functions (such as SUBSTR or INSTR).
- LONG columns cannot be used in the SELECT list of a subquery or queries combined by set operators (UNION, UNION ALL, INTERSECT, or MINUS).
- LONG columns cannot be used in SQL expressions.
- LONG columns cannot be referenced when creating a table with a query (CREATE TABLE... AS SELECT...) or when inserting into a table or view with a query (INSERT INTO... SELECT...).
- A variable or argument of a PL/SQL program unit cannot be declared using the LONG datatype.
- Variables in database triggers cannot be declared using the LONG or LONG RAW datatypes.
- References to :NEW and :OLD in database triggers cannot be used with LONG or LONG RAW columns.
- LONG and LONG RAW columns cannot be used in distributed SQL statements.
- LONG and LONG RAW columns cannot be replicated.

> **Note:** If you design tables containing LONG or LONG RAW data, then you should place each LONG or LONG RAW column in a table separate from any other data associated with it, rather than storing the LONG or LONG RAW column and its associated data together in the same table. You can then relate the two tables with a referential integrity constraint. This design allows SQL statements that access only the associated data to avoid reading through LONG or LONG RAW data.

Example of LONG Datatype

To store information on magazine articles, including the texts of each article, create two tables. For example:

```
CREATE TABLE Article_header
    (Id               NUMBER  PRIMARY KEY,
    Title             VARCHAR2(200),
    First_author      VARCHAR2(30),
    Journal           VARCHAR2(50),
    Pub_date          DATE);

CREATE TABLE article_text
    (Id               NUMBER
                      REFERENCES
                      Article_header,
    Text              LONG);
```

The ARTICLE_TEXT table stores only the text of each article. The ARTICLE_HEADER table stores all other information about the article, including the title, first author, and journal and date of publication. The two tables are related by the referential integrity constraint on the ID column of each table.

This design allows SQL statements to query data other than the text of an article without reading through the text. If you want to select all first authors published in Nature magazine during July 1991, then you can issue this statement that queries the ARTICLE_HEADER table:

```
SELECT First_author
    FROM Article_header
    WHERE Journal = 'NATURE'
        AND TO_CHAR(Pub_date, 'MM YYYY') = '07 1991';
```

If the text of each article were stored in the same table with the first author, publication, and publication date, then Oracle would need to read through the text to perform this query.

Using RAW and LONG RAW Datatypes

Note: The RAW and LONG RAW datatypes are provided for backward compatibility with existing applications. For new applications, you should use the BLOB and BFILE datatypes for large amounts of binary data.

See Also: See *Oracle8i Application Developer's Guide - Large Objects (LOBs)* for information about the BLOB and BFILE datatypes.

The RAW and LONG RAW datatypes store data that is not to be interpreted by Oracle (that is, not to be converted when moving data between different systems). These datatypes are intended for binary data and byte strings. For example, LONG RAW can be used to store graphics, sound, documents, and arrays of binary data; the interpretation is dependent on the use.

Net8 and the Export and Import utilities do not perform character conversion when transmitting RAW or LONG RAW data. When Oracle automatically converts RAW or LONG RAW data to and from CHAR data (as is the case when entering RAW data as a literal in an INSERT statement), the data is represented as one hexadecimal character representing the bit pattern for every four bits of RAW data. For example, one byte of RAW data with bits 11001011 is displayed and entered as 'CB'.

LONG RAW data cannot be indexed, but RAW data can be indexed.

See Also: For more information about restrictions on LONG RAW data, see "Restrictions on LONG and LONG RAW Data".

ROWIDs and the ROWID Datatype

Every row in a nonclustered table of an Oracle database is assigned a unique ROWID that corresponds to the physical address of a row's row piece (initial row piece if the row is chained among multiple row pieces). In the case of clustered tables, rows in different tables that are in the same data block can have the same ROWID.

Each table in an Oracle database internally has a pseudocolumn named ROWID.

> **See Also:** *Oracle8i Concepts* for general information about the ROWID pseudocolumn and the ROWID datatype.

Extended ROWID Format

The Oracle Server uses an *extended ROWID* format, which supports features such as table partitions, index partitions, and clusters.

The extended ROWID includes the following information:

- Data object (segment) identifier
- Datafile identifier
- Block identifier
- Row identifier

The data object identifier is an identification number that Oracle assigns to schema objects in the database, such as nonpartitioned tables or partitions. For example:

```
SELECT DATA_OBJECT_ID FROM ALL_OBJECTS
   WHERE OWNER = 'SCOTT' AND OBJECT_NAME = 'EMP_TAB';
```

This query returns the data object identifier for the EMP_TAB table in the SCOTT schema.

> **See Also:** *Oracle8i Supplied Packages Reference* for information about other ways to get the data object identifier, using the DBMS_ROWID package functions.

Different Forms of the ROWID

Oracle documentation uses the term ROWID in different ways, depending on context. These uses are explained in this section.

Internal ROWID The internal ROWID format is an internal structure which holds information that the server code needs to access a row. The restricted internal ROWID is 6 bytes on most platforms; the extended ROWID is 10 bytes on these platforms.

ROWID Pseudocolumn Each table and nonjoined view has a pseudocolumn called ROWID. For example:

```
CREATE TABLE T_tab (col1 Rowid);

INSERT INTO T_tab SELECT Rowid FROM Emp_tab WHERE Empno = 7499;
```

This command returns the ROWID pseudocolumn of the row of the EMP_TAB table that satisfies the query, and inserts it into the T1 table.

External Character ROWID The extended ROWID pseudocolumn is returned to the client in the form of an 18-character string (for example, "AAAA8mAALAAAAQkAAA"), which represents a base 64 encoding of the components of the extended ROWID in a four-piece format, OOOOOOFFFBBBBBBRRR:

- OOOOOO: The **data object number** identifies the database segment (AAAA8m in the example). Schema objects in the same segment, such as a cluster of tables, have the same data object number.
- FFF: The **datafile** that contains the row (file AAL in the example). File numbers are unique within a database.
- BBBBBB: The **data block** that contains the row (block AAAAQk in the example). Block numbers are relative to their datafile, *not* tablespace. Therefore, two rows with identical block numbers could reside in two different datafiles of the same tablespace.
- RRR: The **row** in the block (row AAA in the example).

There is no need to decode the external ROWID; you can use the functions in the DBMS_ROWID package to obtain the individual components of the extended ROWID.

> **See Also:** *Oracle8i Supplied Packages Reference* for information about the DBMS_ROWID package.

The restricted ROWID pseudocolumn is returned to the client in the form of an 18-character string with a hexadecimal encoding of the datablock, row, and datafile components of the ROWID.

External Binary ROWID Some client applications use a binary form of the ROWID. For example, OCI and some precompiler applications can map the ROWID to a 3GL structure on bind or define calls. The size of the binary ROWID is the same for extended and restricted ROWIDs. The information for the extended ROWID is included in an unused field of the restricted ROWID structure.

The format of the extended binary ROWID, expressed as a C struct, is:

```
struct riddef {
    ub4    ridobjnum; /* data obj#--this field is
                         unused in restricted ROWIDs */
```

```
    ub2    ridfilenum;
    ub1    filler;
    ub4    ridblocknum;
    ub2    ridslotnum;
}
```

ROWID Migration and Compatibility Issues

For backward compatibility, the restricted form of the ROWID is still supported. These ROWIDs exist in massive amounts of Oracle7 data, and the extended form of the ROWID is required only in global indexes on partitioned tables. New tables always get extended ROWIDs.

> **See Also:** *Oracle8i Administrator's Guide.*

It is possible for an Oracle7 client to access an Oracle8 database. Similarly, an Oracle8 client can access an Oracle7 Server. A client in this sense can include a remote database accessing a server using database links, as well as a client 3GL or 4GL application accessing a server.

> **See Also:** There is more information on the ROWID_TO_EXTENDED function in *Oracle8i Supplied Packages Reference* and *Oracle8i Migration*.

Accessing an Oracle7 Database from an Oracle8 Client The ROWID values that are returned are always restricted ROWIDs. Also, Oracle8 uses restricted ROWIDs when returning a ROWID value to an Oracle7 or earlier server.

The following ROWID functionality works when accessing an Oracle7 Server:

- Selecting a ROWID and using the obtained value in a WHERE clause
- WHERE CURRENT OF cursor operations
- Storing ROWIDs in user columns of ROWID or CHAR type
- Interpreting ROWIDs using the hexadecimal encoding (not recommended, use the DBMS_ROWID functions)

Accessing an Oracle8 Database from an Oracle7 Client Oracle8 returns ROWIDs in the extended format. This means that you can only:

- Select a ROWID and use it in a WHERE clause
- Use WHERE CURRENT OF cursor operations

- Store ROWIDs in user columns of CHAR(18) datatype

Import and Export It is not possible for an Oracle7 client to import an Oracle8 table that has a ROWID column (not the ROWID pseudocolumn), if any row of the table contains an extended ROWID value.

Trusted Oracle MLSLABEL Datatype

Trusted Oracle provides the MLSLABEL datatype, which stores Trusted Oracle's internal representation of labels generated by multilevel secure (MLS) operating systems. Trusted Oracle uses labels to control database access.

You can define a column using the MLSLABEL datatype for compatibility with Trusted Oracle applications, but the only valid value for the column in Oracle8 is NULL.

When you create a table in Trusted Oracle, a column called ROWLABEL is automatically appended to the table. This column contains a label of the MLSLABEL datatype for every row in the table.

See Also: *Trusted Oracle* documentation for more information about the MLSLABEL datatype, the ROWLABEL column, and Trusted Oracle.

ANSI/ISO, DB2, and SQL/DS Datatypes

You can define columns of tables in an Oracle database using ANSI/ISO, DB2, and SQL/DS datatypes. Oracle internally converts such datatypes to Oracle datatypes.

The ANSI datatype conversions to Oracle datatypes are shown in Table 4–3. The ANSI/ISO datatypes NUMERIC, DECIMAL, and DEC can specify only fixed-point numbers. For these datatypes, s defaults to 0.

Table 4–3 ANSI Datatype Conversions to Oracle Datatypes

ANSI SQL Datatype	Oracle Datatype
CHARACTER (n), CHAR (n)	CHAR (n)
NUMERIC (p,s), DECIMAL (p,s), DEC (p,s)	NUMBER (p,s)
INTEGER, INT, SMALLINT	NUMBER (38)
FLOAT (p)	FLOAT (p)
REAL	FLOAT (63)
DOUBLE PRECISION	FLOAT (126)
CHARACTER VARYING(n), CHAR VARYING(n)	VARCHAR2 (n)

The IBM products SQL/DS, and DB2 datatypes TIME, TIMESTAMP, GRAPHIC, VARGRAPHIC, and LONG VARGRAPHIC have no corresponding Oracle datatype and cannot be used. The TIME and TIMESTAMP datatypes are subcomponents of the Oracle datatype DATE.

Table 4–4 shows the DB2 and SQL/DS conversions.

Table 4–4 SQL/DS, DB2 Datatype Conversions to Oracle Datatypes

DB2 or SQL/DS Datatype	Oracle Datatype
CHARACTER (n)	CHAR (n)
VARCHAR (n)	VARCHAR2 (n)
LONG VARCHAR	LONG
DECIMAL (p,s)	NUMBER (p,s)
INTEGER, SMALLINT	NUMBER (38)
FLOAT (p)	FLOAT (p)
DATE	DATE

Data Conversion

In some cases, Oracle allows data of one datatype where it expects data of a different datatype. Generally, an expression cannot contain values with different datatypes. However, Oracle can use the following functions to automatically convert data to the expected datatype:

- TO_NUMBER()
- TO_CHAR()
- TO_DATE()
- HEXTORAW()
- RAWTOHEX()
- ROWIDTOCHAR()
- CHARTOROWID()

Implicit datatype conversions work according to the rules explained below.

> **See Also:** If you are using Trusted Oracle, see "Data Conversion for Trusted Oracle" for information about data conversions and the MLSLABEL datatype.

Rule 1: Assignments

For assignments, Oracle can automatically convert the following:

- VARCHAR2 or CHAR to NUMBER
- NUMBER to VARCHAR2
- VARCHAR2 or CHAR to DATE
- DATE to VARCHAR2
- VARCHAR2 or CHAR to ROWID
- ROWID to VARCHAR2
- VARCHAR2 or CHAR to MLSLABEL
- MLSLABEL to VARCHAR2
- VARCHAR2 or CHAR to HEX
- HEX to VARCHAR2

The assignment succeeds if Oracle can convert the datatype of the value used in the assignment to that of the assignment's target.

For the examples in the following list, assume a package with a public variable and a table declared as in the following statements:

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE PACKAGE Test_Pack AS var1 CHAR(5); END;
CREATE TABLE Table1_tab (col1 NUMBER);
```

- `variable := expression`

  The datatype of *expression* must be either the same as, or convertible to, the datatype of *variable*. For example, Oracle automatically converts the data provided in the following assignment within the body of a stored procedure:

  ```
  VAR1 := 0;
  ```

- `INSERT INTO table VALUES (expression1, expression2, ...)`

  The datatypes of *expression1*, *expression2*, and so on, must be either the same as, or convertible to, the datatypes of the corresponding columns in *table*. For example, Oracle automatically converts the data provided in the following `INSERT` statement for `TABLE1` (see table definition above):

  ```
  INSERT INTO Table1_tab VALUES ('19');
  ```

- `UPDATE` *table* `SET` *column = expression*

  The datatype of *expression* must be either the same as, or convertible to, the datatype of *column*. For example, Oracle automatically converts the data provided in the following `UPDATE` statement issued against `TABLE1`:

  ```
  UPDATE Table1_tab SET col1 = '30';
  ```

- `SELECT` *column* `INTO` *variable* `FROM` *table*

  The datatype of *column* must be either the same as, or convertible to, the datatype of *variable*. For example, Oracle automatically converts data selected from the table before assigning it to the variable in the following statement:

  ```
  SELECT Col1 INTO Var1 FROM Table1_tab WHERE Col1 = 30;
  ```

Rule 2: Expression Evaluation

Caution: You may need to set up data structures for certain examples to work:

For expression evaluation, Oracle can automatically perform the same conversions as for assignments. An expression is converted to a type based on its context. For example, operands to arithmetic operators are converted to NUMBER and operands to string functions are converted to VARCHAR2.

Oracle can automatically convert the following:

- VARCHAR2 or CHAR to NUMBER
- VARCHAR2 or CHAR to DATE

Character to NUMBER conversions succeed only if the character string represents a valid number. Character to DATE conversions succeed only if the character string satisfies the session default format, which is specified by the initialization parameter NLS_DATE_FORMAT.

Some common types of expressions follow:

- Simple expressions, such as:

  ```
  Comm + '500'
  ```

- Boolean expressions, such as:

  ```
  Bonus > Sal / '10'
  ```

- Function and procedure calls, such as:

  ```
  MOD (Counter, '2')
  ```

- WHERE clause conditions, such as:

  ```
  WHERE Hiredate = TO_DATE('1997-01-01','yyyy-mm-dd')
  ```

- WHERE clause conditions, such as:

  ```
  WHERE Rowid = 'AAAAaoAATAAAADAAA'
  ```

In general, Oracle uses the rule for expression evaluation when a datatype conversion is needed in places not covered by the rule for assignment conversions.

In assignments of the form:

```
variable := expression
```

Oracle first evaluates *expression* using the conversions covered by Rule 2; *expression* can be as simple or complex as desired. If it succeeds, then the evaluation of *expression* results in a single value and datatype. Then, Oracle tries to assign this value to the assignment's target using Rule 1.

Data Conversion for Trusted Oracle

In Trusted Oracle, labels are stored internally as compact binary structures. Trusted Oracle provides the TO_LABEL function that enables you to convert a label from its internal binary format to an external character format. To convert a label from character format to binary format in Trusted Oracle, you use the TO_CHAR function.

The TO_LABEL function is provided for compatibility with Trusted Oracle applications. It returns the NULL value in Oracle8.

> **See Also:** The *Trusted Oracle* documentation has more information about using the TO_LABEL and TO_CHAR functions to convert label formats.

5

Maintaining Data Integrity

This chapter explains how to enforce the business rules associated with your database and prevent the entry of invalid information into tables by using integrity constraints. Topics include the following:

- Using Integrity Constraints
- Using Referential Integrity Constraints
- Referential Integrity in a Distributed Database
- Using CHECK Integrity Constraints
- Defining Integrity Constraints
- Enabling and Disabling Integrity Constraints
- Altering Integrity Constraints
- Dropping Integrity Constraints
- Managing FOREIGN KEY Integrity Constraints
- Listing Integrity Constraint Definitions

> **See Also:** *Trusted Oracle* documentation for additional information about defining, enabling, disabling, and dropping integrity constraints in Trusted Oracle.

Using Integrity Constraints

You can define integrity constraints to enforce business rules on data in your tables. Once an integrity constraint is enabled, all data in the table must conform to the rule that it specifies. If you subsequently issue a SQL statement that modifies data in the table, then Oracle ensures that the resulting data satisfies the integrity constraint. Without integrity constraints, such business rules must be enforced programmatically by your application.

When to Use Integrity Constraints

Enforcing rules with integrity constraints is less costly than enforcing the equivalent rules by issuing SQL statements in your application. The semantics of integrity constraints are very clearly defined, so the internal operations that Oracle performs to enforce them are optimized beneath the level of SQL statements in Oracle. Because your applications use SQL, they cannot achieve this level of optimization.

Enforcing business rules with SQL statements can be even more costly in a networked environment because the SQL statements must be transmitted over a network. In such cases, using integrity constraints eliminates the performance overhead incurred by this transmission.

Example To ensure that each employee in the EMP_TAB table works for a department that is listed in the DEPT_TAB table, first create a PRIMARY KEY constraint on the DEPTNO column of the DEPT_TAB table with the following statement:

```
ALTER TABLE Dept_tab
    ADD PRIMARY KEY (Deptno);
```

Then create a referential integrity constraint on the DEPTNO column of the EMP_TAB table that references the primary key of the DEPT_TAB table. For example:

```
ALTER TABLE Emp_tab
    ADD FOREIGN KEY (Deptno) REFERENCES Dept_tab(Deptno);
```

If you subsequently add a new employee record to the table, then Oracle automatically ensures that its department number appears in the department table.

To enforce this rule without integrity constraints, your application must test each new employee record to ensure that its department number belongs to an existing department. This testing involves issuing a SELECT statement to query the DEPT_TAB table.

Taking Advantage of Integrity Constraints

For best performance, define and enable integrity constraints and develop your applications to rely on them, rather than on SQL statements in your applications, to enforce business rules.

However, in some cases, you might want to enforce business rules through your application as well as through integrity constraints. Enforcing a business rule in your application might provide faster feedback to the user than an integrity constraint. For example, if your application accepts 20 values from the user and then issues an `INSERT` statement containing these values, then you might want your user to be notified immediately after entering a value that violates a business rule.

Because integrity constraints are enforced only when a SQL statement is issued, an integrity constraint can only notify the user of a bad value after the user has entered all 20 values and the application has issued the `INSERT` statement. However, you can design your application to verify the integrity of each value as it is entered, and notify the user immediately in the event of a bad value.

Using NOT NULL Integrity Constraints

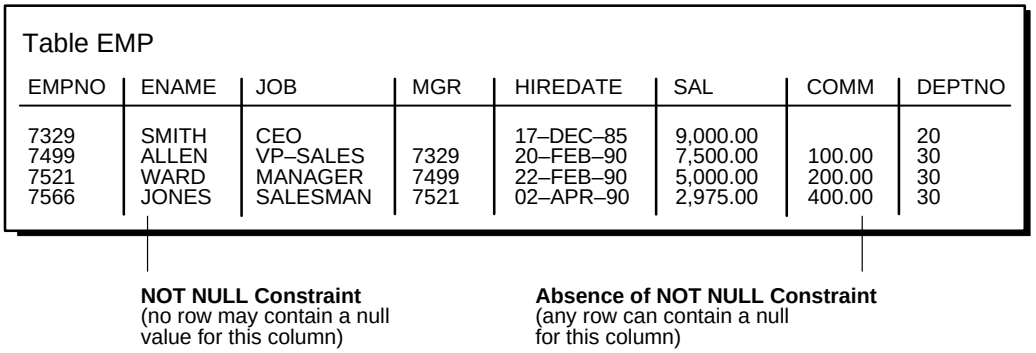
By default, all columns can contain nulls. Only define `NOT NULL` constraints for columns of a table that absolutely require values at all times.

For example, in the `EMP_TAB` table, it might not be detrimental if an employee's manager or hire date were temporarily omitted. Also, some employees might not have a commission. Therefore, these three columns would not be good candidates for `NOT NULL` integrity constraints. However, it might not be permitted to have a row that does not have an employee name. Therefore, this column is a good candidate for the use of a `NOT NULL` integrity constraint.

`NOT NULL` constraints are often combined with other types of integrity constraints to further restrict the values that can exist in specific columns of a table. Use the combination of `NOT NULL` and `UNIQUE` key integrity constraints to force the input of values in the `UNIQUE` key; this combination of data integrity rules eliminates the possibility that any new row's data will ever attempt to conflict with an existing row's data.

See Also: "Relationships Between Parent and Child Tables" on page 5-9

Figure 5–1 NOT NULL Integrity Constraints



Setting Default Column Values

Legal default values include any literal, or any expression that does not refer to a column, LEVEL, ROWNUM, or PRIOR. Default values can include the expressions SYSDATE, USER, USERENV, and UID. The datatype of the default literal or expression must match or be convertible to the column datatype.

If you do not explicitly define a default value for a column, the default for the column is implicitly set to NULL.

When to Use Default Values

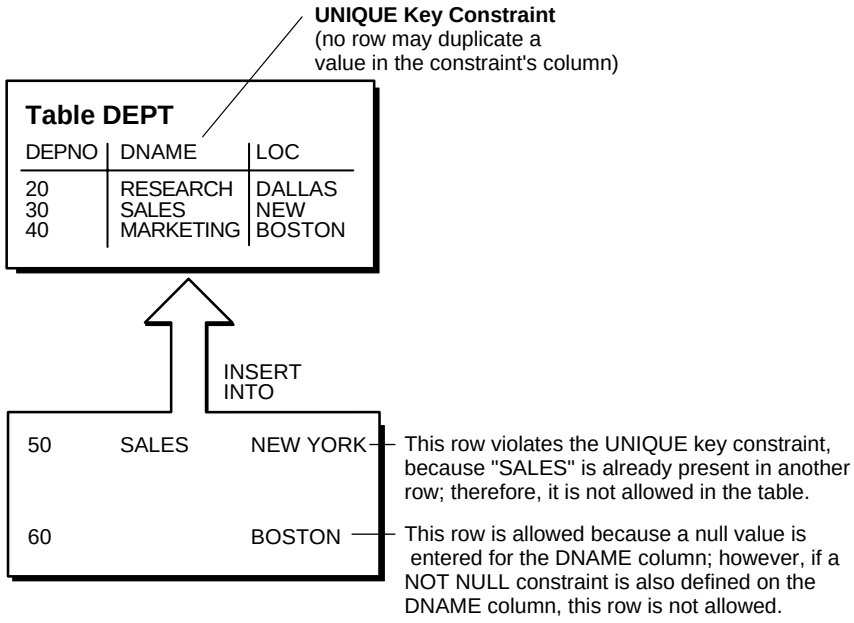
Only assign default values to columns that contain a typical value. For example, in the DEPT_TAB table, if most departments are located at one site, then the default value for the LOC column can be set to this value (such as NEW YORK).

Defaults are also useful when you use a view to make a subset of a table's columns visible. For example, you might allow users to insert rows into a table through a view. The view is defined to show all columns pertinent to end-user operations; however, the base table might also have a column named INSERTER, not included in the definition of the view, which logs the user that originally inserts each row of the table. The column named INSERTER can record the name of the user that inserts a row by defining the column with the USER function. For example:

```
. . ., inserter VARCHAR2(30) DEFAULT USER, . . .
```

> **See Also:** For another example of assigning a default column value, refer to the section "Creating Tables".

Figure 5–2 A UNIQUE Key Constraint



Choosing a Table's Primary Key

Each table can have one primary key. A primary key allows each row in a table to be uniquely identified and ensures that no duplicate rows exist. Use the following guidelines when selecting a primary key:

- Choose a column whose data values are unique.

  The purpose of a table's primary key is to uniquely identify each row of the table. Therefore, the column or set of columns in the primary key must contain unique values for each row.

- Choose a column whose data values are never changed.

  A primary key value is only used to identify a row in the table; primary key values should never contain any data that is used for any other purpose. Therefore, primary key values should rarely need to be changed.

- Choose a column that does not contain any nulls.

  A PRIMARY KEY constraint, by definition, does not allow the input of any row with a null in any column that is part of the primary key.

- Choose a column that is short and numeric.

  Short primary keys are easy to type. You can use sequence numbers to easily generate numeric primary keys.

- Avoid choosing composite primary keys.

  Although composite primary keys are allowed, they do not satisfy the previous recommendations. For example, composite primary key values are long and cannot be assigned by sequence numbers.

Using UNIQUE Key Integrity Constraints

Choose unique keys carefully. In many situations, unique keys are incorrectly comprised of columns that should be part of the table's primary key (see the previous section for more information about primary keys). When deciding whether to use a UNIQUE key constraint, use the rule that a UNIQUE key constraint is only required to prevent the duplication of the key values within the rows of the table. The data in a unique key is such that it cannot be duplicated in the table.

> **Note:** Although UNIQUE key constraints allow the input of nulls, because of the search mechanism for UNIQUE constraints on more than one column, you cannot have identical values in the non-null columns of a partially null composite UNIQUE key constraint.

Do not confuse the concept of a unique key with that of a primary key. Primary keys are used to identify each row of the table uniquely. Therefore, unique keys should not have the purpose of identifying rows in the table.

Some examples of good unique keys include

- An employee's social security number (the primary key is the employee number)
- A truck's license plate number (the primary key is the truck number)
- A customer's phone number, consisting of the two columns AREA and PHONE (the primary key is the customer number)
- A department's name and location (the primary key is the department number)

Using Referential Integrity Constraints

Whenever two tables are related by a common column (or set of columns), define a PRIMARY or UNIQUE key constraint on the column in the parent table, and define a FOREIGN KEY constraint on the column in the child table, to maintain the relationship between the two tables.

> **See Also:** Depending on this relationship, you may want to define additional integrity constraints including the foreign key, as listed in the section "Relationships Between Parent and Child Tables" on page 5-9.

Figure 5–3 shows a foreign key defined on the DEPTNO column of the EMP_TAB table. It guarantees that every value in this column must match a value in the primary key of the DEPT_TAB table (the DEPTNO column); therefore, no erroneous department numbers can exist in the DEPTNO column of the EMP_TAB table.

Foreign keys can be comprised of multiple columns. However, a composite foreign key must reference a composite primary or unique key of the exact same structure (the same number of columns and datatypes). Because composite primary and unique keys are limited to 16 columns, a composite foreign key is also limited to 16 columns.

Nulls and Foreign Keys

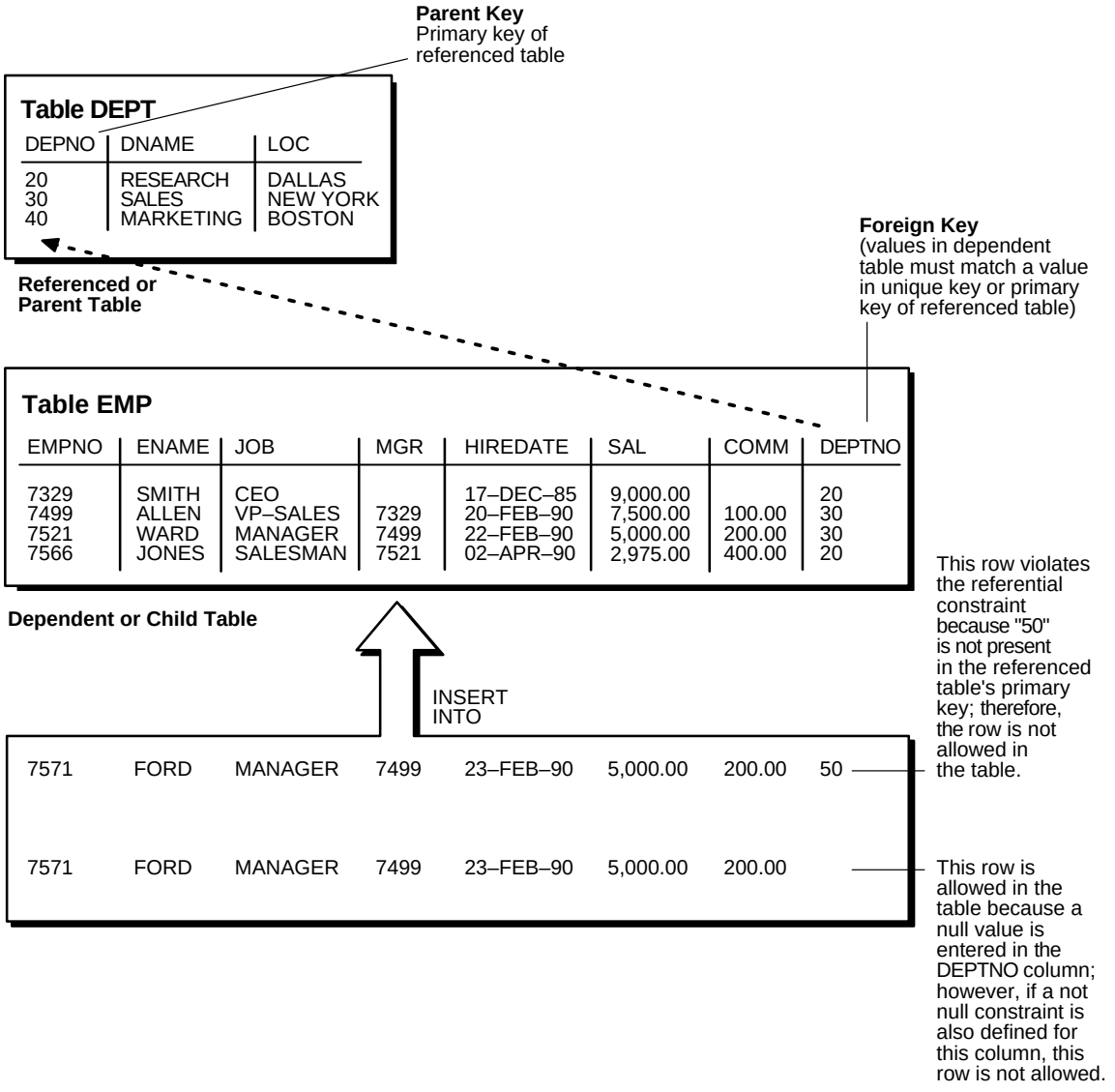
By default (without any NOT NULL or CHECK clauses), and in accordance with the ANSI/ISO standard, the FOREIGN KEY constraint enforces the "match none" rule for composite foreign keys. The "full" and "partial" rules can also be enforced by using CHECK and NOT NULL constraints, as follows:

- To enforce the "match full" rule for nulls in composite foreign keys, which requires that all components of the key be null or all be non-null, define a CHECK constraint that allows only all nulls or all non-nulls in the composite foreign key as follows, assuming a composite key comprised of columns A, B, and C:

```
CHECK ((A IS NULL AND B IS NULL AND C IS NULL) OR
       (A IS NOT NULL AND B IS NOT NULL AND C IS NOT NULL))
```

- In general, it is not possible to use declarative referential integrity to enforce the "match partial" rule for nulls in composite foreign keys, which requires the non-null portions of the key to appear in the corresponding portions in the primary or unique key of a single row in the referenced table. You can often use triggers to handle this case, as described in Chapter 13, "Using Triggers".

Figure 5–3 Referential Integrity Constraints



Relationships Between Parent and Child Tables

Several relationships between parent and child tables can be determined by the other types of integrity constraints defined on the foreign key in the child table.

No Constraints on the Foreign Key When no other constraints are defined on the foreign key, any number of rows in the child table can reference the same parent key value. This model allows nulls in the foreign key.

This model establishes a "one-to-many" relationship between the parent and foreign keys that allows undetermined values (nulls) in the foreign key. An example of such a relationship is shown in Figure 4–3 on page 8 between EMP_TAB and DEPT_TAB; each department (parent key) has many employees (foreign key), and some employees might not be in a department (nulls in the foreign key).

NOT NULL Constraint on the Foreign Key When nulls are not allowed in a foreign key, each row in the child table must explicitly reference a value in the parent key because nulls are not allowed in the foreign key. However, any number of rows in the child table can reference the same parent key value.

This model establishes a "one-to-many" relationship between the parent and foreign keys. However, each row in the child table must have a reference to a parent key value; the absence of a value (a null) in the foreign key is not allowed. The same example in the previous section can be used to illustrate such a relationship. However, in this case, employees must have a reference to a specific department.

UNIQUE Constraint on the Foreign Key When a UNIQUE constraint is defined on the foreign key, one row in the child table can reference a parent key value. This model allows nulls in the foreign key.

This model establishes a "one-to-one" relationship between the parent and foreign keys that allows undetermined values (nulls) in the foreign key. For example, assume that the EMP_TAB table had a column named MEMBERNO, referring to an employee's membership number in the company's insurance plan. Also, a table named INSURANCE has a primary key named MEMBERNO, and other columns of the table keep respective information relating to an employee's insurance policy. The MEMBERNO in the EMP_TAB table should be both a foreign key and a unique key:

- To enforce referential integrity rules between the EMP_TAB and INSURANCE tables (the FOREIGN KEY constraint)
- To guarantee that each employee has a unique membership number (the UNIQUE key constraint)

UNIQUE and NOT NULL Constraints on the Foreign Key When both UNIQUE and NOT NULL constraints are defined on the foreign key, only one row in the child table can reference a parent key value. Because nulls are not allowed in the foreign key, each row in the child table must explicitly reference a value in the parent key.

This model establishes a "one-to-one" relationship between the parent and foreign keys that does not allow undetermined values (nulls) in the foreign key. If you expand the previous example by adding a NOT NULL constraint on the MEMBERNO column of the EMP_TAB table, in addition to guaranteeing that each employee has a unique membership number, then you also ensure that no undetermined values (nulls) are allowed in the MEMBERNO column of the EMP_TAB table.

Multiple FOREIGN KEY Constraints

Oracle allows a column to be referenced by multiple FOREIGN KEY constraints; effectively, there is no limit on the number of dependent keys. This situation might be present if a single column is part of two different composite foreign keys.

Concurrency Control, Indexes, and Foreign Keys

Oracle maximizes the concurrency control of parent keys in relation to dependent foreign key values. You can control what concurrency mechanisms are used to maintain these relationships, and, depending on the situation, this can be highly beneficial. The following sections explain the possible situations and give recommendations for each.

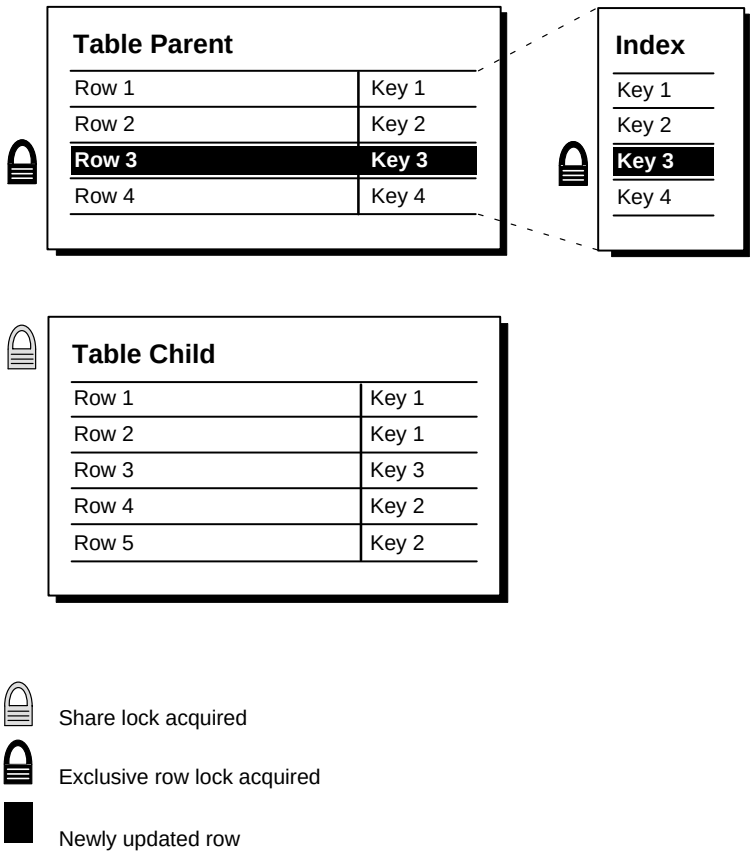
No Index on the Foreign Key Figure 5–4 illustrates the locking mechanisms used by Oracle when no index is defined on the foreign key and when rows are being updated or deleted in the parent table. Inserts into the parent table do not require any locks on the child table.

Notice that a share lock of the entire child table is required until the transaction containing the DELETE statement for the parent table is committed. If the foreign key specifies ON DELETE CASCADE, then the DELETE statement results in a table-level share-subexclusive lock on the child table. A share lock of the entire child table is also required for an UPDATE statement on the parent table that affects any columns referenced by the child table. Share locks allow reading only; therefore, no INSERT, UPDATE, or DELETE statements can be issued on the child table until the transaction containing the UPDATE or DELETE is committed. Queries are allowed on the child table.

This situation is tolerable if updates and deletes can be avoided on the parent.

INSERT, UPDATE, and DELETE statements on the child table do not acquire any locks on the parent table, although INSERT and UPDATE statements will wait for a row-lock on the index of the parent table to clear.

Figure 5–4 Locking Mechanisms When No Index Is Defined on the Foreign Key



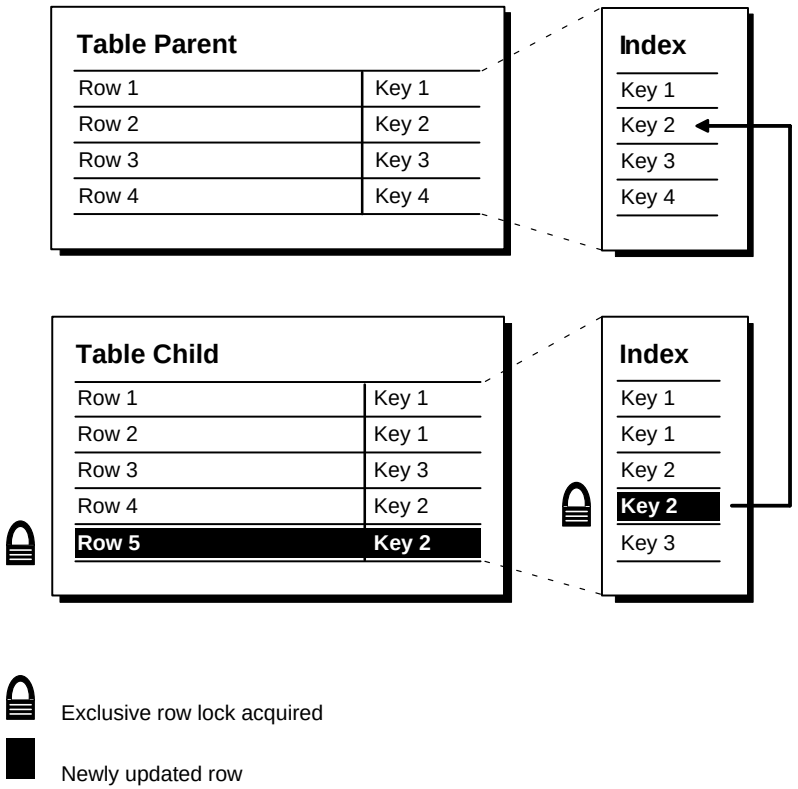
Index on the Foreign Key Figure 5–5 illustrates the locking mechanisms used by Oracle when an index is defined on the foreign key, and new rows are inserted, updated or deleted in the child table.

Notice that no table locks of any kind are acquired on the parent table or any of its indexes as a result of the insert, update or delete. Therefore, any type of DML

statement can be issued on the parent table, including inserts, updates, deletes, and queries.

This situation is preferable if there is any update or delete activity on the parent table while update activity is taking place on the child table. Inserts, updates, and deletes on the parent table do not require any locks on the child table, although updates and deletes will wait for row-level locks on the indexes of the child table to clear.

Figure 5–5 Locking Mechanisms When Index Is Defined on the Foreign Key



If the child table specifies ON DELETE CASCADE, then deletes from the parent table may result in deletes from the child table. In this case, waiting and locking rules are

the same as if you deleted yourself from the child table after performing the delete from the parent table.

Referential Integrity in a Distributed Database

Oracle does not permit declarative referential integrity constraints to be defined across nodes of a distributed database (in other words, a declarative referential integrity constraint on one table cannot specify a foreign key that references a primary or unique key of a remote table).

However, parent/child table relationships across nodes can be maintained using triggers.

> **See Also:** For more information about triggers that enforce referential integrity, refer to Chapter 13, "Using Triggers".
>
> Using triggers to maintain referential integrity requires the distributed option; for more information refer to *Oracle8 Distributed Database Systems*

Note: If you decide to define referential integrity across the nodes of a distributed database using triggers, then be aware that network failures can limit the accessibility of not only the parent table, but also the child table. For example, assume that the child table is in the SALES database, and the parent table is in the HQ database.

If the network connection between the two databases fails, then some DML statements against the child table (those that insert rows into the child table or update a foreign key value in the child table) cannot proceed, because the referential integrity triggers must have access to the parent table in the HQ database.

Using CHECK Integrity Constraints

Use CHECK constraints when you need to enforce integrity rules that can be evaluated based on logical expressions. Never use CHECK constraints when any of the other types of integrity constraints can provide the necessary checking.

> **See Also:** "CHECK and NOT NULL Integrity Constraints" on page 5-16

Examples of appropriate CHECK constraints include the following:

- A CHECK constraint on the SAL column of the EMP_TAB table so that no salary value is greater than 10000
- A CHECK constraint on the LOC column of the DEPT_TAB table so that only the locations "BOSTON", "NEW YORK", and "DALLAS" are allowed
- A CHECK constraint on the SAL and COMM columns to compare the SAL and COMM values of a row and prevent the COMM value from being greater than the SAL value

Restrictions on CHECK Constraints

A CHECK integrity constraint requires that a condition be true or unknown for every row of the table. If a statement causes the condition to evaluate to false, then the statement is rolled back. The condition of a CHECK constraint has the following limitations:

- The condition must be a Boolean expression that can be evaluated using the values in the row being inserted or updated.
- The condition cannot contain subqueries or sequences.
- The condition cannot include the SYSDATE, UID, USER, or USERENV SQL functions.
- The condition cannot contain the pseudocolumns LEVEL, PRIOR, or ROWNUM;

  > **See Also:** *Oracle8i SQL Reference* for an explanation of these pseudocolumns.

- The condition cannot contain a user-defined SQL function.

Designing CHECK Constraints

When using CHECK constraints, consider the ANSI/ISO standard which states that a CHECK constraint is violated only if the condition evaluates to false; true and unknown values do not violate a check condition. Therefore, make sure that any CHECK constraint that you define actually enforces the rule you need enforced.

For example, consider the following CHECK constraint:

```
CHECK (Sal > 0 OR Comm >= 0)
```

At first glance, this rule may be interpreted as "do not allow a row in the EMP_TAB table unless the employee's salary is greater than zero or the employee's commission is greater than or equal to zero." However, note that if a row is inserted with a null salary and a negative commission, then the row does not violate the CHECK constraint, because the entire check condition is evaluated as unknown. In this particular case, you can account for such violations by placing NOT NULL integrity constraints on both the SAL and COMM columns.

Note: If you are not sure when unknown values result in NULL conditions, review the truth tables for the logical operators AND and OR in *Oracle8i SQL Reference*

Multiple CHECK Constraints

A single column can have multiple CHECK constraints that reference the column in its definition. There is no limit to the number of CHECK constraints that can be defined that reference a column.

CHECK and NOT NULL Integrity Constraints

According to the ANSI/ISO standard, a NOT NULL integrity constraint is an example of a CHECK integrity constraint, where the condition is the following:

```
CHECK (Column_name IS NOT NULL)
```

Therefore, NOT NULL integrity constraints for a single column can, in practice, be written in two forms: using the NOT NULL constraint or a CHECK constraint. For ease of use, you should always choose to define NOT NULL integrity constraints, instead of CHECK constraints with the IS NOT NULL condition.

In the case where a composite key can allow only all nulls or all values, you must use a CHECK integrity constraint. For example, the following expression of a CHECK

integrity constraint allows a key value in the composite key made up of columns C1 and C2 to contain either all nulls or all values:

```
CHECK ((C1 IS NULL AND C2 IS NULL) OR
    (C1 IS NOT NULL AND C2 IS NOT NULL))
```

Defining Integrity Constraints

Define an integrity constraint using the constraint clause of the SQL commands CREATE TABLE or ALTER TABLE. The next two sections describe how to use these commands to define integrity constraints.

Note: There are additional considerations if you are using Trusted Oracle; see the *Trusted Oracle* for more information.

The CREATE TABLE Command

The following examples of CREATE TABLE statements show the definition of several integrity constraints:

```
CREATE TABLE Dept_tab (
    Deptno  NUMBER(3) PRIMARY KEY,
    Dname   VARCHAR2(15),
    Loc     VARCHAR2(15),
            CONSTRAINT Dname_ukey UNIQUE (Dname, Loc),
            CONSTRAINT Loc_check1
                    CHECK (loc IN ('NEW YORK', 'BOSTON', 'CHICAGO')));

CREATE TABLE Emp_tab (
    Empno    NUMBER(5) PRIMARY KEY,
    Ename    VARCHAR2(15) NOT NULL,
    Job      VARCHAR2(10),
    Mgr      NUMBER(5) CONSTRAINT Mgr_fkey
                      REFERENCES Emp_tab,
    Hiredate DATE,
    Sal      NUMBER(7,2),
    Comm     NUMBER(5,2),
    Deptno   NUMBER(3) NOT NULL
             CONSTRAINT dept_fkey
                   REFERENCES Dept_tab ON DELETE CASCADE);
```

The ALTER TABLE Command

You can also define integrity constraints using the constraint clause of the ALTER TABLE command. For example, the following examples of ALTER TABLE statements show the definition of several integrity constraints:

```
ALTER TABLE Dept_tab
    ADD PRIMARY KEY (deptno);
```

```
ALTER TABLE Emp_tab
    ADD CONSTRAINT Dept_fkey FOREIGN KEY (Deptno) REFERENCES Dept_tab
    MODIFY (Ename VARCHAR2(15) NOT NULL);
```

Restrictions with the ALTER TABLE Command

Because data is likely to be in the table at the time an ALTER TABLE statement is issued, there are several restrictions to be aware of. Table 5–1 lists each type of constraint and the associated restrictions with the ALTER TABLE command.

Table 5–1 Restrictions for Defining Integrity Constraints with ALTER TABLE

Type of Constraint	Added to Existing Columns of the Table	Added with New Columns to the Table
NOT NULL	Cannot be defined if any row contains a null value for this column*	Cannot be defined if the table contains any rows
UNIQUE	Cannot be defined if duplicate values exist in the key*	Always OK
PRIMARY KEY	Cannot be defined if duplicate or null values exist in the key*	Cannot be defined if the table contains any rows
FOREIGN KEY	Cannot be defined if the foreign key has values that do not reference a parent key value*	Always OK
CHECK	Cannot be defined if the volume has values that do not comply with the check condition*	Always OK

** Assumes DISABLE clause not included in statement.*

If you attempt to define a constraint with an ALTER TABLE statement and you violate one of these restrictions, then the statement is rolled back, and an informative error is returned explaining the violation.

Required Privileges

The creator of a constraint must have the ability to create tables (the CREATE TABLE or CREATE ANY TABLE system privilege), or the ability to alter the table (the ALTER object privilege for the table or the ALTER ANY TABLE system privilege) with the constraint. Additionally, UNIQUE and PRIMARY KEY integrity constraints require that the owner of the table have either a quota for the tablespace that contains the associated index or the UNLIMITED TABLESPACE system privilege. FOREIGN KEY integrity constraints also require some additional privileges.

> **See Also:** "Privileges Required for FOREIGN KEY Integrity Constraints" on page 5-30

Naming Integrity Constraints

Assign names to NOT NULL, UNIQUE KEY, PRIMARY KEY, FOREIGN KEY, and CHECK constraints using the CONSTRAINT option of the constraint clause. This name must be unique with respect to other constraints that you own. If you do not specify a constraint name, then one is assigned by Oracle.

See the previous examples of the CREATE TABLE and ALTER TABLE statements for examples of the CONSTRAINT option of the constraint clause. Note that the name of each constraint is included with other information about the constraint in the data dictionary.

> **See Also:** "Listing Integrity Constraint Definitions" on page 5-32 for examples of data dictionary views.

Enabling and Disabling Constraints Upon Definition

By default, whenever an integrity constraint is defined in a CREATE or ALTER TABLE statement, the constraint is automatically enabled (enforced) by Oracle unless it is specifically created in a disabled state using the DISABLE clause.

> **See Also:** "Enabling and Disabling Integrity Constraints" on page 5-21 has more information about important issues for enabling and disabling constraints.

UNIQUE Key, PRIMARY KEY, and FOREIGN KEY

When defining UNIQUE, PRIMARY KEY, and FOREIGN KEY integrity constraints, you should be aware of several important issues and prerequisites.

> **See Also:** For information about defining and managing FOREIGN KEY constraints, see "Managing FOREIGN KEY Integrity Constraints" on page 5-30.
>
> UNIQUE key and PRIMARY KEY constraints are usually enabled by the database administrator; see the *Oracle8i Administrator's Guide.*

Enabling and Disabling Integrity Constraints

This section explains the mechanisms and procedures for manually enabling and disabling integrity constraints.

enabled constraint	When a constraint is enabled, the rule defined by the constraint is enforced on the data values in the columns that define the constraint. The definition of the constraint is stored in the data dictionary.
disabled constraint	When a constraint is disabled, the rule defined by the constraint is not enforced on the data values in the columns included in the constraint; however, the definition of the constraint is retained in the data dictionary.

In summary, an integrity constraint can be thought of as a statement about the data in a database. This statement is always true when the constraint is enabled; however, the statement may or may not be true when the constraint is disabled because data in violation of the integrity constraint can be in the database.

Why Enable or Disable Constraints?

To enforce the rules defined by integrity constraints, the constraints should always be enabled; however, in certain situations, it is desirable to disable the integrity constraints of a table temporarily for performance reasons. For example:

- When loading large amounts of data into a table using SQL*Loader
- When performing batch operations that make massive changes to a table (such as changing everyone's employee number by adding 1000 to the existing number)
- When importing or exporting one table at a time

In cases such as these, integrity constraints may be temporarily turned off to improve the performance of the operation.

Integrity Constraint Violations

If a row of a table does not adhere to an integrity constraint, then this row is said to be in violation of the constraint and is known as an *exception* to the constraint. If any exceptions exist, then the constraint *cannot* be enabled**.** The rows that violate the constraint must be either updated or deleted in order for the constraint to be enabled.

Exceptions for a specific integrity constraint can be identified while attempting to enable the constraint.

> **See Also:** This procedure is discussed in the section "Exception Reporting".

On Definition

When you define an integrity constraint in a CREATE TABLE or ALTER TABLE statement, you can enable the constraint by including the ENABLE clause in its definition or disable it by including the DISABLE clause in its definition. If neither the ENABLE nor the DISABLE clause is included in a constraint's definition, Oracle automatically enables the constraint.

Enabling Constraints

The following CREATE TABLE and ALTER TABLE statements both define and enable integrity constraints:

```
CREATE TABLE Emp_tab (
    Empno NUMBER(5) PRIMARY KEY);
 ALTER TABLE Emp_tab
    ADD PRIMARY KEY (Empno);
```

An ALTER TABLE statement that defines and attempts to enable an integrity constraint may fail because rows of the table may violate the integrity constraint. In this case, the statement is rolled back and the constraint definition is not stored and not enabled.

> **See Also:** Refer to the section "Exception Reporting" on page 5-25 for more information about rows that violate integrity constraints.

Disabling Constraints

The following CREATE TABLE and ALTER TABLE statements both define and disable integrity constraints:

```
CREATE TABLE Emp_tab (
    Empno NUMBER(5) PRIMARY KEY DISABLE);

ALTER TABLE Emp_tab
    ADD PRIMARY KEY (Empno) DISABLE;
```

An ALTER TABLE statement that defines and disables an integrity constraints never fails. The definition of the constraint is always allowed because its rule is not enforced.

Enabling and Disabling Defined Integrity Constraints

Use the ALTER TABLE command to

- Enable a disabled constraint, using the ENABLE clause
- Disable an enabled constraint, using the DISABLE clause

Enabling Disabled Constraints

The following statements are examples of statements that enable disabled integrity constraints:

```
ALTER TABLE Dept_tab
    ENABLE CONSTRAINT Dname_ukey;

ALTER TABLE Dept_tab
    ENABLE PRIMARY KEY
    ENABLE UNIQUE (Dname)
    ENABLE UNIQUE (Loc);
```

An ALTER TABLE statement that attempts to enable an integrity constraint fails when the rows of the table violate the integrity constraint. In this case, the statement is rolled back and the constraint is not enabled.

> **See Also:** Refer to the section "Exception Reporting" on page 5-25 for more information about rows that violate integrity constraints.

Disabling Enabled Constraints

The following statements are examples of statements that disable enabled integrity constraints:

```
ALTER TABLE Dept_tab
    DISABLE CONSTRAINT Dname_ukey;

ALTER TABLE Dept_tab
    DISABLE PRIMARY KEY
    DISABLE UNIQUE (Dname)
    DISABLE UNIQUE (Loc);
```

Tip — Using the Data Dictionary for Reference: The example statements in the previous sections require that you have some information about a constraint to enable or disable it.

For example, the first statement of each section requires that you know the constraint's name, while the second statement of each section requires that you know the unique key's column list. If you do not have such information, then you can query one of the data dictionary views defined for constraints; for more information about these views, see "Listing Integrity Constraint Definitions" on page 5-32 and *Oracle8i Reference*.

Enabling and Disabling Key Integrity Constraints

When enabling or disabling `UNIQUE`, `PRIMARY KEY`, and `FOREIGN KEY` integrity constraints, you should be aware of several important issues and prerequisites. `UNIQUE` key and `PRIMARY KEY` constraints are usually managed by the database administrator.

See Also: "Managing FOREIGN KEY Integrity Constraints" on page 5-30 and the *Oracle8i Administrator's Guide*

Enabling Constraints after a Parallel Direct Path Load

SQL*Loader permits multiple concurrent sessions to perform a direct path load into the same table. Because each SQL*Loader session can attempt to re-enable constraints on a table after a direct path load, there is a danger that one session may attempt to re-enable a constraint before another session is finished loading data. In this case, the first session to complete the load will be unable to enable the constraint because the remaining sessions possess share locks on the table.

Because there is a danger that some constraints might not be re-enabled after a direct path load, you should check the status of the constraint after completing the load to ensure that it was enabled properly.

PRIMARY and UNIQUE KEY constraints

`PRIMARY KEY` and `UNIQUE` key constraints create indexes on a table when they are enabled, and subsequently can take a significantly long time to enable after a direct path loading session if the table is very large.

You should consider enabling these constraints manually after a load (and not specify the automatic enable feature). This allows you to manually create the required indexes in parallel to save time before enabling the constraint.

> **See Also:** *Oracle8i Tuning* for more information about creating indexes in parallel.

Exception Reporting

If no exceptions are present when you issue a CREATE TABLE... ENABLE... or ALTER TABLE... ENABLE... statement, then the integrity constraint is enabled and all subsequent DML statements are subject to the enabled integrity constraints.

If exceptions exist when you enable a constraint, then an error is returned, and the integrity constraint remains disabled. When a statement is not successfully executed because integrity constraint exceptions exist, the statement is rolled back. If exceptions exist, then you cannot enable the constraint until all exceptions to the constraint are either updated or deleted.

To determine which rows violate the integrity constraint, include the EXCEPTIONS option in the ENABLE clause of a CREATE TABLE or ALTER TABLE statement. The EXCEPTIONS option places the ROWID, table owner, table name, and constraint name of all exception rows into a specified table. For example, the following statement attempts to enable the primary key of the DEPT_TAB table; if exceptions exist, information is inserted into a table named EXCEPTIONS:

> **Caution:** You may need to set up data structures for certain examples to work:

```
ALTER TABLE Dept_tab ENABLE PRIMARY KEY EXCEPTIONS INTO exceptions;
```

Create an appropriate exceptions report table to accept information from the EXCEPTIONS option of the ENABLE clause. Create an exception table by submitting the script UTLEXCPT.SQL. The script creates a tabled named EXCEPTIONS. You can create additional exceptions tables with different names by modifying and resubmitting the script.

If duplicate primary key values exist in the DEPT_TAB table and the name of the PRIMARY KEY constraint on DEPT_TAB is SYS_C00301, the following rows might be placed in the table EXCEPTIONS by the previous statement:

```
SELECT * FROM Exceptions;
```

```
ROWID                  OWNER   TABLE_NAME      CONSTRAINT
------------------     ------  ------------    -----------
AAAA5bAADAAAAEQAAA     SCOTT   DEPT_TAB        SYS_C00301
AAAA5bAADAAAAEQAAB     SCOTT   DEPT_TAB        SYS_C00301
```

A more informative query would be to join the rows in an exception report table and the master table to list the actual rows that violate a specific constraint. For example:

```
SELECT Deptno, Dname, Loc FROM Dept_tab, Exceptions
    WHERE Exceptions.Constraint = 'SYS_C00301'
    AND Dept_tab.Rowid = Exceptions.Row_id;

DEPTNO     DNAME          LOC
---------- -------------- -------------
10         ACCOUNTING     NEW YORK
10         RESEARCH       DALLAS
```

Rows that violate a constraint must be either updated or deleted from the table that contains the constraint. If updating exceptions, then you must change the value that violates the constraint to a value consistent with the constraint or a null (if allowed). After updating or deleting a row in the master table, delete the corresponding rows for the exception in the exception report table to avoid confusion with later exception reports. The statements that update the master table and the exception report table should be in the same transaction to ensure transaction consistency.

For example, to correct the exceptions in the previous examples, the following transaction might be issued:

```
UPDATE Dept_tab SET Deptno = 20 WHERE Dname = 'RESEARCH';
DELETE FROM Exceptions WHERE Constraint = 'SYS_C00301';
COMMIT;
```

When you manage exceptions, your goal should be to eliminate all exceptions in your exception report table. After eliminating all exceptions, you must re-enable the constraint; the constraint is not automatically enabled after the exceptions are handled.

While you are correcting current exceptions for a table with the constraint disabled, other users can issue statements creating new exceptions.

Altering Integrity Constraints

In Oracle 8.0, only certain constraint states could be changed using the ENABLE or DISABLE clauses. With Oracle 8.1, there are expanded capabilities to alter the state of an existing constraint with the MODIFY CONSTRAINT clause.

> **See Also:** For information on the parameters you can modify, see the ALTER TABLE section in *Oracle8i SQL Reference.*

Examples of MODIFY CONSTRAINT

Modify Constraint Example #1

```
CREATE TABLE X1_tab (a1 NUMBER CONSTRAINT y CHECK (a1>3) DEFERRABLE
DISABLE);

ALTER TABLE X1_tab MODIFY CONSTRAINT Y_cnstrt ENABLE;
ALTER TABLE X1_tab MODIFY CONSTRAINT Y_cnstrt RELY;
ALTER TABLE X1_tab MODIFY CONSTRAINT Y_cnstrt INITIALLY DEFERRED;
ALTER TABLE X1_tab MODIFY CONSTRAINT Y_cnstrt ENABLE NOVALIDATE;
```

Modify Constraint Example #2

```
CREATE TABLE X1_tab (A1 NUMBER CONSTRAINT Y_cnstrt
NOT NULL DEFERRABLE INITIALLY DEFERRED NORELY DISABLE);

ALTER TABLE X1_tab ADD CONSTRAINT One_cnstrt UNIQUE(A1)
DEFERRABLE INITIALLY IMMEDIATE RELY USING INDEX PCTFREE = 30
ENABLE VALIDATE;

ALTER TABLE X1_tab MODIFY UNIQUE(A1)
INITIALLY DEFERRED NORELY USING INDEX PCTFREE = 40
ENABLE NOVALIDATE;

ALTER TABLE X1_tab MODIFY CONSTRAINT One_cnstrt
INITIALLY IMMEDIATE RELY;
```

Modify Constraint Example #3

```
CREATE TABLE T1_tab (A1 INT, B1 INT);
ALTER TABLE T1_tab add CONSTRAINT P1_cnstrt PRIMARY KEY(a1) DISABLE;
ALTER TABLE T1_tab MODIFY PRIMARY KEY INITIALLY IMMEDIATE
USING INDEX PCTFREE = 30 ENABLE NOVALIDATE;
ALTER TABLE T1_tab MODIFY PRIMARY KEY
USING INDEX PCTFREE = 35 ENABLE;
```

```
ALTER TABLE T1_tab MODIFY PRIMARY KEY ENABLE NOVALIDATE;
```

Note: RELY and NORELY are new states that can be set or reset when a constraint is created or modified.

Dropping Integrity Constraints

Drop an integrity constraint if the rule that it enforces is no longer true or if the constraint is no longer needed. Drop an integrity constraint using the ALTER TABLE command and the DROP clause. For example, the following statements drop integrity constraints:

```
ALTER TABLE Dept_tab
    DROP UNIQUE (Dname);
ALTER TABLE Dept_tab
    DROP UNIQUE (Loc);

ALTER TABLE Emp_tab
    DROP PRIMARY KEY,
    DROP CONSTRAINT Dept_fkey;

DROP TABLE Emp_tab CASCADE CONSTRAINTS;
```

When dropping UNIQUE, PRIMARY KEY, and FOREIGN KEY integrity constraints, you should be aware of several important issues and prerequisites. UNIQUE and PRIMARY KEY constraints are usually managed by the database administrator.

> **See Also:** "Managing FOREIGN KEY Integrity Constraints" on page 5-30 and the *Oracle8i Administrator's Guide*.

Managing FOREIGN KEY Integrity Constraints

General information about defining, enabling, disabling, and dropping all types of integrity constraints is given in the previous sections. The following section supplements this information, focusing specifically on issues regarding FOREIGN KEY integrity constraints.

Defining FOREIGN KEY Integrity Constraints

The following topics are of interest when defining FOREIGN KEY integrity constraints.

Matching of Datatypes

When defining referential integrity constraints, the corresponding column names of the dependent and referenced tables do not need to match. However, they must be of the same datatype.

Composite Foreign Keys

Because foreign keys reference primary and unique keys of the parent table, and PRIMARY KEY and UNIQUE key constraints are enforced using indexes, composite foreign keys are limited to 16 columns.

Implied Referencing of a Primary Key

If the column list is not included in the REFERENCES option when defining a FOREIGN KEY constraint (single column or composite), then Oracle assumes that you intend to reference the primary key of the specified table. Alternatively, you can explicitly specify the column(s) to reference in the parent table within parentheses. Oracle automatically checks to verify that this column list references a primary or unique key of the parent table. If it does not, then an informative error is returned.

Privileges Required for FOREIGN KEY Integrity Constraints

To create a FOREIGN KEY constraint, the creator of the constraint must have privileged access to both the parent and the child table.

- **The Parent Table** The creator of the referential integrity constraint must own the parent table or have REFERENCES object privileges on the columns that constitute the parent key of the parent table.
- **The Child Table** The creator of the referential integrity constraint must have the ability to create tables (that is, the CREATE TABLE or CREATE ANY TABLE

system privilege) or the ability to alter the child table (that is, the ALTER object privilege for the child table or the ALTER ANY TABLE system privilege).

In both cases, necessary privileges *cannot* be obtained via a role; they must be explicitly granted to the creator of the constraint.

These restrictions allow:

- The owner of the child table to explicitly decide what constraints are enforced on her or his tables and the other users that can create constraints on her or his tables
- The owner of the parent table to explicitly decide if foreign keys can depend on the primary and unique keys in her tables

Specifying Referential Actions for Foreign Keys

Oracle allows two different types of referential integrity actions to be enforced, as specified with the definition of a FOREIGN KEY constraint:

- **The UPDATE/DELETE No Action Restriction** This action prevents the update or deletion of a parent key if there is a row in the child table that references the key. By default, all FOREIGN KEY constraints enforce the no action restriction; no option needs to be specified when defining the constraint to enforce the no action restriction. For example:

```
CREATE TABLE Emp_tab (
FOREIGN KEY (Deptno) REFERENCES Dept_tab);
```

- **The ON DELETE CASCADE Action** This action allows referenced data in the parent key to be deleted (but not updated). If referenced data in the parent key is deleted, all rows in the child table that depend on the deleted parent key values are also deleted. To specify this referential action, include the ON DELETE CASCADE option in the definition of the FOREIGN KEY constraint. For example:

```
CREATE TABLE Emp_tab (
    FOREIGN KEY (Deptno) REFERENCES Dept_tab
        ON DELETE CASCADE);
```

Enabling FOREIGN KEY Integrity Constraints

FOREIGN KEY integrity constraints cannot be enabled if the referenced primary or unique key's constraint is not present or not enabled.

Listing Integrity Constraint Definitions

The data dictionary contains the following views that relate to integrity constraints:

- ALL_CONSTRAINTS
- ALL_CONS_COLUMNS
- CONSTRAINT_COLUMNS
- CONSTRAINT_DEFS
- USER_CONSTRAINTS
- USER_CONS_COLUMNS
- USER_CROSS_REFS
- DBA_CONSTRAINTS
- DBA_CONS_COLUMNS
- DBA_CROSS_REFS

> **See Also:** Refer to *Oracle8i Reference* for detailed information about each view.

Examples

Consider the following CREATE TABLE statements that define a number of integrity constraints:

```
CREATE TABLE Dept_tab (
    Deptno   NUMBER(3) PRIMARY KEY,
    Dname    VARCHAR2(15),
    Loc      VARCHAR2(15),
    CONSTRAINT Dname_ukey UNIQUE (Dname, Loc),
    CONSTRAINT LOC_CHECK1
        CHECK (Loc IN ('NEW YORK', 'BOSTON', 'CHICAGO')));

CREATE TABLE Emp_tab (
    Empno    NUMBER(5) PRIMARY KEY,
    Ename    VARCHAR2(15) NOT NULL,
    Job      VARCHAR2(10),
    Mgr      NUMBER(5) CONSTRAINT Mgr_fkey
             REFERENCES Emp_tab ON DELETE CASCADE,
    Hiredate DATE,
    Sal      NUMBER(7,2),
    Comm     NUMBER(5,2),
```

```
    Deptno   NUMBER(3) NOT NULL
    CONSTRAINT Dept_fkey REFERENCES Dept_tab);
```

Example 1: Listing All of Your Accessible Constraints The following query lists all constraints defined on all tables accessible to the user:

```
SELECT Constraint_name, Constraint_type, Table_name,
       R_constraint_name
    FROM User_constraints;
```

Considering the example statements at the beginning of this section, a list similar to the one below is returned:

```
CONSTRAINT_NAME  C TABLE_NAME  R_CONSTRAINT_NAME
---------------  - ----------- -----------------
SYS_C00275       P DEPT_TAB
DNAME_UKEY       U DEPT_TAB
LOC_CHECK1       C DEPT_TAB
SYS_C00278       C EMP_TAB
SYS_C00279       C EMP_TAB
SYS_C00280       P EMP_TAB
MGR_FKEY         R EMP_TAB     SYS_C00280
DEPT_FKEY        R EMP_TAB     SYS_C00275
```

Notice the following:

- Some constraint names are user specified (such as DNAME_UKEY), while others are system specified (such as SYS_C00275).
- Each constraint type is denoted with a different character in the CONSTRAINT_TYPE column. The table below summarizes the characters used for each constraint type.

Constraint Type	Character
PRIMARY KEY	P
UNIQUE KEY	U
FOREIGN KEY	R
CHECK, NOT NULL	C

> **Note:** An additional constraint type is indicated by the character "V" in the CONSTRAINT_TYPE column. This constraint type corresponds to constraints created by the WITH CHECK OPTION for views. See Chapter 3, "Managing Schema Objects" for more information about views and the WITH CHECK OPTION.

Example 2: Distinguishing NOT NULL Constraints from CHECK Constraints In the previous example, several constraints are listed with a constraint type of "C". To distinguish which constraints are NOT NULL constraints and which are CHECK constraints in the EMP_TAB and DEPT_TAB tables, issue the following query:

```
SELECT Constraint_name, Search_condition
    FROM User_constraints
    WHERE (Table_name = 'DEPT_TAB' OR Table_name = 'EMP_TAB') AND
        Constraint_type = 'C';
```

Considering the example CREATE TABLE statements at the beginning of this section, a list similar to the one below is returned:

```
CONSTRAINT_NAME  SEARCH_CONDITION
---------------  ----------------------------------------
LOC_CHECK1       loc IN ('NEW YORK', 'BOSTON', 'CHICAGO')
SYS_C00278       ENAME IS NOT NULL
SYS_C00279       DEPTNO IS NOT NULL
```

Notice the following:

- NOT NULL constraints are clearly identified in the SEARCH_CONDITION column.
- The conditions for user-defined CHECK constraints are explicitly listed in the SEARCH_CONDITION column.

Example 3: Listing Column Names that Constitute an Integrity Constraint The following query lists all columns that constitute the constraints defined on all tables accessible to you, the user:

```
SELECT Constraint_name, Table_name, Column_name
    FROM User_cons_columns;
```

Considering the example statements at the beginning of this section, a list similar to the one below is returned:

```
CONSTRAINT_NAME  TABLE_NAME  COLUMN_NAME
---------------  -----------  ---------------
```

```
DEPT_FKEY       EMP_TAB     DEPTNO
DNAME_UKEY      DEPT_TAB    DNAME
DNAME_UKEY      DEPT_TAB    LOC
LOC_CHECK1      DEPT_TAB    LOC
MGR_FKEY        EMP_TAB     MGR
SYS_C00275      DEPT_TAB    DEPTNO
SYS_C00278      EMP_TAB     ENAME
SYS_C00279      EMP_TAB     DEPTNO
SYS_C00280      EMP_TAB     EMPNO
```

6

Selecting an Index Strategy

This chapter discusses the procedures necessary to create and manage the different types of objects contained in a user's schema. The topics include:

- Managing Indexes
- Function-Based Indexes
- Managing Clusters, Clustered Tables, and Cluster Indexes
- Managing Hash Clusters and Clustered Tables

See Also: Specific information is described in the following locations:

- Procedures, functions, and packages — Chapter 10
- Object types — Chapter 16
- Dependency information — Chapter 10
- If you use symmetric replication, then see *Oracle8i Replication* for information on managing schema objects, such as snapshots.
- If you use Trusted Oracle, then there are additional privileges required and issues to consider when managing schema objects; see the *Trusted Oracle* documentation.

Managing Indexes

Indexes are used in Oracle to provide quick access to rows in a table. Indexes provide faster access to data for operations that return a small portion of a table's rows.

Oracle does not limit the number of indexes you can create on a table. However, you should consider the performance benefits of indexes and the needs of your database applications to determine which columns to index.

The following sections explain how to create, alter, and drop indexes using SQL commands. Some simple guidelines to follow when managing indexes are included.

> **See Also:** See *Oracle8i Tuning* for performance implications of index creation.

Create Indexes After Inserting Table Data

With one notable exception, you should usually create indexes after you have inserted or loaded (using SQL*Loader or Import) data into a table. It is more efficient to insert rows of data into a table that has no indexes and then to create the indexes for subsequent queries, etc. If you create indexes before table data is loaded, then every index must be updated every time you insert a row into the table. The exception to this rule is that you must create an index for a cluster before you insert any data into the cluster.

When you create an index on a table that already has data, Oracle must use sort space to create the index. Oracle uses the sort space in memory allocated for the creator of the index (the amount per user is determined by the initialization parameter `SORT_AREA_SIZE`), but must also swap sort information to and from temporary segments allocated on behalf of the index creation. If the index is extremely large, it might be beneficial to complete the following steps:

1. Create a new temporary tablespace using the `CREATE TABLESPACE` command.
2. Use the `TEMPORARY TABLESPACE` option of the `ALTER USER` command to make this your new temporary tablespace.
3. Create the index using the `CREATE INDEX` command.
4. Drop this tablespace using the `DROP TABLESPACE` command. Then use the `ALTER USER` command to reset your temporary tablespace to your original temporary tablespace.

Under certain conditions, you can load data into a table with the SQL*Loader "direct path load", and an index can be created as data is loaded.

See Also: *Oracle8i Utilities*

Index the Correct Tables and Columns Use the following guidelines for determining when to create an index:

- Create an index if you frequently want to retrieve less than 15% of the rows in a large table. The percentage varies greatly according to the relative speed of a table scan and how clustered the row data is about the index key. The faster the table scan, the lower the percentage; the more clustered the row data, the higher the percentage.
- Index columns used for joins to improve performance on joins of multiple tables.

  See Also: Primary and unique keys automatically have indexes, but you might want to create an index on a foreign key; see Chapter 5, "Maintaining Data Integrity" for more information.

- Small tables do not require indexes; if a query is taking too long, then the table might have grown from small to large.

Some columns are strong candidates for indexing. Columns with one or more of the following characteristics are candidates for indexing:

- Values are relatively unique in the column.
- There is a wide range of values.
- The column contains many nulls, but queries often select all rows having a value. In this case, the following phrase:

  ```
  WHERE COL_X > -9.99 *power(10,125)
  ```

  is preferable to

  ```
  WHERE COL_X IS NOT NULL
  ```

  This is because the first uses an index on `COL_X` (assuming that `COL_X` is a numeric column).

Columns with the following characteristics are less suitable for indexing:

- The column has few distinct values (for example, a column for the sex of employees).
- There are many nulls in the column and you do not search on the non-null values.

LONG and LONG RAW columns cannot be indexed.

The size of a single index entry cannot exceed roughly one-half (minus some overhead) of the available space in the data block. Consult with the database administrator for assistance in determining the space required by an index.

Limit the Number of Indexes per Table A table can have any number of indexes. However, the more indexes, the more overhead is incurred as the table is altered. When rows are inserted or deleted, all indexes on the table must be updated. When a column is updated, all indexes on the column must be updated.

Thus, there is a trade-off between speed of retrieval for queries on a table and speed of accomplishing updates on the table. For example, if a table is primarily read-only, then more indexes might be useful; but, if a table is heavily updated, then fewer indexes might be preferable.

Order Index Columns for Performance The order in which columns are named in the CREATE INDEX command does not need to correspond to the order in which they appear in the table. However, the order of columns in the CREATE INDEX statement is significant because query performance can be affected by the order chosen. In general, you should put the column expected to be used most often first in the index.

For example, assume the columns of the VENDOR_PARTS table are as shown in Figure 6–1.

Figure 6–1 The VENDOR_PARTS Table

Table VENDOR_PARTS

VEND ID	PART NO	UNIT COST
1012	10–440	.25
1012	10–441	.39
1012	457	4.95
1010	10–440	.27
1010	457	5.10
1220	08–300	1.33
1012	08–300	1.19
1292	457	5.28

Assume that there are five vendors, and each vendor has about 1000 parts.

Suppose that the VENDOR_PARTS table is commonly queried by SQL statements such as the following:

```
SELECT * FROM vendor_parts
    WHERE part_no = 457 AND vendor_id = 1012;
```

To increase the performance of such queries, you might create a composite index putting the most selective column first; that is, the column with the *most* values:

```
CREATE INDEX ind_vendor_id
    ON vendor_parts (part_no, vendor_id);
```

Indexes speed retrieval on any query using the *leading portion* of the index. So in the above example, queries with WHERE clauses using only the PART_NO column also note a performance gain. Because there are only five distinct values, placing a separate index on VENDOR_ID would serve no purpose.

Creating Indexes

You can create an index for a table to improve the performance of queries issued against the corresponding table. You can also create an index for a cluster. You can create a *composite* index on multiple columns up to a maximum of 16 columns. A composite index key cannot exceed roughly one-half (minus some overhead) of the available space in the data block.

Oracle automatically creates an index to enforce a UNIQUE or PRIMARY KEY integrity constraint. In general, it is better to create such constraints to enforce uniqueness and not explicitly use the obsolete CREATE UNIQUE INDEX syntax.

Use the SQL command CREATE INDEX to create an index. The following statement

```
CREATE INDEX emp_ename ON Emp_tab(ename)
    TABLESPACE users
    STORAGE (INITIAL     20K
             NEXT        20k
             PCTINCREASE 75)
             PCTFREE      0;
```

Notice that several storage settings are explicitly specified for the index.

Privileges Required to Create an Index

To create a new index, you must own, or have the INDEX object privilege for, the corresponding table. The schema that contains the index must also have a quota for the tablespace intended to contain the index, or the UNLIMITED TABLESPACE system privilege. To create an index in another user's schema, you must have the CREATE ANY INDEX system privilege.

Dropping Indexes

You might drop an index for the following reasons:

- The index is not providing anticipated performance improvements for queries issued against the associated table (the table is very small, or there are many rows in the table but very few index entries, etc.).
- Applications do not contain queries that use the index.
- The index is no longer needed and must be dropped before being rebuilt.

When you drop an index, all extents of the index's segment are returned to the containing tablespace and become available for other objects in the tablespace.

Use the SQL command `DROP INDEX` to drop an index. For example, to drop the `EMP_ENAME` index, enter the following statement:

```
DROP INDEX Emp_ename;
```

If you drop a table, then all associated indexes are dropped.

Privileges Required to Drop an Index To drop an index, the index must be contained in your schema or you must have the `DROP ANY INDEX` system privilege.

Function-Based Indexes

A function-based index is an index built on an expression. It extends your indexing capabilities beyond indexing on a column. A function-based index increases the variety of ways in which you can access data.

> **Note:** You can create function-based indexes only if you are using the Oracle8*i* release, or higher.

The expression used in a function-based index can be an arithmetic expression or an expression that contains a PL/SQL function, package function, C callout, or SQL function. Function-based indexes also support linguistic sorts based on linguistic sort keys (collation), efficient linguistic collation of SQL statements, and case-insensitive sorts.

Like other indexes, function-based indexes improve query performance. For example, if you need to access a computationally complex expression often, then you can store it in an index. Then when you need to access the expression, it is

already computed. You can find a detailed description of the advantages of function-based indexes in "Using Function-Based Indexes" on page 6-7.

Function-based indexes have all of the same properties as indexes on columns. However, unlike indexes on columns which can be used by both cost-based and rule-based optimization, function-based indexes can be used by only by cost-based optimization. Other restrictions on function-based indexes are described in "Restrictions on Function-Based Indexes" on page 6-12.

> **See Also:** For more information on function-based indexes, see *Oracle8i Concepts*. For information on creating function-based indexes, see *Oracle8i Administrator's Guide*.

Using Function-Based Indexes

The following list describes the advantages of function-based indexes in greater detail:

- **Increase the number of situations where the optimizer can perform a range scan instead of a full table scan.** For example: consider the expression in the WHERE clause below:

  ```
  CREATE INDEX Idx ON Example_tab(Column_a + Column_b);
  SELECT * FROM Example_tab WHERE Column_a + Column_b < 10;
  ```

  In the CREATE INDEX statement, idx is the name of the index, Example_tab is the name of the table, and column_a and column_b represent columns. The optimizer can use a range scan for this query because the index is built on (column_a + column_b). Range scans typically produce fast response times if the predicate has low selectivity (that is, if the predicate selects less than 15% of the rows of a large table). In addition, the optimizer can estimate selectivity of predicates involving expressions more accurately if the expressions are materialized in a function-based index (expressions of function-based indexes are represented as virtual columns and ANALYZE can build histograms on such columns).

- **Precompute the value of a computationally intensive function and store it in the index.** If you have a computationally intensive expression that you access often, then you can store it in an index. When you need to access it, the value is already computed. This can greatly improve query execution performance.

- **Create indexes on object columns and REF columns.** Methods that describe objects can be used as functions on which to build indexes. For example, you can use the MAP method to build indexes on an object type column.

- **Create more powerful sorts.** You can perform case-insensitive sorts with the UPPER and LOWER functions, descending order sorts with the DESC function, and linguistic-based sorts with the NLSSORT function.

Note: The DESC keyword in the CREATE INDEX statement is no longer ignored. Oracle sorts columns with the DESC keyword in descending order. Such indexes are treated as function-based indexes. Descending indexes cannot be bitmapped or reverse, and cannot be used in bitmapped optimizations. To get the pre-Oracle 8.1 release DESC functionality, remove the DESC keyword from the CREATE INDEX statement.

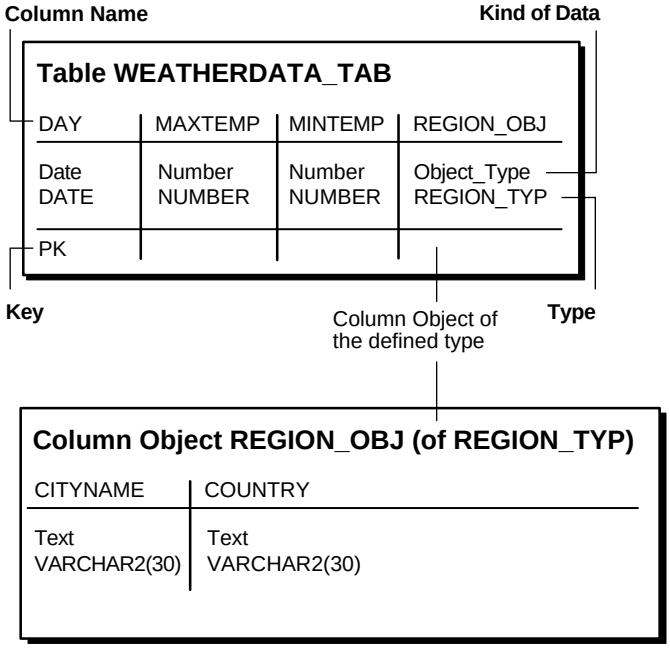
See Also: For examples of how to use function-based indexes, see the *Oracle8i Administrator's Guide*.

Example

As an example, consider a weather research institute that maintains tables of weather data for various cities. Some of their projects include tracking daily temperature fluctuations throughout the year. Other projects include tracking fluctuations as a function of the city's distance from the equator. By building indexes on the complex functions that they want to calculate, the institute can optimize the execution of the queries they submit. The following section contains examples of indexes that could be created and the queries that could use them.

The table, Weatherdata_tab, contains columns for the minimum daily temperature (Mintemp), maximum daily temperature (Maxtemp), the day the temperature was recorded (Day), and the Region (Region_Obj). Region_Obj is an object column that contains columns for country (Country) and city (Cityname). Figure 6–2 illustrates the Weatherdata_tab schema.

Figure 6–2 WEATHERDATA_TAB Schema Design



An index is created that calculates the difference in temperature for the cities in the tables. A query that could use the `delta_index` index returns the contents of the table for temperature differences less than 20:

Note: You may need to set up data structures similar to the following for certain examples to work:

```
CREATE OR REPLACE FUNCTION distance_from_equator(input
NUMBER) RETURN NUMBER DETERMINISTIC IS
   distance NUMBER;
BEGIN
   distance := 100000;
   RETURN (distance);
END;
```

```
CREATE INDEX Delta_index
ON Weatherdata_tab (Maxtemp - Mintemp);
```

```
SELECT *
FROM Weatherdata_tab
WHERE (Maxtemp - Mintemp) < '20';
```

An index is created that calls the object method `distance_from_equator` to calculate the distance from the equator for each city in the table. The method is applied to the object column `Region_Obj`. A query that could use the `distance_index` index returns the names of the cities that are at a distance greater than 1000 miles from the equator:

```
CREATE INDEX Distance_index
ON Weatherdata_tab (Distance_from_equator (Reg_obj));

SELECT *
FROM Weatherdata_tab
WHERE (Distance_from_equator (Reg_Obj)) > '1000';
```

An index is created that satisfies the queries of German-speaking users that sorts temperature data by city name. A query that could use the `City_index` index returns the contents of the table, ordered by city name. The German sort order for city name is used. Note that in the `SELECT` statement, a `WHERE` clause is not needed. This is because in a German session, `NLSSORT` is set to `German`.

```
CREATE INDEX City_index
ON Weatherdata_tab (NLSSORT(Cityname, 'NLS_SORT=German'));

SELECT *
FROM Weatherdata_tab
ORDER BY Cityname;
```

An index is created on the difference between the maximum and minimum temperatures, and on the maximum temperature. The result of the difference is sorted in descending order. A query that could use the `compare_index` index returns the contents of the table that satisfy the condition where the difference is less than 20 and the maximum temperature is greater than 75.

```
CREATE INDEX compare_index
ON Weatherdata_tab ((Maxtemp - Mintemp) DESC, Maxtemp);

SELECT *
FROM Weatherdata_tab WHERE ((Maxtemp - Mintemp) < '20' AND Maxtemp > '75');
```

Example Function-Based Indexes

Example 1:

The following command creates a function-based index IDX on table EMP_TAB.

```
CREATE INDEX Idx ON Emp_tab (UPPER(Ename));
```

The SELECT command uses the function-based index on UPPER(e_name) to return all of the employees with name like :KEYCOL.

```
SELECT *
FROM Emp_tab
WHERE UPPER(Ename) like :KEYCOL;
```

Example 2:

The following command creates a function-based index IDX on table Fbi_tab where A, B, and C represent columns.

```
CREATE INDEX Idx
On Fbi_tab (A + B * (C - 1), A, B);
```

The SELECT statement can either use index range scan (notice that the expression is a prefix of index IDX) or index fast full scan (which may be preferable if the index has specified a high parallel degree).

```
SELECT a
FROM Fbi_tab
Where A + B * (C - 1) < 100;
```

Example 3:

This example demonstrates how a function-based index can be used to support an NLS Sort Index. Given a string, the NLSSORT function returns a sort key. The following CREATE INDEX statement creates an NLS_SORT sort on table NLS_TAB with collation sequence GERMAN.

```
CREATE INDEX Nls_index
ON Nls_tab (NLSSORT(Name, 'NLS_SORT = German'));
```

The SELECT statement selects all of the contents of the table and orders it by NAME. The rows are ordered using the German collation sequence.

```
SELECT *
FROM Nls_tab
ORDER BY Name;
```

Example 4:

This example demonstrates a case-insensitive search. The UPPER function converts the ENAMEs to all uppercase letters:

```
CREATE INDEX Case_insensitive_idx
ON Emp_tab (UPPER(Ename));
```

An example query which would use this index is:

```
SELECT *
FROM Emp_tab
WHERE UPPER(Ename) = 'JOE';
```

Restrictions on Function-Based Indexes

Note the following restrictions on function-based indexes:

- Only cost-based optimization can use function-based indexes.
- A function-based index expression cannot read or write database and package state. In addition, a PL/SQL function, either a top level function or a package-level function, used in this expression has to be declared as DETERMINISTIC. There is no error checking whether or not a subprogram is qualified as DETERMINISTIC. It is up to you to ensure that a subprogram is DETERMINISTIC.

  The following semantic rules demonstrate how to use the keyword DETERMINISTIC:

  - A top level subprogram can be declared as DETERMINISTIC.
  - A PACKAGE level subprogram can be declared as DETERMINISTIC in the PACKAGE specification but not in the PACKAGE BODY. Errors will be raised if DETERMINISTIC is used inside a PACKAGE BODY.
  - A private subprogram (declared inside another subprogram or a PACKAGE BODY) cannot be declared as DETERMINISTIC.
  - A DETERMINISTIC subprogram can call another subprogram whether the called program is declared as DETERMINISTIC or not.
- Function-based indexes cannot be built on LOB columns.
- Expressions used in a function-based index should reference only columns in a row in the table. Hence, these expressions cannot contain any aggregate functions.

- Function-based indexes that return VARCHAR2 or RAW data types from a PL/SQL function are not permitted due to length restrictions. A possible work around is to use substrings to limit the size of the function's output. For example:

  Note: You may need to set up data structures similar to the following for certain examples to work:

  ```
  CREATE OR REPLACE FUNCTION x(input IN VARCHAR2)
  RETURN VARCHAR2 AS
  output VARCHAR2(12);
  BEGIN
     output :=input;
     RETURN (output);
  END;

  SELECT SUBSTR(x('hello'),1,100) FROM DUAL;
  ```

  ```
  SUBSTR (F(X), 1, 100)
  ```

  Where F(X) represents the PL/SQL function. The SUBSTR command would need to be used for the function when creating the index and when referencing the function in queries.

Managing Clusters, Clustered Tables, and Cluster Indexes

Because clusters store related rows of different tables together in the same data blocks, two primary benefits are achieved when clusters are properly used:

- Disk I/O is reduced and access time improves for joins of clustered tables.
- In a cluster, a *cluster key value* (the related value) is only stored once, no matter how many rows of different tables contain the value. Therefore, less storage may be required to store related table data in a cluster than is necessary in non-clustered table format.

Guidelines for Creating Clusters

Some guidelines for creating clusters are outlined below.

> **See Also:** For performance characteristics, see *Oracle8i Tuning*.

Choose Appropriate Tables to Cluster Use clusters to store one or more tables that are primarily queried (not predominantly inserted into or updated), and for which queries often join data of multiple tables in the cluster or retrieve related data from a single table.

Choose Appropriate Columns for the Cluster Key Choose cluster key columns carefully. If multiple columns are used in queries that join the tables, then make the cluster key a composite key. In general, the same column characteristics that make a good index apply for cluster indexes.

> **See Also:** "Index the Correct Tables and Columns" on page 6-3 has more information about these guidelines.

A good cluster key has enough unique values so that the group of rows corresponding to each key value fills approximately one data block. Too few rows per cluster key value can waste space and result in negligible performance gains. Cluster keys that are so specific that only a few rows share a common value can cause wasted space in blocks, unless a small `SIZE` was specified at cluster creation time.

Too many rows per cluster key value can cause extra searching to find rows for that key. Cluster keys on values that are too general (for example, `MALE` and `FEMALE`) result in excessive searching and can result in worse performance than with no clustering.

A cluster index cannot be unique or include a column defined as `LONG`.

Performance Considerations

Also note that clusters can reduce the performance of DML statements (INSERTs, UPDATEs, and DELETEs) as compared to storing a table separately with its own index. These disadvantages relate to the use of space and the number of blocks that must be visited to scan a table. Because multiple tables share each block, more blocks must be used to store a clustered table than if that same table were stored non-clustered. You should decide about using clusters with these trade-offs in mind.

To identify data that would be better stored in clustered form than in non-clustered form, look for tables that are related via referential integrity constraints, and tables that are frequently accessed together using SELECT statements that join data from two or more tables. If you cluster tables on the columns used to join table data, then you reduce the number of data blocks that must be accessed to process the query; all the rows needed for a join on a cluster key are in the same block. Therefore, query performance for joins is improved.

Similarly, it may be useful to cluster an individual table. For example, the EMP_TAB table could be clustered on the DEPTNO column to cluster the rows for employees in the same department. This would be advantageous if applications commonly process rows, department by department.

Like indexes, clusters do not affect application design. The existence of a cluster is transparent to users and to applications. Data stored in a clustered table is accessed via SQL just like data stored in a non-clustered table.

Creating Clusters, Clustered Tables, and Cluster Indexes

Use a cluster to store one or more tables that are frequently joined in queries. Do not use a cluster to cluster tables that are frequently accessed individually.

Once you create a cluster, tables can be created in the cluster. However, before you can insert any rows into the clustered tables, you must create a cluster index. The use of clusters does not affect the creation of additional indexes on the clustered tables; you can create and drop them as usual.

Use the SQL command CREATE CLUSTER to create a cluster. The following statement creates a cluster named EMP_DEPT, which stores the EMP_TAB and DEPT_TAB tables, clustered by the DEPTNO column:

```
CREATE CLUSTER Emp_dept (Deptno NUMBER(3))
                        PCTUSED 80
                        PCTFREE 5;
```

Create a table in a cluster using the SQL command CREATE TABLE with the CLUSTER option. For example, the EMP_TAB and DEPT_TAB tables can be created in the EMP_DEPT cluster using the following statements:

```
CREATE TABLE Dept_tab (
    Deptno NUMBER(3) PRIMARY KEY,
    . . . )
    CLUSTER Emp_dept (Deptno);

CREATE TABLE Emp_tab (
    Empno NUMBER(5) PRIMARY KEY,
    Ename VARCHAR2(15) NOT NULL,
    . . .
    Deptno NUMBER(3) REFERENCES Dept_tab)
    CLUSTER Emp_dept (Deptno);
```

A table created in a cluster is contained in the schema specified in the CREATE TABLE statement; a clustered table might not be in the same schema that contains the cluster.

You must create a cluster index before any rows can be inserted into any clustered table. For example, the following statement creates a cluster index for the EMP_DEPT cluster:

```
CREATE INDEX Emp_dept_index
    ON CLUSTER Emp_dept
    INITRANS   2
    MAXTRANS   5
    PCTFREE    5;
```

> **Note:** A cluster index cannot be unique. Furthermore, Oracle is not guaranteed to enforce uniqueness of columns in the cluster key if they have UNIQUE or PRIMARY KEY constraints.

The cluster key establishes the relationship of the tables in the cluster.

Privileges Required to Create a Cluster, Clustered Table, and Cluster Index

To create a cluster in your schema, you must have the CREATE CLUSTER system privilege and a quota for the tablespace intended to contain the cluster or the UNLIMITED TABLESPACE system privilege. To create a cluster in another user's schema, you must have the CREATE ANY CLUSTER system privilege, and the owner must have a quota for the tablespace intended to contain the cluster or the UNLIMITED TABLESPACE system privilege.

To create a table in a cluster, you must have either the CREATE TABLE or CREATE ANY TABLE system privilege. You do not need a tablespace quota or the UNLIMITED TABLESPACE system privilege to create a table in a cluster.

To create a cluster index, your schema must contain the cluster, and you must have the following privileges:

- The CREATE ANY INDEX system privilege or, if you own the cluster, the CREATE INDEX privilege
- A quota for the tablespace intended to contain the cluster index, or the UNLIMITED TABLESPACE system privilege

Manually Allocating Storage for a Cluster

Oracle dynamically allocates additional extents for the data segment of a cluster, as required. In some circumstances, you might want to explicitly allocate an additional extent for a cluster. For example, when using the Oracle Parallel Server, an extent of a cluster can be allocated explicitly for a specific instance.

You can allocate a new extent for a cluster using the SQL command ALTER CLUSTER with the ALLOCATE EXTENT option.

See Also: *Oracle8i Parallel Server Concepts and Administration*

Dropping Clusters, Clustered Tables, and Cluster Indexes

Drop a cluster if the tables currently within the cluster are no longer necessary. When you drop a cluster, the tables within the cluster and the corresponding cluster index are dropped; all extents belonging to both the cluster's data segment and the index segment of the cluster index are returned to the containing tablespace and become available for other segments within the tablespace.

You can individually drop clustered tables without affecting the table's cluster, other clustered tables, or the cluster index. Drop a clustered table in the same manner as a non-clustered table—use the SQL command DROP TABLE.

See "Dropping Tables" for more information about individually dropping tables.

Note: When you drop a single clustered table from a cluster, each row of the table must be deleted from the cluster. To maximize efficiency, if you intend to drop the entire cluster including all tables, then use the DROP CLUSTER command with the INCLUDING TABLES option.

You should only use the DROP TABLE command to drop an individual table from a cluster when the rest of the cluster is going to remain.

You can drop a cluster index without affecting the cluster or its clustered tables. However, you cannot use a clustered table if it does not have a cluster index. Cluster indexes are sometimes dropped as part of the procedure to rebuild a fragmented cluster index.

See Also: "Dropping Indexes" on page 6-6

To drop a cluster that contains no tables, as well as its cluster index, if present, use the SQL command DROP CLUSTER. For example, the following statement drops the empty cluster named EMP_DEPT:

```
DROP CLUSTER Emp_dept;
```

If the cluster contains one or more clustered tables, and if you intend to drop the tables as well, then add the INCLUDING TABLES option of the DROP CLUSTER command. For example:

```
DROP CLUSTER Emp_dept INCLUDING TABLES;
```

If you do not include the INCLUDING TABLES option, and if the cluster contains tables, then an error is returned.

If one or more tables in a cluster contain primary or unique keys that are referenced by FOREIGN KEY constraints of tables outside the cluster, then you cannot drop the cluster unless you also drop the dependent FOREIGN KEY constraints. Use the CASCADE CONSTRAINTS option of the DROP CLUSTER command, as in

```
DROP CLUSTER Emp_dept INCLUDING TABLES CASCADE CONSTRAINTS;
```

An error is returned if the above option is not used in the appropriate situation.

Privileges Required to Drop a Cluster

To drop a cluster, your schema must contain the cluster, or you must have the DROP ANY CLUSTER system privilege. You do not have to have any special privileges to drop a cluster that contains tables, even if the clustered tables are not owned by the owner of the cluster.

Managing Hash Clusters and Clustered Tables

The following sections explain how to create, alter, and drop hash clusters and clustered tables using SQL commands.

Creating Hash Clusters and Clustered Tables

A hash cluster is used to store individual tables or a group of clustered tables that are static and often queried by equality queries. Once you create a hash cluster, you can create tables. To create a hash cluster, use the SQL command CREATE CLUSTER. The following statement creates a cluster named TRIAL_CLUSTER that is used to store the TRIAL_TAB table, clustered by the TRIALNO column:

Note: You may need to use a setup similar to the following for certain examples to work:

```
ALTER TABLESPACE SYSTEM ADD DATAFILE 'disk1:moredata1' SIZE 50K
AUTOEXTEND ON;
```

```
CREATE CLUSTER Trial_cluster (
    Trialno NUMBER(5,0))
    PCTUSED 80
    PCTFREE 5
    SIZE    2K
    HASH IS Trialno HASHKEYS 100000;

CREATE TABLE Trial_tab (
    Trialno NUMBER(5) PRIMARY KEY,
    ...)
    CLUSTER Trial_cluster (Trialno);
```

Controlling Space Usage Within a Hash Cluster

When you create a hash cluster, it is important that you correctly choose the cluster key and set the HASH IS, SIZE, and HASHKEYS parameters to achieve the desired performance and space usage for the cluster. The following sections provide guidance, as well as examples of setting these parameters.

Choosing the Key

Choosing the correct cluster key is dependent on the most common types of queries issued against the clustered tables. For example, consider the EMP_TAB table in a

hash cluster. If queries often select rows by employee number, then the EMPNO column should be the cluster key; if queries often select rows by department number, then the DEPTNO column should be the cluster key. For hash clusters that contain a single table, the cluster key is typically the entire primary key of the contained table. A hash cluster with a composite key must use Oracle's internal hash function.

Setting HASH IS

Only specify the HASH IS parameter if the cluster key is a single column of the NUMBER datatype and contains uniformly distributed integers. If the above conditions apply, then you can distribute rows in the cluster such that each unique cluster key value hashes to a unique hash value (with no collisions). If the above conditions do not apply, you should use the internal hash function.

Dropping Hash Clusters

Drop a hash cluster using the SQL command DROP CLUSTER:

```
DROP CLUSTER Emp_dept;
```

Drop a table in a hash cluster using the SQL command DROP TABLE. The implications of dropping hash clusters and tables in hash clusters are the same as for index clusters.

> **See Also:** "Dropping Clusters, Clustered Tables, and Cluster Indexes" on page 6-17

When to Use Hashing

Storing a table in a hash cluster is an alternative to storing the same table with an index. Hashing is useful in the following situations:

- Most queries are equality queries on the cluster key. For example:

  ```
  SELECT . . . WHERE Cluster_key = . . . ;
  ```

  In such cases, the cluster key in the equality condition is hashed, and the corresponding hash key is usually found with a single read. With an indexed table, the key value must first be found in the index (usually several reads), and then the row is read from the table (another read).

- The table or tables in the hash cluster are primarily static in size such that you can determine the number of rows and amount of space required for the tables

in the cluster. If tables in a hash cluster require more space than the initial allocation for the cluster, then performance degradation can be substantial because overflow blocks are required.

- A hash cluster with the HASH IS *col*, HASHKEYS *n*, and SIZE *m* clauses is an ideal representation for an array (table) of *n* items (rows) where each item consists of *m* bytes of data. For example:

  ```
  ARRAY X[100] OF NUMBER(8)
  ```

  This could be represented as the following:

  ```
  CREATE CLUSTER C(Subscript INTEGER)
      HASH IS Subscript HASHKEYS 100 SIZE 100;

  CREATE TABLE X(Subscript NUMBER(2), Value NUMBER(8))
      CLUSTER C(Subscript);
  ```

Alternatively, hashing is not advantageous in the following situations:

- Most queries on the table retrieve rows over a range of cluster key values. For example, in full table scans, or queries:

  ```
  SELECT . . . WHERE Cluster_key < . . . ;
  ```

  A hash function cannot be used to determine the location of specific hash keys; instead, the equivalent of a full table scan must be done to fetch the rows for the query. With an index, key values are ordered in the index, so cluster key values that satisfy the WHERE clause of a query can be found with relatively few I/Os.

- A table is not static, but is continually growing. If a table grows without limit, then the space required over the life of the table (thus, of its cluster) cannot be predetermined.

- Applications frequently perform full table scans on the table and the table is sparsely populated. A full table scan in this situation takes longer under hashing.

- You cannot afford to preallocate the space the hash cluster will eventually need.

In most cases, you should decide (based on the above information) whether to use hashing or indexing. If you use indexing, consider whether it is best to store a table individually or as part of a cluster.

See Also: "Guidelines for Creating Clusters" on page 6-14

If you decide to use hashing, then a table can still have separate indexes on any columns, including the cluster key.

See Also: For additional guidelines on the performance characteristics of hash clusters, see *Oracle8i Tuning*.

7

Managing Index-Organized Tables

This chapter covers the following topics:

- Overview of Index-Organized Tables
- Features of Index-Organized Tables
- When to Use Index-Organized Tables
- Example

Overview of Index-Organized Tables

An index-organized table—in contrast to an ordinary table—has its own way of structuring, storing, and indexing data. A comparison with an ordinary table may help to explain its uniqueness.

Index-Organized Tables versus Ordinary Tables

A row in an *ordinary table* has a stable physical location. Once it is given its first physical location, it never completely moves. Even if the row is partially moved with the addition of new data, there is always a row piece at the original physical address—identified by the original physical rowid—from which the system can find the rest of the row. As long as the row exists, its physical rowid does not change.

When you index a column in an ordinary table, the newly created index stores both the column data as well as the rowid.

A row in an *index-organized table* does *not* have a stable physical location. An index-organized table is, on the one hand, like an ordinary table with an index on one or more of its columns. It is unique, however, in that it holds its data, not in stable rows, but in sorted order in the leaves of a B*-tree index built on the table's primary key. These rows may move around to retain the sorted order. An insertion, for example, can cause an index leaf to split and the existing row to be moved to a different slot, or even to a different block.

The leaves of the B*-tree index hold the primary key and the actual row data. Changes to the table data—for example, adding new rows, or updating or deleting existing rows—result only in updating the index.

> **See Also:** For more information on B*-tree indexes, see *Oracle8i Concepts*

Advantages of Index-Organized Tables

Because they store rows in the B*-tree index based on the primary key, index-organized tables offer the following advantages over ordinary tables:

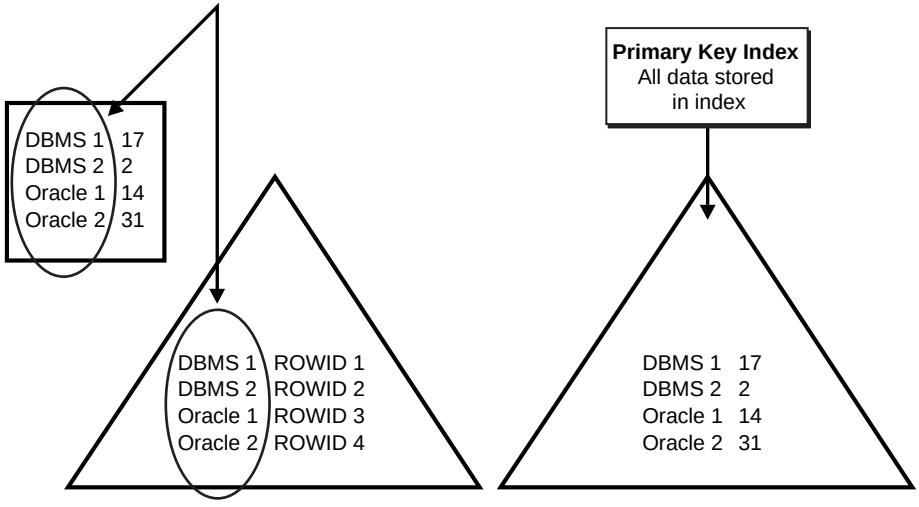
Fast access to table data for queries involving exact match and/or range search on a primary key Once a search has located the key values, the remaining data is present at that location. There is no need to follow a rowid back to table data, as would be the case with an ordinary table and index structure. The index-organized table thus shows its efficiency by eliminating one I/O, namely, the read of the table.

Best table organization for 24x7 operations When your database must be available 100% of the time, index-organized tables provide the following advantages:

- You can reorganize an index-organized table or an index-organized table partition (to recover space or improve performance) without rebuilding its indexes. This results in a short reorganization maintenance window.
- You can reorganize an index-organized table online. This and the ability to perform online reorganization of secondary indexes eliminates the reorganization maintenance window.

Reduced storage requirements This is because the key columns are not duplicated in both the table and the index, and because no additional storage is needed for rowids.

Figure 7–1 Conventional Table and an Index versus Index-Organized Table



Features of Index-Organized Tables

You can move your existing data into an index-organized table and do all the operations you would perform in an ordinary table. Some of the features now available to you in using index-organized tables include the following.

Same Support for Alter Table Options as in Ordinary Tables All of the alter options available on ordinary tables are now available for index-organized tables. This includes `ADD`, `MODIFY`, and `DROP COLUMNS` and `CONSTRAINTS`. However, the primary key constraint for an index-organized table cannot be dropped, deferred, or disabled.

Logical ROWID Support Because of the inherent movability of rows in a B*-tree index, a secondary index on an index-organized table cannot be based on a *physical* rowid which is inherently fixed. Instead, a secondary index for an index-organized table is based on what is called the *logical* rowid. A logical rowid has no permanent physical address and can move across data blocks when new rows are inserted. However, if the physical location of a row changes, its logical rowid remains valid.

A logical rowid includes the table's primary key and a guess which identifies the block location of a row at the time the guess is made. The guess makes rowid access to non-volatile index-organized tables comparable to access of ordinary tables.

Logical rowids are similar to physical rowids in the following ways:

- Users can select `ROWID` from an index-organized table and access the rows using `WHERE ROWID = <value predicate>`.
- The access through the logical rowid is the fastest possible way to get to a specific row, even if it takes more than one block access to get it.
- Logical rowid of a row does not change as long as the primary key value does not change. However, unlike the physical rowid which remains immovable through all updates, the logical rowid can move when hew rows are inserted.

Oracle 8*i*, release 8.1, introduces a single datatype, called universal rowid, to support both logical and physical rowids.

Applications which use rowids today may, if using index-organized tables, have to change to use universal rowids, but the changes are simpler due to the availability of `UROWID` datatype. This allows applications to access logical and physical rowids in a unified manner.

> **For more information:** See "Declaring a Universal Rowid Datatype" on page 7-11.

Secondary Index Support Secondary indexes on index-organized tables differ from indexes on ordinary tables in two ways:

- They store logical rowids instead of physical rowids. Thus, a table maintenance operation such as ALTER TABLE MOVE does not make the secondary index unusable.
- The logical rowid also includes a guess that provides a direct access to the primary key index leaf block. If the guess is correct, a secondary index scan would incur a single additional I/O once the secondary key is found. The performance would be similar to that of a secondary index-scan on an ordinary table.

Both unique and non-unique secondary indexes, as well as function-based secondary indexes, are supported. However, bit-mapped secondary indexes on index-organized tables are currently not supported.

LOB Columns You can create internal and external LOB columns in index-organized tables to store large unstructured data such as audio, video, and images. The SQL DDL, DML, and piece-wise operations on LOBs in index-organized tables exhibit the same behavior as in ordinary tables. The main differences are:

- Tablespace mapping—By default (or unless specified otherwise), the LOB's data and index segments are created in the tablespace in which the primary key index segment of the index-organized table is created.
- Inline vs. Out-of-line storage—By default, all LOBs in index-organized tables created without an overflow segment are stored out-of-line (that is, the default storage attribute is DISABLE STORAGE IN ROW). Specifying an ENABLE STORAGE IN ROW for such LOBs, will result in an error. However, LOBs in index-organized tables with overflow segments have the same characteristics as those in ordinary tables.

Other LOB features—such as BFILEs, temporary LOBs, and varying character width LOBs—are also supported in index-organized tables. You use them as you would ordinary tables. Support for LOBs in partitioned index-organized tables is not currently available.

Parallel Query Queries on index-organized tables involving primary key index scan can be executed in parallel. However, parallel execution of secondary index-only scan queries is not yet supported.

Object Support Most of the object features are supported on index-organized tables, including Object Type, VARRAYS, Nested Table, and REF Columns. However, you cannot create object tables (TABLE OF <object type>) as index-organized tables.

SQL*Loader This utility supports both ordinary and direct path load of index-organized tables and their associated indexes (including partitioning support). However, direct path parallel load to an index-organized table is not supported. An alternate method of achieving the same result is to perform parallel load to an ordinary table using SQL*Loader, then use the parallel CREATE TABLE AS SELECT option to build the index-organized table.

Export/Import This utility supports export (both ordinary and direct path) and import of non-partitioned and partitioned index-organized tables.

Distributed Database and Replication Support You can replicate both non-partitioned and partitioned index-organized tables.

Tools The Oracle Enterprise Manager supports generating SQL statements for CREATE and ALTER operations on an index-organized table.

Key Compression Key compression allows elimination of repeated occurrences of key column prefixes in index-organized tables and indexes. The salient characteristics of the scheme are:

- Key compression breaks an index key into a prefix entry and suffix entry. Compression is achieved by sharing the prefix entries among all the suffix entries in an index block.
- Only keys in the leaf blocks of a B*-tree are compressed. Keys in the branch blocks of a B*-tree are still suffix truncated but not subjected to key compression.

When to Use Index-Organized Tables

There are several occasions when you may prefer to use index-organized tables over ordinary tables.[1]

When You Want to Avoid Redundant Data Storage For tables, where the majority of columns form the primary key, there is a significant amount of redundant data stored. You can avoid this redundant storage by using an index-organized table. Also, by using an index-organized table, you increase the efficiency of the primary key-based access to non-key columns.

When Developing VLDB and OLTP Applications The ability to partition an index-organized table on a range of column values makes the use of index-organized tables suitable for VLDB applications.

One major advantage of an index-organized table over an ordinary table stems from the logical nature of the index-organized table's secondary indexes. After an ALTER TABLE MOVE and SPLIT operation, *global* indexes on index-organized tables remain usable because the index rows contain logical rowids. In the case of ordinary tables, by contrast, these operations result in making the global index unusable, requiring a complete index rebuild, which can be very expensive.

Similarly, after an ALTER TABLE MOVE operation, *local* indexes on index-organized tables are still usable. On the other hand, for ordinary tables, the MOVE operation results in making a secondary local index unusable.

The partition maintenance operations described above do make the local and global indexes on index-organized table perform slower as the guess component of logical rowid becomes invalid. However, the indexes are still usable via the primary key-component of the logical rowid.

In addition, the ALTER TABLE MOVE operation can be done on-line. This functionality makes index-organized tables ideal for applications requiring 24X7 availability.

When Developing Time-series Applications The ability to cluster rows based on the primary key makes index-organized tables attractive for time-series

[1] If you use Oracle Advanced Queuing, you may be familiar with index-organized tables already. Oracle Advance Queuing provides message queuing as an integrated part of the Oracle8*i* server, and uses index-organized tables to hold metadata information for multiple consumer queues. In this case, the index-organized table acts as an "index," storing queue metadata as part of a primary key B*-tree index on the queue identifier. DML operations in turn have to update the "index," and this occurs efficiently by updating the underlying index-organized table.

applications. Typically, a time-series is a set of time-stamped rows belonging to a single item such as stock price. Data is typically accessed through an item identifier such as a stock symbol and a time stamp. By defining, an index-organized table with primary key (stock symbol, time stamp), the Oracle8 Time Series Data Cartridge is able to store and manipulate time-series data efficiently. You can achieve further storage savings by compressing repeated occurrences of the item identifier (for example. the stock symbol) in a time series by using an index-organized table with key compression.

When Using Nested Tables For a nested table column, Oracle internally creates a storage table to hold all the nested table rows. The rows belonging to a single nested table instance are identified by a NESTED_TABLE_ID column. If an ordinary table is used as nested table column storage, the nested table rows typically get de-clustered. By contrast, when you use an index-organized table, the nested table rows can be clustered based on the NESTED_TABLE_ID column. In Oracle 8*i*, Release 8.1, you can specify the storage of the nested table to be an index-organized table, as illustrated in the following.

```
CREATE TYPE Project_t AS OBJECT(Pno NUMBER, Pname VARCHAR2(80));
CREATE TYPE Project_set AS TABLE OF Project_t;
CREATE TABLE Employees (Eno NUMBER, Projects PROJECT_SET)
   NESTED TABLE Projects_ntab STORE AS Emp_project_tab
                ((PRIMARY KEY(Nested_table_id, Pno)) ORGANIZATION INDEX)
                RETURN AS LOCATOR;
```

When Using Extensible Indexing Oracle 8*i*, Release 8.1 introduces the Extensible Indexing Framework which allows you to add a new access method to the database. Typically, domain-specific indexing schemes need some storage mechanism to hold their index data. Index-organized tables are ideal candidates for such domain index storage. Oracle8 Spatial and Text Database Cartridges have implemented domain-specific indexing schemes that use index-organized tables for storing their index data.

Example

Note: You may need to set up the following data structures for certain examples to work; such as:

```
CONNECT system/manager
GRANT CREATE TABLESPACE TO scott;
CONNECT scott/tiger
CREATE TABLESPACE Ind_tbs DATAFILE 'disk1:moredata2'
SIZE 100K;
CREATE TABLE Doc_tab DATAFILE 'disk1:moredata2' SIZE
100K;
CREATE TABLESPACE Ovf_tbs DATAFILE 'disk1:moredata3'
SIZE 100K;
CREATE TABLESPACE Ind_ts0 DATAFILE 'disk1:moredata5'
SIZE 100K REUSE;
CREATE TABLESPACE Ov_ts0 DATAFILE 'disk1:moredata6'
SIZE 100K REUSE;
CREATE TABLESPACE Ind_ts1 DATAFILE 'disk1:moredata7'
SIZE 100K REUSE;
CREATE TABLESPACE Ov_ts1 DATAFILE 'disk1:moredata8'
SIZE 100K REUSE;
CREATE TABLESPACE Ind_ts2 DATAFILE 'disk1:moredata9'
SIZE 100K REUSE;
CREATE TABLESPACE Ov_ts2 DATAFILE 'disk1:moredata10'
SIZE 100K REUSE;
CREATE TABLE Doc_tab (tok VARCHAR2(4),id
VARCHAR2(14),freq NUMBER);
```

This example illustrates some of the basic tasks in creating and using index-organized tables. In this example, a text search engine uses an inverted index[1] to allow a user to query for specific words or phrases over the Web. It then returns to the user a list of hypertext links to documents containing the queried words and phrases, and it ranks those links in the order of relevance.

This example illustrates the following tasks:

[1] An inverted index breaks each document into individual words or tokens. For each word, the inverted index builds a list of documents in which the word occurs, then stores that list in the database. The application performs a content-based search by scanning the inverted index looking for tokens of interest. From a development standpoint, an inverted index typically contains entries of the form <token, document_id, occurrence_data> for each distinct word in a document.

Moving Existing Data from an Ordinary Table into an Index-Organized Table

The CREATE TABLE AS SELECT command allows you to move existing data from an ordinary table into an index-organized table. In the following example, an index-organized table, called docindex, is created from an ordinary table called doctable.

```
CREATE TABLE Docindex
   (    Token,
        Doc_id,
        Token_frequency,
        CONSTRAINT Pk_docindex PRIMARY KEY (Token, Doc_id)
   )
ORGANIZATION INDEX TABLESPACE Ind_tbs
PARALLEL (DEGREE 2)
AS SELECT * from Doc_tab;
```

Note that the PARALLEL clause allows the table creation to be performed in parallel.

Creating Index-Organized Tables

To create an index-organized table, you use the ORGANIZATION INDEX clause. In the following example, an inverted index—typically used by Web text-search engines—uses an index-organized table.

```
CREATE TABLE Docindex
   (  Token           CHAR(20),
```

```
      Doc_id          NUMBER,
      Token_frequency NUMBER,
      CONSTRAINT Pk_docindex PRIMARY KEY (Token, Doc_id)
   )
ORGANIZATION INDEX TABLESPACE Ind_tbs;
```

Declaring a Universal Rowid Datatype

The following example shows how you declare the UROWID datatype.

```
DECLARE
     Rid UROWID;
BEGIN
     INSERT INTO Docindex VALUES ('Or80', 2, 30)
                 RETURNING Rowid INTO RID;
     UPDATE Docindex SET Token='Or81' WHERE ROWID = Rid;
END;
```

Creating Secondary Indexes on Index-Organized Tables

You can create secondary indexes on index-organized tables to provide multiple access paths. The following example shows the creation of an index on (doc_id, token).

```
CREATE INDEX Doc_id_index on Docindex(Doc_id, Token);
```

This secondary index allows Oracle to efficiently process queries involving predicates on doc_id, as the following example illustrates.

```
SELECT Token FROM Docindex WHERE Doc_id = 1;
```

Manipulating Index-Organized Tables

Applications manipulate the index-organized tables just like an ordinary table, using standard SQL statements for SELECT, INSERT, UPDATE, or DELETE operations. For example, you can manipulate the docindex table as follows:

```
INSERT INTO Docindex VALUES ('Oracle8.1', 3, 17);
SELECT * FROM Docindex;
UPDATE Docindex SET Token = 'Oracle8' WHERE Token = 'Oracle8.1';
DELETE FROM Docindex WHERE Doc_id = 1;
```

Also, you can use SELECT FOR UPDATE statements to lock rows of an index-organized table. All of these operations result in manipulating the primary key B*-tree index. Both query and DML operations involving index-organized tables are optimized by using this cost-based approach.

Specifying an Overflow Data Segment

Storing all non-key columns in the primary key B*-tree index structure may not always be desirable because, for example:

- Each additional non-key column stored in the primary key index reduces the dense clustering of index rows in the B*-tree index leaf blocks

  or because

- A leaf block of aB*-tree must hold at least two index rows, and putting all non-key columns as part of an index row may not be possible.

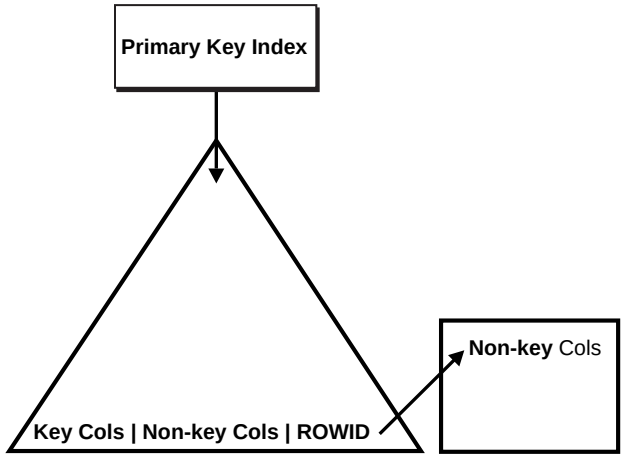
To overcome these problems, you can associate an overflow data segment with an index-organized table. In the following example, an additional column, `token_offsets`, is required for the `docindex` table. This example shows how you can create an index-organized table and use the `OVERFLOW` option to create an overflow data segment.

```
CREATE TABLE Docindex2
   (   Token           CHAR(20),
       Doc_id          NUMBER,
       Token_frequency NUMBER,
       Token_offsets   VARCHAR(512),
       CONSTRAINT Pk_docindex2 PRIMARY KEY (Token, Doc_id)
   )
ORGANIZATION INDEX TABLESPACE Ind_tbs PCTTHRESHOLD 20
OVERFLOW TABLESPACE Ovf_tbs INITRANS 4;
```

For the overflow data segment, you can specify physical storage attributes such as `TABLESPACE`, `INITRANS`, and so on.

For an index-organized table with an overflow segment, the index row contains a <key, row head> pair, where the row head contains the first few non-key columns and a rowid that points to an overflow row-piece containing the remaining column values. Although this approach incurs the storage cost of one rowid per row, it nevertheless avoids key column duplication.

Figure 7–2 Overflow Segment



Determining the Last Non-key Column Included in the Index Row Head Piece

To determine the last non-key column to include in the index row head piece, you use the PCTTHRESHOLD option specified as a percentage of the leaf block size. The remaining non-key columns are stored in the overflow data segment as one or more row-pieces. Specifically, the last non-key column to be included is chosen so that the index row size (key +row head) does not exceed the specified threshold (which, in the following example, is 20% of the index leaf block). By default, PCTTHRESHOLD is set at 50 when omitted.

The PCTTHRESHOLD option determines the last non-key column to be included in the index on a per row basis. It does not, however, allow you to specify that the same set of columns be included in the index for all rows in the table. For this purpose, the INCLUDING option is provided.

The CREATE TABLE statement in the following example includes all the columns up to the token_frequency column in the index leaf block and forces the token_offsets column to the overflow segment.

```
CREATE TABLE Docindex3
   (   Token           CHAR(20),
       Doc_id          NUMBER,
       Token_frequency NUMBER,
       Token_offsets   VARCHAR(512),
       CONSTRAINT Pk_docindex3 PRIMARY KEY (Token, Doc_id)
   )
ORGANIZATION INDEX TABLESPACE Ind_tbs INCLUDING Token_frequency
```

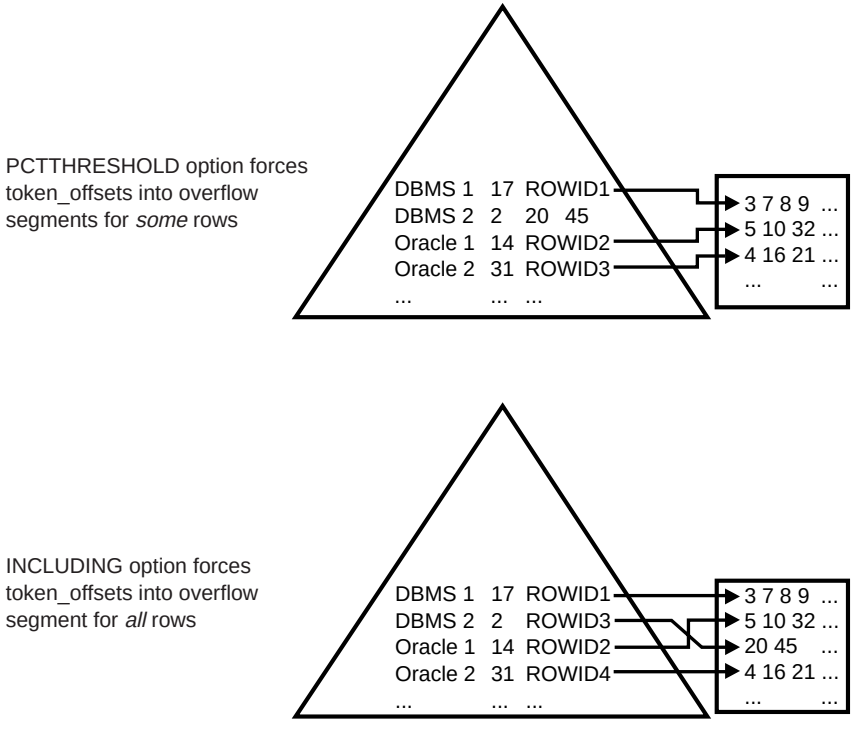
```
OVERFLOW TABLESPACE Ovf_tbs;
```

Such vertical partitioning of a row between the index and data segments allows for higher clustering of rows in the index. This results in better query performance for the columns stored in the index. For example, if the `token_offsets` column is infrequently accessed, then pushing this column out of the index results in better clustering of index rows in the primary key B*-tree structure (Figure 7–3). This in turn results in overall improved query performance. However, there is one additional block access for columns stored in the overflow data segment, and this can slow performance.

Storing Columns in the Overflow Segment

The `INCLUDING` option ensures that all columns after the specified including column are stored in the overflow segment. If the including column specified is such that corresponding index row size exceeds the specified threshold, then the last non-key column to be included is determined according to the `PCTTHRESHOLD` option.

Figure 7–3 PCTTHRESHOLD versus INCLUDING Column Usage



Modifying Physical and Storage Attributes

You can use the ALTER TABLE command to modify physical and storage attributes for both the index and overflow data segments as well as alter PCTTHRESHOLD and INCLUDING column values. The following example sets the INITRANS of index segment to 4, PCTTHRESHOLD to 20, and the INITRANS of the overflow data segment to 6. The altered values are used for subsequent operations on the table.

```
ALTER TABLE Docindex INITRANS 4 PCTTHRESHOLD 20 OVERFLOW INITRANS 6;
```

For index-organized tables created without an overflow data segment, you can add an overflow data segment using ALTER TABLE ADD OVERFLOW option. The following example shows how to add an overflow segment to the docindex table.

```
ALTER TABLE Docindex ADD OVERFLOW;
```

Analyzing an Index-Organized Table

Index-organized tables are analyzed just like ordinary tables using the ANALYZE command. The following example illustrates how you could use the ANALYZE command to analyze the docindex table.

```
ANALYZE TABLE Docindex COMPUTE STATISTICS;
```

Using the ANALYZE command analyzes both the primary key index segment and the overflow data segment, and computes logical as well as physical statistics for the table. Also, you can determine how many rows have one or more chained overflow row-pieces using the ANALYZE LIST CHAINED ROWS option. However, to identify the chain rows, you must create a slightly different CHAINED_ROWS table that includes primary key columns. With the logical rowid support added in Oracle8*i*, Release 8.1.5, a separate CHAINED_ROWS table is no longer needed.

Loading, exporting/importing, replicating an Index-Organized Table

Data can be loaded into both non-partitioned and partitioned index-organized tables using the ordinary or direct path with the SQL*Loader. The data can also be exported or imported using the Export/Import utility. Index-organized tables can also be replicated in a distributed database just like ordinary tables.

Partitioning an Index-Organized Table

You can partition index-organized tables by range of column values. However, to create such partitioned index-organized tables *the set of partitioning columns must be a subset of primary key columns*. By imposing this restriction, only a single partition needs to be searched for to verify the uniqueness of the primary key during DML operations. This preserves the partition independence property.

The following are key aspects of partitioned index-organized tables:

- You must specify the ORGANIZATION INDEX clause to create an index-organized table as part of table-level attributes. This property is implicitly inherited by all partitions.
- You must specify the OVERFLOW option as part of table-level attribute to create an index-organized table with overflow data segment.
- The OVERFLOW option results in the creation of overflow data segments, which are themselves equi-partitioned with the primary key index segments. That is, each partition has an index segment and an overflow data segment.

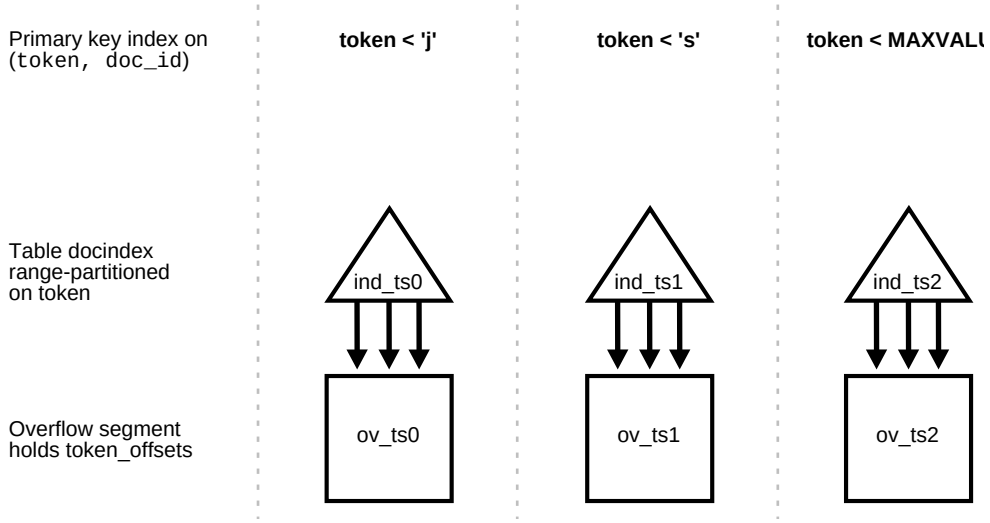
- As in ordinary partitioned tables, you can specify default values for physical attributes at the table-level. These can be overridden for each partition (both for index and overflow data segment).
- The tablespace for index segment, if not specified for a partition, is set to the table level default. If the table level default is not specified, then the default tablespace for the user is used.
- The default values for PCTTHRESHOLD and INCLUDING column can only be specified at the table-level.
- All the attributes that are specified before the OVERFLOW keyword are applicable to primary index segments. All the attributes specified after the OVERFLOW keyword are applicable to overflow data segments.
- The tablespace for an overflow data segment, if not specified for a partition, is set to the table level default. If the table-level default is not specified, then the tablespace of the corresponding partition's index segment is used.

The following example continues the example of the docindex table. It illustrates a range partition on token values.

```
CREATE TABLE Docindex4
   (Token           CHAR(20),
    Doc_id          NUMBER,
    Token_frequency NUMBER,
    Token_offsets   VARCHAR(512),
    CONSTRAINT Pk_docindex4 PRIMARY KEY (Token, Doc_id)
   )
ORGANIZATION INDEX INITRANS 4  INCLUDING Token_frequency
OVERFLOW INITRANS 6
      PARTITION BY RANGE(token)
          ( PARTITION P1 VALUES LESS THAN ('j')
TABLESPACE Ind_ts0 OVERFLOW TABLESPACE Ov_ts0,
   PARTITION P2 VALUES LESS THAN ('s')
TABLESPACE Ind_ts1 OVERFLOW TABLESPACE Ov_ts1,
  PARTITION P3 VALUES LESS THAN (MAXVALUE)
TABLESPACE Ind_ts2 OVERFLOW TABLESPACE Ov_ts2);
```

This will result in creation of the table shown in Figure 7–4. The INCLUDING column results in storing the token_offsets in the overflow data segment for each partition.

Figure 7–4 Range-partitioned Index-organized Table with Overflow Segment



Support for partitioned indexes on index-organized tables is very similar to that for an ordinary table. Local prefixed, local non-prefixed, and global prefixed partitioned indexes are supported on index-organized tables. The only difference is that these indexes store logical rowids instead of physical rowids.

All of the ALTER TABLE operations, except MERGE, are available for partitioned index-organized tables. However, there are some differences in behavior with respect to ordinary tables:

- For ALTER TABLE MOVE partition operations, *all indexes—local, global, and non-partitioned—remain* USABLE because the indexes contain logical rowids. However, the guess stored in the logical rowid becomes invalid.
- For SPLIT partition operations, all indexes or global index partitions remain usable.
- For ALTER TABLE EXCHANGE partition, the target table must be a compatible index-organized table.
- Users can use the ALTER TABLE ADD OVERFLOW command to add an overflow segment and specify table-level default and partition-level physical and storage attributes. This operation results in adding an overflow data segment to each partition.

ALTER INDEX operations are very similar to those on ordinary tables. The only difference is that operations that reconstruct the entire index—namely, ALTER INDEX REBUILD and SPLIT_PARTITION—result in reconstructing the guess stored as part of the logical rowid.

Query and DML operations on partitioned index-organized tables work the same as on ordinary partitioned tables.

Key Compression

You enable key compression by using the COMPRESS clause when specifying physical attributes for the index segment. In addition, the prefix length (as number of columns) can be specified to identify how the key can be broken into a prefix and a suffix. The valid range of values for prefix length are [1, number of primary key columns minus 1].

```
CREATE TABLE Docindex5
   ( Token           CHAR(20),
     Doc_id          NUMBER,
     Token_frequency NUMBER,
     Token_offsets   VARCHAR(512),
     CONSTRAINT pk_docindex5 PRIMARY KEY (Token, Doc_id)
   )
ORGANIZATION INDEX TABLESPACE Ind_tbs COMPRESS 1 INCLUDING Token_frequency
OVERFLOW TABLESPACE Ovf_tbs;
```

Common prefixes of length 1 (that is, token column) will be compressed in the primary key (token, doc_id) occurrences. For the list of primary key values ('DBMS', 1), ('DBMS', 2), ('Oracle', 1), ('Oracle', 2), the repeated occurrences of 'DBMS' and 'Oracle' are compressed away.

If a prefix length is not specified, by default it is set to number of primary key columns minus 1. The compress option can be specified during creation of an index-organized table or as part of moving the index-organized table using ALTER TABLE MOVE option. For example, you can disable compression as follows:

```
ALTER TABLE Docindex5 MOVE NOCOMPRESS;
```

Similarly, the indexes for ordinary tables and index-organized tables can be compressed using the COMPRESS option.

Key Compression for Partitioned Index-Organized Tables Key compression is also supported for partitioned index-organized tables. The compression clause must be specified as part of table-level defaults. For each partition, compression can be

enabled or disabled. However, the prefix length cannot be changed at partition level.

```
CREATE TABLE Docindex6
   ( Token           CHAR(20),
     Doc_id          NUMBER,
     Token_frequency NUMBER,
     Token_offsets   VARCHAR(512),
     CONSTRAINT Pk_docindex6 PRIMARY KEY (Token, Doc_id)
   )
ORGANIZATION INDEX INITRANS 4 COMPRESS 1 INCLUDING Token_frequency
OVERFLOW INITRANS 6
            PARTITION BY RANGE(Token)
           ( PARTITION P1 VALUES LESS THAN ('j')
TABLESPACE Ind_ts0 OVERFLOW TABLESPACE Ov_ts0,
   PARTITION P2 VALUES LESS THAN ('s')
TABLESPACE Ind_ts1 NOCOMPRESS OVERFLOW TABLESPACE Ov_ts1,
  PARTITION P3 VALUES LESS THAN (MAXVALUE)
TABLESPACE Ind_ts2 OVERFLOW TABLESPACE Ov_ts2
);
```

All partitions inherit the table-level default for prefix length. Partitions P1 and P3 are created with key-compression enabled. For partition P2, the compression is disabled by the partition level NOCOMPRESS option.

For ALTER TABLE MOVE and SPLIT operations, the COMRPESS option can be altered. The following example rebuilds the partition with key compression enabled.

```
ALTER TABLE Docindex6 MOVE PARTITION P2 COMPRESS;
```

Rebuilding an Index-Organized Table

A new SQL command, ALTER TABLE MOVE, allows you to move, that is, rebuild the table. This should be used when the B*-tree structure containing an index-organized table gets fragmented due to a large number of inserts, updates, or deletes. The MOVE option rebuilds the primary key B*-tree index.

By default, the overflow data segment is not rebuilt, except when:

- The OVERFLOW clause is explicitly specified,
- The PCTHRESHOLD and / or INCLUDING column value are altered as part of the MOVE statement.
- Any LOBs are moved explicitly

By default, LOB columns related to index and data segments are not rebuilt, except when the LOB columns are explicitly specified as part of the MOVE statement. The following example rebuilds the B*-tree index containing the table data after setting the INITRANS to 6 for index blocks.

```
ALTER TABLE docindex MOVE INITRANS 6;
```

The following example rebuilds both the primary key index and overflow data segment.

```
ALTER TABLE docindex MOVE TABLESPACE Ovf_tbs OVERFLOW TABLESPACE ov_ts0;
```

By default, during the move, the table is not available for other operations. However, you can move an index-organized table using the ONLINE option. The following example allows the table to be available for DML and query operations during the actual move operation. This feature makes the index-organized table suitable for applications requiring 24X7 availability.

Caution: You may need to set your COMPATIBLE initialization parameter to '8.1.3.0' or higher to get the following to work:

```
ALTER TABLE Docindex MOVE ONLINE;
```

The MOVE option is also available for ordinary tables. However, ONLINE move is supported only for index-organized tables which do not have an overflow segment.

8

Processing SQL Statements

This chapter describes how Oracle processes Structured Query Language (SQL) statements. Topics include the following:

- SQL Statement Execution
- Controlling Transactions
- Read-Only Transactions
- Using Cursors
- Explicit Data Locking
- Explicitly Acquiring Row Locks
- SERIALIZABLE and ROW_LOCKING Parameters
- User Locks
- Concurrency Control Using Serializable Transactions
- Autonomous Transactions

Although some Oracle tools and applications simplify or mask the use of SQL, all database operations are performed using SQL. Any other data access method would circumvent the security built into Oracle and potentially compromise data security and integrity.

SQL Statement Execution

Table 8–1 outlines the stages commonly used to process and execute a SQL statement. In some cases, these steps might be executed in a slightly different order. For example, the DEFINE stage could occur just before the FETCH stage, depending on how your code is written.

For many Oracle tools, several of the stages are performed automatically. Most users do not need to be concerned with, or aware of, this level of detail. However, you might find this information useful when writing Oracle applications.

> **See Also:** Refer to *Oracle8i Concepts* for a description of each stage of SQL statement processing for each type of SQL statement.

FIPS Flagging

The Federal Information Processing Standard for SQL (FIPS 127-2) requires a way to identify SQL statements that use vendor-supplied extensions. Oracle provides a FIPS flagger to help you write portable applications.

When FIPS flagging is active, your SQL statements are checked to see whether they include extensions that go beyond the ANSI/ISO SQL92 standard. If any non-standard constructs are found, then the Oracle Server flags them as errors and displays the violating syntax.

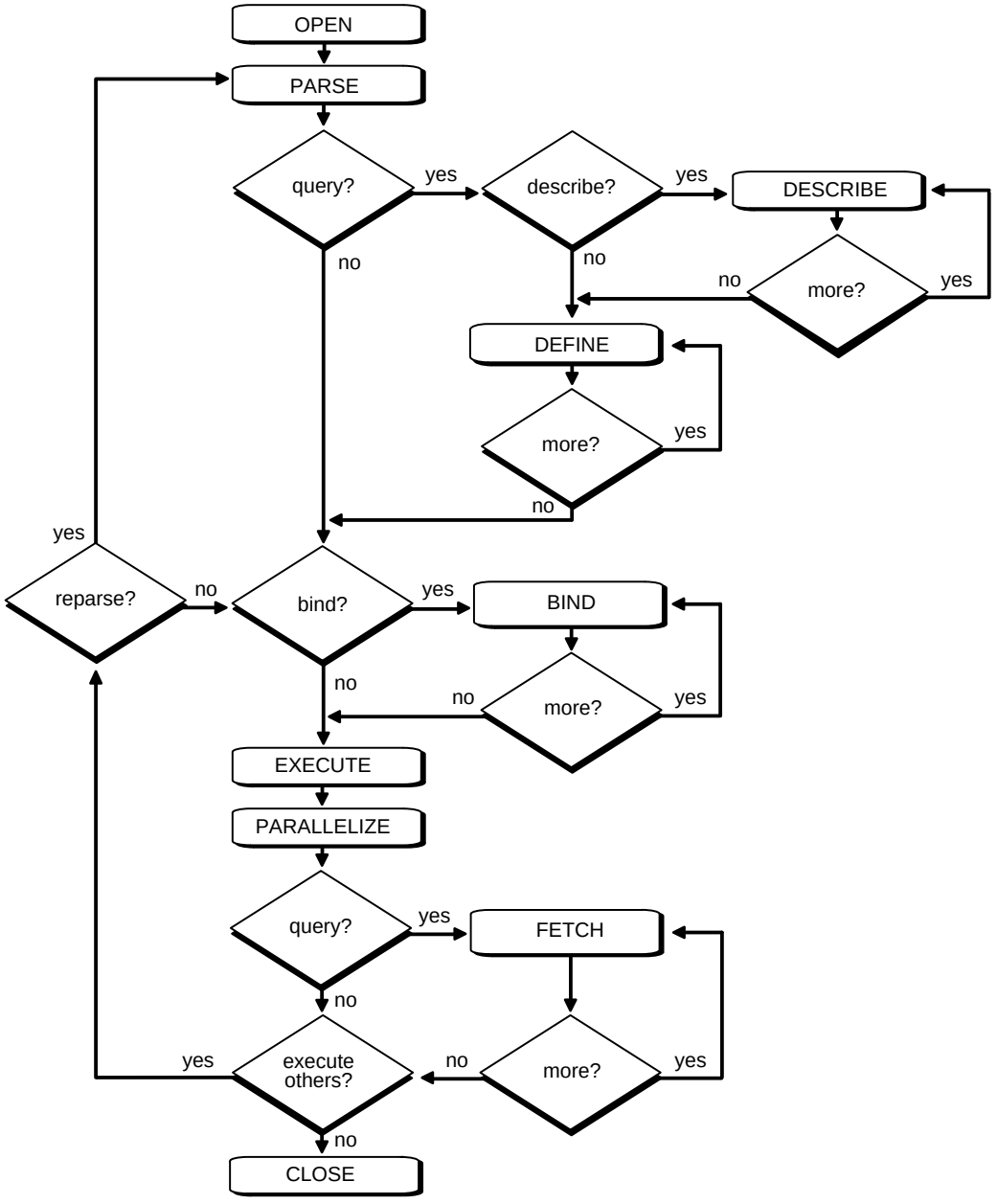
The FIPS flagging feature supports flagging through interactive SQL statements submitted using Enterprise Manager or SQL*Plus. The Oracle Precompilers and SQL*Module also support FIPS flagging of embedded and module language SQL.

When flagging is on and non-standard SQL is encountered, the following message is returned:

```
ORA-00097: Use of Oracle SQL feature not in SQL92 level Level
```

Where *level* can be either ENTRY, INTERMEDIATE, or FULL.

Figure 8–1 The Stages in Processing a SQL Statement



Controlling Transactions

In general, only application designers using the programming interfaces to Oracle are concerned with which types of actions should be grouped together as one transaction. Transactions must be defined properly so work is accomplished in logical units and data is kept consistent. A transaction should consist of all of the necessary parts for one logical unit of work, no more and no less. Data in all referenced tables should be in a consistent state before the transaction begins and after it ends. Transactions should consist of only the SQL statements or PL/SQL blocks that comprise one consistent change to the data.

A transfer of funds between two accounts (the transaction or logical unit of work), for example, should include the debit to one account (one SQL statement) and the credit to another account (one SQL statement). Both actions should either fail or succeed together as a unit of work; the credit should not be committed without the debit. Other non-related actions, such as a new deposit to one account, should not be included in the transfer of funds transaction.

Improving Performance

In addition to determining which types of actions form a transaction, when you design an application, you must also determine if you can take any additional measures to improve performance. You should consider the following performance enhancements when designing and writing your application. Unless otherwise noted, each of these features is described in *Oracle8i Concepts*.

- Use the `BEGIN_DISCRETE_TRANSACTION` procedure to improve the performance of short, non-distributed transactions.
- Use the `SET TRANSACTION` command with the `USE ROLLBACK SEGMENT` parameter to explicitly assign a transaction to an appropriate rollback segment. This can eliminate the need to dynamically allocate additional extents, which can reduce overall system performance.
- Use the `SET TRANSACTION` command with the `ISOLATION LEVEL` set to `SERIALIZABLE` to get ANSI/ISO serializable transactions.

  See Also:

  - "Serializable Transaction Interaction" on page 8-26
  - *Oracle8i Concepts*.

- Establish standards for writing SQL statements so that you can take advantage of shared SQL areas. Oracle recognizes identical SQL statements and allows

them to share memory areas. This reduces memory storage usage on the database server, thereby increasing system throughput.

- Use the ANALYZE command to collect statistics that can be used by Oracle to implement a cost-based approach to SQL statement optimization. You can supply additional "hints" to the optimizer as needed.
- Call the DBMS_APPLICATION_INFO.SET_ACTION procedure before beginning a transaction to register and name a transaction for later use when measuring performance across an application. You should specify what type of activity a transaction performs so that the system tuners can later see which transactions are taking up the most system resources.
- Increase user productivity and query efficiency by including user-written PL/SQL functions in SQL expressions as described in "Calling Stored Functions from SQL Expressions".
- Create explicit cursors when writing a PL/SQL application.
- When writing precompiler programs, increasing the number of cursors using MAX_OPEN_CURSORS can often reduce the frequency of parsing and improve performance.

See Also: "Using Cursors" on page 8-9

Committing a Transaction

To commit a transaction, use the COMMIT command. The following two statements are equivalent and commit the current transaction:

```
COMMIT WORK;
COMMIT;
```

The COMMIT command allows you to include the COMMENT parameter along with a comment (less than 50 characters) that provides information about the transaction being committed. This option is useful for including information about the origin of the transaction when you commit distributed transactions:

```
COMMIT COMMENT 'Dallas/Accts_pay/Trans_type 10B';
```

See Also: For additional information about committing in-doubt distributed transactions, see *Oracle8 Distributed Database Systems.*

Rolling Back a Transaction

To roll back an entire transaction or a part of a transaction (that is, to a savepoint), use the ROLLBACK command. For example, either of the following statements rolls back the entire current transaction:

```
ROLLBACK WORK;
ROLLBACK;
```

The WORK option of the ROLLBACK command has no function.

To roll back to a savepoint defined in the current transaction, the TO option of the ROLLBACK command must be used. For example, either of the following statements rolls back the current transaction to the savepoint named POINT1:

```
SAVEPOINT Point1;
...
ROLLBACK TO SAVEPOINT Point1;
ROLLBACK TO Point1;
```

See Also: For additional information about rolling back in-doubt distributed transactions, see *Oracle8 Distributed Database Systems.*

Defining a Transaction Savepoint

To define a *savepoint* in a transaction, use the SAVEPOINT command. The following statement creates the savepoint named ADD_EMP1 in the current transaction:

```
SAVEPOINT Add_emp1;
```

If you create a second savepoint with the same identifier as an earlier savepoint, then the earlier savepoint is erased. After a savepoint has been created, you can roll back to the savepoint.

There is no limit on the number of active savepoints per session. An active savepoint is one that has been specified since the last commit or rollback.

An Example of COMMIT, SAVEPOINT, and ROLLBACK

The following series of SQL statements illustrates the use of COMMIT, SAVEPOINT, and ROLLBACK statements within a transaction:

SQL Statement	Results
`SAVEPOINT a;`	First savepoint of this transaction
`DELETE...;`	First DML statement of this transaction
`SAVEPOINT b;`	Second savepoint of this transaction
`INSERT INTO...;`	Second DML statement of this transaction
`SAVEPOINT c;`	Third savepoint of this transaction
`UPDATE...;`	Third DML statement of this transaction.
`ROLLBACK TO c;`	`UPDATE` statement is rolled back, savepoint C remains defined
`ROLLBACK TO b;`	`INSERT` statement is rolled back, savepoint C is lost, savepoint B remains defined
`ROLLBACK TO c;`	`ORA-01086` error; savepoint C no longer defined
`INSERT INTO...;`	New DML statement in this transaction
`COMMIT;`	Commits all actions performed by the first DML statement (the `DELETE` statement) and the last DML statement (the second `INSERT` statement)
	All other statements (the second and the third statements) of the transaction had been rolled back before the `COMMIT`. The savepoint A is no longer active.

Privileges Required for Transaction Management

No privileges are required to control your own transactions; any user can issue a `COMMIT`, `ROLLBACK`, or `SAVEPOINT` statement within a transaction.

Read-Only Transactions

By default, the consistency model for Oracle guarantees statement-level read consistency, but does not guarantee transaction-level read consistency (repeatable reads). If you want transaction-level read consistency, and if your transaction does not require updates, then you can specify a *read-only transaction.* After indicating that your transaction is read-only, you can execute as many queries as you like against any database table, knowing that the results of each query in the read-only transaction are consistent with respect to a single point in time.

A read-only transaction does not acquire any additional data locks to provide transaction-level read consistency. The multi-version consistency model used for statement-level read consistency is used to provide transaction-level read consistency; all queries return information with respect to the system control number (SCN) determined when the read-only transaction begins. Because no data locks are acquired, other transactions can query and update data being queried concurrently by a read-only transaction.

Changed data blocks queried by a read-only transaction are reconstructed using data from rollback segments. Therefore, long running read-only transactions sometimes receive a "snapshot too old" error (`ORA-01555`). Create more, or larger, rollback segments to avoid this. Alternatively, you could issue long-running queries when online transaction processing is at a minimum, or you could obtain a shared lock on the table you were querying, prohibiting any other modifications during the transaction.

A read-only transaction is started with a `SET TRANSACTION` statement that includes the `READ ONLY` option. For example:

```
SET TRANSACTION READ ONLY;
```

The `SET TRANSACTION` statement must be the first statement of a new transaction; if any DML statements (including queries) or other non-DDL statements (such as `SET ROLE`) precede a `SET TRANSACTION READ ONLY` statement, then an error is returned. Once a `SET TRANSACTION READ ONLY` statement successfully executes, only `SELECT` (without a `FOR UPDATE` clause), `COMMIT`, `ROLLBACK`, or non-DML statements (such as `SET ROLE`, `ALTER SYSTEM`, `LOCK TABLE`) are allowed in the transaction. Otherwise, an error is returned. A `COMMIT`, `ROLLBACK`, or DDL statement terminates the read-only transaction (a DDL statement causes an implicit commit of the read-only transaction and commits in its own transaction).

Using Cursors

PL/SQL implicitly declares a cursor for all SQL data manipulation statements, including queries that return only one row. For queries that return more than one row, you can explicitly declare a cursor to process the rows individually.

A *cursor* is a handle to a specific private SQL area. In other words, a cursor can be thought of as a name for a specific private SQL area. A PL/SQL *cursor variable* enables the retrieval of multiple rows from a stored procedure. Cursor variables allow you to pass cursors as parameters in your 3GL application. Cursor variables are described in *PL/SQL User's Guide and Reference.*

Although most Oracle users rely on the automatic cursor handling of the Oracle utilities, the programmatic interfaces offer application designers more control over cursors. In application development, a cursor is a named resource available to a program, which can be specifically used for parsing SQL statements embedded within the application.

Declaring and Opening Cursors

There is no absolute limit to the total number of cursors one session can have open at one time, subject to two constraints:

- Each cursor requires virtual memory, so a session's total number of cursors is limited by the memory available to that process.
- A system-wide limit of cursors per session is set by the initialization parameter named `OPEN_CURSORS` found in the parameter file (such as `INIT.ORA`).

> **See Also:** Parameters are described in *Oracle8i Reference.*

Explicitly creating cursors for precompiler programs can offer some advantages in tuning those applications. For example, increasing the number of cursors can often reduce the frequency of parsing and improve performance. If you know how many cursors may be required at a given time, then you can make sure you can open that many simultaneously.

Using a Cursor to Re-Execute Statements

After each stage of execution, the cursor retains enough information about the SQL statement to re-execute the statement without starting over, as long as no other SQL statement has been associated with that cursor. This is illustrated in Figure 8–1. Notice that the statement can be re-executed without including the parse stage.

By opening several cursors, the parsed representation of several SQL statements can be saved. Repeated execution of the same SQL statements can thus begin at the describe, define, bind, or execute step, saving the repeated cost of opening cursors and parsing.

Closing Cursors

Closing a cursor means that the information currently in the associated private area is lost and its memory is deallocated. Once a cursor is opened, it is not closed until one of the following events occurs:

- The user program terminates its connection to the server.
- If the user program is an OCI program or precompiler application, then it explicitly closes any open cursor during the execution of that program. (However, when this program terminates, any cursors remaining open are implicitly closed.)

Cancelling Cursors

Cancelling a cursor frees resources from the current fetch.The information currently in the associated private area is lost but the cursor remains open, parsed, and associated with its bind variables.

Note: You cannot cancel cursors using Pro*C or PL/SQL.

See Also: For more information about cancelling cursors, see *Oracle Call Interface Programmer's Guide.*

Explicit Data Locking

Oracle always performs necessary locking to ensure data concurrency, integrity, and statement-level read consistency. However, options are available to override the default locking mechanisms. Situations where it would be advantageous to override the default locking of Oracle include the following:

- An application desires transaction-level read consistency or "repeatable reads"—transactions must query a consistent set of data for the duration of the transaction, knowing that the data has not been changed by any other transactions of the system. Transaction-level read consistency can be achieved by using explicit locking, read-only transactions, serializable transactions, or overriding default locking for the system.
- An application requires a transaction to have exclusive access to a resource. To proceed with its statements, the transaction with exclusive access to a resource does not have to wait for other transactions to complete.

The automatic locking mechanisms can be overridden at two different levels:

transaction level	Transactions including the following SQL statements override Oracle's default locking: the `LOCK TABLE` command, the `SELECT` command including the `FOR UPDATE` clause, and the `SET TRANSACTION` command with the `READ ONLY` or `ISOLATION LEVEL SERIALIZABLE` options. Locks acquired by these statements are released after the transaction is committed or rolled back.
system level	An instance can be started with non-default locking by adjusting the initialization parameters `SERIALIZABLE` and `ROW_LOCKING`.

The following sections describe each option available for overriding the default locking of Oracle. The initialization parameter `DML_LOCKS` determines the maximum number of DML locks allowed.

> **See Also:** See the *Oracle8i Reference* for a discussion of parameters.

The default value should be sufficient; however, if you are using additional manual locks, then you may need to increase this value.

> **Caution:** **If you override the default locking of Oracle at any level, then be sure that the overriding locking procedures operate correctly: Ensure that data integrity is guaranteed, data concurrency is acceptable, and deadlocks are not possible or are appropriately handled.**

Explicitly Acquiring Table Locks

A transaction explicitly acquires the specified table locks when a LOCK TABLE statement is executed. A LOCK TABLE statement manually overrides default locking. When a LOCK TABLE statement is issued on a view, the underlying base tables are locked. The following statement acquires exclusive table locks for the EMP_TAB and DEPT_TAB tables on behalf of the containing transaction:

```
LOCK TABLE Emp_tab, Dept_tab
    IN EXCLUSIVE MODE NOWAIT;
```

You can specify several tables or views to lock in the same mode; however, only a single lock mode can be specified per LOCK TABLE statement.

> **Note:** When a table is locked, all rows of the table are locked. No other user can modify the table.

You can also indicate if you do or do not want to wait to acquire the lock. If you specify the NOWAIT option, then you only acquire the table lock if it is immediately available. Otherwise an error is returned to notify that the lock is not available at this time. In this case, you can attempt to lock the resource at a later time. If NOWAIT is omitted, then the transaction does not proceed until the requested table lock is acquired. If the wait for a table lock is excessive, then you might want to cancel the lock operation and retry at a later time; you can code this logic into your applications.

> **Note:** A distributed transaction waiting for a table lock can time-out waiting for the requested lock if the elapsed amount of time reaches the interval set by the initialization parameter `DISTRIBUTED_LOCK_TIMEOUT`. Because no data has been modified, no actions are necessary as a result of the time-out. Your application should proceed as if a deadlock has been encountered. For more information on distributed transactions, refer to *Oracle8 Distributed Database Systems.*

The following paragraphs provide guidance on when it can be advantageous to acquire each type of table lock using the `LOCK TABLE` command.

ROW SHARE and ROW EXCLUSIVE

```
LOCK TABLE Emp_tab IN ROW SHARE MODE;
LOCK TABLE Emp_tab IN ROW EXCLUSIVE MODE;
```

Row share and row exclusive table locks offer the highest degree of concurrency. Conditions that possibly warrant the explicit acquisition of a row share or row exclusive table lock include the following:

- Your transaction needs to prevent another transaction from acquiring an intervening share, share row, or exclusive table lock for a table before the table can be updated in your transaction. If another transaction acquires an intervening share, share row, or exclusive table lock, then no other transactions can update the table until the locking transaction commits or rolls back.
- Your transaction needs to prevent a table from being altered or dropped before the table can be modified later in your transaction.

SHARE

```
LOCK TABLE Emp_tab IN SHARE MODE;
```

Share table locks are rather restrictive data locks. The following conditions could warrant the explicit acquisition of a share table lock:

- Your transaction only queries the table and requires a consistent set of the table's data for the duration of the transaction (requires transaction-level read consistency for the locked table).

- It is acceptable if other transactions attempting to update the locked table concurrently must wait until all transactions with the share table locks commit or roll back.
- It is acceptable to allow other transactions to acquire concurrent share table locks on the same table, also allowing them the option of transaction-level read consistency.

> **Caution: Your transaction may or may not update the table later in the same transaction. However, if multiple transactions concurrently hold share table locks for the same table, no transaction can update the table (even if row locks are held as the result of a** SELECT... FOR UPDATE **statement). Therefore, if concurrent share table locks on the same table are common, updates cannot proceed and deadlocks are common. In this case, use share row exclusive or exclusive table locks instead.**

For example, assume that two tables, EMP_TAB and BUDGET_TAB, require a consistent set of data in a third table, DEPT_TAB. For a given department number, you want to update the information in both of these tables, and ensure that no new members are added to the department between these two transactions.

Although this scenario is quite rare, it can be accommodated by locking the DEPT_TAB table in SHARE MODE, as shown in the following example. Because the DEPT_TAB table is not highly volatile, few, if any, users would need to update it while it was locked for the updates to EMP_TAB and BUDGET_TAB.

Note: You may need to set up data structures similar to the following for certain examples to work:

```
CREATE TABLE dept_tab(
   deptno NUMBER(2) NOT NULL,
   dname VARCHAR2(14),
   loc VARCHAR2(13));

CREATE TABLE emp_tab (
   empno NUMBER(4) NOT NULL,
   ename VARCHAR2(10),
   job VARCHAR2(9),
   mgr NUMBER(4),
   hiredate DATE,
   sal NUMBER(7,2),
   comm NUMBER(7,2),
   deptno NUMBER(2));

CREATE TABLE Budget_tab (
   totsal NUMBER(7,2),
   deptno NUMBER(2) NOT NULL);
```

```
LOCK TABLE Dept_tab IN SHARE MODE;
UPDATE Emp_tab
    SET sal = sal * 1.1
    WHERE deptno IN
      (SELECT deptno FROM Dept_tab WHERE loc = 'DALLAS');
UPDATE Budget_tab
    SET Totsal = Totsal * 1.1
    WHERE Deptno IN
      (SELECT Deptno FROM Dept_tab WHERE Loc = 'DALLAS');

COMMIT; /* This releases the lock */
```

SHARE ROW EXCLUSIVE

```
LOCK TABLE Emp_tab IN SHARE ROW EXCLUSIVE MODE;
```

Conditions that warrant the explicit acquisition of a share row exclusive table lock include the following:

- Your transaction requires both transaction-level read consistency for the specified table and the ability to update the locked table.

- You are not concerned about explicit row locks being obtained (via SELECT... FOR UPDATE) by other transactions, which may or may not make UPDATE and INSERT statements in the locking transaction wait to update the table (deadlocks might be observed).
- You only want a single transaction to have the above behavior.

EXCLUSIVE

```
LOCK TABLE Emp_tab IN EXCLUSIVE MODE;
```

Conditions that warrant the explicit acquisition of an exclusive table lock include the following:

- Your transaction requires immediate update access to the locked table. Therefore, if your transaction holds an exclusive table lock, then other transactions cannot lock specific rows in the locked table.
- Your transaction also observes transaction-level read consistency for the locked table until the transaction is committed or rolled back.
- You are not concerned about low levels of data concurrency, making transactions that request exclusive table locks wait in line to update the table sequentially.

Privileges Required

You can automatically acquire any type of table lock on tables in your schema; however, to acquire a table lock on a table in another schema, you must have the LOCK ANY TABLE system privilege or any object privilege (for example, SELECT or UPDATE) for the table.

Explicitly Acquiring Row Locks

You can override default locking with a SELECT statement that includes the FOR UPDATE clause. SELECT... FOR UPDATE is used to acquire exclusive row locks for selected rows (as an UPDATE statement does) in anticipation of actually updating the selected rows.

You can use a SELECT... FOR UPDATE statement to lock a row without actually changing it. For example, several triggers in Chapter 13, "Using Triggers", show how to implement referential integrity. In the EMP_DEPT_CHECK trigger (see "Foreign Key Trigger for Child Table"), the row that contains the referenced parent key value is locked to guarantee that it remains for the duration of the transaction; if the parent key is updated or deleted, referential integrity would be violated.

SELECT... FOR UPDATE statements are often used by interactive programs that allow a user to modify fields of one or more specific rows (which might take some time); row locks on the rows are acquired so that only a single interactive program user is updating the rows at any given time.

If a SELECT... FOR UPDATE statement is used when defining a cursor, then the rows in the return set are locked before the first fetch, when the cursor is opened; rows are not individually locked as they are fetched from the cursor. Locks are only released when the transaction that opened the cursor is committed or rolled back; locks are not released when a cursor is closed.

Each row in the return set of a SELECT... FOR UPDATE statement is locked individually; the SELECT... FOR UPDATE statement waits until the other transaction releases the conflicting row lock. Therefore, if a SELECT... FOR UPDATE statement locks many rows in a table, and if the table experiences reasonable update activity, then it would most likely improve performance if you instead acquired an exclusive table lock.

When acquiring row locks with SELECT... FOR UPDATE, you can indicate if you do or do not want to wait to acquire the lock. If you specify the NOWAIT option, then you only acquire the row lock if it is immediately possible. Otherwise, an error is returned to notify you that the lock is not possible at this time. In this case, you can attempt to lock the row later.

If NOWAIT is omitted, then the transaction does not proceed until the requested row lock is acquired. If the wait for a row lock is excessive, then users might want to cancel the lock operation and retry later; you can code such logic into your applications.

As described on "Explicitly Acquiring Table Locks" on page 8-12, a distributed transaction waiting for a row lock can time-out waiting for the requested lock if the

elapsed amount of time reaches the interval set by the initialization parameter `DISTRIBUTED_LOCK_TIMEOUT`.

SERIALIZABLE and ROW_LOCKING Parameters

Two factors determine how an instance handles locking: the SERIALIZABLE option of the SET TRANSACTION or ALTER SESSION command and the ROW_LOCKING initialization parameter. By default, SERIALIZABLE is set to FALSE and ROW_LOCKING is set to ALWAYS.

In almost every case, these parameters should not be altered. They are provided for sites that must run in ANSI/ISO compatible mode, or that want to use applications written to run with earlier versions of Oracle. Only these sites should consider altering these parameters, as there is a significant performance degradation caused by using other than the defaults.

> **See Also:** For detailed explanations of these parameters, see *Oracle8i Reference*.

The settings for these parameters should be changed only when an instance is shut down. If multiple instances are accessing a single database, then all instances should use the same setting for these parameters.

Summary of Non-Default Locking Options

Three combinations of settings for SERIALIZABLE and ROW_LOCKING, other than the default settings, are available to change the way locking occurs for transactions. Table 8–1 summarizes the non-default settings and why you might choose to execute your transactions in a non-default way.

Table 8–1 Summary of Non-Default Locking Options

Case	Description	SERIALIZABLE	ROW_LOCKING
1	Equivalent to Version 5 and earlier Oracle releases (no concurrent inserts, updates, or deletes in a table)	Disabled (default)	INTENT
2	ANSI compatible	Enabled	ALWAYS
3	ANSI compatible, with table-level locking (no concurrent inserts, updates, or deletes in a table)	Enabled	INTENT

Table 8–2 illustrates the difference in locking behavior resulting from the three possible settings of the SERIALIZABLE option and ROW_LOCKING initialization parameter, as shown in Table 8–1.

Table 8–2 Non-default Locking Behavior

STATEMENT	CASE 1		CASE 2		CASE 3	
	row	table	row	table	row	table
SELECT	-	-	-	S	-	S
INSERT	X	SRX	X	RX	X	SRX
UPDATE	X	SRX	X	SRX	X	SRX
DELETE	X	SRX	X	SRX	X	SRX
SELECT...FOR UPDATE	X	RS	X	S	X	S
LOCK TABLE... IN..						
ROW SHARE MODE	RS	RS	RS	RS	RS	RS
ROW EXCLUSIVE MODE	RX	RX	RX	RX	RX	RX
SHARE MODE	S	S	S	S	S	S
SHARE ROW EXCLUSIVE MODE	SRX	SRX	SRX	SRX	SRX	SRX
EXCLUSIVE MODE	X	X	X	X	X	X
DDL statements	-	X	-	X	-	X

User Locks

Creating User Locks

You can use Oracle Lock Management services for your applications. It is possible to request a lock of a specific mode, give it a unique name recognizable in another procedure in the same or another instance, change the lock mode, and release it. Because a reserved user lock is the same as an Oracle lock, it has all the functionality of an Oracle lock, such as deadlock detection. Be certain that any user locks used in distributed transactions are released upon `COMMIT`, or an undetected deadlock may occur.

> **See Also:** *Oracle8i Supplied Packages Reference* has detailed information on the `DBMS_LOCK` package.

Sample User Locks

Some uses of user locks are:

- Providing exclusive access to a device, such as a terminal
- Providing application-level enforcement of read locks
- Detect when a lock is released and cleanup after the application
- Synchronizing applications and enforce sequential processing

The following Pro*COBOL precompiler example shows how locks can be used to ensure that there are no conflicts when multiple people need to access a single device.

```
*****************************************************************
* Print Check                                                   *
* Any cashier may issue a refund to a customer returning goods. *
* Refunds under $50 are given in cash, above that by check.     *
* This code prints the check. The one printer is opened by all  *
* the cashiers to avoid the overhead of opening and closing it  *
* for every check. This means that lines of output from multiple*
* cashiers could become interleaved if we don't ensure exclusive*
* access to the printer. The DBMS_LOCK package is used to       *
* ensure exclusive access.                                      *
*****************************************************************
CHECK-PRINT
*
*    Get the lock "handle" for the printer lock.
```

```
   MOVE "CHECKPRINT" TO LOCKNAME-ARR.
   MOVE 10 TO LOCKNAME-LEN.
   EXEC SQL EXECUTE
      BEGIN DBMS_LOCK.ALLOCATE_UNIQUE ( :LOCKNAME, :LOCKHANDLE );
      END; END-EXEC.
*
*   Lock the printer in exclusive mode (default mode).
   EXEC SQL EXECUTE
      BEGIN DBMS_LOCK.REQUEST ( :LOCKHANDLE );
      END; END-EXEC.
*   We now have exclusive use of the printer, print the check.

  ...

*
*   Unlock the printer so other people can use it
*
   EXEC SQL EXECUTE
      BEGIN DBMS_LOCK.RELEASE ( :LOCKHANDLE );

      END; END-EXEC.
```

Viewing and Monitoring Locks

Oracle provides two facilities to display locking information for ongoing transactions within an instance:

Enterprise Manager Monitors (Lock and Latch Monitors)	The Monitor feature of Enterprise Manager provides two monitors for displaying lock information of an instance. Refer to *Oracle Enterprise Manager Administrator's Guide* for complete information about the Enterprise Manager monitors.
UTLLOCKT.SQL	The UTLLOCKT.SQL script displays a simple character lock wait-for graph in tree structured fashion. Using any *ad hoc* SQL tool (such as SQL*Plus) to execute the script, it prints the sessions in the system that are waiting for locks and the corresponding blocking locks. The location of this script file is operating system dependent. (You must have run the CATBLOCK.SQL script before using UTLLOCKT.SQL.)

Concurrency Control Using Serializable Transactions

By default, the Oracle Server permits concurrently executing transactions to modify, add, or delete rows in the same table, and in the same data block. Changes made by one transaction are not seen by another concurrent transaction until the transaction that made the changes commits.

If a transaction A attempts to update or delete a row that has been locked by another transaction B (by way of a DML or SELECT... FOR UPDATE statement), then A's DML command blocks until B commits or rolls back. Once B commits, transaction A can see changes that B has made to the database.

For most applications, this concurrency model is the appropriate one. In some cases, however, it is advantageous to allow transactions to be serializable. Serializable transactions must execute in such a way that they appear to be executing one at a time (serially), rather than concurrently. In other words, concurrent transactions executing in serialized mode are only permitted to make database changes that they could have made if the transactions were scheduled to run one after the other.

The ANSI/ISO SQL standard SQL92 defines three possible kinds of transaction interaction, and four levels of isolation that provide increasing protection against these interactions. These interactions and isolation levels are summarized in Table 8–3.

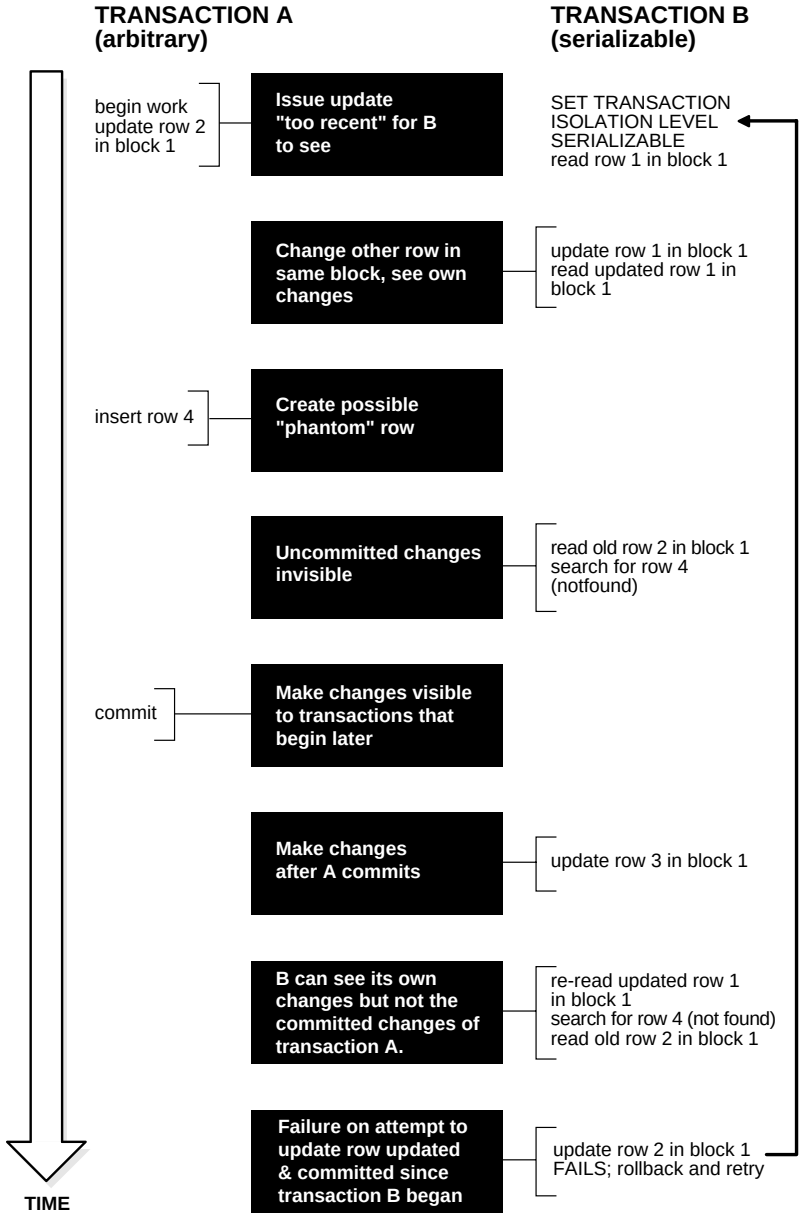
Table 8–3 ANSI Isolation Levels

Isolation Level	Dirty Read (1)	Non-Repeatable Read (2)	Phantom Read (3)
READ UNCOMMITTED	Possible	Possible	Possible
READ COMMITTED	Not possible	Possible	Possible
REPEATABLE READ	Not possible	Not possible	Possible
SERIALIZABLE	Not possible	Not possible	Not possible
Notes:	(1) A transaction can read uncommitted data changed by another transaction.		
	(2) A transaction re-read data committed by another transaction and sees the new data.		
	(3) A transaction can re-execute a query, and discover new rows inserted by another committed transaction.		

The behavior of Oracle with respect to these isolation levels is summarized below:

READ UNCOMMITTED	Oracle never permits "dirty reads." This is not required for high throughput with Oracle.
READ COMMITTED	Oracle meets the READ COMMITTED isolation standard. This is the default mode for all Oracle applications. Note that because an Oracle query only sees data that was committed at the beginning of the query (the snapshot time), Oracle offers more consistency than actually required by the ANSI/ISO SQL92 standards for READ COMMITTED isolation.
REPEATABLE READ	Oracle does not support this isolation level, except as provided by SERIALIZABLE.
SERIALIZABLE	You can set this isolation level using the SET TRANSACTION command or the ALTER SESSION command, as described on.

Figure 8–2 Time Line for Two Transactions



Serializable Transaction Interaction

Figure 8–3 on page 8-28 shows how a serializable transaction (Transaction B) interacts with another transaction (A, which can be either SERIALIZABLE or READ COMMITTED).

When a serializable transaction fails with an ORA-08177 error ("cannot serialize access"), the application can take any of several actions:

- Commit the work executed to that point
- Execute additional, different, statements, perhaps after rolling back to a prior savepoint in the transaction
- Roll back the entire transaction and try it again

Oracle stores control information in each data block to manage access by concurrent transactions. To use the SERIALIZABLE isolation level, you must use the INITRANS clause of the CREATE TABLE or ALTER TABLE command to set aside storage for this control information. To use serializable mode, INITRANS must be set to at least 3.

Setting the Isolation Level

You can change the isolation level of a transaction using the ISOLATION LEVEL clause of the SET TRANSACTION command. The SET TRANSACTION command must be the first command issued in a transaction. If it is not, then the following error is issued:

```
ORA-01453: SET TRANSACTION must be first statement of transaction
```

Use the ALTER SESSION command to set the transaction isolation level on a session-wide basis.

> **See Also:** *Oracle8i Reference* for the complete syntax of the SET TRANSACTION and ALTER SESSION commands.

The INITRANS Parameter

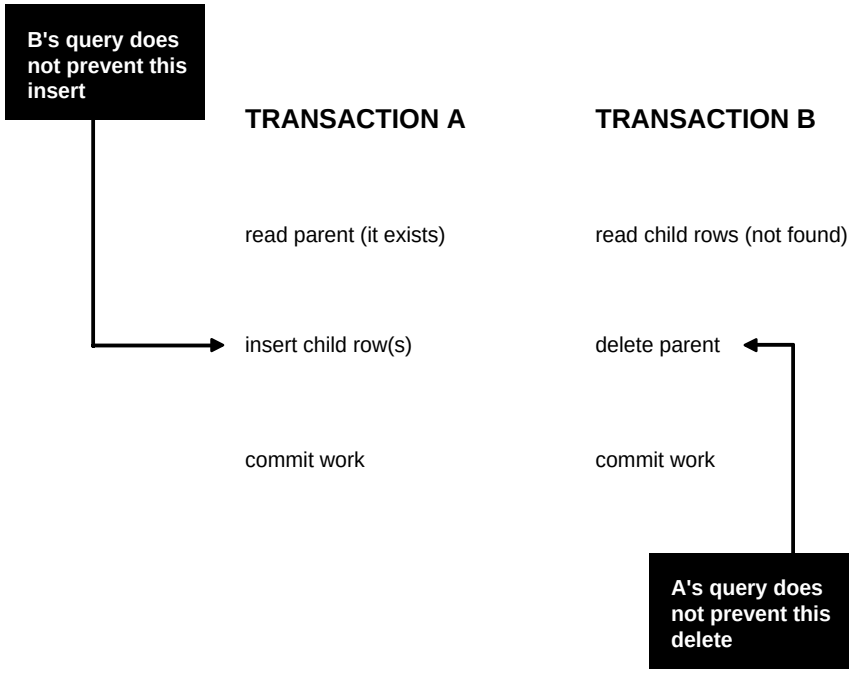
Oracle stores control information in each data block to manage access by concurrent transactions. Therefore, if you set the transaction isolation level to serializable, then you must use the ALTER TABLE command to set INITRANS to at least 3. This parameter causes Oracle to allocate sufficient storage in each block to record the history of recent transactions that accessed the block. Higher values should be used for tables that will undergo many transactions updating the same blocks.

Referential Integrity and Serializable Transactions

Because Oracle does not use read locks, even in SERIALIZABLE transactions, data read by one transaction can be overwritten by another. Transactions that perform database consistency checks at the application level should not assume that the data they read will not change during the execution of the transaction (even though such changes are not visible to the transaction). Database inconsistencies can result unless such application-level consistency checks are coded carefully, even when using SERIALIZABLE transactions. Note, however, that the examples shown in this section are applicable for both READ COMMITTED and SERIALIZABLE transactions.

Figure 8–3 on page 8-28 two different transactions that perform application-level checks to maintain the referential integrity parent/child relationship between two tables. One transaction reads the parent table to determine that a row with a specific primary key value exists before inserting corresponding child rows. The other transaction checks to see that no corresponding detail rows exist before proceeding to delete a parent row. In this case, both transactions assume (but do not ensure) that data they read will not change before the transaction completes.

Figure 8–3 Referential Integrity Check



Note that the read issued by transaction A does not prevent transaction B from deleting the parent row. Likewise, transaction B's query for child rows does not prevent the insertion of child rows by transaction A. Therefore the above scenario leaves in the database a child row with no corresponding parent row. This result would occur even if both A and B are SERIALIZABLE transactions, because neither transaction prevents the other from making changes in the data it reads to check consistency.

As this example illustrates, for some transactions, application developers must specifically ensure that the data read by one transaction is not concurrently written by another. This requires a greater degree of transaction isolation than defined by SQL92 SERIALIZABLE mode.

Using SELECT FOR UPDATE

Fortunately, it is straightforward in Oracle to prevent the anomaly described above. *Transaction A* can use SELECT FOR UPDATE to query and lock the parent row and thereby prevent transaction B from deleting the row. *Transaction B* can prevent *Transaction A* from gaining access to the parent row by reversing the order of its processing steps. *Transaction B* first deletes the parent row, and then rolls back if its subsequent query detects the presence of corresponding rows in the child table.

Referential integrity can also be enforced in Oracle using database triggers, instead of a separate query as in *Transaction A* above. For example, an INSERT into the child table can fire a PRE-INSERT row-level trigger to check for the corresponding parent row. The trigger queries the parent table using SELECT FOR UPDATE, ensuring that parent row (if it exists) remains in the database for the duration of the transaction inserting the child row. If the corresponding parent row does not exist, then the trigger rejects the insert of the child row.

SQL statements issued by a database trigger execute in the context of the SQL statement that caused the trigger to fire. All SQL statements executed within a trigger see the database in the same state as the triggering statement. Thus, in a READ COMMITTED transaction, the SQL statements in a trigger see the database as of the beginning of the triggering statement's execution, and in a transaction executing in SERIALIZABLE mode, the SQL statements see the database as of the beginning of the transaction. In either case, the use of SELECT FOR UPDATE by the trigger correctly enforces referential integrity, as explained above.

READ COMMITTED and SERIALIZABLE Isolation

Oracle gives the application developer a choice of two transaction isolation levels with different characteristics. Both the READ COMMITTED and SERIALIZABLE isolation levels provide a high degree of consistency and concurrency. Both levels provide the contention-reducing benefits of Oracle's "read consistency" multi-version concurrency control model and exclusive row-level locking implementation, and are designed for real-world application deployment. The rest of this section compares the two isolation modes and provides information helpful in choosing between them.

Transaction Set Consistency

A useful way to describe the READ COMMITTED and SERIALIZABLE isolation levels in Oracle is to consider the following:

- A collection of database tables (or any set of data)
- A particular sequence of reads of rows in those tables
- The set of transactions committed at any particular time

An operation (a query or a transaction) is "transaction set consistent" if all its reads return data written by the same set of committed transactions. In an operation that is not transaction set consistent, some reads reflect the changes of one set of transactions, and other reads reflect changes made by other transactions. An operation that is not transaction set consistent in effect sees the database in a state that reflects no single set of committed transactions.

Oracle provides transactions executing in READ COMMITTED mode with transaction set consistency on a per-statement basis (because all rows read by a query must have been committed before the query began). Similarly, Oracle SERIALIZABLE mode provides transaction set consistency on a per-transaction basis, because all statements in a SERIALIZABLE transaction execute with respect to an image of the database as of the beginning of the transaction.

In other database systems (unlike in Oracle), a single query run in READ COMMITTED mode provides results that are not transaction set consistent. The query is not transaction set consistent, because it may see only a subset of the changes made by another transaction. This means, for example, that a join of a master table with a detail table could see a master record inserted by another transaction, but not the corresponding details inserted by that transaction, or vice versa. Oracle's READ COMMITTED mode does not experience this effect, and so provides a greater degree of consistency than read-locking systems.

In read-locking systems, at the cost of preventing concurrent updates, SQL92 REPEATABLE READ isolation provides transaction set consistency at the statement level, but not at the transaction level. The absence of phantom protection means two queries issued by the same transaction can see data committed by different sets of other transactions. Only the throughput-limiting and deadlock-susceptible SERIALIZABLE mode in these systems provides transaction set consistency at the transaction level.

Functionality Comparison Summary

Table 8–4 summarizes key similarities and differences between READ COMMITTED and SERIALIZABLE transactions.

Table 8–4 Read Committed vs. Serializable Transaction

	Read Committed	Serializable
Dirty write	Not Possible	Not Possible
Dirty read	Not Possible	Not Possible
Non-repeatable read	Possible	Not Possible
Phantoms	Possible	Not Possible
Compliant with ANSI/ISO SQL 92	Yes	Yes
Read snapshot time	Statement	Transaction
Transaction set consistency	Statement level	Transaction level
Row-level locking	Yes	Yes
Readers block writers	No	No
Writers block readers	No	No
Different-row writers block writers	No	No
Same-row writers block writers	Yes	Yes
Waits for blocking transaction	Yes	Yes
Subject to "can't serialize access" error	No	Yes
Error after blocking transaction aborts	No	No
Error after blocking transaction commits	No	Yes

Choosing an Isolation Level

Application designers and developers should choose an isolation level that is appropriate to the specific application and workload, and may choose different isolation levels for different transactions. The choice should be based on performance and consistency needs, and consideration of application coding requirements.

For environments with many concurrent users rapidly submitting transactions, designers must assess transaction performance requirements in terms of the expected transaction arrival rate and response time demands, and choose an isolation level that provides the required degree of consistency while satisfying performance expectations. Frequently, for high performance environments, the choice of isolation levels involves making a trade-off between consistency and concurrency (transaction throughput).

Both Oracle isolation modes provide high levels of consistency and concurrency (and performance) through the combination of row-level locking and Oracle's multi-version concurrency control system. Because readers and writers don't block one another in Oracle, while queries still see consistent data, both `READ COMMITTED` and `SERIALIZABLE` isolation provide a high level of concurrency for high performance, without the need for reading uncommitted ("dirty") data.

`READ COMMITTED` isolation can provide considerably more concurrency with a somewhat increased risk of inconsistent results (due to phantoms and non-repeatable reads) for some transactions. The `SERIALIZABLE` isolation level provides somewhat more consistency by protecting against phantoms and non-repeatable reads, and may be important where a read / write transaction executes a query more than once. However, `SERIALIZABLE` mode requires applications to check for the "can't serialize access" error, and can significantly reduce throughput in an environment with many concurrent transactions accessing the same data for update. Application logic that checks database consistency must take into account the fact reads don't block writes in either mode.

Application Tips

When a transaction runs in serializable mode, any attempt to change data that was changed by another transaction since the beginning of the serializable transaction results in the following error:

```
ORA-08177: Can't serialize access for this transaction.
```

When you get an `ORA-08177` error, the appropriate action is to roll back the current transaction, and re-execute it. After a rollback, the transaction acquires a new transaction snapshot, and the DML operation is likely to succeed.

Because a rollback and repeat of the transaction is required, it is good development practice to put DML statements that might conflict with other concurrent transactions towards the beginning of your transaction, whenever possible.

Autonomous Transactions

This section gives a brief overview of autonomous transactions and what you can do with them.

> **See Also:** For detailed information on autonomous transactions, see *PL/SQL User's Guide and Reference*and Chapter 13, "Using Triggers".

At times, you may want to commit or roll back some changes to a table independently of a primary transaction's final outcome. For example, in a stock purchase transaction, you may want to commit a customer's information regardless of whether the overall stock purchase actually goes through. Or, while running that same transaction, you may want to log error messages to a debug table even if the overall transaction rolls back. Autonomous transactions allow you to do such tasks.

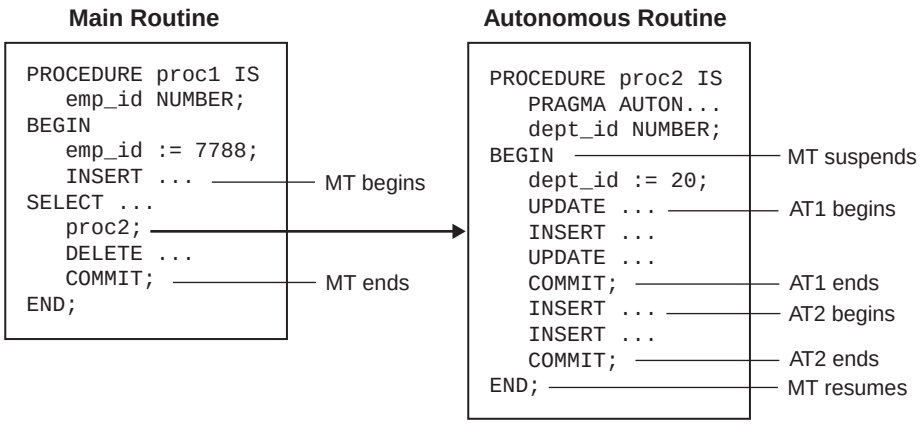
An *autonomous* transaction (AT) is an independent transaction started by another transaction, the *main* transaction (MT). It lets you suspend the main transaction, do SQL operations, commit, or roll back those operations, then resume the main transaction.

An autonomous *transaction* executes within an autonomous *scope*. An autonomous scope is a routine you mark with the pragma (compiler directive) `AUTONOMOUS_TRANSACTION`. The pragma instructs the PL/SQL compiler to mark a routine as `autonomous` (independent). In this context, the term *routine* includes:

- Top-level (not nested) anonymous PL/SQL blocks
- Local, stand-alone, and packaged functions and procedures
- Methods of a SQL object type
- PL/SQL triggers

Figure 8–4 shows how control flows from the main routine (MT) to an autonomous routine (AT) and back again. As you can see, the autonomous routine can commit more than one transaction (AT1 and AT2) before control returns to the main routine.

Figure 8–4 Transaction Control Flow



When you enter the executable section of an autonomous routine, the main transaction suspends. When you exit the routine, the main transaction resumes. `COMMIT` and `ROLLBACK` end the active autonomous transaction but do not exit the autonomous routine. As Figure 8–4 shows, when one transaction ends, the next SQL statement begins another transaction.

A few more characteristics of autonomous transactions:

- The changes autonomous transactions effect do not depend on the state or the eventual disposition of the main transaction. For example:
  - An autonomous transaction does not see any changes made by the main transaction.
  - When an autonomous transaction commits or rolls back, it does not affect the outcome of the main transaction.
- The changes an autonomous transaction effects are visible to other transactions as soon as that autonomous transaction commits. This means that users can access the updated information without having to wait for the main transaction to commit.
- Autonomous transactions can start other autonomous transactions.

Figure 8–5 illustrates some of the possible sequences autonomous transactions can follow.

Figure 8–5 Possible Sequences of Autonomous Transactions

A main transaction scope (MT Scope) begins the main transaction, MTx. MTx invokes the first autonomous transaction scope (AT Scope1). MTx suspends. AT Scope 1 begins the transaction Tx1.1.

At Scope 1 commits or rolls back Tx1.1, than ends. MTx resumes.

MTx invokes AT Scope 2. MT suspends, passing control to AT Scope 2 which, initially, is performing queries.

AT Scope 2 then begins Tx2.1 by, say, doing an update. AT Scope 2 commits or rolls back Tx2.1.

Later, AT Scope 2 begins a second transaction, Tx2.2, then commits or rolls it back.

AT Scope 2 performs a few queries, then ends, passing control back to MTx.

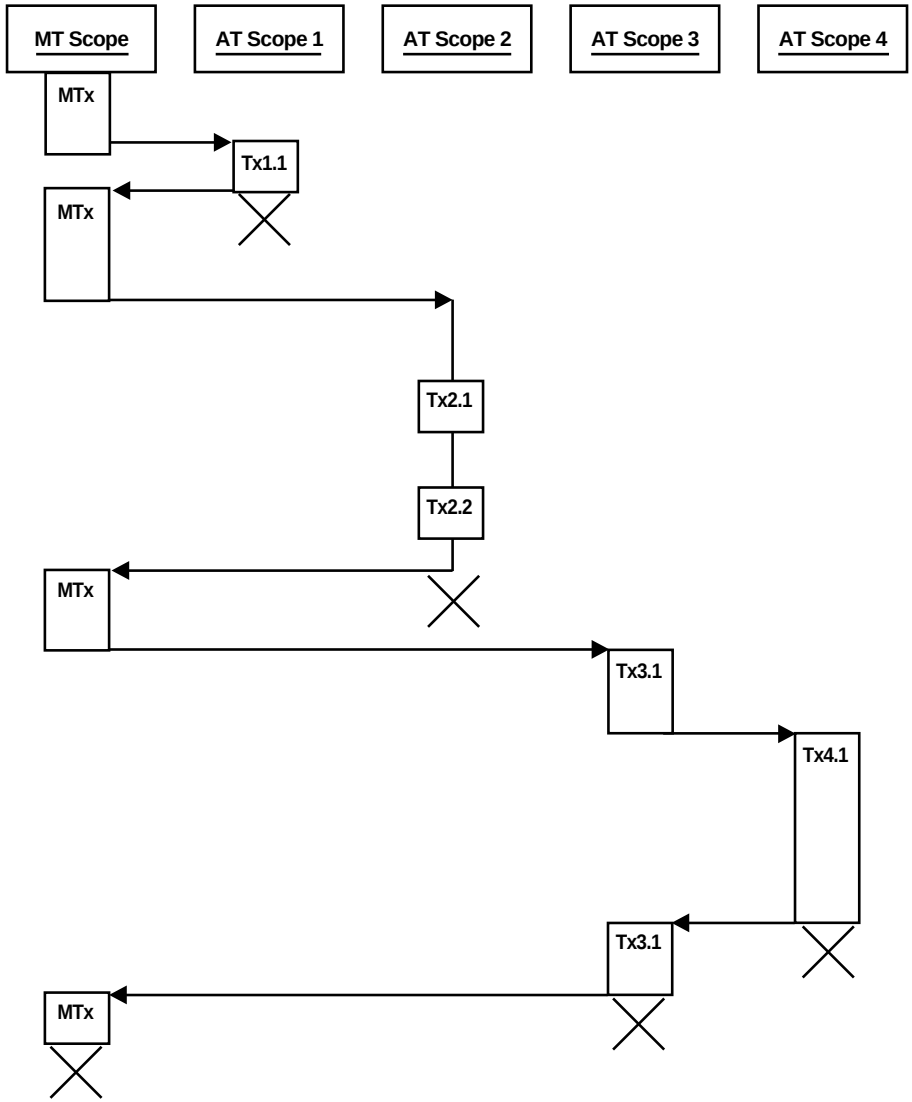
MTx invokes AT Scope 3. MTx suspends, AT Scope 3 begins.

AT Scope 3 begins Tx3.1 which, in turn, invokes AT Scope 4. Tx3.1 suspends, AT Scope 4 begins.

AT Scope 4 begins Tx4.1, commits or rolls it back, then ends. AT Scope 3 resumes.

AT Scope 3 commits or rolls back Tx3.1, then ends. MTx resumes.

Finally, MT Scope commits or rolls back MTx, then ends.



Examples

The two examples in this section illustrate some of the ways you can use autonomous transactions.

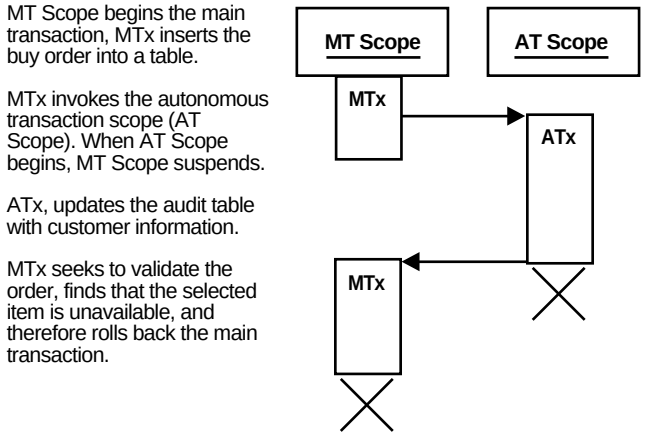
As these examples illustrate, there are four possible outcomes that can occur when you use autonomous and main transactions. The following table presents these possible outcomes. As you can see, there is no dependency between the outcome of an autonomous transaction and that of a main transaction.

Autonomous Transaction	Main Transaction
Commits	Commits
Commits	Rolls back
Rolls back	Commits
Rolls back	Rolls back

Entering a Buy Order

In this example, a customer enters a buy order. That customer's information (e.g., name, address, phone) is committed to a customer information table—even though the sale does not go through.

Figure 8–6 Example: A Buy Order



Example: Making a Bank Withdrawal

In the following banking application, a customer tries to make a withdrawal from his or her account. In the process, a main transaction calls one of two autonomous transaction scopes (AT Scope 1, and AT Scope 2).

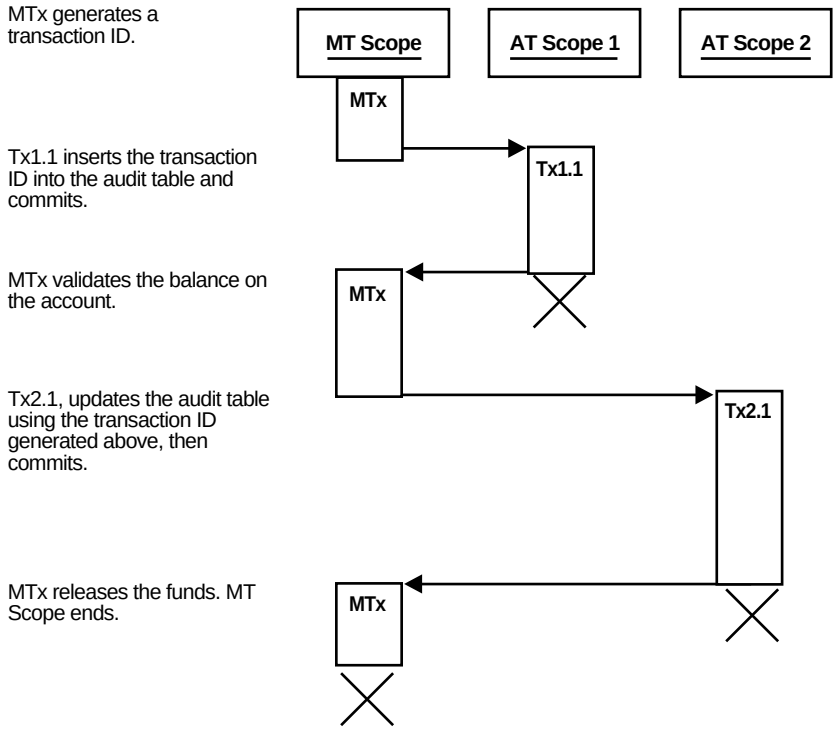
The following diagrams illustrate three possible scenarios for this transaction.

- Scenario 1: There are sufficient funds to cover the withdrawal and therefore the bank releases the funds
- Scenario 2: There are insufficient funds to cover the withdrawal, but the customer has overdraft protection. The bank therefore releases the funds.
- Scenario 3: There are insufficient funds to cover the withdrawal, the customer does not have overdraft protection, and the bank therefore withholds the requested funds.

Scenario 1:

There are sufficient funds to cover the withdrawal and therefore the bank releases the funds

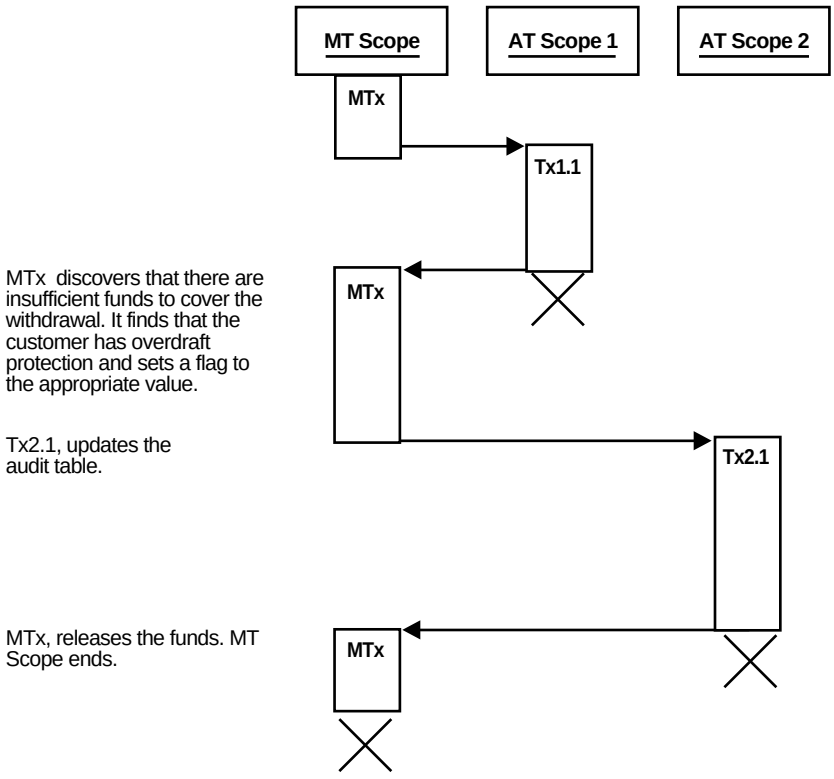
Figure 8–7 Example: Bank Withdrawal—Sufficient Funds



Scenario 2:

There are insufficient funds to cover the withdrawal, but the customer has overdraft protection. The bank therefore releases the funds.

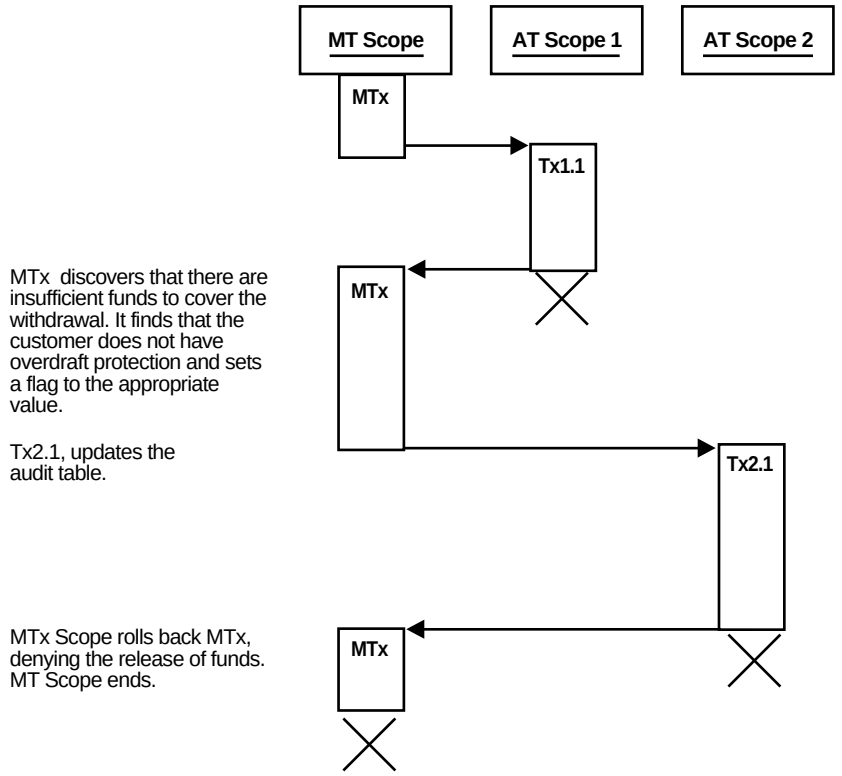
Figure 8–8 Example: Bank Withdrawal—Insufficient Funds WITH Overdraft Protection



Scenario 3:

There are insufficient funds to cover the withdrawal, the customer does *not* have overdraft protection, and the bank therefore withholds the requested funds.

Figure 8–9 Example: Bank Withdrawal—Insufficient Funds WITHOUT Overdraft Protection



Defining Autonomous Transactions

> **Note:** This section is provided here to round out your *general* understanding of autonomous transactions. For a more thorough understanding of autonomous transactions, see *PL/SQL User's Guide and Reference.*

To define autonomous transactions, you use the pragma (compiler directive) AUTONOMOUS_TRANSACTION. The pragma instructs the PL/SQL compiler to mark the procedure, function, or PL/SQL block as autonomous (independent).

You can code the pragma anywhere in the declarative section of a procedure, function, or PL/SQL block. But, for readability, code the pragma at the top of the section. The syntax follows:

```
PRAGMA AUTONOMOUS_TRANSACTION;
```

In the following example, you mark a packaged function as autonomous:

```
CREATE OR REPLACE PACKAGE Banking AS
    FUNCTION Balance (Acct_id INTEGER) RETURN REAL;
    -- add additional functions and/or packages
END Banking;

CREATE OR REPLACE PACKAGE BODY Banking AS
    FUNCTION Balance (Acct_id INTEGER) RETURN REAL IS
        PRAGMA AUTONOMOUS_TRANSACTION;
        My_bal REAL;
    BEGIN
       --add appropriate code
    END;
    -- add additional functions and/or packages...
END Banking;
```

You cannot use the pragma to mark all subprograms in a package (or all methods in an object type) as autonomous. Only individual routines can be marked autonomous. For example, the following pragma is illegal:

```
CREATE OR REPLACE PACKAGE Banking AS
    PRAGMA AUTONOMOUS_TRANSACTION; -- illegal
    FUNCTION Balance (Acct_id INTEGER) RETURN REAL;
    END Banking;
```

9

Dynamic SQL

Dynamic SQL is a programming technique that enables you to build SQL statements dynamically at runtime. You can create more general purpose, flexible applications by using dynamic SQL because the full text of a SQL statement may be unknown at compilation. For example, dynamic SQL lets you create a procedure that operates on a table whose name is not known until runtime.

In past releases of Oracle, the only way to implement dynamic SQL in a PL/SQL application was by using the `DBMS_SQL` package. Oracle8*i* introduces native dynamic SQL, an alternative to the `DBMS_SQL` package. Using native dynamic SQL, you can place dynamic SQL statements directly into PL/SQL blocks.

This chapter covers the following topics:

What Is Dynamic SQL?

Dynamic SQL enables you to write programs that reference SQL statements whose full text is not known until runtime. Before discussing dynamic SQL in detail, a clear definition of static SQL may provide a good starting point for understanding dynamic SQL. Static SQL statements do not change from execution to execution. The full text of static SQL statements are known at compilation, which provides the following benefits:

- Successful compilation verifies that the SQL statements reference valid database objects.
- Successful compilation verifies that the necessary privileges are in place to access the database objects.
- Performance of static SQL is generally better than dynamic SQL.

Because of these advantages, you should use dynamic SQL only if you cannot use static SQL to accomplish your goals, or if using static SQL is cumbersome compared to dynamic SQL. However, static SQL has limitations that can be overcome with dynamic SQL. You may not always know the full text of the SQL statements that must be executed in a PL/SQL procedure. Your program may accept user input that defines the SQL statements to execute, or your program may need to complete some processing work to determine the correct course of action. In such cases, you should use dynamic SQL.

For example, consider a reporting application that performs standard queries on tables in a data warehouse environment where the exact table name is unknown until runtime. To accommodate the large amount of data in the data warehouse efficiently, you create a new table every quarter to store the invoice information for the quarter. These tables all have exactly the same definition and are named according to the starting month and year of the quarter, for example `INV_01_1997`, `INV_04_1997`, `INV_07_1997`, `INV_10_1997`, `INV_01_1998`, etc. In such a case, you can use dynamic SQL in your reporting application to specify the table name at runtime.

With static SQL, all of the data definition information, such as table definitions, referenced by the SQL statements in your program must be known at compilation. If the data definition changes, you must change and recompile the program. Dynamic SQL programs can handle changes in data definition information, because the SQL statements can change "on the fly" at runtime. Therefore, dynamic SQL is much more flexible than static SQL. Dynamic SQL enables you to write application code that is reusable because the code defines a process that is independent of the specific SQL statements used.

In addition, dynamic SQL lets you execute SQL statements that are not supported in static SQL programs, such as data definition language (DDL) statements. Support for these statements allows you to accomplish more with your PL/SQL programs.

Note: The phrase *dynamic SQL programs* means programs that include dynamic SQL; such programs also can include static SQL. *Static SQL programs* are those programs that include only static SQL and no dynamic SQL.

When to Use Dynamic SQL

You should use dynamic SQL in cases where static SQL does not support the operation you want to perform, or in cases where you do not know the exact SQL statements that must be executed by a PL/SQL procedure. These SQL statements may depend on user input, or they may depend on processing work done by the program. The following sections describe typical situations where you should use dynamic SQL and typical problems that can be solved by using dynamic SQL.

To Execute Dynamic DML Statements

You can use dynamic SQL to execute DML statements in which the exact SQL statement is not known until runtime. For examples, see the DML examples in the "Examples of DBMS_SQL Package Code and Native Dynamic SQL Code" on page 9-19 and "Sample DML Operation" on page 9-10.

To Execute Statements Not Supported by Static SQL in PL/SQL

In PL/SQL, you cannot execute the following types of statements using static SQL:

- Data definition language (DDL) statements, such as `CREATE`, `DROP`, `GRANT`, and `REVOKE`
- Session control language (SCL) statements, such as `ALTER SESSION` and `SET ROLE`

  See Also: *Oracle8i SQL Reference* for information about DDL and SCL statements.

Use dynamic SQL if you need to execute any of these types of statements within a PL/SQL block.

In addition, static SQL in PL/SQL does not allow the use of the TABLE clause in the SELECT statements. There is no such limitation in dynamic SQL. For example, the following PL/SQL block contains a SELECT statement that uses the TABLE clause and native dynamic SQL:

```
CREATE TYPE t_emp AS OBJECT (id NUMBER, name VARCHAR2(20))
/
CREATE TYPE t_emplist AS TABLE OF t_emp
/

CREATE TABLE dept_new (id NUMBER, emps t_emplist)
    NESTED TABLE emps STORE AS emp_table;

INSERT INTO dept_new VALUES (
    10,
    t_emplist(
        t_emp(1, 'SCOTT'),
        t_emp(2, 'BRUCE')));

DECLARE
    deptid NUMBER;
    ename  VARCHAR2(20);
BEGIN
    EXECUTE IMMEDIATE 'SELECT d.id, e.name
        FROM dept_new d, TABLE(d.emps) e  -- not allowed in static SQL
                                          -- in PL/SQL
        WHERE e.id = 1'
        INTO deptid, ename;
END;
/
```

To Execute Dynamic Queries

You can use dynamic SQL to create applications that execute dynamic queries, which are queries whose full text is not known until runtime. Many types of applications need to use dynamic queries, including:

- Applications that allow users to input or choose query search or sorting criteria at runtime
- Applications that allow users to input or choose optimizer hints at run time
- Applications that query a database where the data definitions of tables are constantly changing
- Applications that query a database where new tables are created often

For examples, see "Query Example" on page 9-19, and see the query examples in "A Dynamic SQL Scenario Using Native Dynamic SQL" on page 9-9.

To Reference Database Objects that Do Not Exist at Compilation

Many types of applications must interact with data that is generated periodically. For example, it may be possible to determine the definition of the database tables at compilation, but not the names of the tables, because new tables are being generated periodically. Your application needs to access the data, but there is no way to know the exact names of the tables until runtime.

Dynamic SQL can solve this problem, because dynamic SQL allows you to wait until runtime to specify the table names you need to access. For example, in the sample data warehouse application discussed in "What Is Dynamic SQL?" on page 9-2, new tables are generated every quarter, and these tables always have the same definition. In this case, you might allow a user to specify the name of the table at runtime with a dynamic SQL query similar to the following:

```
CREATE OR REPLACE PROCEDURE query_invoice(
       month VARCHAR2,
       year VARCHAR2) IS
    TYPE cur_typ IS REF CURSOR;
    c cur_typ;
    query_str VARCHAR2(200);
    inv_num NUMBER;
    inv_cust VARCHAR2(20);
    inv_amt NUMBER;
BEGIN
    query_str := 'SELECT num, cust, amt FROM inv_' || month ||'_'|| year
      || ' WHERE invnum = :id';
    OPEN c FOR query_str USING inv_num;
    LOOP
        FETCH c INTO inv_num, inv_cust, inv_amt;
        EXIT WHEN c%NOTFOUND;
        -- process row here
    END LOOP;
    CLOSE c;
END;
/
```

To Optimize Execution Dynamically

If you use static SQL, you must decide at compilation how you want to construct your SQL statements, whether to have hints in your statements, and, if you include hints, exactly which hints to have. However, you can use dynamic SQL to build a SQL statement in a way that optimizes the execution and / or concatenates the hints into a SQL statement dynamically. This allows you to change the hints based on your current database statistics, without requiring recompilation.

For example, the following procedure uses a variable called `a_hint` to allow users to pass a hint option to the `SELECT` statement:

```
CREATE OR REPLACE PROCEDURE query_emp
      (a_hint VARCHAR2) AS
   TYPE cur_typ IS REF CURSOR;
   c cur_typ;
BEGIN
   OPEN c FOR 'SELECT ' || a_hint ||
      ' empno, ename, sal, job FROM emp WHERE empno = 7566';
      -- process
END;
/
```

In this example, the user can pass any of the following values for `a_hint`:

- `a_hint = '/*+ ALL_ROWS */'`
- `a_hint = '/*+ FIRST_ROWS */'`
- `a_hint = '/*+ CHOOSE */'`
- Any other valid hint option

See Also: *Oracle8i Tuning* for more information about using hints.

To Invoke Dynamic PL/SQL Blocks

You can use the EXECUTE IMMEDIATE statement to invoke anonymous PL/SQL blocks. The ability to invoke dynamic PL/SQL blocks can be useful for application extension and customization where the module to be executed is determined dynamically at runtime.

For example, suppose you want to write an application that takes an event number and dispatches to a handler for the event. The name of the handler is in the form EVENT_HANDLER_*event_num*, where *event_num* is the number of the event. One approach would be to implement the dispatcher as a switch statement, as shown below, where the code handles each event by making a static call to its appropriate handler.

```
CREATE OR REPLACE PROCEDURE event_handler_1(param number) AS BEGIN
   -- process event
   RETURN;
END;
/

CREATE OR REPLACE PROCEDURE event_handler_2(param number) AS BEGIN
   -- process event
   RETURN;
END;
/

CREATE OR REPLACE PROCEDURE event_handler_3(param number) AS BEGIN
   -- process event
   RETURN;
END;
/

CREATE OR REPLACE PROCEDURE event_dispatcher
   (event number, param number) IS
BEGIN
  IF (event = 1) THEN
    EVENT_HANDLER_1(param);
  ELSIF (event = 2) THEN
    EVENT_HANDLER_2(param);
  ELSIF (event = 3) THEN
    EVENT_HANDLER_3(param);
  END IF;
END;
/
```

This code is not very extensible because the dispatcher code must be updated whenever a handler for a new event is added. However, using native dynamic SQL, you can write an extensible event dispatcher similar to the following:

```
CREATE OR REPLACE PROCEDURE event_dispatcher
   (event NUMBER, param NUMBER) IS
BEGIN
  EXECUTE IMMEDIATE
     'BEGIN
        EVENT_HANDLER_' || to_char(event) || '(:1);
     END;'
  USING param;
END;
/
```

To Perform Dynamic Operations Using Invoker-Rights

By using the invoker-rights feature with dynamic SQL, you can build applications that issue dynamic SQL statements under the privileges and schema of the invoker. These two features, invoker-rights and dynamic SQL, enable you to build reusable application subcomponents that can operate on and access the invoker's data and modules.

> **See Also:** *PL/SQL User's Guide and Reference* for information about using invokers-rights and native dynamic SQL.

A Dynamic SQL Scenario Using Native Dynamic SQL

The scenario described in this section illustrates the power and flexibility of native dynamic SQL. This scenario includes examples that show you how to perform the following operations using native dynamic SQL:

- Execute DDL and DML operations
- Execute single row and multiple row queries

Data Model

The database in this scenario is a company's human resources database (named `hr`) with the following data model:

A master table named `offices` contains the list of all company locations. The `offices` table has the following definition:

Column Name	Null?	Type
LOCATION	NOT_NULL	VARCHAR2(200)

Multiple `emp_`*`location`* tables contain the employee information, where *`location`* is the name of city where the office is located. For example, a table named `emp_houston` contains employee information for the company's Houston office, while a table named `emp_boston` contains employee information for the company's Boston office.

Each `emp_`*`location`* table has the following definition:

Column Name	Null?	Type
EMPNO	NOT_NULL	NUMBER(4)
ENAME	NOT_NULL	VARCHAR2(10)
JOB	NOT_NULL	VARCHAR2(9)
SAL	NOT_NULL	NUMBER(7,2)
DEPTNO	NOT_NULL	NUMBER(2)

The following sections describe various native dynamic SQL operations that can be performed on the data in the `hr` database.

Sample DML Operation

The following native dynamic SQL procedure gives a raise to all employees with a particular job title:

```
CREATE OR REPLACE PROCEDURE salary_raise (raise_percent NUMBER, job VARCHAR2) IS
    TYPE loc_array_type IS TABLE OF VARCHAR2(40)
        INDEX BY binary_integer;
    dml_str VARCHAR2(200);
    loc_array loc_array_type;
BEGIN
    -- bulk fetch the list of office locations
    SELECT location BULK COLLECT INTO loc_array
        FROM offices;
    -- for each location, give a raise to employees with the given 'job'
    FOR i IN loc_array.first..loc_array.last LOOP
        dml_str := 'UPDATE emp_' || loc_array(i)
        || ' SET sal = sal * (1+(:raise_percent/100))'
        || ' WHERE job = :job_title';
    EXECUTE IMMEDIATE dml_str USING raise_percent, job;
    END LOOP;
END;
/
```

Sample DDL Operation

The `EXECUTE IMMEDIATE` statement can perform DDL operations. For example, the following procedure adds an office location:

```
CREATE OR REPLACE PROCEDURE add_location (loc VARCHAR2) IS
BEGIN
    -- insert new location in master table
    INSERT INTO offices VALUES (loc);
    -- create an employee information table
    EXECUTE IMMEDIATE
    'CREATE TABLE ' || 'emp_' || loc ||
    '(
        empno   NUMBER(4) NOT NULL,
        ename   VARCHAR2(10),
        job     VARCHAR2(9),
        sal     NUMBER(7,2),
        deptno  NUMBER(2)
    )';
END;
/
```

The following procedure deletes an office location:

```
CREATE OR REPLACE PROCEDURE drop_location (loc VARCHAR2) IS
BEGIN
    -- delete the employee table for location 'loc'
    EXECUTE IMMEDIATE 'DROP TABLE ' || 'emp_' || loc;
    -- remove location from master table
    DELETE FROM offices WHERE location = loc;
END;
/
```

Sample Dynamic Single-Row Query

The EXECUTE IMMEDIATE statement can perform dynamic single-row queries. You can specify bind variables in the USING clause and fetch the resulting row into the target specified in the INTO clause of the statement.

The following function retrieves the number of employees at a particular location performing a specified job:

```
CREATE OR REPLACE FUNCTION get_num_of_employees (loc VARCHAR2, job VARCHAR2)
    RETURN NUMBER IS
    query_str VARCHAR2(1000);
    num_of_employees NUMBER;
BEGIN
    query_str := 'SELECT COUNT(*) FROM '
        || ' emp_' || loc
        || ' WHERE job = :job_title';
    EXECUTE IMMEDIATE query_str
        INTO num_of_employees
        USING job;
    RETURN num_of_employees;
END;
/
```

Sample Dynamic Multiple-Row Query

The OPEN-FOR, FETCH, and CLOSE statements can perform dynamic multiple-row queries. For example, the following procedure lists all of the employees with a particular job at a specified location:

```
CREATE OR REPLACE PROCEDURE list_employees(loc VARCHAR2, job VARCHAR2) IS
    TYPE cur_typ IS REF CURSOR;
    c           cur_typ;
    query_str   VARCHAR2(1000);
    emp_name    VARCHAR2(20);
    emp_num     NUMBER;
BEGIN
    query_str := 'SELECT ename, empno FROM emp_' || loc
        || ' WHERE job = :job_title';
    -- find employees who perform the specified job
    OPEN c FOR query_str USING job;
    LOOP
        FETCH c INTO emp_name, emp_num;
        EXIT WHEN c%NOTFOUND;
        -- process row here
    END LOOP;
    CLOSE c;
END;
/
```

Native Dynamic SQL vs. the DBMS_SQL Package

Oracle provides two methods for using dynamic SQL within PL/SQL: native dynamic SQL and the DBMS_SQL package. Native dynamic SQL enables you to place dynamic SQL statements directly into PL/SQL code. These dynamic statements include DML statements (including queries), PL/SQL anonymous blocks, DDL statements, transaction control statements, and session control statements.

To process most native dynamic SQL statements, you use the EXECUTE IMMEDIATE statement. However, to process a multi-row query (SELECT statement), you use OPEN-FOR, FETCH, and CLOSE statements.

Note: To use native dynamic SQL, the COMPATIBLE initialization parameter must be set to 8.1.0 or higher. See *Oracle8i Migration* for more information about the COMPATIBLE parameter.

The DBMS_SQL package is a PL/SQL library that offers a programmatic API to execute SQL statements dynamically. The DBMS_SQL package has programmatic interfaces to open a cursor, parse a cursor, supply binds, etc. Programs that use the DBMS_SQL package make calls to this package to perform dynamic SQL operations.

The following sections provide detailed information about the advantages of both methods.

> **See Also:** The *PL/SQL User's Guide and Reference* for detailed information about using native dynamic SQL and the *Oracle8i Supplied Packages Reference* for detailed information about using the DBMS_SQL package. In the *PL/SQL User's Guide and Reference*, native dynamic SQL is referred to simply as dynamic SQL.

Advantages of Native Dynamic SQL

Native dynamic SQL provides the following advantages over the DBMS_SQL package:

Ease of Use

Native dynamic SQL is much simpler to use than the DBMS_SQL package. Because native dynamic SQL is integrated with SQL, you can use it in the same way that you currently use static SQL within PL/SQL code. In addition, native dynamic SQL code is typically more compact and readable than equivalent code that uses the DBMS_SQL package.

The DBMS_SQL package is not as easy to use as native dynamic SQL. There are many procedures and functions that must be used in a strict sequence. Typically, performing simple operations requires a large amount of code when you use the DBMS_SQL package. You can avoid this complexity by using native dynamic SQL instead.

Table 9–1 illustrates the difference in the amount of code required to perform the same operation using the DBMS_SQL package and native dynamic SQL.

Table 9–1 Code Comparison of DBMS_SQL Package and Native Dynamic SQL

DBMS_SQL Package

```
CREATE PROCEDURE insert_into_table (
      table_name  VARCHAR2,
      deptnumber  NUMBER,
      deptname    VARCHAR2,
      location    VARCHAR2) IS
   cur_hdl         INTEGER;
   stmt_str        VARCHAR2(200);
   rows_processed  BINARY_INTEGER;

BEGIN
   stmt_str := 'INSERT INTO ' ||
      table_name || ' VALUES
      (:deptno, :dname, :loc)';

   -- open cursor
   cur_hdl := dbms_sql.open_cursor;

   -- parse cursor
   dbms_sql.parse(cur_hdl, stmt_str,
      dbms_sql.native);

   -- supply binds
   dbms_sql.bind_variable
      (cur_hdl, ':deptno', deptnumber);
   dbms_sql.bind_variable
      (cur_hdl, ':dname', deptname);
   dbms_sql.bind_variable
      (cur_hdl, ':loc', location);

    -- execute cursor
    rows_processed :=
    dbms_sql.execute(cur_hdl);

    -- close cursor
    dbms_sql.close_cursor(cur_hdl);

END;
/
```

Native Dynamic SQL

```
CREATE PROCEDURE insert_into_table (
      table_name  VARCHAR2,
      deptnumber  NUMBER,
      deptname    VARCHAR2,
      location    VARCHAR2) IS
   stmt_str    VARCHAR2(200);

BEGIN
   stmt_str := 'INSERT INTO ' ||
      table_name || ' values
      (:deptno, :dname, :loc)';

   EXECUTE IMMEDIATE stmt_str
      USING
      deptnumber, deptname, location;

END;
/
```

Performance Improvements

The performance of native dynamic SQL in PL/SQL is comparable to the performance of static SQL because the PL/SQL interpreter has built-in support for native dynamic SQL. Therefore, the performance of programs that use native dynamic SQL is much better than that of programs that use the DBMS_SQL package. Typically, native dynamic SQL statements perform 1.5 to 3 times better than equivalent statements that use the DBMS_SQL package. Of course, your performance gains may vary depending on your application.

The DBMS_SQL package is based on a procedural API and, as a result, incurs high procedure call and data copy overhead. For example, every time you bind a variable, the DBMS_SQL package copies the PL/SQL bind variable into its space for later use during execution. Similarly, every time you execute a fetch, first the data is copied into the space managed by the DBMS_SQL package and then the fetched data is copied, one column at a time, into the appropriate PL/SQL variables, resulting in substantial overhead resulting from data copying. In contrast, native dynamic SQL bundles the statement preparation, binding, and execution steps into a single operation, which minimizes the data copying and procedure call overhead and improves performance.

Performance Tip When using either native dynamic SQL or the DBMS_SQL package, you can improve performance by using bind variables, because using bind variables allows Oracle to share a single cursor for multiple SQL statements.

For example, the following native dynamic SQL code does not use bind variables:

```
CREATE OR REPLACE PROCEDURE del_dept (
   my_deptno  dept.deptno%TYPE) IS
BEGIN
   EXECUTE IMMEDIATE 'DELETE FROM dept WHERE deptno = ' || to_char (my_deptno);
END;
/
```

For each distinct my_deptno variable, a new cursor is created, which can cause resource contention and poor performance. Instead, bind my_deptno as a bind variable, as in the following example:

```
CREATE OR REPLACE PROCEDURE del_dept (
   my_deptno  dept.deptno%TYPE) IS
BEGIN
   EXECUTE IMMEDIATE 'DELETE FROM dept WHERE deptno = :1' USING my_deptno;
END;
/
```

Here, the same cursor is reused for different values of the bind my_deptno, thereby improving performance and scalabilty.

Support for User-Defined Types

Native dynamic SQL supports all of the types supported by static SQL in PL/SQL. Therefore, native dynamic SQL provides support for user-defined types, such as user-defined objects, collections, and REFs. The DBMS_SQL package does not support these user-defined types.

> **Note:** The DBMS_SQL package provides limited support for arrays. See the *Oracle8i Supplied Packages Reference* for information.

Support for Fetching Into Records

Native dynamic SQL and static SQL both support fetching into records, but the DBMS_SQL package does not. With native dynamic SQL, the rows resulting from a query can be directly fetched into PL/SQL records.

In the following example, the rows from a query are fetched into the emp_rec record:

```
DECLARE
    TYPE EmpCurTyp IS REF CURSOR;
    c EmpCurTyp;
    emp_rec emp%ROWTYPE;
    stmt_str VARCHAR2(200);
    e_job emp.job%TYPE;

BEGIN
   stmt_str := 'SELECT * FROM emp WHERE job = :1';
    -- in a multi-row query
    OPEN c FOR stmt_str USING 'MANAGER';
    LOOP
        FETCH c INTO emp_rec;
        EXIT WHEN c%NOTFOUND;
    END LOOP;
    CLOSE c;
    -- in a single-row query
    EXECUTE IMMEDIATE stmt_str INTO emp_rec USING 'PRESIDENT';

END;
/
```

Advantages of the DBMS_SQL Package

The DBMS_SQL package provides the following advantages over native dynamic SQL:

Support for Client-Side Programs

Currently, the DBMS_SQL package is supported in client-side programs, but native dynamic SQL is not. Every call to the DBMS_SQL package from the client-side program translates to a PL/SQL remote procedure call (RPC); these calls occur when you need to bind a variable, define a variable, or execute a statement.

Support for DESCRIBE

The DESCRIBE_COLUMNS procedure in the DBMS_SQL package can be used to describe the columns for a cursor opened and parsed through DBMS_SQL. The functionality is similar to the DESCRIBE command in SQL*Plus. Native dynamic SQL does not have a DESCRIBE facility.

Support for Bulk Dynamic SQL

Bulk SQL is the ability to process multiple rows of data in a single DML statement. Bulk SQL improves performance by reducing the amount of context switching between SQL and the host language. Currently, the DBMS_SQL package supports bulk dynamic SQL.

Although there is no direct support for bulk operations in native dynamic SQL, you can simulate a native dynamic bulk SQL statement by placing the bulk SQL statement in a 'BEGIN ... END' block and executing the block dynamically. This workaround enables you to realize the benefits of bulk SQL within a native dynamic SQL program. For example, the following native dynamic SQL code copies the ename column of one table to another:

```
CREATE TYPE name_array_type IS
   VARRAY(100) of VARCHAR2(50)
/

CREATE OR REPLACE PROCEDURE copy_ename_column
   (table1 VARCHAR2, table2 VARCHAR2) IS
   ename_col  NAME_ARRAY_TYPE;
```

```
BEGIN
  -- bulk fetch the 'ename' column into a VARRAY of VARCHAR2s.
  EXECUTE IMMEDIATE
     'BEGIN
        SELECT ename BULK COLLECT INTO :tab
           FROM ' || table1 || ';
     END;'
   USING OUT ename_col;

   -- bulk insert the 'ename' column into another table.
   EXECUTE IMMEDIATE
      'BEGIN
         FORALL i IN :first .. :last
            INSERT INTO ' || table2 || ' VALUES (:tab(i));
      END;'
   USING ename_col.first, ename_col.last, ename_col;
END;
/
```

Multiple Row Updates and Deletes with a RETURNING Clause

The DBMS_SQL package supports statements with a RETURNING clause that update or delete multiple rows. Native dynamic SQL only supports a RETURNING clause if a single row is returned.

> **See Also:** "DML Returning Example" on page 9-22 for examples of DBMS_SQL package code and native dynamic SQL code that uses a RETURNING clause.

Support for SQL Statements Larger than 32KB

The DBMS_SQL package supports SQL statements larger than 32KB; native dynamic SQL does not.

Reuse of SQL Statements

The PARSE procedure in the DBMS_SQL package parses a SQL statement once. After the initial parsing, the statement can be used multiple times with different sets of bind arguments.

In contrast, native dynamic SQL prepares a SQL statement for execution each time the statement is used. Statement preparation typically involves parsing, optimization, and plan generation. Preparing a statement each time it is used incurs a small performance penalty. However, Oracle's shared cursor mechanism

minimizes the cost, and the performance penalty is typically trivial when compared to the performance benefits of native dynamic SQL.

Examples of DBMS_SQL Package Code and Native Dynamic SQL Code

The following examples illustrate the differences in the code necessary to complete operations with the DBMS_SQL package and native dynamic SQL. Specifically, the following types of examples are presented:

- A query
- A DML operation
- A DML returning operation

In general, the native dynamic SQL code is more readable and compact, which can improve developer productivity.

Query Example

The following example includes a dynamic query statement with one bind variable (:jobname) and two select columns (ename and sal):

```
stmt_str := 'SELECT ename, sal FROM emp WHERE job = :jobname';
```

This example queries for employees with the job description SALESMAN in the job column of the emp table. Table 9–2 shows sample code that accomplishes this query using the DBMS_SQL package and native dynamic SQL.

Table 9–2 Querying Using the DBMS_SQL Package and Native Dynamic SQL

DBMS_SQL Query Operation	Native Dynamic SQL Query Operation

DECLARE
  stmt_str varchar2(200);
  cur_hdl int;
  rows_processed int;
  name varchar2(10);
  salary int;
BEGIN
cur_hdl := dbms_sql.open_cursor; -- open cursor
stmt_str := 'SELECT ename, sal FROM emp WHERE
job = :jobname';
dbms_sql.parse(cur_hdl, stmt_str, dbms_
sql.native);
 	
-- supply binds (bind by name)
dbms_sql.bind_variable(
  cur_hdl, 'jobname', 'SALESMAN');
 	
-- describe defines
dbms_sql.define_column(cur_hdl, 1, name, 200);
dbms_sql.define_column(cur_hdl, 2, salary);
 	
rows_processed := dbms_sql.execute(cur_hdl); --
execute
 	
LOOP
  -- fetch a row
  IF dbms_sql.fetch_rows(cur_hdl) > 0 then
 	
  -- fetch columns from the row
  dbms_sql.column_value(cur_hdl, 1, name);
  dbms_sql.column_value(cur_hdl, 2, salary);
 	
  -- <process data>
 	
  ELSE
  EXIT;
  END IF;
END LOOP;
dbms_sql.close_cursor(cur_hdl); -- close cursor
END;
/
	DECLARE
	  TYPE EmpCurTyp IS REF CURSOR;
	  cur EmpCurTyp;
	  stmt_str VARCHAR2(200);
	  name VARCHAR2(20);
	  salary NUMBER;
	BEGIN
	  stmt_str := 'SELECT ename, sal FROM emp
	  WHERE job = :1';
	  OPEN cur FOR stmt_str USING 'SALESMAN';
	
	LOOP
	  FETCH cur INTO name, salary;
	  EXIT WHEN cur%NOTFOUND;
	  -- <process data>
	END LOOP;
	CLOSE cur;
	END;
	/

DML Example

The following example includes a dynamic INSERT statement for a table with three columns:

```
stmt_str := 'INSERT INTO dept_new VALUES (:deptno, :dname, :loc)';
```

This example inserts a new row for which the column values are in the PL/SQL variables deptnumber, deptname, and location. Table 9–3 shows sample code that accomplishes this DML operation using the DBMS_SQL package and native dynamic SQL.

Table 9–3 DML Operation Using the DBMS_SQL Package and Native Dynamic SQL

DBMS_SQL DML Operation	Native Dynamic SQL DML Operation

DECLARE
  stmt_str VARCHAR2(200);
  cur_hdl NUMBER;
  deptnumber NUMBER := 99;
  deptname VARCHAR2(20);
  location VARCHAR2(10);
  rows_processed NUMBER;
BEGIN
  stmt_str := 'INSERT INTO dept_new VALUES
  (:deptno, :dname, :loc)';
  cur_hdl := DBMS_SQL.OPEN_CURSOR;
  DBMS_SQL.PARSE(
  cur_hdl, stmt_str, DBMS_SQL.NATIVE);
  -- supply binds
  DBMS_SQL.BIND_VARIABLE
  (cur_hdl, ':deptno', deptnumber);
  DBMS_SQL.BIND_VARIABLE
  (cur_hdl, ':dname', deptname);
  DBMS_SQL.BIND_VARIABLE
  (cur_hdl, ':loc', location);
  rows_processed := dbms_sql.execute(cur_hdl);
  -- execute
  DBMS_SQL.CLOSE_CURSOR(cur_hdl); -- close
END;
/
	DECLARE
	  stmt_str VARCHAR2(200);
	  deptnumber NUMBER := 99;
	  deptname VARCHAR2(20);
	  location VARCHAR2(10);
	BEGIN
	  stmt_str := 'INSERT INTO dept_new VALUES
	  (:deptno, :dname, :loc)';
	  EXECUTE IMMEDIATE stmt_str
	  USING deptnumber, deptname, location;
	END;
	/

DML Returning Example

The following example includes a dynamic UPDATE statement that updates the location of a department when given the department number (deptnumber) and a new location (location), and then returns the name of the department:

```
stmt_str := 'UPDATE dept_new
            SET loc = :newloc
            WHERE deptno = :deptno
            RETURNING dname INTO :dname';
```

This example inserts a new row for which the column values are in the PL/SQL variables deptnumber, deptname, and location. Table 9–4 shows sample code that accomplishes this DML returning operation using the DBMS_SQL package and native dynamic SQL.

Table 9–4 DML Returning Operation Using the DBMS_SQL Package and Native Dynamic SQL

DBMS_SQL DML Returning Operation	Native Dynamic SQL DML Returning Operation

DECLARE
  deptname_array dbms_sql.Varchar2_Table;
  cur_hdl INT;
  stmt_str VARCHAR2(200);
  location VARCHAR2(20);
  deptnumber NUMBER := 10;
  rows_processed NUMBER;
BEGIN
 stmt_str := 'UPDATE dept_new
  SET loc = :newloc
  WHERE deptno = :deptno
  RETURNING dname INTO :dname';
 	
  cur_hdl := dbms_sql.open_cursor;
  dbms_sql.parse
  (cur_hdl, stmt_str, dbms_sql.native);
  -- supply binds
  dbms_sql.bind_variable
  (cur_hdl, ':newloc', location);
  dbms_sql.bind_variable
  (cur_hdl, ':deptno', deptnumber);
  dbms_sql.bind_array
  (cur_hdl, ':dname', deptname_array);
  -- execute cursor
  rows_processed := dbms_sql.execute(cur_hdl);
  -- get RETURNING column into OUT bind array
  dbms_sql.variable_value
  (cur_hdl, ':dname', deptname_array);
  dbms_sql.close_cursor(cur_hdl);
END;
/
	DECLARE
	  deptname_array dbms_sql.Varchar2_Table;
	  stmt_str VARCHAR2(200);
	  location VARCHAR2(20);
	  deptnumber NUMBER := 10;
	  deptname VARCHAR2(20);
	BEGIN
	  stmt_str := 'UPDATE dept_new
	  SET loc = :newloc
	  WHERE deptno = :deptno
	  RETURNING dname INTO :dname';
	  EXECUTE IMMEDIATE stmt_str
	  USING location, deptnumber, OUT deptname;
	END;
	/

Application Development Languages Other Than PL/SQL

So far, the discussion in this chapter has been about PL/SQL support for dynamic SQL. However, you can use other application development languages to implement programs that use dynamic SQL. These application development languages include C/C++, COBOL, and Java.

If you use C/C++, you can develop applications that use dynamic SQL with the Oracle Call Interface (OCI), or you can use the Pro*C/C++ precompiler to add dynamic SQL extensions to your C code. Similarly, if you use COBOL, you can use the Pro*COBOL precompiler to add dynamic SQL extensions to your COBOL code. If you use Java, you can develop applications that use dynamic SQL with JDBC.

In the past, the only way to use dynamic SQL in PL/SQL applications was by using the `DBMS_SQL` package. There are a number of limitations to using this package, including performance concerns. Consequently, application developers may have used one of the alternatives to PL/SQL discussed above to implement dynamic SQL. However, with the introduction of native dynamic SQL in PL/SQL, many of the drawbacks to using PL/SQL for dynamic SQL are now eliminated.

If you have an application that uses OCI, Pro*C/C++, or Pro*COBOL for dynamic SQL execution, the network roundtrips required to perform dynamic SQL operations may hurt performance. Because these applications typically reside on clients, more network calls are required to complete dynamic SQL operations. If you have this type of application, consider moving the dynamic SQL functionality to stored procedures and stored functions in PL/SQL that use native dynamic SQL. Doing so might improve the performance of your application because the stored procedures can reside on the server, thereby eliminating the network overhead. You can then call the PL/SQL stored procedures and stored functions from the application.

> **See Also:** *Oracle Call Interface Programmer's Guide, Pro*C/C++ Precompiler Programmer's Guide, Pro*COBOL Precompiler Programmer's Guide,* and *Oracle8i Java Stored Procedures Developer's Guide* for information about calling Oracle stored procedures and stored functions from non-PL/SQL applications.

10

Using Procedures and Packages

This chapter discusses some of the procedural capabilities of Oracle for application development, including:

- PL/SQL Program Units
- Wrapping PL/SQL Code
- Remote Dependencies
- Cursor Variables
- Compile-Time Errors
- Run-Time Error Handling
- Debugging
- Calling Stored Procedures
- Calling Remote Procedures
- Calling Stored Functions from SQL Expressions

PL/SQL Program Units

PL/SQL is a modern, block-structured programming language. It provides a number of features that make developing powerful database applications very convenient. For example, PL/SQL provides procedural constructs, such as loops and conditional statements, that are not available in standard SQL.

You can directly enter SQL data manipulation language (DML) statements inside PL/SQL blocks, and you can use procedures, supplied by Oracle, to perform data definition language (DDL) statements.

PL/SQL code runs on the server, so using PL/SQL lets you centralize significant parts of your database applications for increased maintainability and security. It also enables you to achieve a significant reduction of network overhead in client/server applications.

Note: Some Oracle tools, such as Oracle Forms, contain a PL/SQL engine, and can run PL/SQL locally.

You can even use PL/SQL for some database applications in place of 3GL programs that use embedded SQL or the Oracle Call Interface (OCI).

PL/SQL program units include:

- Anonymous Blocks
- Stored Program Units (Procedures, Functions, and Packages)
- Triggers

See Also: For complete information about the PL/SQL language, see the *PL/SQL User's Guide and Reference*.

Anonymous Blocks

An anonymous block is a PL/SQL program unit that has no name, and it does not require the explicit presence of the `BEGIN` and `END` keywords to enclose the executable statements. An anonymous block consists of an optional *declarative* part, an *executable* part, and one or more optional *exception handlers*.

The declarative part declares PL/SQL variables, exceptions, and cursors. The executable part contains PL/SQL code and SQL statements, and can contain nested blocks. Exception handlers contain code that is called when the exception is raised,

either as a predefined PL/SQL exception (such as NO_DATA_FOUND or ZERO_DIVIDE) or as an exception that you define.

The following short example of a PL/SQL anonymous block prints the names of all employees in department 20 in the Emp_tab table, using the DBMS_OUTPUT package:

```
DECLARE
   Emp_name    VARCHAR2(10);
   Cursor      c1 IS SELECT Ename FROM Emp_tab
                  WHERE Deptno = 20;
BEGIN
   OPEN c1;
   LOOP
      FETCH c1 INTO Emp_name;
      EXIT WHEN c1%NOTFOUND;
      DBMS_OUTPUT.PUT_LINE(Emp_name);
   END LOOP;
END;
```

Note: If you test this block using SQL*Plus, then enter the statement SET SERVEROUTPUT ON, so that output using the DBMS_OUTPUT procedures (for example, PUT_LINE) is activated. Also, end the example with a slash (/) to activate it.

See Also: For complete information about the DBMS_OUTPUT package, see *Oracle8i Supplied Packages Reference*.

Exceptions let you handle Oracle error conditions within PL/SQL program logic. This allows your application to prevent the server from issuing an error that could cause the client application to abend. The following anonymous block handles the predefined Oracle exception NO_DATA_FOUND (which would result in an ORA-01403 error if not handled):

```
DECLARE
   Emp_number   INTEGER := 9999;
   Emp_name     VARCHAR2(10);
BEGIN
   SELECT Ename INTO Emp_name FROM Emp_tab
      WHERE Empno = Emp_number;   -- no such number
   DBMS_OUTPUT.PUT_LINE('Employee name is ' || Emp_name);
EXCEPTION
   WHEN NO_DATA_FOUND THEN
      DBMS_OUTPUT.PUT_LINE('No such employee: ' || Emp_number);
END;
```

You can also define your own exceptions, declare them in the declaration part of a block, and define them in the exception part of the block. An example follows:

```
DECLARE
   Emp_name           VARCHAR2(10);
   Emp_number         INTEGER;
   Empno_out_of_range EXCEPTION;
BEGIN
   Emp_number := 10001;
   IF Emp_number > 9999 OR Emp_number < 1000 THEN
      RAISE Empno_out_of_range;
   ELSE
      SELECT Ename INTO Emp_name FROM Emp_tab
         WHERE Empno = Emp_number;
      DBMS_OUTPUT.PUT_LINE('Employee name is ' || Emp_name);
END IF;
EXCEPTION
   WHEN Empno_out_of_range THEN
      DBMS_OUTPUT.PUT_LINE('Employee number ' || Emp_number ||
       ' is out of range.');
END;
```

See Also: "Run-Time Error Handling" on page 10-44 and see the *PL/SQL User's Guide and Reference.*

Anonymous blocks are usually used interactively from a tool, such as SQL*Plus, or in a precompiler, OCI, or SQL*Module application. They are usually used to call stored procedures or to open cursor variables.

See Also: "Cursor Variables" on page 10-38.

Stored Program Units (Procedures, Functions, and Packages)

A stored procedure, function, or package is a PL/SQL program unit that has the following features:

- Has a name.
- Can take parameters, and can return values.
- Is stored in the data dictionary.
- Can be called by many users.

> **Note:** The term *stored procedure* is sometimes used generically to cover both stored procedures and stored functions. The only difference between procedures and functions is that functions always return a single value to the caller, while procedures do not return a value to the caller.

Naming Procedures and Functions

Because a procedure or function is stored in the database, it must be named. This distinguishes it from other stored procedures and makes it possible for applications to call it. Each publicly-visible procedure or function in a schema must have a unique name, and the name must be a legal PL/SQL identifier.

> **Note:** If you plan to call a stored procedure using a stub generated by SQL*Module, then the stored procedure name must also be a legal identifier in the calling host 3GL language, such as Ada or C.

Parameters for Procedures and Functions

Stored procedures and functions can take parameters. The following example shows a stored procedure that is similar to the anonymous block in "Anonymous Blocks" on page 10-2.

> **Caution:** To execute the following, use CREATE OR REPLACE PROCEDURE...

```
PROCEDURE Get_emp_names (Dept_num IN NUMBER) IS
   Emp_name       VARCHAR2(10);
   CURSOR         c1 (Depno NUMBER) IS
                     SELECT Ename FROM Emp_tab
                        WHERE deptno = Depno;
BEGIN
   OPEN c1(Dept_num);
   LOOP
      FETCH c1 INTO Emp_name;
      EXIT WHEN C1%NOTFOUND;
      DBMS_OUTPUT.PUT_LINE(Emp_name);
   END LOOP;
   CLOSE c1;
END;
```

In this stored procedure example, the department number is an input parameter which is used when the parameterized cursor `C1` is opened.

The formal parameters of a procedure have three major parts:

Name	This must be a legal PL/SQL identifier.
Mode	This indicates whether the parameter is an input-only parameter (`IN`), an output-only parameter (`OUT`), or is both an input and an output parameter (`IN OUT`). If the mode is not specified, then `IN` is assumed.
Datatype	This is a standard PL/SQL datatype.

Parameter Modes Parameter modes define the behavior of formal parameters. The three parameter modes, `IN` (the default), `OUT`, and `IN OUT`, can be used with any subprogram. However, avoid using the `OUT` and `IN OUT` modes with functions. The purpose of a function is to take no arguments and return a single value. It is poor programming practice to have a function return multiple values. Also, functions should be free from side effects, which change the values of variables not local to the subprogram.

Table 10–1 summarizes the information about parameter modes.

> **See Also:** Parameter modes are explained in detail in the *PL/SQL User's Guide and Reference.*

Table 10–1 Parameter Modes

IN	OUT	IN OUT
The default.	Must be specified.	Must be specified.
Passes values to a subprogram.	Returns values to the caller.	Passes initial values to a subprogram; returns updated values to the caller.
Formal parameter acts like a constant.	Formal parameter acts like an uninitialized variable.	Formal parameter acts like an initialized variable.
Formal parameter cannot be assigned a value.	Formal parameter cannot be used in an expression; must be assigned a value.	Formal parameter should be assigned a value.
Actual parameter can be a constant, initialized variable, literal, or expression.	Actual parameter must be a variable.	Actual parameter must be a variable.

Parameter Datatypes The datatype of a formal parameter consists of one of the following:

- An *unconstrained* type name, such as `NUMBER` or `VARCHAR2`.
- A type that is *constrained* using the `%TYPE` or `%ROWTYPE` attributes.

> **Note:** Numerically constrained types such as `NUMBER(2)` or `VARCHAR2(20)` are not allowed in a parameter list.

%TYPE and %ROWTYPE Attributes

Use the type attributes `%TYPE` and `%ROWTYPE` to constrain the parameter. For example, the `Get_emp_names` procedure specification in "Parameters for Procedures and Functions" on page 10-5 could be written as the following:

```
PROCEDURE Get_emp_names(Dept_num IN Emp_tab.Deptno%TYPE)
```

This has the `Dept_num` parameter take the same datatype as the `Deptno` column in the `Emp_tab` table. The column and table must be available when a declaration using `%TYPE` (or `%ROWTYPE`) is elaborated.

Using `%TYPE` is recommended, because if the type of the column in the table changes, then it is not necessary to change the application code.

If the Get_emp_names procedure is part of a package, then you can use previously-declared public (package) variables to constrain a parameter datatype. For example:

```
Dept_number    number(2);
...
PROCEDURE Get_emp_names(Dept_num IN Dept_number%TYPE);
```

Use the %ROWTYPE attribute to create a record that contains all the columns of the specified table. The following example defines the Get_emp_rec procedure, which returns all the columns of the Emp_tab table in a PL/SQL record for the given empno:

> **Caution:** To execute the following, use CREATE OR REPLACE PROCEDURE...

```
PROCEDURE Get_emp_rec (Emp_number  IN  Emp_tab.Empno%TYPE,
                       Emp_ret     OUT Emp_tab%ROWTYPE) IS
BEGIN
   SELECT Empno, Ename, Job, Mgr, Hiredate, Sal, Comm, Deptno
      INTO Emp_ret
      FROM Emp_tab
      WHERE Empno = Emp_number;
END;
```

You could call this procedure from a PL/SQL block as follows:

```
DECLARE
   Emp_row      Emp_tab%ROWTYPE;     -- declare a record matching a
                                     -- row in the Emp_tab table
BEGIN
   Get_emp_rec(7499, Emp_row);   -- call for Emp_tab# 7499
   DBMS_OUTPUT.PUT(Emp_row.Ename || ' '                || Emp_row.Empno);
   DBMS_OUTPUT.PUT(' '           || Emp_row.Job || ' ' || Emp_row.Mgr);
   DBMS_OUTPUT.PUT(' '           || Emp_row.Hiredate   || ' ' || Emp_row.Sal);
   DBMS_OUTPUT.PUT(' '           || Emp_row.Comm || ' '|| Emp_row.Deptno);
   DBMS_OUTPUT.NEW_LINE;
END;
```

Stored functions can also return values that are declared using %ROWTYPE. For example:

```
FUNCTION Get_emp_rec (Dept_num IN Emp_tab.Deptno%TYPE)
   RETURN Emp_tab%ROWTYPE IS ...
```

Tables and Records You can pass PL/SQL tables as parameters to stored procedures and functions. You can also pass tables of records as parameters.

Default Parameter Values Parameters can take default values. Use the DEFAULT keyword or the assignment operator to give a parameter a default value. For example, the specification for the Get_emp_names procedure could be written as the following:

```
PROCEDURE Get_emp_names (Dept_num IN NUMBER DEFAULT 20) IS ...
```

or

```
PROCEDURE Get_emp_names (Dept_num IN NUMBER := 20) IS ...
```

When a parameter takes a default value, it can be omitted from the actual parameter list when you call the procedure. When you do specify the parameter value on the call, it overrides the default value.

> **Note:** Unlike in an anonymous PL/SQL block, you do not use the keyword DECLARE before the declarations of variables, cursors, and exceptions in a stored procedure. In fact, it is an error to use it.

Creating Stored Procedures and Functions

Use your usual text editor to write the procedure or function. At the beginning of the procedure, place the following statement:

```
CREATE PROCEDURE Procedure_name AS   ...
```

For example, to use the example in "%TYPE and %ROWTYPE Attributes" on page 10-7, create a text (source) file called get_emp.sql containing the following code:

```
CREATE PROCEDURE Get_emp_rec (Emp_number  IN  Emp_tab.Empno%TYPE,
                              Emp_ret     OUT Emp_tab%ROWTYPE) AS
BEGIN
   SELECT Empno, Ename, Job, Mgr, Hiredate, Sal, Comm, Deptno
      INTO Emp_ret
      FROM Emp_tab
      WHERE Empno = Emp_number;
END;
/
```

Then, using an interactive tool such as SQL*Plus, load the text file containing the procedure by entering the following statement:

```
SQLPLUS> @get_emp
```

This loads the procedure into the current schema from the `get_emp.sql` file (`.sql` is the default file extension). Note the slash (/) at the end of the code. This is not part of the code; it just activates the loading of the procedure.

Use the CREATE [OR REPLACE] FUNCTION... statement to store functions.

Caution: When developing a new procedure, it is usually much more convenient to use the CREATE OR REPLACE**... PROCEDURE statement. This replaces any previous version of that procedure in the same schema with the newer version, but note that this is done without warning.**

You can use either the keyword IS or AS after the procedure parameter list.

> **See Also:** See the *Oracle8i Reference* for the complete syntax of the CREATE PROCEDURE and CREATE FUNCTION statements.

Privileges to Create Procedures and Functions To create a stand-alone procedure or function, or package specification or body, you must meet the following prerequisites:

- You must have the CREATE PROCEDURE system privilege to create a procedure or package in your schema, or the CREATE ANY PROCEDURE system privilege to create a procedure or package in another user's schema.

  Note: To create without errors (to compile the procedure or package successfully) requires the following additional privileges:

  - The owner of the procedure or package must be explicitly granted the necessary object privileges for all objects referenced within the body of the code.
  - The owner cannot obtain required privileges through roles.

If the privileges of a procedure's or a package's owner change, then the procedure must be reauthenticated before it is run. If a necessary privilege to a referenced

object is revoked from the owner of the procedure or package, then the procedure cannot be run.

The EXECUTE privilege on a procedure gives a user the right to run a procedure owned by another user. Privileged users run the procedure under the security domain of the procedure's owner. Therefore, users never need to be granted the privileges to the objects referenced by a procedure. This allows for more disciplined and efficient security strategies with database applications and their users. Furthermore, all procedures and packages are stored in the data dictionary (in the SYSTEM tablespace). No quota controls the amount of space available to a user who creates procedures and packages.

> **See Also:** "Privileges Required to Execute a Procedure" on page 10-53.

Altering Stored Procedures and Functions

To alter a stored procedure or function, you must first drop it using the DROP PROCEDURE or DROP FUNCTION statement, then recreate it using the CREATE PROCEDURE or CREATE FUNCTION statement. Alternatively, use the CREATE OR REPLACE PROCEDURE or CREATE OR REPLACE FUNCTION statement, which first drops the procedure or function if it exists, then recreates it as specified.

> **Caution: The procedure or function is dropped without any warning.**

Dropping Procedures and Functions

A stand-alone procedure, a stand-alone function, a package body, or an entire package can be dropped using the SQL statements DROP PROCEDURE, DROP FUNCTION, DROP PACKAGE BODY, and DROP PACKAGE, respectively. A DROP PACKAGE statement drops both a package's specification and body.

The following statement drops the `Old_sal_raise` procedure in your schema:

```
DROP PROCEDURE Old_sal_raise;
```

Privileges to Drop Procedures and Functions To drop a procedure, function, or package, the procedure or package must be in your schema, or you must have the DROP ANY PROCEDURE privilege. An individual procedure within a package cannot be dropped; the containing package specification and body must be re-created without the procedures to be dropped.

External Procedures

A PL/SQL procedure executing on an Oracle Server can call an external procedure written in a 3GL. The 3GL procedure runs in a separate address space from that of the Oracle Server.

> **See Also:** For information about external procedures, see the Chapter 11, "External Routines".

PL/SQL Packages

A *package* is an encapsulated collection of related program objects (e.g., procedures, functions, variables, constants, cursors, and exceptions) stored together in the database.

Using packages is an alternative to creating procedures and functions as standalone schema objects. Packages have many advantages over stand-alone procedures and functions. For example, they:

- Let you organize your application development more efficiently.
- Let you grant privileges more efficiently.
- Let you modify package objects without recompiling dependent schema objects.
- Enable Oracle to read multiple package objects into memory at once.
- Can contain global variables and cursors that are available to all procedures and functions in the package.
- Let you *overload* procedures or functions. Overloading a procedure means creating multiple procedures with the same name in the same package, each taking arguments of different number or datatype.

> **See Also:** The *PL/SQL User's Guide and Reference* has more information about subprogram name overloading.

The *specification* part of a package *declares* the public types, variables, constants, and subprograms that are visible outside the immediate scope of the package. The *body* of a package *defines* the objects declared in the specification, as well as private objects that are not visible to applications outside the package.

Example The following example shows a package specification for a package named `Employee_management`. The package contains one stored function and two stored procedures. The body for this package defines the function and the procedures:

```
CREATE PACKAGE BODY Employee_management AS
   FUNCTION Hire_emp (Name VARCHAR2, Job VARCHAR2,
      Mgr NUMBER, Hiredate DATE, Sal NUMBER, Comm NUMBER,
      Deptno NUMBER) RETURN NUMBER IS
       New_empno    NUMBER(10);

-- This function accepts all arguments for the fields in
-- the employee table except for the employee number.
-- A value for this field is supplied by a sequence.
-- The function returns the sequence number generated
-- by the call to this function.

   BEGIN
      SELECT Emp_sequence.NEXTVAL INTO New_empno FROM dual;
      INSERT INTO Emp_tab VALUES (New_empno, Name, Job, Mgr,
         Hiredate, Sal, Comm, Deptno);
      RETURN (New_empno);
   END Hire_emp;

   PROCEDURE fire_emp(emp_id IN NUMBER) AS

-- This procedure deletes the employee with an employee
-- number that corresponds to the argument Emp_id. If
-- no employee is found, then an exception is raised.

   BEGIN
      DELETE FROM Emp_tab WHERE Empno = Emp_id;
      IF SQL%NOTFOUND THEN
      Raise_application_error(-20011, 'Invalid Employee
         Number: ' || TO_CHAR(Emp_id));
   END IF;
END fire_emp;

PROCEDURE Sal_raise (Emp_id IN NUMBER, Sal_incr IN NUMBER) AS

-- This procedure accepts two arguments. Emp_id is a
-- number that corresponds to an employee number.
-- SAL_INCR is the amount by which to increase the
-- employee's salary. If employee exists, then update
-- salary with increase.

   BEGIN
      UPDATE Emp_tab
         SET Sal = Sal + Sal_incr
         WHERE Empno = Emp_id;
```

```
      IF SQL%NOTFOUND THEN
         Raise_application_error(-20011, 'Invalid Employee
            Number: ' || TO_CHAR(Emp_id));
      END IF;
   END Sal_raise;
END Employee_management;
```

Note: If you want to try this example, then first create the sequence number Emp_sequence. Do this with the following SQL*Plus statement:

```
SQL> CREATE SEQUENCE Emp_sequence
   > START WITH 8000 INCREMENT BY 10;
```

Creating Packages

Each part of a package is created with a different statement. Create the package specification using the CREATE PACKAGE statement. The CREATE PACKAGE statement declares public package objects.

To create a package body, use the CREATE PACKAGE BODY statement. The CREATE PACKAGE BODY statement defines the procedural code of the public procedures and functions declared in the package specification.

You can also define private, or local, package procedures, functions, and variables in a package body. These objects can only be accessed by other procedures and functions in the body of the same package. They are not visible to external users, regardless of the privileges they hold.

It is often more convenient to add the OR REPLACE clause in the CREATE PACKAGE or CREATE PACKAGE BODY statements when you are first developing your application. The effect of this option is to drop the package or the package body without warning. The CREATE statements would then be the following:

```
CREATE OR REPLACE PACKAGE Package_name AS ...
```

and

```
CREATE OR REPLACE PACKAGE BODY Package_name AS ...
```

Creating Packaged Objects The body of a package can contain include:

- Procedures and functions declared in the package specification.
- Definitions of cursors declared in the package specification.
- Local procedures and functions, not declared in the package specification.
- Local variables.

Procedures, functions, cursors, and variables that are declared in the package specification are *global*. They can be called, or used, by external users that have EXECUTE permission for the package or that have EXECUTE ANY PROCEDURE privileges.

When you create the package body, make sure that each procedure that you define in the body has the same parameters, *by name, datatype, and mode*, as the declaration in the package specification. For functions in the package body, the parameters *and* the return type must agree in name and type.

Privileges to Create or Drop Packages The privileges required to create or drop a package specification or package body are the same as those required to create or drop a stand-alone procedure or function.

> **See Also:** "Privileges to Create Procedures and Functions" on page 10-10 and "Privileges to Drop Procedures and Functions" on page 10-11.

Naming Packages and Package Objects

The names of a package and all public objects in the package must be unique within a given schema. The package specification and its body must have the same name. All package constructs must have unique names within the scope of the package, unless overloading of procedure names is desired.

Package Invalidations and Session State

Each session that references a package object has its own instance of the corresponding package, including persistent state for any public and private variables, cursors, and constants. If any of the session's instantiated packages (specification or body) are subsequently invalidated and recompiled, then all other dependent package instantiations (including state) for the session are lost.

For example, assume that session S instantiates packages P1 and P2, and that a procedure in package P1 calls a procedure in package P2. If P1 is invalidated and recompiled (for example, as the result of a DDL operation), then the session S

instantiations of both P1 and P2 are lost. In such situations, a session receives the following error the first time it attempts to use any object of an invalidated package instantiation:

```
ORA-04068: existing state of packages has been discarded
```

The second time a session makes such a package call, the package is reinstantiated for the session without error.

> **Note:** Oracle has been optimized to not return this message to the session calling the package that it invalidated. Thus, in the example above, session S receives this message the first time it called package P2, but it does not receive it when calling P1.

In most production environments, DDL operations that can cause invalidations are usually performed during inactive working hours; therefore, this situation might not be a problem for end-user applications. However, if package specification or body invalidations are common in your system during working hours, then you might want to code your applications to detect for this error when package calls are made.

Oracle Supplied Packages

There are many built-in packages provided with the Oracle Server, either to extend the functionality of the database or to give PL/SQL access to SQL features. You may take advantage of the functionality provided by these packages when creating your application, or you may simply want to use these packages for ideas in creating your own stored procedures.

This section lists each of the supplied packages and indicates where they are described in more detail. These packages run as the calling user, rather than the package owner. Unless otherwise noted, the packages are callable through public synonyms of the same name.

Table 10–2 List of Oracle Supplied Packages

Package Name	Description	Documentation
Calendar (see Note #2 below)	Provides calendar maintenance functions.	*Oracle8i Time Series User's Guide*
DBMS_ALERT	Provides support for the asynchronous notification of database events.	*Oracle8i Supplied Packages Reference*
DBMS_APPLICATION_INFO	Lets you register an application name with the database for auditing or performance tracking purposes.	*Oracle8i Supplied Packages Reference*
DBMS_AQ	Lets you add a message (of a predefined object type) onto a queue or to dequeue a message.	*Oracle8i Supplied Packages Reference*
DBMS_AQADM	Lets you perform administrative functions on a queue or queue table for messages of a predefined object type.	*Oracle8i Supplied Packages Reference*
DBMS_DDL	Provides access to some SQL DDL statements from stored procedures, and provides special administration operations not available as DDLs.	*Oracle8i Supplied Packages Reference*
DBMS_DEBUG	A PL/SQL API to the PL/SQL debugger layer, Probe, in the Oracle server.	*Oracle8i Supplied Packages Reference*
DBMS_DEFER	Provides the user interface to a replicated transactional deferred remote procedure call facility. Requires the Distributed Option.	*Oracle8i Supplied Packages Reference*
DBMS_DEFER_QUERY	Permits querying the deferred remote procedure calls (RPC) queue data that is not exposed through views. Requires the Distributed Option.	*Oracle8i Supplied Packages Reference*
DMBS_DEFER_SYS	Provides the system administrator interface to a replicated transactional deferred remote procedure call facility. Requires the Distributed Option.	*Oracle8i Supplied Packages Reference*
DBMS_DESCRIBE	Describes the arguments of a stored procedure with full name translation and security checking.	*Oracle8i Supplied Packages Reference*
DBMS_DISTRIBUTED_TRUST_ADMIN	Maintains the Trusted Database List, which is used to determine if a privileged database link from a particular server can be accepted.	*Oracle8i Supplied Packages Reference*
DBMS_HS	Lets you create and modify objects in the Heterogeneous Services dictionary.	*Oracle8i Supplied Packages Reference*

Table 10–2 List of Oracle Supplied Packages

Package Name	Description	Documentation
DBMS_HS_PASSTHROUGH	Lets you use Heterogeneous Services to send pass-through SQL statements to non-Oracle systems.	*Oracle8i Supplied Packages Reference*
DBMS_IOT	Creates a table into which references to the chained rows for an Index Organized Table can be placed using the ANALYZE command.	*Oracle8i Supplied Packages Reference*
DBMS_JOB	Lets you schedule administrative procedures that you want performed at periodic intervals; it is also the interface for the job queue.	*Oracle8i Supplied Packages Reference*
DBMS_LOB	Provides general purpose routines for operations on Oracle Large Object (LOBs) datatypes - BLOB, CLOB (read-write), and BFILEs (read-only).	*Oracle8i Supplied Packages Reference*
DBMS_LOCK	Lets you request, convert and release locks through Oracle Lock Management services.	*Oracle8i Supplied Packages Reference*
DBMS_LOGMNR	Provides functions to initialize and run the log reader.	*Oracle8i Supplied Packages Reference*
DBMS_LOGMNR_D	Queries the dictionary tables of the current database, and creates a text based file containing their contents.	*Oracle8i Supplied Packages Reference*
DBMS_OFFLINE_OG	Provides public APIs for offline instantiation of master groups.	*Oracle8i Supplied Packages Reference*
DBMS_OFFLINE_SNAPSHOT	Provides public APIs for offline instantiation of snapshots.	*Oracle8i Supplied Packages Reference*
DBMS_OLAP	Provides procedures for summaries, dimensions, and query rewrites.	*Oracle8i Supplied Packages Reference*
DBMS_ORACLE_TRACE_AGENT	Provides client callable interfaces to the Oracle TRACE instrumentation within the Oracle7 Server.	*Oracle8i Supplied Packages Reference*
DBMS_ORACLE_TRACE_USER	Provides public access to the Oracle release 7 Server Oracle TRACE instrumentation for the calling user.	*Oracle8i Supplied Packages Reference*
DBMS_OUTPUT	Accumulates information in a buffer so that it can be retrieved out later.	*Oracle8i Supplied Packages Reference*
DBMS_PCLXUTIL	Provides intra-partition parallelism for creating partition-wise local indexes.	*Oracle8i Supplied Packages Reference*

Table 10–2 List of Oracle Supplied Packages

Package Name	Description	Documentation
DBMS_PIPE	Provides a DBMS pipe service which enables messages to be sent between sessions.	*Oracle8i Supplied Packages Reference*
DBMS_PROFILER	Provides a Probe Profiler API to profile existing PL/SQL applications and identify performance bottlenecks.	*Oracle8i Supplied Packages Reference*
DBMS_RANDOM	Provides a built-in random number generator.	*Oracle8i Supplied Packages Reference*
DBMS_RECTIFIER_DIFF	Provides APIs used to detect and resolve data inconsistencies between two replicated sites.	*Oracle8i Supplied Packages Reference*
DBMS_REFRESH	Lets you create groups of snapshots that can be refreshed together to a transactionally consistent point in time. Requires the Distributed Option.	*Oracle8i Supplied Packages Reference*
DBMS_REPAIR	Provides data corruption repair procedures.	*Oracle8i Supplied Packages Reference*
DBMS_REPCAT	Provides routines to administer and update the replication catalog and environment. Requires the Replication Option.	*Oracle8i Supplied Packages Reference*
DBMS_REPCAT_ADMIN	Lets you create users with the privileges needed by the symmetric replication facility. Requires the Replication Option.	*Oracle8i Supplied Packages Reference*
DBMS_REPCAT_INSTATIATE	Instantiates deployment templates. Requires the Replication Option.	*Oracle8i Supplied Packages Reference*
DBMS_REPCAT_RGT	Controls the maintenance and definition of refresh group templates. Requires the Replication Option.	*Oracle8i Supplied Packages Reference*
DBMS_REPUTIL	Provides routines to generate shadow tables, triggers, and packages for table replication.	*Oracle8i Supplied Packages Reference*
DBMS_RESOURCE_MANAGER	Maintains plans, consumer groups, and plan directives; it also provides semantics so that you may group together changes to the plan schema.	*Oracle8i Supplied Packages Reference*
DBMS_RESOURCE_MANAGER_PRIVS	Maintains privileges associated with resource consumer groups.	*Oracle8i Supplied Packages Reference*
DBMS_RLS	Provides row level security administrative interface.	*Oracle8i Supplied Packages Reference*
DBMS_ROWID	Provides procedures to create ROWIDs and to interpret their contents.	*Oracle8i Supplied Packages Reference*

Table 10–2 List of Oracle Supplied Packages

Package Name	Description	Documentation
DBMS_SESSION	Provides access to SQL ALTER SESSION statements, and other session information, from stored procedures.	*Oracle8i Supplied Packages Reference*
DBMS_SHARED_POOL	Lets you keep objects in shared memory, so that they will not be aged out with the normal LRU mechanism.	*Oracle8i Supplied Packages Reference*
DBMS_SNAPSHOT (synonym DBMS_MVIEW)	Lets you refresh snapshots that are not part of the same refresh group and purge logs. Requires the Distributed Option.	*Oracle8i Supplied Packages Reference*
DBMS_SPACE	Provides segment space information not available through standard SQL.	*Oracle8i Supplied Packages Reference*
DBMS_SPACE_ADMIN	Provides tablespace and segment space administration not available through the standard SQL.	*Oracle8i Supplied Packages Reference*
DBMS_SQL	Lets you use dynamic SQL to access the database.	*Oracle8i Supplied Packages Reference*
DBMS_STANDARD	Provides language facilities that help your application interact with Oracle.	(see Note #1 below)
DBMS_STATS	Provides a mechanism for users to view and modify optimizer statistics gathered for database objects.	*Oracle8i Supplied Packages Reference*
DBMS_TRACE	Provides routines to start and stop PL/SQL tracing.	*Oracle8i Supplied Packages Reference*
DBMS_TRANSACTION	Provides access to SQL transaction statements from stored procedures and monitors transaction activities.	*Oracle8i Supplied Packages Reference*
DBMS_TTS	Checks if the transportable set is self-contained.	*Oracle8i Supplied Packages Reference*
DBMS_UTILITY	Provides various utility routines.	*Oracle8i Supplied Packages Reference*
DEBUG_EXTPROC	Lets you debug external procedures on platforms with debuggers that can attach to a running process.	*Oracle8i Supplied Packages Reference*
OUTLN_PKG	Provides the interface for procedures and functions associated with management of stored outlines.	*Oracle8i Supplied Packages Reference*

Table 10–2 List of Oracle Supplied Packages

Package Name	Description	Documentation
PLITBLM	Handles index-table operations.	(see Note #1 below)
SDO_ADMIN (see Note #3 below)	Provides functions implementing spatial index creation and maintenance for spatial objects.	*Oracle8i Spatial User's Guide and Reference*
SDO_GEOM (see Note #3 below)	Provides functions implementing geometric operations on spatial objects.	*Oracle8i Spatial User's Guide and Reference*
SDO_MIGRATE (see Note #3 below)	Provides functions for migrating spatial data from release 7.3.3 and 7.3.4 to 8.1.x.	*Oracle8i Spatial User's Guide and Reference*
SDO_TUNE (see Note #3 below)	Provides functions for selecting parameters that determine the behavior of the spatial indexing scheme used in the Spatial Cartridge.	*Oracle8i Spatial User's Guide and Reference*
STANDARD	Declares types, exceptions, and subprograms which are available automatically to every PL/SQL program.	(see Note #1 below)
TimeSeries (see Note #2 below)	Provides functions that perform operations, such as extraction, retrieval, arithmetic, and aggregation, on time series data.	*Oracle8i Time Series User's Guide*
TimeScale (see Note #2 below)	Provides scaleup and scaledown functions.	*Oracle8i Time Series User's Guide*
TSTools (see Note #2 below)	Provides administrative tools procedures.	*Oracle8i Time Series User's Guide*
UTL_COLL	Enables PL/SQL programs to use collection locators to query and update.	*Oracle8i Supplied Packages Reference*
UTL_FILE	Enables your PL/SQL programs to read and write operating system (OS) text files and provides a restricted version of standard OS stream file I/O.	*Oracle8i Supplied Packages Reference*
UTL_HTTP	Enables HTTP callouts from PL/SQL and SQL to access data on the Internet or to call Oracle Web Server Cartridges.	*Oracle8i Supplied Packages Reference*
UTL_PG	Provides functions for converting COBOL numeric data into Oracle numbers and Oracle numbers into COBOL numeric data.	*Oracle Procedural Gateway for APPC User's Guide*
UTL_RAW	Provides SQL functions for RAW datatypes that concat, substr, etc. to and from RAWS.	*Oracle8i Supplied Packages Reference*

Table 10–2 List of Oracle Supplied Packages

Package Name	Description	Documentation
UTL_REF	Enables a PL/SQL program to access an object by providing a reference to the object.	*Oracle8i Supplied Packages Reference*
Vir_Pkg (see Note #2 below)	Provides analytical and conversion functions for Visual Information Retrieval.	*Oracle8i Visual Information Retrieval User's Guide and Reference*

Note #1:

The DBMS_STANDARD, STANDARD, and PLITBLM packages contain subprograms to help implement basic language features. Oracle does not recommend that the subprograms be directly called. For this reason, these three supplied packages are not documented in this book.

Note #2:

Time-Series, Image, Visual Information Retrieval, Audio, and Server-Managed Video Cartridge packages are installed in user ORDSYS without public synonyms.

Note #3:

Spatial Cartridge packages are installed in user MDSYS with public synonyms.

Bulk Binds

Oracle uses two engines to run PL/SQL blocks and subprograms: the PL/SQL engine and the SQL engine. The PL/SQL engine runs procedural statements, while the SQL engine runs SQL statements. During execution, every SQL statement causes a context switch between the two engines, which results in a performance penalty.

Performance can be improved substantially by minimizing the number of context switches required to run a particular block or subprogram. When a SQL statement runs inside a loop that uses collection elements as bind variables, the large number of context switches required by the block can cause poor performance. Collections include the following:

- Varrays
- Nested tables
- Index-by tables
- Host arrays

Binding is the assignment of values to PL/SQL variables in SQL statements. *Bulk binding* is binding an entire collection at once. Without bulk binds, the elements in a

collection are sent to the SQL engine individually, whereas bulk binds pass the entire collection back and forth between the two engines.

Using bulk binds, you can improve performance by reducing the number of context switches required to run SQL statements that use collection elements. Typically, using bulk binds improves performance for SQL statements that affect four or more database rows. The more rows affected by a SQL statement, the greater the performance gain will be with bulk binds.

Note: This section provides an overview of bulk binds to help you decide if you should use them in your PL/SQL applications. For detailed information about using bulk binds, see the *PL/SQL User's Guide and Reference.*

Caution: You may need to set up or drop data structures for certain examples to work.

When to Use Bulk Binds The following sections discuss common scenarios where bulk binds can improve performance. If you have, or plan to have, similar scenarios in your applications, then you should consider using bulk binds.

DML Statements Referencing Collections Bulk binds can be used to improve the performance of DML statements that reference collections. To bulk-bind an input collection before sending it to the SQL engine, use the FORALL keyword. The SQL statement must be an INSERT, UPDATE, or DELETE statement that references collection elements.

For example, the following PL/SQL block increases the salary for employees whose manager's ID number is 7902, 7698, or 7839, without using bulk binds:

```
DECLARE
   TYPE Numlist IS VARRAY (100) OF NUMBER;
   Id NUMLIST := NUMLIST(7902, 7698, 7839);
BEGIN
   FOR i IN Id.FIRST..Id.LAST LOOP
      UPDATE Emp_tab SET Sal = 1.1 * Sal
      WHERE Mgr = Id(i);
   END LOOP;
END;
```

To run this block, PL/SQL sends a SQL statement to the SQL engine for each employee that is updated. If there are many employees to update, then the large number of context switches between the PL/SQL engine and the SQL engine can hurt performance.

Use the FORALL keyword to bulk-bind the collection and improve performance:

```
DECLARE
   TYPE Numlist IS VARRAY (100) OF NUMBER;
   Id NUMLIST := NUMLIST(7902, 7698, 7839);
BEGIN
   FORALL i IN Id.FIRST..Id.LAST   -- bulk-bind the VARRAY
      UPDATE Emp_tab SET Sal = 1.1 * Sal
      WHERE Mgr = Id(i);
END;
```

SELECT Statements Referencing Collections Bulk binds can be used to improve the performance of SELECT statements that reference collections. To bulk-bind output collections before returning them to the PL/SQL engine, use the keywords BULK COLLECT INTO.

For example, the following PL/SQL block returns the employee name and job for employees whose manager's ID number is 7698, without using bulk binds:

```
DECLARE
   TYPE Var_tab IS TABLE OF VARCHAR2(20) INDEX BY BINARY_INTEGER;
   Empno VAR_TAB;
   Ename VAR_TAB;
   Counter NUMBER;
   CURSOR C IS
      SELECT Empno, Ename FROM Emp_tab WHERE Mgr = 7698;
BEGIN

-- Initialize variable tracing number of employees returned.

   counter := 1;

-- Find all employees whose manager's ID number is 7698.

   FOR rec IN C LOOP
      Empno(Counter) := rec.Empno;
      Ename(Counter) := rec.Ename;
      Counter := Counter + 1;
   END LOOP;
END;
```

PL/SQL sends a SQL statement to the SQL engine for each employee that is selected. If there are many employees selected, then the large number of context switches between the PL/SQL engine and the SQL engine can hurt performance.

Use the BULK COLLECT INTO keywords to bulk-bind the collection and improve performance:

```
DECLARE
   TYPE Emplist IS VARRAY(100) OF NUMBER;
   Empids EMPLIST := EMPLIST(7369, 7499, 7521, 7566, 7654, 7698);
   TYPE Bonlist IS TABLE OF Emp_tab.Sal%TYPE;
   Bonlist_inst BONLIST;
BEGIN
   Bonlist_inst := BONLIST(1,2,3,4,5);
   FOR i IN Empids.FIRST..empIDs.LAST LOOP
      UPDATE Emp_tab SET Bonus = 0.1 * Sal
         WHERE empno = Empids(i)
       RETURNING Sal INTO BONLIST(i);
   END LOOP;
END;
```

FOR Loops that Reference Collections and the Returning Into Clause Bulk binds can be used to improve the performance of FOR loops that reference collections and return DML. If you have, or plan to have, PL/SQL code that does this, then you can use the FORALL keyword along with the BULK COLLECT INTO keywords to improve performance.

For example, the following PL/SQL block updates the Emp_tab table by computing bonuses for a collection of employees; then it returns the bonuses in a column called Bonlist. Both actions are performed without using bulk binds:

```
DECLARE
   TYPE Emplist IS VARRAY(100) OF NUMBER;
   Empids EMPLIST := EMPLIST(7369, 7499, 7521, 7566, 7654, 7698);
   TYPE Bonlist IS TABLE OF Emp_tab.sal%TYPE;
   Bonlist_inst BONLIST;
BEGIN
   Bonlist_inst := BONLIST(1,2,3,4,5);
   FOR i IN Empids.FIRST..Empids.LAST LOOP
      UPDATE Emp_tab Set Bonus = 0.1 * sal
         WHERE Empno = Empids(i)
       RETURNING Sal INTO BONLIST(i);
   END LOOP;
END;
```

PL/SQL sends a SQL statement to the SQL engine for each employee that is updated. If there are many employees updated, then the large number of context switches between the PL/SQL engine and the SQL engine can hurt performance.

Use the FORALL and BULK COLLECT INTO keywords together to bulk-bind the collection and improve performance:

```
DECLARE
   TYPE Emplist IS VARRAY(100) OF NUMBER;
   TYPE Numlist IS TABLE OF Emp_tab.Sal%TYPE;
   Empids EMPLIST := EMPLIST(7369, 7499, 7521, 7566, 7654, 7698);
   Bonlist NUMLIST;
BEGIN
   FORALL i IN Empids.FIRST..empIDs.LAST
      UPDATE Emp_tab SET Bonus = 0.1 * Sal
      WHERE Empno = Empids(i)
      RETURNING Sal BULK COLLECT INTO Bonlist;
END;
```

Triggers

A trigger is a special kind of PL/SQL anonymous block. You can define triggers to fire before or after SQL statements, either on a statement level or for each row that is affected. You can also define INSTEAD OF triggers or system triggers (triggers on DATABASE and SCHEMA).

See Also: Chapter 13, "Using Triggers".

Wrapping PL/SQL Code

You can deliver your stored procedures in object code format using the PL/SQL Wrapper. Wrapping your PL/SQL code hides your application internals. To run the PL/SQL Wrapper, enter the WRAP statement at your system prompt using the following syntax:

```
wrap INAME=input_file [ONAME=ouput_file]
```

See Also: For complete instructions on using the PL/SQL Wrapper, see the *PL/SQL User's Guide and Reference*.

Remote Dependencies

Dependencies among PL/SQL program units can be handled in two ways:

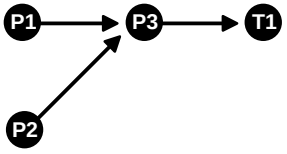
- Timestamps
- Signatures

Timestamps

If timestamps are used to handle dependencies among PL/SQL program units, then whenever you alter a program unit or a relevant schema object, all of its dependent units are marked as invalid and must be recompiled before they can be run.

Each program unit carries a timestamp that is set by the server when the unit is created or recompiled. Figure 10–1 demonstrates this graphically. Procedures P1 and P2 call stored procedure P3. Stored procedure P3 references table T1. In this example, each of the procedures is dependent on table T1. P3 depends upon T1 directly, while P1 and P2 depend upon T1 indirectly.

Figure 10–1 Dependency Relationships



If P3 is altered, then P1 and P2 are marked as invalid immediately, if they are on the same server as P3. The compiled states of P1 and P2 contain records of the timestamp of P3. Therefore, if the procedure P3 is altered and recompiled, then the timestamp on P3 no longer matches the value that was recorded for P3 during the compilation of P1 and P2.

If P1 and P2 are on a client system, or on another Oracle Server in a distributed environment, then the timestamp information is used to mark them as invalid at runtime.

Disadvantages of the Timestamp Model

The disadvantage of this dependency model is that it is unnecessarily restrictive. Recompilation of dependent objects across the network are often performed when not strictly necessary, leading to performance degradation.

Furthermore, on the client side, the timestamp model can lead to situations that block an application from running at all, if the client-side application is built using PL/SQL version 2. Earlier releases of tools, such as Oracle Forms, that used PL/SQL version 1 on the client side did not use this dependency model, because PL/SQL version 1 had no support for stored procedures.

For releases of Oracle Forms that are integrated with PL/SQL version 2 on the client side, the timestamp model can present problems. For example, during the installation of the application, the application is rendered invalid unless the client-side PL/SQL procedures that it uses are recompiled at the client site. Also, if a client-side procedure depends on a server procedure, and if the server procedure is changed or automatically recompiled, then the client-side PL/SQL procedure must then be recompiled. Yet in many application environments (such as Forms runtime applications), there is no PL/SQL compiler available on the client. This blocks the application from running at all. The client application developer must then redistribute new versions of the application to all customers.

Signatures

To alleviate some of the problems with the timestamp-only dependency model, Oracle provides the additional capability of remote dependencies using signatures. The signature capability affects only remote dependencies. Local (same server) dependencies are not affected, as recompilation is always possible in this environment.

A signature is associated with each compiled stored program unit. It identifies the unit using the following criteria:

- The name of the unit (the package, procedure, or function name).
- The types of each of the parameters of the subprogram.
- The modes of the parameters (`IN`, `OUT`, `IN OUT`).
- The number of parameters.
- The type of the return value for a function.

The user has control over whether signatures or timestamps govern remote dependencies.

See Also: "Controlling Remote Dependencies" on page 10-35.

When the signature dependency model is used, a dependency on a remote program unit causes an invalidation of the dependent unit if the dependent unit contains a call to a subprogram in the parent unit, and if the signature of this subprogram has been changed in an incompatible manner.

For example, consider a procedure Get_emp_name stored on a server in Boston (BOSTON_SERVER). The procedure is defined as the following:

Note: You may need to set up data structures, similar to the following, for certain examples to work:

```
CONNECT system/manager
CREATE PUBLIC DATABASE LINK boston_server USING 'inst1_alias';
CONNECT scott/tiger
```

```
CREATE OR REPLACE PROCEDURE Get_emp_name (
   emp_number   IN  NUMBER,
   hire_date    OUT VARCHAR2,
   emp_name     OUT VARCHAR2) AS
BEGIN
   SELECT ename, to_char(hiredate, 'DD-MON-YY')
      INTO emp_name, hire_date
      FROM emp
      WHERE empno = emp_number;
END;
```

When Get_emp_name is compiled on BOSTON_SERVER, its signature, as well as its timestamp, is recorded.

Now, assume that on another server in California, some PL/SQL code calls Get_emp_name identifying it using a DBlink called BOSTON_SERVER, as follows:

```
CREATE OR REPLACE PROCEDURE print_ename (emp_number IN NUMBER) AS
   hire_date    VARCHAR2(12);
   ename        VARCHAR2(10);
BEGIN
   get_emp_name@BOSTON_SERVER(emp_number, hire_date, ename);
   dbms_output.put_line(ename);
   dbms_output.put_line(hire_date);
END;
```

When this California server code is compiled, the following actions take place:

- A connection is made to the Boston server.
- The signature of `Get_emp_name` is transferred to the California server.
- The signature is recorded in the compiled state of `Print_ename`.

At runtime, during the remote procedure call from the California server to the Boston server, the recorded signature of `Get_emp_name` that was saved in the compiled state of `Print_ename` gets sent to the Boston server, regardless of whether or not there were any changes.

If the timestamp dependency mode is in effect, then a mismatch in timestamps causes an error status to be returned to the calling procedure.

However, if the signature mode is in effect, then any mismatch in timestamps is ignored, and the recorded signature of `Get_emp_name` in the compiled state of `Print_ename` on the California server is compared with the current signature of `Get_emp_name` on the Boston server. If they match, then the call succeeds. If they do not match, then an error status is returned to the `Print_name` procedure.

Note that the `Get_emp_name` procedure on the Boston server could have been changed. Or, its timestamp could be different from that recorded in the `Print_name` procedure on the California server, possibly due to the installation of a new release of the server. As long as the signature remote dependency mode is in effect on the California server, a timestamp mismatch does not cause an error when `Get_emp_name` is called.

Note: `DETERMINISTIC`, `PARALLEL_ENABLE`, and purity information do not show in the signature mode. Optimizations based on these settings are not automatically reconsidered if a function on a remote system is redefined with different settings. This may lead to incorrect query results when calls to the remote function occur, even indirectly, in a SQL statement, or if the remote function is used, even indirectly, in a function-based index.

When Does a Signature Change?

Datatypes A signature changes when you switch from one class of datatype to another. Within each datatype class, there can be several types. Changing a parameter datatype from one type to another within a class does not cause the signature to change.

Table 10–3 lists the classes of types.

Table 10–3 Datatypes

Varchar Types	**Number Types**
VARCHAR2	NUMBER
VARCHAR	INTEGER
STRING	INT
LONG	SMALLINT
ROWID	DECIMAL
Character Types	DEC
CHARACTER	REAL
CHAR	FLOAT
Raw Types	NUMERIC
RAW	DOUBLE PRECISION
LONG RAW	NUMERIC
Integer Types	**Date Type**
BINARY_INTEGER	DATE
PLS_INTEGER	**MLS Label Type**
BOOLEAN	MLSLABEL
NATURAL	
POSITIVE	
POSITIVEN	
NATURALN	

Modes Changing to or from an explicit specification of the default parameter mode IN does not change the signature of a subprogram. For example, you change

```
PROCEDURE P1 (Param1 NUMBER);
```

to

```
PROCEDURE P1 (Param1 IN NUMBER);
```

This does not change the signature. Any other change of parameter mode *does* change the signature.

Default Parameter Values Changing the specification of a default parameter value does not change the signature. For example, procedure `P1` has the same signature in the following two examples:

```
PROCEDURE P1 (Param1 IN NUMBER := 100);
PROCEDURE P1 (Param1 IN NUMBER := 200);
```

An application developer who requires that callers get the new default value must recompile the called procedure, but no signature-based invalidation occurs when a default parameter value assignment is changed.

Examples of Signatures

Using the `Get_emp_names` procedure defined in "Parameters for Procedures and Functions" on page 10-5, if the procedure body is changed to the following:

```
DECLARE
   Emp_number  NUMBER;
   Hire_date   DATE;
BEGIN
-- date format model changes

   SELECT Ename, To_char(Hiredate, 'DD/MON/YYYY')
      INTO Emp_name, Hire_date
      FROM Emp_tab
      WHERE Empno = Emp_number;
END;
```

Then, the specification of the procedure has not changed, and, therefore, its signature has not changed.

But, if the procedure specification is changed to the following:

```
CREATE OR REPLACE PROCEDURE Get_emp_name (
   Emp_number  IN  NUMBER,
   Hire_date   OUT DATE,
   Emp_name    OUT VARCHAR2) AS
```

And, if the body is changed accordingly, then the signature changes, because the parameter `Hire_date` has a different datatype.

However, if the name of that parameter changes to When_hired, and the datatype remains VARCHAR2, and the mode remains OUT, then the signature does *not* change. Changing the *name* of a formal parameter does not change the signature of the unit.

Consider the following example:

```
CREATE OR REPLACE PACKAGE Emp_package AS
    TYPE Emp_data_type IS RECORD (
        Emp_number NUMBER,
        Hire_date  VARCHAR2(12),
        Emp_name   VARCHAR2(10));
    PROCEDURE Get_emp_data
        (Emp_data IN OUT Emp_data_type);
END;

CREATE OR REPLACE PACKAGE BODY Emp_package AS
    PROCEDURE Get_emp_data
        (Emp_data IN OUT Emp_data_type) IS
   BEGIN
       SELECT Empno, Ename, TO_CHAR(Hiredate, 'DD/MON/YY')
           INTO Emp_data
           FROM Emp_tab
           WHERE Empno = Emp_data.Emp_number;
   END;
END;
```

If the package specification is changed so that the record's field names are changed, but the types remain the same, then this does not affect the signature. For example, the following package specification has the same signature as the previous package specification example:

```
CREATE OR REPLACE PACKAGE Emp_package AS
    TYPE Emp_data_type IS RECORD (
        Emp_num    NUMBER,         -- was Emp_number
        Hire_dat   VARCHAR2(12),   -- was Hire_date
        Empname    VARCHAR2(10));  -- was Emp_name
    PROCEDURE Get_emp_data
        (Emp_data IN OUT Emp_data_type);
END;
```

Changing the name of the type of a parameter does not cause a change in the signature if the type remains the same as before. For example, the following package specification for Emp_package is the same as the first one:

```
CREATE OR REPLACE PACKAGE Emp_package AS
    TYPE Emp_data_record_type IS RECORD (
        Emp_number NUMBER,
        Hire_date  VARCHAR2(12),
        Emp_name   VARCHAR2(10));
    PROCEDURE Get_emp_data
        (Emp_data IN OUT Emp_data_record_type);
END;
```

Controlling Remote Dependencies

The dynamic initialization parameter REMOTE_DEPENDENCIES_MODE controls whether the timestamp or the signature dependency model is in effect.

- If the initialization parameter file contains the following specification:

  ```
  REMOTE_DEPENDENCIES_MODE = TIMESTAMP
  ```

  Then only timestamps are used to resolve dependencies (if this is not explicitly overridden dynamically).

- If the initialization parameter file contains the following parameter specification:

  ```
  REMOTE_DEPENDENCIES_MODE = SIGNATURE
  ```

  Then signatures are used to resolve dependencies (if this not explicitly overridden dynamically).

- You can alter the mode dynamically by using the DDL statements. For example:

  ```
  ALTER SESSION SET REMOTE_DEPENDENCIES_MODE =
      {SIGNATURE | TIMESTAMP}
  ```

  The above example alters the dependency model for the current session.

  ```
  ALTER SYSTEM SET REMOTE_DEPENDENCIES_MODE =
      {SIGNATURE | TIMESTAMP}
  ```

  The above example alters the dependency model on a system-wide basis after startup.

If the REMOTE_DEPENDENCIES_MODE parameter is not specified, either in the init.ora parameter file or using the ALTER SESSION or ALTER SYSTEM DDL statements, then timestamp is the default value. Therefore, unless you explicitly use the REMOTE_DEPENDENCIES_MODE parameter, or the appropriate DDL statement, your server is operating using the timestamp dependency model.

When you use REMOTE_DEPENDENCIES_MODE=SIGNATURE, you should be aware of the following:

- If you change the default value of a parameter of a remote procedure, then the local procedure calling the remote procedure is not invalidated. If the call to the remote procedure does not supply the parameter, then the default value is used. In this case, because invalidation / recompilation does not automatically occur, the old default value is used. If you want to see the new default values, then you must recompile the calling procedure manually.
- If you add a new overloaded procedure in a package (a new procedure with the same name as an existing one), then local procedures that call the remote procedure are not invalidated. If it turns out that this overloading results in a rebinding of existing calls from the local procedure under the timestamp mode, then this rebinding does not happen under the signature mode, because the local procedure does not get invalidated. You must recompile the local procedure manually to achieve the new rebinding.
- If the types of parameters of an existing packaged procedure are changed so that the new types have the same shape as the old ones, then the local calling procedure is not invalidated or recompiled automatically. You must recompile the calling procedure manually to get the semantics of the new type.

Dependency Resolution

When REMOTE_DEPENDENCIES_MODE = TIMESTAMP (the default value), dependencies among program units are handled by comparing timestamps at runtime. If the timestamp of a called remote procedure does not match the timestamp of the called procedure, then the calling (dependent) unit is invalidated and must be recompiled. In this case, if there is no local PL / SQL compiler, then the calling application cannot proceed.

In the timestamp dependency mode, signatures are not compared. If there is a local PL / SQL compiler, then recompilation happens automatically when the calling procedure is run.

When REMOTE_DEPENDENCIES_MODE = SIGNATURE, the recorded timestamp in the calling unit is first compared to the current timestamp in the called remote unit. If they match, then the call proceeds. If the timestamps do not match, then the signature of the called remote subprogram, as recorded in the calling subprogram, is compared with the current signature of the called subprogram. If they do not match (using the criteria described in the section "When Does a Signature Change?" on page 10-31), then an error is returned to the calling session.

Suggestions for Managing Dependencies

Oracle recommends that you follow these guidelines for setting the REMOTE_DEPENDENCIES_MODE parameter:

- Server-side PL/SQL users can set the parameter to TIMESTAMP (or let it default to that) to get the timestamp dependency mode.
- Server-side PL/SQL users can choose to use the signature dependency mode if they have a distributed system and they want to avoid possible unnecessary recompilations.
- Client-side PL/SQL users should set the parameter to SIGNATURE. This allows:
  - Installation of new applications at client sites, without the need to recompile procedures.
  - Ability to upgrade the server, without encountering timestamp mismatches.
- When using signature mode on the server side, add new procedures to the end of the procedure (or function) declarations in a package specification. Adding a new procedure in the middle of the list of declarations can cause unnecessary invalidation and recompilation of dependent procedures.

Cursor Variables

A cursor is a static object; a cursor variable is a pointer to a cursor. Because cursor variables are pointers, they can be passed and returned as parameters to procedures and functions. A cursor variable can also refer to different cursors in its lifetime.

Some additional advantages of cursor variables include:

- **Encapsulation** Queries are centralized in the stored procedure that opens the cursor variable.
- **Ease of maintenance** If you need to change the cursor, then you only need to make the change in one place: the stored procedure. There is no need to change each application.
- **Convenient security** The user of the application is the username used when the application connects to the server. The user must have EXECUTE permission on the stored procedure that opens the cursor. But, the user does not need to have READ permission on the tables used in the query. This capability can be used to limit access to the columns in the table, as well as access to other stored procedures.

  See Also: The *PL/SQL User's Guide and Reference* has a complete discussion of cursor variables.

Declaring and Opening Cursor Variables

Memory is usually allocated for a cursor variable in the client application using the appropriate ALLOCATE statement. In Pro*C, use the EXEC SQL ALLOCATE <cursor_name> statement. In OCI, use the Cursor Data Area.

You can also use cursor variables in applications that run entirely in a single server session. You can declare cursor variables in PL/SQL subprograms, open them, and use them as parameters for other PL/SQL subprograms.

Examples of Cursor Variables

This section includes several examples of cursor variable usage in PL/SQL. For additional cursor variable examples that use the programmatic interfaces, see the following manuals:

- *Pro*C/C++ Precompiler Programmer's Guide*
- *Pro*COBOL Precompiler Programmer's Guide*
- *Oracle Call Interface Programmer's Guide*
- *SQL*Module for Ada Programmer's Guide*

Fetching Data

The following package defines a PL/SQL cursor variable type `Emp_val_cv_type`, and two procedures. The first procedure, `Open_emp_cv`, opens the cursor variable using a bind variable in the `WHERE` clause. The second procedure, `Fetch_emp_data`, fetches rows from the `Emp_tab` table using the cursor variable.

```
CREATE OR REPLACE PACKAGE Emp_data AS
  TYPE Emp_val_cv_type IS REF CURSOR RETURN Emp_tab%ROWTYPE;
  PROCEDURE Open_emp_cv (Emp_cv          IN OUT Emp_val_cv_type,
                         Dept_number     IN     INTEGER);
  PROCEDURE Fetch_emp_data (emp_cv       IN     Emp_val_cv_type,
                            emp_row      OUT    Emp_tab%ROWTYPE);
END Emp_data;

CREATE OR REPLACE PACKAGE BODY Emp_data AS
  PROCEDURE Open_emp_cv (Emp_cv      IN OUT Emp_val_cv_type,
                         Dept_number IN     INTEGER) IS
  BEGIN
    OPEN emp_cv FOR SELECT * FROM Emp_tab WHERE deptno = dept_number;
  END open_emp_cv;
  PROCEDURE Fetch_emp_data (Emp_cv      IN  Emp_val_cv_type,
                            Emp_row     OUT Emp_tab%ROWTYPE) IS
  BEGIN
    FETCH Emp_cv INTO Emp_row;
  END Fetch_emp_data;
END Emp_data;
```

The following example shows how to call the `Emp_data` package procedures from a PL/SQL block:

```
DECLARE
-- declare a cursor variable
   Emp_curs Emp_data.Emp_val_cv_type;
   Dept_number Dept_tab.Deptno%TYPE;
   Emp_row Emp_tab%ROWTYPE;

BEGIN
   Dept_number := 20;
-- open the cursor using a variable
   Emp_data.Open_emp_cv(Emp_curs, Dept_number);
-- fetch the data and display it
   LOOP
     Emp_data.Fetch_emp_data(Emp_curs, Emp_row);
     EXIT WHEN Emp_curs%NOTFOUND;
     DBMS_OUTPUT.PUT(Emp_row.Ename || '  ');
     DBMS_OUTPUT.PUT_LINE(Emp_row.Sal);
   END LOOP;
END;
```

Implementing Variant Records

The power of cursor variables comes from their ability to point to different cursors. In the following package example, a discriminant is used to open a cursor variable to point to one of two different cursors:

```
CREATE OR REPLACE PACKAGE Emp_dept_data AS
  TYPE Cv_type IS REF CURSOR;
  PROCEDURE Open_cv (Cv          IN OUT cv_type,
                     Discrim     IN     POSITIVE);
END Emp_dept_data;

CREATE OR REPLACE PACKAGE BODY Emp_dept_data AS
  PROCEDURE Open_cv (Cv      IN OUT cv_type,
                     Discrim IN     POSITIVE) IS
  BEGIN
    IF Discrim = 1 THEN
      OPEN Cv FOR SELECT * FROM Emp_tab WHERE Sal > 2000;
    ELSIF Discrim = 2 THEN
      OPEN Cv FOR SELECT * FROM Dept_tab;
    END IF;
  END Open_cv;
END Emp_dept_data;
```

You can call the `Open_cv` procedure to open the cursor variable and point it to either a query on the `Emp_tab` table or the `Dept_tab` table. The following PL/SQL

block shows how to fetch using the cursor variable, and then use the ROWTYPE_MISMATCH predefined exception to handle either fetch:

```
DECLARE
  Emp_rec  Emp_tab%ROWTYPE;
  Dept_rec Dept_tab%ROWTYPE;
  Cv       Emp_dept_data.CV_TYPE;

BEGIN
  Emp_dept_data.open_cv(Cv, 1); -- Open Cv For Emp_tab Fetch
  Fetch cv INTO Dept_rec;       -- but fetch into Dept_tab record
                                -- which raises ROWTYPE_MISMATCH
  DBMS_OUTPUT.PUT(Dept_rec.Deptno);
  DBMS_OUTPUT.PUT_LINE('  ' || Dept_rec.Loc);

EXCEPTION
  WHEN ROWTYPE_MISMATCH THEN
    BEGIN
      DBMS_OUTPUT.PUT_LINE
           ('Row type mismatch, fetching Emp_tab data...');
      FETCH Cv INTO Emp_rec;
      DBMS_OUTPUT.PUT(Emp_rec.Deptno);
      DBMS_OUTPUT.PUT_LINE('  ' || Emp_rec.Ename);
    END;
```

Compile-Time Errors

When you use SQL*Plus to submit PL/SQL code, and when the code contains errors, you receive notification that compilation errors have occurred, but there is no immediate indication of what the errors are. For example, if you submit a stand-alone (or stored) procedure PROC1 in the file proc1.sql as follows:

```
SVRMGR> @proc1
```

And, if there are one or more errors in the code, then you receive a notice such as the following:

```
MGR-00072: Warning: Procedure proc1 created with compilation errors
```

In this case, use the SHOW ERRORS statement in SQL*Plus to get a list of the errors that were found. SHOW ERRORS with no argument lists the errors from the most recent compilation. You can qualify SHOW ERRORS using the name of a procedure, function, package, or package body:

```
SQL> SHOW ERRORS PROC1
SQL> SHOW ERRORS PROCEDURE PROC1
```

See Also: See the *SQL*Plus User's Guide and Reference* for complete information about the SHOW ERRORS statement.

Note: Before issuing the SHOW ERRORS statement, use the SET CHARWIDTH statement to get long lines on output. The value 132 is usually a good choice. For example:

```
SET CHARWIDTH 132
```

Assume that you want to create a simple procedure that deletes records from the employee table using SQL*Plus:

```
CREATE OR REPLACE PROCEDURE Fire_emp(Emp_id NUMBER) AS
   BEGIN
      DELETE FROM Emp_tab WHER Empno = Emp_id;
   END
/
```

Notice that the CREATE PROCEDURE statement has two errors: the DELETE statement has an error (the 'E' is absent from WHERE), and the semicolon is missing after END.

After the CREATE PROCEDURE statement is entered and an error is returned, a SHOW ERRORS statement returns the following lines:

```
SHOW ERRORS;

ERRORS FOR PROCEDURE Fire_emp:
LINE/COL       ERROR
-------------- -----------------------------------------
3/27           PL/SQL-00103: Encountered the symbol "EMPNO" wh. . .
5/0            PL/SQL-00103: Encountered the symbol "END" when . . .
2 rows selected.
```

Notice that each line and column number where errors were found is listed by the SHOW ERRORS statement.

Alternatively, you can query the following data dictionary views to list errors when using any tool or application:

- USER_ERRORS
- ALL_ERRORS
- DBA_ERRORS

The error text associated with the compilation of a procedure is updated when the procedure is replaced, and it is deleted when the procedure is dropped.

Original source code can be retrieved from the data dictionary using the following views: ALL_SOURCE, USER_SOURCE, and DBA_SOURCE.

> **See Also:** *Oracle8i Reference* for more information about these data dictionary views.

Run-Time Error Handling

Oracle allows user-defined errors in PL/SQL code to be handled so that user-specified error numbers and messages are returned to the client application. After received, the client application can handle the error based on the user-specified error number and message returned by Oracle.

User-specified error messages are returned using the RAISE_APPLICATION_ERROR procedure. For example:

```
RAISE_APPLICATION_ERROR(Error_number, 'text', Keep_error_stack)
```

This procedure stops procedure execution, rolls back any effects of the procedure, and returns a user-specified error number and message (unless the error is trapped by an exception handler). ERROR_NUMBER must be in the range of -20000 to -20999.

Error number -20000 should be used as a generic number for messages where it is important to relay information to the user, but having a unique error number is not required. Text must be a character expression, 2 Kbytes or less (longer messages are ignored). Keep_error_stack can be TRUE if you want to add the error to any already on the stack, or FALSE if you want to replace the existing errors. By default, this option is FALSE.

Note: Some of the Oracle-supplied packages, such as DBMS_OUTPUT, DBMS_DESCRIBE, and DBMS_ALERT, use application error numbers in the range -20000 to -20005. See the descriptions of these packages for more information.

The RAISE_APPLICATION_ERROR procedure is often used in exception handlers or in the logic of PL/SQL code. For example, the following exception handler selects the string for the associated user-defined error message and calls the RAISE_APPLICATION_ERROR procedure:

```
...
WHEN NO_DATA_FOUND THEN
   SELECT Error_string INTO Message
   FROM Error_table,
   V$NLS_PARAMETERS V
   WHERE Error_number = -20101 AND Lang = v.value AND
      v.parameter = "NLS_LANGUAGE";
   Raise_application_error(-20101, Message);
...
```

> **See Also:** For information on exception handling when calling remote procedures, see"Handling Errors in Remote Procedures" on page 10-47.

The following section includes an example of passing a user-specified error number from a trigger to a procedure.

Declaring Exceptions and Exception Handling Routines

User-defined exceptions are explicitly defined and signaled within the PL/SQL block to control processing of errors specific to the application. When an exception is *raised* (signaled), the usual execution of the PL/SQL block stops, and a routine called an exception handler is called. Specific exception handlers can be written to handle any internal or user-defined exception.

Application code can check for a condition that requires special attention using an `IF` statement. If there is an error condition, then two options are available:

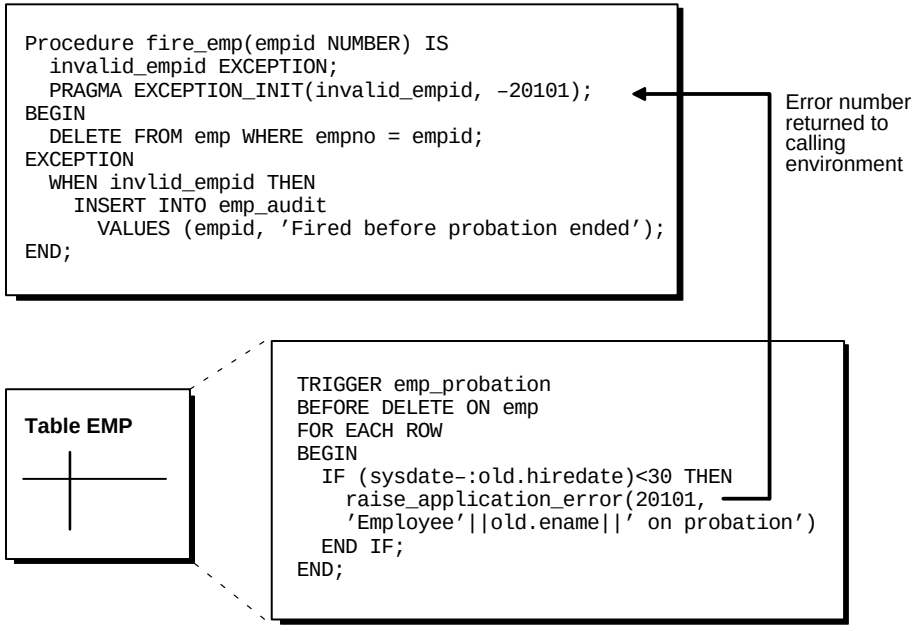
- Enter a `RAISE` statement that names the appropriate exception. A `RAISE` statement stops the execution of the procedure, and control passes to an exception handler (if any).
- Call the `RAISE_APPLICATION_ERROR` procedure to return a user-specified error number and message.

You can also define an exception handler to handle user-specified error messages. For example, Figure 10–2 on page 10-46 illustrates the following:

- An exception and associated exception handler in a procedure
- A conditional statement that checks for an error (such as transferring funds not available) and enters a user-specified error number and message within a trigger
- How user-specified error numbers are returned to the calling environment (in this case, a procedure), and how that application can define an exception that corresponds to the user-specified error number

Declare a user-defined exception in a procedure or package body (private exceptions), or in the specification of a package (public exceptions). *Define* an exception handler in the body of a procedure (stand-alone or package).

Figure 10–2 Exceptions and User-Defined Errors



Unhandled Exceptions

In database PL/SQL program units, an unhandled user-error condition or internal error condition that is not trapped by an appropriate exception handler causes the implicit rollback of the program unit. If the program unit includes a `COMMIT` statement before the point at which the unhandled exception is observed, then the implicit rollback of the program unit can only be completed back to the previous `COMMIT`.

Additionally, unhandled exceptions in database-stored PL/SQL program units propagate back to client-side applications that call the containing program unit. In such an application, only the application program unit call is rolled back (not the entire application program unit), because it is submitted to the database as a SQL statement.

If unhandled exceptions in database PL/SQL program units are propagated back to database applications, then the database PL/SQL code should be modified to handle the exceptions. Your application can also trap for unhandled exceptions when calling database program units and handle such errors appropriately.

Handling Errors in Distributed Queries

You can use a trigger or a stored procedure to create a distributed query. This distributed query is decomposed by the local Oracle into a corresponding number of remote queries, which are sent to the remote nodes for execution. The remote nodes run the queries and send the results back to the local node. The local node then performs any necessary post-processing and returns the results to the user or application.

If a portion of a distributed statement fails, possibly due to an integrity constraint violation, then Oracle returns error number ORA-02055. Subsequent statements, or procedure calls, return error number ORA-02067 until a rollback or a rollback to savepoint is entered.

You should design your application to check for any returned error messages that indicates that a portion of the distributed update has failed. If you detect a failure, then you should rollback the entire transaction (or rollback to a savepoint) before allowing the application to proceed.

Handling Errors in Remote Procedures

When a procedure is run locally or at a remote location, four types of exceptions can occur:

- PL/SQL user-defined exceptions, which must be declared using the keyword EXCEPTION.
- PL/SQL predefined exceptions, such as NO_DATA_FOUND.
- SQL errors, such as ORA-00900 and ORA-02015.
- Application exceptions, which are generated using the RAISE_APPLICATION_ERROR() procedure.

When using local procedures, all of these messages can be trapped by writing an exception handler, such as shown in the following example:

```
EXCEPTION
    WHEN ZERO_DIVIDE THEN
    /* ...handle the exception */
```

Notice that the WHEN clause requires an exception name. If the exception that is raised does not have a name, such as those generated with RAISE_APPLICATION_ERROR, then one can be assigned using PRAGMA_EXCEPTION_INIT, as shown in the following example:

```
DECLARE
    ...
    Null_salary EXCEPTION;
    PRAGMA EXCEPTION_INIT(Null_salary, -20101);
BEGIN
    ...
    RAISE_APPLICATION_ERROR(-20101, 'salary is missing');
    ...
EXCEPTION
    WHEN Null_salary THEN
        ...
```

When calling a remote procedure, exceptions are also handled by creating a local exception handler. The remote procedure must return an error number to the local calling procedure, which then handles the exception, as shown in the previous example. Because PL/SQL user-defined exceptions always return `ORA-06510` to the local procedure, these exceptions cannot be handled. All other remote exceptions can be handled in the same manner as local exceptions.

Debugging

A free Java-based debugger is available from Oracle for debugging PL/SQL applications. This is a lightweight debugger which can be run as an applet from the Microsoft or Netscape browser, or as a stand-alone application to debug PL/SQL stored procedures. The debugger works with Oracle 7.3.4 and higher.

If you are using PL/SQL for writing Web-based applications in conjunction with the Applications Server, and if you would like to debug and look at the generated HTML, you can use this debugger as well (check restrictions in the `README` file).

You can download the debugger from:
`http://www.oracle.com/st/products/features/plsql.html`

The `DBMS_DEBUG` API, provided with Oracle8*i*, implements server-side debuggers, and it provides a way to debug server-side PL/SQL program units. Several of the debuggers currently available, such as Oracle Procedure Builder and various third-party vendor solutions, use this API.

Oracle Procedure Builder is an advanced client-server debugger that transparently debugs your database applications. It lets you run PL/SQL procedures and triggers in a controlled debugging environment, and you can set breakpoints, list the values of variables, and perform other debugging tasks. Oracle Procedure Builder is part of the Oracle Developer tool set.

> **See Also:** *Oracle Procedure Builder Developer's Guide*

You can also debug stored procedures and triggers using the `DBMS_OUTPUT` supplied package. Put `PUT` and `PUT_LINE` statements in your code to output the value of variables and expressions to your terminal.

> **See Also:** See *Oracle8i Supplied Packages Reference* for more information about the `DBMS_DEBUG` and the `DBMS_OUTPUT` packages.

Calling Stored Procedures

Note: You may need to set up data structures, similar to the following, for certain examples to work:

```
CREATE TABLE Emp_tab (
   Empno    NUMBER(4) NOT NULL,
   Ename    VARCHAR2(10),
   Job      VARCHAR2(9),
   Mgr      NUMBER(4),
   Hiredate DATE,
   Sal      NUMBER(7,2),
   Comm     NUMBER(7,2),
   Deptno   NUMBER(2));

CREATE OR REPLACE PROCEDURE fire_emp1(Emp_id NUMBER) AS
   BEGIN
      DELETE FROM Emp_tab WHERE Empno = Emp_id;
   END;
VARIABLE Empnum NUMBER;
```

Procedures can be called from many different environments. For example:

- A procedure can be called within the body of another procedure or a trigger.
- A procedure can be interactively called by a user using an Oracle tool.
- A procedure can be explicitly called within an application, such as a SQL*Forms or a precompiler application.
- A stored function can be called from a SQL statement in a manner similar to calling a built-in SQL function, such as `LENGTH` or `ROUND`.

This section includes some common examples of calling procedures from within these environments.

See Also: "Calling Stored Functions from SQL Expressions" on page 10-57.

A Procedure or Trigger Calling Another Procedure

A procedure or trigger can call another stored procedure. For example, included in the body of one procedure might be the following line:

```
. . .
Sal_raise(Emp_id, 200);
. . .
```

This line calls the `Sal_raise` procedure. `Emp_id` is a variable within the context of the procedure. Recursive procedure calls are allowed within PL/SQL: A procedure can call itself.

Interactively Calling Procedures From Oracle Tools

A procedure can be called interactively from an Oracle tool, such as SQL*Plus. For example, to call a procedure named `SAL_RAISE`, owned by you, you can use an anonymous PL/SQL block, as follows:

```
BEGIN
    Sal_raise(7369, 200);
END;
```

> **Note:** Interactive tools, such as SQL*Plus, require you to follow these lines with a slash (/) to run the PL/SQL block.

An easier way to run a block is to use the SQL*Plus statement `EXECUTE`, which wraps `BEGIN` and `END` statements around the code you enter. For example:

```
EXECUTE Sal_raise(7369, 200);
```

Some interactive tools allow session variables to be created. For example, when using SQL*Plus, the following statement creates a session variable:

```
VARIABLE Assigned_empno NUMBER
```

After defined, any session variable can be used for the duration of the session. For example, you might run a function and capture the return value using a session variable:

```
EXECUTE :Assigned_empno := Hire_emp('JSMITH', 'President',
   1032, SYSDATE, 5000, NULL, 10);
PRINT Assigned_empno;
ASSIGNED_EMPNO
--------------
          2893
```

> **See Also:** See the *SQL*Plus User's Guide and Reference* for SQL*Plus information. See your tools documentation for information about performing similar operations using your development tool.

Calling Procedures within 3GL Applications

A 3GL database application, such as a precompiler or an OCI application, can include a call to a procedure within the code of the application.

To run a procedure within a PL/SQL block in an application, simply call the procedure. The following line within a PL/SQL block calls the `Fire_emp` procedure:

```
Fire_emp1(:Empnun);
```

In this case, `:Empno` is a host (bind) variable within the context of the application.

To run a procedure within the code of a precompiler application, you must use the `EXEC` call interface. For example, the following statement calls the `Fire_emp` procedure in the code of a precompiler application:

```
EXEC SQL EXECUTE
   BEGIN
      Fire_emp1(:Empnum);
   END;
END-EXEC;
```

> **See Also:** For more information about calling PL/SQL procedures from within 3GL applications, see the following manuals:
>
> *Oracle Call Interface Programmer's Guide*
>
> *Pro*C/C++ Precompiler Programmer's Guide*,
>
> *SQL*Module for Ada Programmer's Guide*

Name Resolution When Calling Procedures

References to procedures and packages are resolved according to the algorithm described in the "Name Resolution in SQL Statements" section of Chapter 3, "Managing Schema Objects".

Privileges Required to Execute a Procedure

If you are the owner of a stand-alone procedure or package, then you can run the stand-alone procedure or packaged procedure, or any public procedure or packaged procedure at any time, as described in the previous sections. If you want to run a stand-alone or packaged procedure owned by another user, then the following conditions apply:

- You must have the EXECUTE privilege for the stand-alone procedure or package containing the procedure, or you must have the EXECUTE ANY PROCEDURE system privilege. If you are executing a remote procedure, then you must be granted the EXECUTE privilege or EXECUTE ANY PROCEDURE system privilege directly, not through a role.
- You must include the owner's name in the call. For example:

Note: You may need to set up the following data structures for certain examples to work:

```
CONNECT sys/change_on_install AS Sysdba;
CREATE USER Jward IDENTIFIED BY Jward;
GRANT CREATE ANY PACKAGE TO Jward;
GRANT CREATE SESSION TO Jward;
GRANT EXECUTE ANY PROCEDURE TO Jward;
CONNECT Scott/Tiger
```

```
EXECUTE Jward.Fire_emp (1043);

EXECUTE Jward.Hire_fire.Fire_emp (1043);
```

Note: A stored subprogram or package runs in the privilege domain of the owner of the procedure. The owner must be explicitly granted the necessary object privileges to all objects referenced within the body of the code.

Specifying Values for Procedure Arguments

When you call a procedure, specify a value or parameter for each of the procedure's arguments. Identify the argument values using either of the following methods, or a combination of both:

- List the values in the order the arguments appear in the procedure declaration.
- Specify the argument names and corresponding values, in any order.

For example, these statements each call the procedure Sal_raise to increase the salary of employee number 7369 by 500:

```
Sal_raise(7369, 500);

Sal_raise(Sal_incr=>500, Emp_id=>7369);

Sal_raise(7369, Sal_incr=>500);
```

The first statement identifies the argument values by listing them in the order in which they appear in the procedure specification.

The second statement identifies the argument values by name and in an order different from that of the procedure specification. If you use argument names, then you can list the arguments in any order.

The third statement identifies the argument values using a combination of these methods. If you use a combination of order and argument names, then values identified in order must precede values identified by name.

If you used the DEFAULT option to define default values for IN parameters to a subprogram (see the *PL/SQL User's Guide and Reference*),then you can pass different numbers of actual parameters to the first subprogram, accepting or overriding the default values as you please. If an actual value is not passed, then the corresponding default value is used. If you want to assign a value to an argument that occurs after an omitted argument (for which the corresponding default is used), then you must explicitly designate the name of the argument, as well as its value.

Calling Remote Procedures

Call remote procedures using an appropriate database link and the procedure's name. The following SQL*Plus statement runs the procedure Fire_emp located in the database and pointed to by the local database link named NY:

```
EXECUTE fire_emp1@boston_server(1043);
```

> **See Also:** For information on exception handling when calling remote procedures, see "Handling Errors in Remote Procedures" on page 10-47.

Remote Procedure Calls and Parameter Values

You must explicitly pass values to all remote procedure parameters, even if there are defaults. You cannot access remote package variables and constants.

Referencing Remote Objects

Remote objects can be referenced within the body of a locally defined procedure. The following procedure deletes a row from the remote employee table:

```
CREATE OR REPLACE PROCEDURE fire_emp(emp_id NUMBER) IS
BEGIN
    DELETE FROM emp@boston_server WHERE empno = emp_id;
END;
```

The list below explains how to properly call remote procedures, depending on the calling environment.

- Remote procedures (stand-alone and packaged) can be called from within a procedure, an OCI application, or a precompiler application by specifying the remote procedure name, a database link, and the arguments for the remote procedure.

  ```
  CREATE OR REPLACE PROCEDURE local_procedure(arg IN NUMBER) AS
  BEGIN
    fire_emp1@boston_server(arg);
  END;
  ```

- In the previous example, you could create a synonym for FIRE_EMP1@BOSTON_SERVER. This would enable you to call the remote procedure from an Oracle tool application, such as a SQL*Forms application, as well from within a procedure, OCI application, or precompiler application.

  ```
  CREATE SYNONYM synonym1 for  fire_emp1@boston_server;
  CREATE OR REPLACE PROCEDURE local_procedure(arg IN NUMBER) AS
  BEGIN
    synonym1(arg);
  END;
  ```

- If you do not want to use a synonym, then you could write a local cover procedure to call the remote procedure.

  ```
  DECLARE
     arg NUMBER;
  BEGIN
     local_procedure(arg);
  END;
  ```

  Here, `local_procedure` is defined as in the first item of this list.

See Also: "Synonyms for Procedures and Packages" on page 10-56

Caution: Unlike stored procedures, which use compile-time binding, runtime binding is used when referencing remote procedures. The user account to which you connect depends on the database link.

All calls to remotely stored procedures are assumed to perform updates; therefore, this type of referencing always requires two-phase commit of that transaction (even if the remote procedure is read-only). Furthermore, if a transaction that includes a remote procedure call is rolled back, then the work done by the remote procedure is also rolled back. A procedure called remotely cannot execute a `COMMIT`, `ROLLBACK`, or `SAVEPOINT` statement.

A *distributed update* modifies data on two or more nodes. A distributed update is possible using a procedure that includes two or more remote updates that access data on different nodes. Statements in the construct are sent to the remote nodes, and the execution of the construct succeeds or fails as a unit. If part of a distributed update fails and part succeeds, then a rollback (of the entire transaction or to a savepoint) is required to proceed. Consider this when creating procedures that perform distributed updates.

Pay special attention when using a local procedure that calls a remote procedure. If a timestamp mismatch is found during execution of the local procedure, then the remote procedure is not run, and the local procedure is invalidated.

Synonyms for Procedures and Packages

Synonyms can be created for stand-alone procedures and packages to do the following:

- Hide the identity of the name and owner of a procedure or package.
- Provide location transparency for remotely stored procedures (stand-alone or within a package).

When a privileged user needs to call a procedure, an associated synonym can be used. Because the procedures defined within a package are not individual objects (the package is the object), synonyms cannot be created for individual procedures within a package.

Calling Stored Functions from SQL Expressions

You can include user-written PL/SQL functions in SQL expressions. (You must be using PL/SQL release 2.1 or higher.) By using PL/SQL functions in SQL statements, you can do the following:

- Increase user productivity by extending SQL. Expressiveness of the SQL statement increases where activities are too complex, too awkward, or unavailable with SQL.
- Increase query efficiency. Functions used in the WHERE clause of a query can filter data using criteria that would otherwise need to be evaluated by the application.
- Manipulate character strings to represent special datatypes (for example, latitude, longitude, or temperature).
- Provide parallel query execution: If the query is parallelized, then SQL statements in your PL/SQL function may also be run in parallel (using the parallel query option).

Using PL/SQL Functions

PL/SQL functions must be created as top-level functions or declared within a package specification before they can be named within a SQL statement. Stored PL/SQL functions are used in the same manner as built-in Oracle functions (such as SUBSTR or ABS).

PL/SQL functions can be placed wherever an Oracle function can be placed within a SQL statement, or, wherever expressions can occur in SQL. For example, they can be called from the following:

- The select list of the SELECT statement.
- The condition of the WHERE and HAVING clause.
- The CONNECT BY, START WITH, ORDER BY, and GROUP BY clauses.
- The VALUES clause of the INSERT statement.
- The SET clause of the UPDATE statement.

You cannot call stored PL/SQL functions from a CHECK constraint clause of a CREATE or ALTER TABLE statement or use them to specify a default value for a column. These situations require an unchanging definition.

Note: Unlike functions, which are called as part of an expression, procedures are called as statements. Therefore, PL/SQL procedures are *not* directly callable from SQL statements. However, functions called from a PL/SQL statement or referenced in a SQL expression can call a PL/SQL procedure.

Syntax

Use the following syntax to reference a PL/SQL function from SQL:

```
[[schema.]package.]function_name[@dblink][(param_1...param_n)]
```

For example, to reference a function you created that is called `My_func`, in the `My_funcs_pkg` package, in the `Scott` schema, that takes two numeric parameters, you could call the following:

```
SELECT Scott.My_funcs_pkg.My_func(10,20) FROM dual;
```

Naming Conventions

If only one of the optional schema or package names is given, then the first identifier can be either a schema name or a package name. For example, to determine whether `Payroll` in the reference `Payroll.Tax_rate` is a schema or package name, Oracle proceeds as follows:

- Oracle first checks for the `Payroll` package in the current schema.
- If the `PAYROLL` package is found in the current schema, then Oracle looks for a `Tax_rate` function in the `Payroll` package. If a `Tax_rate` function is not found in the `Payroll` package, then an error message is returned.
- If a `Payroll` package is not found, then Oracle looks for a schema named `Payroll` that contains a top-level `Tax_rate` function. If the `Tax_rate` function is not found in the `Payroll` schema, then an error message is returned.

You can also refer to a stored top-level function using any synonym that you have defined for it.

Name Precedence

In SQL statements, the names of database columns take precedence over the names of functions with no parameters. For example, if schema `Scott` creates the following two objects:

```
CREATE TABLE Emp_tab(New_sal NUMBER ...);
CREATE FUNCTION New_sal RETURN NUMBER IS ...;
```

Then, in the following two statements, the reference to `New_sal` refers to the column `Emp_tab.New_sal`:

```
SELECT New_sal FROM Emp_tab;
SELECT Emp_tab.New_sal FROM Emp_tab;
```

To access the function `new_sal`, enter the following:

```
SELECT Scott.New_sal FROM Emp_tab;
```

Example For example, to call the `Tax_rate` PL/SQL function from schema `Scott`, run it against the `Ss_no` and `sal` columns in `Tax_table`, and place the results in the variable `Income_tax`, specify the following:

Note: You may need to set up data structures similar to the following for certain examples to work:

```
CREATE TABLE Tax_table (
   Ss_no  NUMBER,
   Sal    NUMBER);

CREATE OR REPLACE FUNCTION tax_rate (ssn IN NUMBER, salary IN
NUMBER) RETURN NUMBER IS
   sal_out NUMBER;
   BEGIN
      sal_out := salary * 1.1;
   END;
```

```
DECLARE
   Tax_id     NUMBER;
   Income_tax NUMBER;
BEGIN
   SELECT scott.tax_rate (Ss_no, Sal)
      INTO Income_tax
      FROM Tax_table
      WHERE Ss_no = Tax_id;
END;
```

These sample calls to PL/SQL functions are allowed in SQL expressions:

```
Circle_area(Radius)
Payroll.Tax_rate(Empno)
scott.Payroll.Tax_rate@boston_server(Dependents, Empno)
```

Arguments

To pass any number of arguments to a function, supply the arguments within the parentheses. You must use positional notation; named notation is not currently supported. For functions that do not accept arguments, use `()`.

Using Default Values

The stored function `Gross_pay` initializes two of its formal parameters to default values using the `DEFAULT` clause. For example:

```
CREATE OR REPLACE FUNCTION Gross_pay
    (Emp_id  IN NUMBER,
     St_hrs  IN NUMBER DEFAULT 40,
     Ot_hrs  IN NUMBER DEFAULT 0) RETURN NUMBER AS
  ...
```

When calling `Gross_pay` from a procedural statement, you can always accept the default value of `St_hrs`. This is because you can use named notation, which lets you skip parameters. For example:

```
IF Gross_pay(Eenum, Ot_hrs => Otime) > Pay_limit
THEN ...
```

However, when calling `Gross_pay` from a SQL expression, you cannot accept the default value of `St_hrs`, unless you accept the default value of `Ot_hrs`. This is because you cannot use named notation.

Privileges

To call a PL/SQL function from SQL, you must either own or have `EXECUTE` privileges on the function. To select from a view defined with a PL/SQL function, you must have `SELECT` privileges on the view. No separate `EXECUTE` privileges are necessary to select from the view.

Meeting Basic Requirements

To be callable from SQL expressions, a user-defined PL/SQL function must meet the following basic requirements:

- It must be a stored function, *not* a function defined within a PL/SQL block or subprogram.
- It must be a row function, *not* a column (group) function; in other words, it cannot take an entire column of data as its argument.
- All its formal parameters must be IN parameters; none can be an OUT or IN OUT parameter.
- The datatypes of its formal parameters must be Oracle Server internal types, such as CHAR, DATE, or NUMBER, *not* PL/SQL types, such as BOOLEAN, RECORD, or TABLE.
- Its return type (the datatype of its result value) must be an Oracle Server internal type.

For example, the following stored function meets the basic requirements:

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE TABLE Payroll(
                Srate             NUMBER
                Orate             NUMBER
                Acctno            NUMBER);
```

```
CREATE FUNCTION Gross_pay
      (Emp_id IN NUMBER,
       St_hrs IN NUMBER DEFAULT 40,
       Ot_hrs IN NUMBER DEFAULT 0) RETURN NUMBER AS
   St_rate  NUMBER;
   Ot_rate  NUMBER;

BEGIN
   SELECT Srate, Orate INTO St_rate, Ot_rate FROM Payroll
      WHERE Acctno = Emp_id;
   RETURN St_hrs * St_rate + Ot_hrs * Ot_rate;
END Gross_pay;
```

Controlling Side Effects

The *purity* of a stored function refers to the side effects of that function on database tables or package variables. Side effects can prevent the parallelization of a query, yield order-dependent (and therefore, indeterminate) results, or require that

package state be maintained across user sessions. Various side effects are not allowed when a function is called from a SQL query or DML statement.

In previous releases, Oracle leveraged the PL/SQL compiler to enforce restrictions during the compilation of a stored function or a SQL statement. In Oracle8*i*, the compile-time restrictions have been relaxed, and a smaller set of restrictions are enforced during execution.

> **See Also:** "Restrictions" on page 10-62.

This change provides uniform support for stored functions written in PL/SQL, Java, and C, and it allows programmers the most flexibility possible.

PL/SQL Compilation Checking

A user-written function can now be called from a SQL statement *without* any compile-time checking of its purity: `PRAGMA RESTRICT_REFERENCES` is no longer required on functions called from SQL statements.

`PRAGMA RESTRICT_REFERENCES` remains available as a means of asking the PL/SQL compiler to verify that a function has only the side effects that you expect. SQL statements, package variable accesses, or calls to functions that violate the declared restrictions will continue to raise PL/SQL compilation errors to help you isolate the code that has unintended effects.

Because Oracle no longer requires that the pragma on functions called from SQL statements, different applications may choose different style standards on whether and where to use `PRAGMA RESTRICT REFERENCES`. An existing PL/SQL application will most likely want to continue using the pragma even on new functionality, to ease integration with the existing code. A newly created Java application will most likely not want to use the pragma at all, because the Java compiler does not have the functionality to assist in isolating unintended effects.

> **See Also:** "Using PRAGMA RESTRICT_REFERENCES" on page 10-66.

Restrictions

When a SQL statement is run, checks are made to see if it is logically embedded within the execution of an already running SQL statement. This occurs if the statement is run from a trigger or from a function that was in turn called from the already running SQL statement. In these cases, further checks occur to determine if the new SQL statement is safe in the specific context.

The following restrictions are enforced:

- A function called from a query or DML statement may not end the current transaction, create or rollback to a savepoint, or ALTER the system or session.
- A function called from a query (SELECT) statement or from a parallelized DML statement may not execute a DML statement or otherwise modify the database.
- A function called from a DML statement may not read or modify the particular table being modified by that DML statement.

These restrictions apply regardless of what mechanism is used to run the SQL statement inside the function or trigger. For example:

- They apply to a SQL statement called from PL/SQL, whether embedded directly in a function or trigger body, run using the new native dynamic mechanism (EXECUTE IMMEDIATE), or run using the DBMS_SQL package.
- They apply to statements embedded in Java with SQLJ syntax or run using JDBC.
- They apply to statements run with OCI using the callback context from within an "external" C function.

You can avoid these restrictions if the execution of the new SQL statement is not logically embedded in the context of the already running statement. PL/SQL's new autonomous transactions provide one escape. Another escape is available using OCI from an external C function, if you create a new connection, rather than using the handle available from the OCIExtProcContext argument.

Declaring a Function

The keywords DETERMINISTIC and PARALLEL_ENABLE can be used in the syntax for declaring a function. These are optimization hints, informing the query optimizer and other aspects of Oracle8*i* about those functions that need not be called redundantly and about those that may be used within a parallelized query or parallelized DML statement. Only functions that are DETERMINISTIC are allowed in function-based indexes and in certain snapshots and materialized views.

A function that is dependent solely on the values passed into it as arguments, and does not meaningfully reference or modify the contents of package variables or the database, or have any other side-effects, is termed *deterministic*. Such a function reliably produces the exact same result value for any particular combination of argument values passed into it.

The DETERMINISTIC keyword is placed after the return value type in a declaration of the function. For example:

```
CREATE FUNCTION F1 (P1 NUMBER) RETURN NUMBER DETERMINISTIC IS
BEGIN
  RETURN P1 * 2;
END;
```

This keyword may be placed on a function defined in a CREATE FUNCTION statement, in a function's declaration in a CREATE PACKAGE statement, or on a method's declaration in a CREATE TYPE statement. It should not be repeated on the function's or method's body in a CREATE PACKAGE BODY or CREATE TYPE BODY statement.

Certain performance optimizations occur on calls to functions that are marked DETERMINISTIC, without any other action being required. However, the database has no reasonable way to recognize if the function's behavior indeed is truly deterministic. If the DETERMINISTIC keyword is applied to a function whose behavior is not truly deterministic, then the result of queries involving that function is unpredictable.

Two new features in Oracle8*i* require that any function used with them is declared DETERMINISTIC.

- Any function used in a function-based index is required to be DETERMINISTIC.
- Any function used in a materialized view must be DETERMINISTIC if that view is to be marked ENABLE QUERY REWRITE.

Both of these features attempt to use previously calculated results rather than calling the function when it is possible to do so.

It is also preferable that only functions declared DETERMINISTIC are used in any materialized view or snapshot that is declared REFRESH FAST. Oracle allows in REFRESH FAST snapshots those functions that have a PRAGMA RESTRICT_REFERENCES noting that they are RNDS, and those PL/SQL functions defined with a CREATE FUNCTION statement whose code can be examined to determine that they do not read the database nor call any other routine which might, as these have been allowed historically.

Functions that are used in a WHERE, ORDER BY, or GROUP BY clause, are MAP or ORDER methods of a SQL type, or in any other way are part of determining whether or where a row should appear in a result set also should be DETERMINISTIC as discussed above. Oracle cannot require that they be explicitly declared DETERMINISTIC without breaking existing applications, but the use of the keyword might be a wise choice of style within your application.

Parallel Query/Parallel DML

Oracle's parallel execution feature divides the work of executing a SQL statement across multiple processes. Functions called from a SQL statement which is run in parallel may have a separate copy run in each of these processes, with each copy called for only the subset of rows that are handled by that process.

Each process has its own copy of package variables. When parallel execution begins, these are initialized based on the information in the package specification and body as if a new user is logging into the system; the values in package variables are not copied from the original login session. And changes made to package variables are not automatically propagated between the various sessions or back to the original session. Java `STATIC` class attributes are similarly initialized and modified independently in each process. Because a function can use package (or Java `STATIC`) variables to accumulate some value across the various rows it encounters, Oracle cannot assume that it is safe to parallelize the execution of all user-defined functions.

For query (`SELECT`) statements, in previous releases, the parallel query optimization looked to see if a function was noted as `RNPS` and `WNPS` in a `PRAGMA RESTRICT_REFERENCES` declaration; those functions that were marked as both `RNPS` and `WNPS` could be run in parallel. Functions defined with a `CREATE FUNCTION` statement had their code implicitly examined to determine if they were actually pure enough; parallelized execution might occur even though a pragma cannot be specified on these functions.

> **See Also:** "Using PRAGMA RESTRICT_REFERENCES" on page 10-66.

For DML statements, in previous releases, the parallelization optimization looked to see if a function was noted as having all four of `RNDS`, `WNDS`, `RNPS` and `WNPS` specified in a `PRAGMA RESTRICT_REFERENCES` declaration; those functions that were marked as neither reading nor writing to either the database or package variables could run in parallel. Again, those functions defined with a `CREATE FUNCTION` statement had their code implicitly examined to determine if they were actually pure enough; parallelized execution might occur even though a pragma cannot be specified on these functions.

In Oracle8*i*, we continue to parallelize those functions that Oracle7 and Oracle8 would recognize as parallelizable. In addition, a new keyword, `PARALLEL_ENABLE`, has been added. This is the preferred way now for users to mark their code as safe for parallel execution. This keyword is syntactically similar to

DETERMINISTIC as described above; it is placed after the return value type in a declaration of the function, as in:

```
CREATE FUNCTION F1 (P1 NUMBER) RETURN NUMBER PARALLEL_ENABLE IS
BEGIN
  RETURN P1 * 2;
END;
```

This keyword may be placed on a function defined in a CREATE FUNCTION statement, in a function's declaration in a CREATE PACKAGE statement, or on a method's declaration in a CREATE TYPE statement. It should not be repeated on the function's or method's body in a CREATE PACKAGE BODY or CREATE TYPE BODY statement.

Note that a PL/SQL function that is defined with CREATE FUNCTION may still be run in parallel without any explicit declaration that it is safe to do so, if the system can determine that it neither reads nor writes package variables nor calls any function that might do so. A Java method or C function is never seen by the system as safe to run in parallel unless the programmer explicitly indicates PARALLEL_ENABLE on the "call specification" or provides a PRAGMA RESTRICT_REFERENCES indicating that the function is sufficiently pure.

An additional runtime restriction is imposed on functions run in parallel as part of a parallelized DML statement. Such a function is not permitted to in turn execute a DML statement; it is subject to the same restrictions that are enforced on functions that are run inside a query (SELECT) statement.

See Also: "Restrictions" on page 10-62.

Using PRAGMA RESTRICT_REFERENCES

To assert the purity level, code the pragma RESTRICT_REFERENCES in the package specification (not in the package body). The pragma must follow the function declaration, but it does not need to follow it immediately. Only one pragma can reference a given function declaration.

To code the pragma RESTRICT_REFERENCES, use the following syntax:

```
PRAGMA RESTRICT_REFERENCES (
    Function_name, WNDS [, WNPS] [, RNDS] [, RNPS] [, TRUST] );
```

Where:

WNDS	Writes no database state (does not modify database tables).
RNDS	Reads no database state (does not query database tables).
WNPS	Writes no package state (does not change the values of packaged variables).
RNPS	Reads no package state (does not reference the values of packaged variables).
TRUST	Allows easy calling from functions that do have RESTRICT_REFERENCES declarations to those that do not.

You can pass the arguments in any order. If any SQL statement inside the function body violates a rule, then you get an error when the statement is parsed.

In the example below, the function compound neither reads nor writes database or package state; therefore, you can assert the maximum purity level. Always assert the highest purity level that a function allows. That way, the PL/SQL compiler never rejects the function unnecessarily.

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE TABLE Accts (
 Yrs      NUMBER
 Amt      NUMBER
 Acctno   NUMBER
 Rte      NUMBER);
```

```
CREATE PACKAGE Finance AS  -- package specification
   FUNCTION Compound
         (Years  IN NUMBER,
          Amount IN NUMBER,
          Rate   IN NUMBER) RETURN NUMBER;
   PRAGMA RESTRICT_REFERENCES (Compound, WNDS, WNPS, RNDS, RNPS);
END Finance;

CREATE PACKAGE BODY Finance AS  --package body
   FUNCTION Compound
         (Years  IN NUMBER,
          Amount IN NUMBER,
          Rate   IN NUMBER) RETURN NUMBER IS
```

```
   BEGIN
      RETURN Amount * POWER((Rate / 100) + 1, Years);
   END Compound;
                  -- no pragma in package body
END Finance;
```

Later, you might call compound from a PL/SQL block, as follows:

```
DECLARE
   Interest NUMBER;
   Acct_id NUMBER;
BEGIN
   SELECT Finance.Compound(Yrs, Amt, Rte)  -- function call
   INTO   Interest
   FROM   Accounts
   WHERE  Acctno = Acct_id;
```

Using the Keyword TRUST The keyword TRUST in the RESTRICT_REFERENCES syntax allows easy calling from functions that have RESTRICT_REFERENCES declarations to those that do not. When TRUST is present, the restrictions listed in the pragma are not actually enforced, but rather are simply trusted to be true.

When calling from a section of code that is using pragmas to one that is not, there are two likely usage styles. One is to place a pragma on the routine to be called, for example on a "call specification" for a Java method. Then, calls from PL/SQL to this method will complain if the method is less restricted than the calling function. For example:

```
CREATE OR REPLACE PACKAGE P1 IS
   FUNCTION F1 (P1 NUMBER) RETURN NUMBER IS
      LANGUAGE JAVA NAME 'CLASS1.METHODNAME(int) return int';
      PRAGMA RESTRICT_REFERENCES(F1,WNDS,TRUST);
   FUNCTION F2 (P1 NUMBER) RETURN NUMBER;

   PRAGMA RESTRICT_REFERENCES(F2,WNDS);
END;

CREATE OR REPLACE PACKAGE BODY P1 IS
   FUNCTION F2 (P1 NUMBER) RETURN NUMBER IS
   BEGIN
      RETURN F1(P1);
   END;
END;
```

Here, F2 can call F1, as F1 has been declared to be WNDS.

The other approach is to mark only the caller, which may then make a call to any function without complaint. For example:

```
CREATE OR REPLACE PACKAGE P1a IS
   FUNCTION F1 (P1 NUMBER) RETURN NUMBER IS
      LANGUAGE JAVA NAME 'CLASS1.METHODNAME(int) return int';
   FUNCTION F2 (P1 NUMBER) RETURN NUMBER;
   PRAGMA RESTRICT_REFERENCES(F2,WNDS,TRUST);
END;

CREATE OR REPLACE PACKAGE BODY P1a IS
   FUNCTION F2 (P1 NUMBER) RETURN NUMBER IS
   BEGIN
      RETURN F1(P1);
   END;
END;
```

Here, F2 can call F1 because while F2 is promised to be WNDS (because TRUST is specified), the body of F2 is not actually examined to determine if it truly satisfies the WNDS restriction. Because F2 is not examined, its call to F1 is allowed, even though there is no PRAGMA RESTRICT_REFERENCES for F1.

Differences between Static and Dynamic SQL Statements. Static INSERT, UPDATE, and DELETE statements do not violate RNDS if these statements do not explicitly read any database states, such as columns of a table. However, dynamic INSERT, UPDATE, and DELETE statements *always* violate RNDS, regardless of whether or not the statements explicitly read database states.

The following INSERT violates RNDS if it's executed dynamically, but it does *not* violate RNDS if it's executed statically.

```
INSERT INTO my_table values(3, 'SCOTT');
```

The following UPDATE always violates RNDS statically and dynamically, because it explicitly reads the column name of my_table.

```
UPDATE my_table SET id=777 WHERE name='SCOTT';
```

Overloading

PL/SQL lets you *overload* packaged (but not stand-alone) functions. You can use the same name for different functions if their formal parameters differ in number, order, or datatype family.

However, a RESTRICT_REFERENCES pragma can apply to only one function declaration. Therefore, a pragma that references the name of overloaded functions always applies to the nearest foregoing function declaration.

In the following example, the pragma applies to the second declaration of valid:

```
CREATE PACKAGE Tests AS
    FUNCTION Valid (x NUMBER) RETURN CHAR;
    FUNCTION Valid (x DATE) RETURN CHAR;
    PRAGMA RESTRICT_REFERENCES (valid, WNDS);
 END;
```

Serially Reusable PL/SQL Packages

PL/SQL packages usually consume user global area (UGA) memory corresponding to the number of package variables and cursors in the package. This limits scalability, because the memory increases linearly with the number of users. The solution is to allow some packages to be marked as SERIALLY_REUSABLE (using pragma syntax).

For serially reusable packages, the package global memory is not kept in the UGA per user; rather, it is kept in a small pool and reused for different users. This means that the global memory for such a package is only used within a unit of work. At the end of that unit of work, the memory can therefore be released to the pool to be reused by another user (after running the initialization code for all the global variables).

The unit of work for serially reusable packages is implicitly a call to the server; for example, an OCI call to the server, or a PL/SQL client-to-server RPC call, or a server-to-server RPC call.

Package States

The state of a nonreusable package (one not marked SERIALLY_REUSABLE) persists for the lifetime of a session. A package's *state* includes global variables, cursors, and so on.

The state of a serially reusable package persists only for the lifetime of a call to the server. On a subsequent call to the server, if a reference is made to the serially reusable package, then Oracle creates a new *instantiation* (described below) of the serially reusable package and initializes all the global variables to NULL or to the default values provided. Any changes made to the serially reusable package state in the previous calls to the server are not visible.

Note: Creating a new instantiation of a serially reusable package on a call to the server does not necessarily imply that Oracle allocates memory or configures the instantiation object. Oracle simply looks for an available instantiation work area (which is allocated and configured) for this package in a least-recently used (LRU) pool in SGA.

At the end of the call to the server, this work area is returned back to the LRU pool. The reason for keeping the pool in the SGA is that the work area can be reused across users who have requests for the same package.

Why Serially Reusable Packages?

Because the state of a non-reusable package persists for the lifetime of the session, this locks up UGA memory for the whole session. In applications, such as Oracle Office, a log-on session can typically exist for days together. Applications often need to use certain packages only for certain localized periods in the session and would ideally like to de-instantiate the package state in the middle of the session, after they are done using the package.

With SERIALLY_REUSABLE packages, application developers have a way of modelling their applications to manage their memory better for scalability. Package state that they care about only for the duration of a call to the server should be captured in SERIALLY_REUSABLE packages.

Syntax

A package can be marked serially reusable by a pragma. The syntax of the pragma is:

```
PRAGMA SERIALLY_REUSABLE;
```

A package specification can be marked serially reusable, whether or not it has a corresponding package body. If the package has a body, then the body must have the serially reusable pragma, if its corresponding specification has the pragma; it cannot have the serially reusable pragma unless the specification also has the pragma.

Semantics

A package that is marked SERIALLY_REUSABLE has the following properties:

- Its package variables are meant for use only within the work boundaries, which correspond to calls to the server (either OCI call boundaries or PL/SQL RPC calls to the server).

  Note: If the application programmer makes a mistake and depends on a package variable that is set in a previous unit of work, then the application program can fail. PL/SQL cannot check for such cases.

- A pool of package instantiations is kept, and whenever a "unit of work" needs this package, one of the instantiations is "reused", as follows:
  - The package variables are reinitialized (for example, if the package variables have default values, then those values are reinitialized).
  - The initialization code in the package body is run again.
- At the "end work" boundary, cleanup is done.
  - If any cursors were left open, then they are silently closed.
  - Some non-reusable secondary memory is freed (such as memory for collection variables or long VARCHAR2s).
  - This package instantiation is returned back to the pool of reusable instantiations kept for this package.
- Serially reusable packages cannot be accessed from within triggers. If you attempt to access a serially reusable package from a trigger, then Oracle issues the error message "cannot access Serially Reusable package <*string*> in the context of a trigger."

Examples

Example 1 This example has a serially reusable package specification (there is no body). It demonstrates how package variables act across call boundaries.

```
CONNECT Scott/Tiger

CREATE OR REPLACE PACKAGE Sr_pkg IS
  PRAGMA SERIALLY_REUSABLE;
  N NUMBER := 5;                -- default initialization
END Sr_pkg;
```

Suppose your Enterprise Manager (or SQL*Plus) application issues the following:

```
CONNECT Scott/Tiger

# first CALL to server
BEGIN
   Sr_pkg.N := 10;
END;

# second CALL to server
BEGIN
   DBMS_OUTPUT.PUT_LINE(Sr_pkg.N);
END;
```

The above program prints:

```
5
```

> **Note:** If the package had not had the pragma SERIALLY_REUSABLE, then the program would have printed '10'.

Example 2 This example has both a package specification and package body, which are serially reusable. Like Example 1, this example demonstrates how the package variables act across call boundaries.

```
CONNECT Scott/Tiger

DROP PACKAGE Sr_pkg;
CREATE OR REPLACE PACKAGE Sr_pkg IS
   PRAGMA SERIALLY_REUSABLE;
   TYPE Str_table_type IS TABLE OF VARCHAR2(200) INDEX BY BINARY_INTEGER;
   Num     NUMBER        := 10;
```

```
   Str     VARCHAR2(200) := 'default-init-str';
   Str_tab STR_TABLE_TYPE;

    PROCEDURE Print_pkg;
    PROCEDURE Init_and_print_pkg(N NUMBER, V VARCHAR2);
END Sr_pkg;
CREATE OR REPLACE PACKAGE BODY Sr_pkg IS
   -- the body is required to have the pragma because the
  -- specification of this package has the pragma
  PRAGMA SERIALLY_REUSABLE;
   PROCEDURE Print_pkg IS
   BEGIN
      DBMS_OUTPUT.PUT_LINE('num: ' || Sr_pkg.Num);
      DBMS_OUTPUT.PUT_LINE('str: ' || Sr_pkg.Str);
      DBMS_OUTPUT.PUT_LINE('number of table elems: ' || Sr_pkg.Str_tab.Count);
      FOR i IN 1..Sr_pkg.Str_tab.Count LOOP
         DBMS_OUTPUT.PUT_LINE(Sr_pkg.Str_tab(i));
      END LOOP;
   END;
   PROCEDURE Init_and_print_pkg(N NUMBER, V VARCHAR2) IS
   BEGIN
   -- init the package globals
      Sr_pkg.Num := N;
      Sr_pkg.Str := V;
      FOR i IN 1..n LOOP
         Sr_pkg.Str_tab(i) := V || ' ' || i;
   END LOOP;
   -- now print the package
   Print_pkg;
   END;
 END Sr_pkg;

SET SERVEROUTPUT ON;

Rem SR package access in a CALL:

BEGIN
   -- initialize and print the package
   DBMS_OUTPUT.PUT_LINE('Initing and printing pkg state..');
   Sr_pkg.Init_and_print_pkg(4, 'abracadabra');
   -- print it in the same call to the server.
   -- we should see the initialized values.
   DBMS_OUTPUT.PUT_LINE('Printing package state in the same CALL...');
   Sr_pkg.Print_pkg;
END;
```

```
Initing and printing pkg state..
num: 4
str: abracadabra
number of table elems: 4
abracadabra 1
abracadabra 2
abracadabra 3
abracadabra 4
Printing package state in the same CALL...
num: 4
str: abracadabra
number of table elems: 4
abracadabra 1
abracadabra 2
abracadabra 3
abracadabra 4

REM SR package access in subsequent CALL:
BEGIN
   -- print the package in the next call to the server.
   -- We should that the package state is reset to the initial (default) values.
   DBMS_OUTPUT.PUT_LINE('Printing package state in the next CALL...');
   Sr_pkg.Print_pkg;
END;
Statement processed.
Printing package state in the next CALL...
num: 10
str: default-init-str
number of table elems: 0
```

Example 3 This example demonstrates that any open cursors in serially reusable packages get closed automatically at the end of a work boundary (which is a call). *Also, in a new call, these cursors need to be opened again.*

```
REM  For serially reusable pkg: At the end work boundaries
REM  (which is currently the OCI call boundary) all open
REM  cursors will be closed.
REM
REM  Because the cursor is closed - every time we fetch we
REM  will start at the first row again.

CONNECT Scott/Tiger
DROP PACKAGE  Sr_pkg;
DROP TABLE People;
```

```
CREATE TABLE People (Name VARCHAR2(20));
INSERT INTO  People  VALUES ('ET');
INSERT INTO  People  VALUES ('RAMBO');
CREATE OR REPLACE PACKAGE Sr_pkg IS
   PRAGMA SERIALLY_REUSABLE;
   CURSOR C IS SELECT Name FROM People;
END Sr_pkg;
SQL> SET SERVEROUTPUT ON;
SQL>
CREATE OR REPLACE PROCEDURE Fetch_from_cursor IS
Name VARCHAR2(200);
BEGIN
   IF (Sr_pkg.C%ISOPEN) THEN
      DBMS_OUTPUT.PUT_LINE('cursor is already open.');
   ELSE
      DBMS_OUTPUT.PUT_LINE('cursor is closed; opening now.');
      OPEN Sr_pkg.C;
   END IF;
   -- fetching from cursor.
   FETCH sr_pkg.C INTO name;
   DBMS_OUTPUT.PUT_LINE('fetched: ' || Name);
   FETCH Sr_pkg.C INTO name;
   DBMS_OUTPUT.PUT_LINE('fetched: ' || Name);
   -- Oops forgot to close the cursor (Sr_pkg.C).
   -- But, because it is a Serially Reusable pkg's cursor,
   -- it will be closed at the end of this CALL to the server.
END;
EXECUTE fetch_from_cursor;
cursor is closed; opening now.
fetched: ET
fetched: RAMBO
```

11

External Routines

The Need to Work with Multiple Languages

Oracle offers you the possibility of working in different languages:

- **PL/SQL**, as described in the *PL/SQL User's Guide and Reference*
- **C**, by means of the Oracle Call Interface (OCI), as described in the *Oracle Call Interface Programmer's Guide*
- **C++**, by means of the Pro*C/C++ precompiler, as described in the *Pro*C/C++ Precompiler Programmer's Guide*
- **COBOL**, by means of the Pro*COBOL precompiler, as described in the *Pro*COBOL Precompiler Programmer's Guide*
- **Visual Basic**, by means of Oracle Objects For OLE (OO4O), as described in the *Oracle Objects for OLE/ActiveX Programmer's Guide*

> **Note:** This guide is not yet available in book form.

- **Java**, by means of the JDBC Application Programmers Interlace (API), as described in *Oracle8 Database Programming with Java.*

> **Note:** This guide is not yet available in book form.

How should you choose between these different implementation possibilities? Each of these languages offers different advantages: Ease of use, the availability of programmers with specific expertise, the need for portability, and the existence of legacy code are powerful determinants.

However, the choice may narrow depending on how your application needs to work with the Oracle ORDBMS:

- PL/SQL is a powerful development tool, specialized for SQL transaction processing.
- Some computation-intensive tasks are executed most efficiently in a lower level language, such as C.
- The need for portability, together with the need for security, may influence you to select Java.

Most significantly, from the point of view of performance, you should note that only PL/SQL and Java methods run within the address space of the server. C/C++ methods are dispatched as external procedures, and run on the server but outside the address space of the server. Pro*COBOL and Pro*C are precompilers, and Visual Basic accesses Oracle via the OCI, which is implemented in C.

Note: Java functionality is not available with this release.

Taking all these factors into account suggests that there may be a number of situations in which you may need to implement your application in more than one language. For instance, the introduction of Java running within the address space of the server suggest that you may want to import existing Java applications into the database, and then leverage this technology by calling Java functions from PL/SQL and SQL.

Until Oracle 8.0, the Oracle RDBMS supported SQL and the stored procedure language PL/SQL. In Oracle 8.0, PL/SQL introduced **external procedures**, which allowed the capability of writing C functions as PL/SQL bodies. These C functions are callable from PL/SQL and SQL (via PL/SQL). With 8.1, Oracle provides a special-purpose interface, the **call specification**, that lets you call **external routines** from other languages. While this service is designed for intercommunication between SQL, PL/SQL, C, and Java, it is accessible from any base language that can call these languages. For example, your routine can be written in a language other than Java or C and still be usable by SQL or PL/SQL, provided that is callable by C. Therefore, if you have a candidate C++ routine, you would use a C++ extern "C" statement in that routine to make it callable by C.

This means that the strengths and capabilities of different languages are available to you, irrespective of your programmatic environment: You are not restricted to one language with its inherent limitations. The use of external routines promotes

reusability and modularity because you can deploy specific languages for specific purposes.

What is an External Routine?

An *external routine*, previously referred to as an *external procedure*, is a routine stored in a **dynamic link library** (DLL), or **libunit** in the case of a Java class method. You register the routine with the base language, and then call it to perform special-purpose processing.

For instance, if you are working in PL/SQL, then the language loads the library dynamically at runtime, and then calls the routine as if it were a PL/SQL subprogram. These routines participate fully in the current transaction and can 'call back' to the database to perform SQL operations.

The routines are loaded only when necessary, so memory is conserved. The decoupling of the call specification from its implementation body means that the routines can be enhanced without affecting the calling programs.

External routines let you:

- Move computation-bound programs from client to server where they execute faster (because they avoid the roundtrips entailed in across-network communication)
- Interface the database server with external systems and data sources
- Extend the functionality of the database server itself

The Call Specification

Until now, you published an external routine to Oracle via an AS EXTERNAL clause in a PL/SQL wrapper. This wrapper defined the mapping to, and allowed the calling of, external C routines. Oracle 8.1 introduces **call specifications**, which include the AS EXTERNAL wrapper as a subset of the new AS LANGUAGE clause. AS LANGUAGE call specifications allow the publishing of external C routines, as before, but also Java class methods.

Note: Call specifications also allow you to publish with the AS EXTERNAL clause, introduced in Oracle 8.0. For new applications, however, you should use the AS LANGUAGE clause.

In general, call specifications enable:

- Dispatching the appropriate C or Java target routine
- Datatype conversions
- Parameter mode mappings
- Automatic memory allocation and cleanup
- Purity constraints to be specified, where necessary, for packaged functions called from SQL.
- Calling Java methods or C routines from database triggers
- Location flexibility: You can put AS LANGUAGE call specifications in package or type specifications, or package (or type) bodies to optimize performance and hide implementation details

To use an already-existing program as an external routine, load, publish, and then call it.

Loading External Routines

To make your external C routines or Java methods available to PL/SQL, you must first load them. The manner of doing this depends upon whether the routine is written in C or Java.

See Also: *Oracle8i Java Stored Procedures Developer's Guide*

For help in creating a DLL, look in the RDBMS subdirectory */public*, where a template *makefile* can be found.

Loading Java Class Methods

One way to load Java programs is to use the CREATE JAVA statement, which you can execute interactively from SQL*Plus. When implicitly invoked by the CREATE JAVA statement, the Java Virtual Machine (JVM)] library manager loads Java

binaries (.class files) and resources from local BFILEs or LOB columns into RDBMS libunits.

Suppose a compiled Java class is stored in the following OS file:

```
/home/java/bin/Agent.class
```

Creating a class libunit in schema scott from file Agent.class requires two steps: First, create a directory object on the server's file system. The name of the directory object is an alias for the directory path leading to Agent.class.

To create the directory object, you must grant user scott the CREATE ANY DIRECTORY privilege, then execute the CREATE DIRECTORY statement, as follows:

```
CONNECT System/Manager
GRANT CREATE ANY DIRECTORY TO Scott IDENTIFIED BY Tiger;
CONNECT Scott/Tiger
CREATE DIRECTORY Bfile_dir AS '/home/java/bin';
```

Now, you are ready to create the class libunit, as follows:

```
CREATE JAVA CLASS USING BFILE (Bfile_dir, 'Agent.class');
```

The name of the libunit is derived from the name of the class.

Alternatively, you can use the command-line utility LoadJava. This uploads Java binaries and resources into a system-generated database table, then uses the CREATE JAVA statement to load the Java files into RDBMS libunits. You can upload Java files from OS file systems, Java IDEs, intranets, or the Internet.

See Also: *Oracle8i Java Stored Procedures Developer's Guide*

Loading External C Routines

In order to set up to use external routines written in C, or callable by C, you and your DBA take the following steps:

Note: This feature is available only on platforms that support DLLs or dynamically loadable shared libraries such as Solaris .so libraries.

---

1. Set Up the Environment

Your DBA sets up the environment for calling external routines by adding entries to the files tnsname.ora and listener.ora and by starting a Listener process exclusively for external routines.

See Also: *Oracle8i Administrator's Guide.*

The Listener sets a few required environment variables (such as ORACLE_HOME, ORACLE_SID, and LD_LIBRARY_PATH) for extproc. Otherwise, it provides extproc with a "clean" environment. The environment variables set for extproc are independent of those set for the client, server, and Listener. Therefore, external routines, which run in the extproc process, cannot read environment variables set for the client, server, or Listener process.

Note: It is possible for you to set and read environment variables themselves by using the standard C routines setenv() and getenv(), respectively. Environment variables, set this way, are specific to the extproc process, which means that they can be read by all functions executed in that process, but not by any other process running on the same machine.

---

2. Identify the DLL

In this context, a DLL is any dynamically loadable operating-system file that stores external routines.

For safety, your DBA controls access to the DLL. Using the CREATE LIBRARY statement, the DBA creates a schema object called an **alias library**, which represents the DLL. Then, if you are an authorized user, the DBA grants you EXECUTE privileges on the alias library. Alternatively, the DBA may you CREATE ANY LIBRARY privileges, in which case you can create your own alias libraries using the following syntax:

```
CREATE LIBRARY library_name {IS | AS} 'file_path';
```

You must specify the full path to the DLL, because the linker cannot resolve references to just the DLL name. In the following example, you create alias library c_utils, which represents DLL utils.so:

```
CREATE LIBRARY C_utils AS '/DLLs/utils.so';
```

3. Designate the External Routine

You find or write a new external C routine, then add it to the DLL, or simply designate a routine already in the DLL.

External C routines are loaded into DLLs. After creating and including your external routine within a DLL, you create the alias library which represents the DLL, like this:

```
CREATE LIBRARY C_utils AS '/DLLs/utils.so';
```

Publishing an External Routine

Oracle can only use external routines that have been published. Publishing is accomplished with a call specification, which maps names, parameter types, and return types for your Java class method or C external routine to their SQL counterparts. It is written like any other PL/SQL stored subprogram except that, in its body, instead of declarations and a BEGIN.. END block, you code the AS LANGUAGE clause.

The call specification syntax, which follows the normal CREATE OR REPLACE syntax for a procedure, function, package specification, package body, type specification, or type body, is:

```
{IS | AS} LANGUAGE {C | JAVA}
```

Note: Oracle uses a PL/SQL variant of the ANSI SQL92 External Procedure, but replaces the ANSI keyword AS EXTERNAL with this call specification syntax. This new syntax, introduced for Java class methods, has now been extended to C routines.

Oracle8i Java Stored Procedures Developer's Guide

This is then followed by either:

```
NAME  <java_string_literal_name>
```

Where *java_string_literal_name* is the signature of your Java method, or by:

```
LIBRARY <library_name>
[NAME <c_string_literal_name>]
[WITH CONTEXT]
[PARAMETERS (external_parameter[, external_parameter]...)];
```

Where library_name is the name of your alias library, c_string_literal_name is the name of your external C routine, and external_parameter stands for:

```
{  CONTEXT
 | SELF [{TDO | property}]
```

```
 | {parameter_name | RETURN} [property] [BY REFERENCE] [external_datatype]}
```

`property` stands for:

```
{INDICATOR [{STRUCT | TDO}] | LENGTH | MAXLEN | CHARSETID | CHARSETFORM}
```

Note: Unlike Java, C doesn't understand SQL types; therefore, the syntax is more intricate

The AS LANGUAGE Clause for Java Class Methods

The **[**AS**]** LANGUAGE clause is the interface between PL/SQL and a Java class method.

See Also: *Oracle8i Java Stored Procedures Developer's Guide*

The AS LANGUAGE Clause for External C Routines

The following subclauses tell PL/SQL where to locate the external C routine, how to call it, and what to pass to it. Only the LIBRARY subclause is required.

LIBRARY

Specifies a local alias library. (You cannot use a database link to specify a remote library.) The library name is a PL/SQL identifier. Therefore, if you enclose the name in double quotes, then it becomes case sensitive. (By default, the name is stored in upper case.) You must have EXECUTE privileges on the alias library.

NAME

Specifies the external C routine to be called. If you enclose the routine name in double quotes, then it becomes case sensitive. (By default, the name is stored in upper case.) If you omit this subclause, then the routine name defaults to the upper-case name of the PL/SQL subprogram.

Note: The terms LANGUAGE and CALLING STANDARD apply only to the superseded AS EXTERNAL clause.

LANGUAGE

Specifies the third-generation language in which the external routine was written. If you omit this subclause, then the language name defaults to C.

CALLING STANDARD

Specifies the Windows NT calling standard (C or Pascal) under which the external routine was compiled. (Under the Pascal Calling Standard, arguments are reversed on the stack, and the called function must pop the stack.) If you omit this subclause, then the calling standard defaults to C.

WITH CONTEXT

Specifies that a context pointer will be passed to the external routine. The context data structure is opaque to the external routine but is available to service routines called by the external routine.

PARAMETERS

Specifies the positions and datatypes of parameters passed to the external routine. It can also specify parameter properties, such as current length and maximum length, and the preferred parameter passing method (by value or by reference).

Publishing Java Class Methods

Java classes and their methods are stored in RDBMS libunits in which you can load Java sources, binaries and resources using the LOADJAVA utility or the CREATEJAVA SQL statements. Libunits can be considered analogous to DLLs written, for example, in C—although they map one-to-one with Java classes, whereas DLLs can contain more than one routine.

See Also: *Oracle8i Java Stored Procedures Developer's Guide*

The NAME-clause string uniquely identifies the Java method. The PL/SQL function or procedure and Java must correspond with regard to parameters. If the Java method takes no parameters, then you must code an empty parameter list for it.

When you load Java classes into the RDBMS, they are not published to SQL automatically. This is because the methods of many Java classes are called only from other Java classes, or take parameters for which there is no appropriate SQL type.

Suppose you want to publish the following Java method named J_calcFactorial, which returns the factorial of its argument:

```
package myRoutines.math;
public class Factorial {
   public static int J_calcFactorial (int n) {
      if (n == 1) return 1;
```

```
      else return n * J_calcFactorial(n - 1);
   }
}
```

The following call specification publishes Java method `J_calcFactorial` as PL/SQL stored function `plsToJavaFac_func`, using SQL*Plus:

```
CREATE OR REPLACE FUNCTION Plstojavafac_func (N NUMBER) RETURN NUMBER AS
   LANGUAGE JAVA
   NAME 'myRoutines.math.Factorial.J_calcFactorial(int) return int';
```

Publishing External C Routines

In the following example, you write a PL/SQL standalone function named `plsCallsCdivisor_func` that publishes C function `Cdivisor_func` as an external function:

```
CREATE OR REPLACE FUNCTION Plscallscdivisor_func (
/* Find greatest common divisor of x and y: */
   x     BINARY_INTEGER,
   y     BINARY_INTEGER)
RETURN BINARY_INTEGER
AS LANGUAGE C
   LIBRARY C_utils
   NAME "Cdivisor_func"; /* Quotation marks preserve case. *
```

Locations of Call Specifications

For both Java class methods and external C routines, call specifications can be specified in any of the following locations:

- Standalone PL/SQL Procedures and Functions
- PL/SQL Package Specifications
- PL/SQL Package Bodies
- Object Type Specifications
- Object Type Bodies

Note: Under Oracle 8.0, AS EXTERNAL call specifications could not be placed in package or type bodies.

We have already shown an example of call specification located in a standalone PL/SQL function. Here are some examples showing some of the other locations.

Note: In the following examples, the AUTHID and SQL_NAME_RESOLVE clauses may or may not be required to fully stipulate a call specification. See the *Invoker-rights* section of this manual for rules on their placement and defaults.

Example: Locating a Call Specification in a PL/SQL Package

```
CREATE OR REPLACE PACKAGE Demo_pack
AUTHID DEFINER
AS
   PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS LANGUAGE C
      NAME "C_demoExternal"
      LIBRARY SomeLib
      WITH CONTEXT
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);
END;
```

Example: Locating a Call Specification in a PL/SQL Package Body

```
CREATE OR REPLACE PACKAGE Demo_pack
   AUTHID CURRENT_USER
AS
   PROCEDURE plsToC_demoExternal_proc(x BINARY_INTEGER, y VARCHAR2, z DATE);
END;

CREATE OR REPLACE PACKAGE BODY Demo_pack
   SQL_NAME_RESOLVE CURRENT_USER
AS
   PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS LANGUAGE JAVA
      NAME 'pkg1.class4.methodProc1(int,java.lang.String,java.sql.Date)';
END;
```

Example: Locating a Call Specification in an Object Type Specification

Note: You may need to set up the following data structures for certain examples to work:

```
CONN SYS/CHANGE_ON_INSTALL AS SYSDBA;
GRANT CREATE ANY LIBRARY TO scott;
CONNECT scott/tiger
CREATE OR REPLACE LIBRARY SOMELIB AS '/tmp/lib.so';
```

```
CREATE OR REPLACE TYPE Demo_typ
AUTHID DEFINER
AS OBJECT
   (Attribute1   VARCHAR2(2000), SomeLib varchar2(20),
   MEMBER PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z
DATE)
   AS LANGUAGE C
      NAME "C_demoExternal"
      LIBRARY SomeLib
      WITH CONTEXT
    --  PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE)
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE, SELF)
);
```

Example: Locating a Call Specification in an Object Type Body

```
CREATE OR REPLACE TYPE Demo_typ
AUTHID CURRENT_USER
AS OBJECT
   (attribute1 NUMBER,
   MEMBER PROCEDURE plsToJ_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z
DATE)
);

CREATE OR REPLACE TYPE BODY Demo_typ
AS
   MEMBER PROCEDURE plsToJ_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z
DATE)
   AS LANGUAGE JAVA
      NAME 'pkg1.class4.J_demoExternal(int,java.lang.String,java.sql.Date)';
END;
```

Example: Java with AUTHID

Here is an example of a publishing a Java class method in a standalone PL/SQL subprogram.

```
CREATE OR REPLACE PROCEDURE plsToJ_demoExternal_proc (x BINARY_INTEGER, y
VARCHAR2, z DATE)
   AUTHID CURRENT_USER
AS LANGUAGE JAVA
   NAME 'pkg1.class4.methodProc1(int,java.lang.String,java.sql.Date)';
```

Example: C with Optional AUTHID

Here is an example of AS EXTERNAL publishing a C routine in a standalone PL/SQL program, in which the AUTHID clause is optional. This maintains compatibility with the external procedures of Oracle 8.0.

```
CREATE OR REPLACE PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y
VARCHAR2, z DATE)
AS
   EXTERNAL
   LANGUAGE C
   NAME "C_demoExternal"
   LIBRARY SomeLib
   WITH CONTEXT
   PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);
```

Example: Mixing Call Specifications in a Package

```
CREATE OR REPLACE PACKAGE Demo_pack
AUTHID DEFINER
AS
   PROCEDURE plsToC_InBodyOld_proc (x BINARY_INTEGER, y VARCHAR2, z DATE);
   PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z DATE);
   PROCEDURE plsToC_InBody_proc (x BINARY_INTEGER, y VARCHAR2, z DATE);
   PROCEDURE plsToJ_InBody_proc (x BINARY_INTEGER, y VARCHAR2, z DATE);

   PROCEDURE plsToJ_InSpec_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   IS LANGUAGE JAVA
      NAME 'pkg1.class4.J_InSpec_meth(int,java.lang.String,java.sql.Date)';

PROCEDURE C_InSpec_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS LANGUAGE C
      NAME "C_demoExternal"
      LIBRARY SomeLib
      WITH CONTEXT
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);
```

```
END;

CREATE OR REPLACE PACKAGE BODY Demo_pack
AS
PROCEDURE plsToC_InBodyOld_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS EXTERNAL
      LANGUAGE C
      NAME "C_InBodyOld"
      LIBRARY SomeLib
      WITH CONTEXT
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);
PROCEDURE plsToC_demoExternal_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS LANGUAGE C
      NAME "C_demoExternal"
      LIBRARY SomeLib
      WITH CONTEXT
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);

PROCEDURE plsToC_InBody_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   AS LANGUAGE C
      NAME "C_InBody"
      LIBRARY SomeLib
      WITH CONTEXT
      PARAMETERS(CONTEXT, x INT, y STRING, z OCIDATE);
PROCEDURE plsToJ_InBody_proc (x BINARY_INTEGER, y VARCHAR2, z DATE)
   IS LANGUAGE JAVA
      NAME 'pkg1.class4.J_InBody_meth(int,java.lang.String,java.sql.Date)';
END;
```

Passing Parameters to Java Class Methods with Call Specifications

See Also: *Oracle8i Java Stored Procedures Developer's Guide*

Passing Parameters to External C Routines with Call Specifications

Call specifications allows a mapping between PL/SQL and C datatypes. Datatype mappings are shown below.

Passing parameters to an external C routine is complicated by several circumstances:

- The available set of PL/SQL datatypes does not correspond one-to-one with the set of C datatypes.

- Unlike C, PL/SQL includes the RDBMS concept of nullity. Therefore, PL/SQL parameters can be NULL, whereas C parameters cannot.
- The external routine might need the current length or maximum length of CHAR, LONG RAW, RAW, and VARCHAR2 parameters.
- The external routine might need characterset information about CHAR, VARCHAR2, and CLOB parameters.
- PL/SQL might need the current length, maximum length, or null status of values returned by the external routine.

In the following sections, you learn how to specify a parameter list that deals with these circumstances.

Note: The maximum number of parameters that you can pass to a C external routine is 128. However, if you pass float or double parameters by value, then the maximum is less than 128. How much less depends on the number of such parameters and your operating system. To get a rough estimate, count each float or double passed by value as two parameters.

Specifying Datatypes

Do not pass parameters to an external routine directly. Instead, pass them to the PL/SQL subprogram that published the external routine. Therefore, you must specify PL/SQL datatypes for the parameters. Each PL/SQL datatype maps to a default external datatype, as shown in Table 11–1.

Table 11–1 Parameter Datatype Mappings

PL/SQL Type	Supported External Types	Default External Type
BINARY_INTEGER BOOLEAN PLS_INTEGER	[UNSIGNED] CHAR [UNSIGNED] SHORT [UNSIGNED] INT [UNSIGNED] LONG SB1, SB2, SB4 UB1, UB2, UB4 SIZE_T	INT
NATURAL NATURALN POSITIVE POSITIVEN SIGNTYPE	[UNSIGNED] CHAR [UNSIGNED] SHORT [UNSIGNED] INT [UNSIGNED] LONG SB1, SB2, SB4 UB1, UB2, UB4 SIZE_T	UNSIGNED INT
FLOAT REAL	FLOAT	FLOAT
DOUBLE PRECISION	DOUBLE	DOUBLE
CHAR CHARACTER LONG NCHAR NVARCHAR2 ROWID VARCHAR VARCHAR2	STRING OCISTRING	STRING
LONG RAW RAW	RAW OCIRAW	RAW
BFILE BLOB CLOB NCLOB	OCILOBLOCATOR	OCILOBLOCATOR

Table 11–1 Parameter Datatype Mappings (Cont.)

NUMBER DEC DECIMAL INT INTEGER NUMERIC SMALLINT	[UNSIGNED] CHAR [UNSIGNED] SHORT [UNSIGNED] INT [UNSIGNED] LONG SB1, SB2, SB4 UB1, UB2, UB4 SIZE_T OCINUMBER	OCINUMBER
DATE	OCIDATE	OCIDATE
composite object types: ADTs	dvoid	dvoid
composite object types: collections (varrays, nested tables, index-by tables	OCICOLL	OCICOLL

External Datatype Mappings

Each external datatype maps to a C datatype, and the datatype conversions are performed implicitly. To avoid errors when declaring C prototype parameters, refer to Table 11–2, which shows the C datatype to specify for a given external datatype and PL/SQL parameter mode. For example, if the external datatype of an OUT parameter is STRING, then specify the datatype char * in your C prototype.

Table 11–2 External Datatype Mappings

	Datatypes Used in C Prototype		
External Datatype	**IN, RETURN**	**IN by REFERENCE, RETURN by REFERENCE**	**IN OUT, OUT**
CHAR	char	char *	char *
UNSIGNED CHAR	unsigned char	unsigned char *	unsigned char *
SHORT	short	short *	short *
UNSIGNED SHORT	unsigned short	unsigned short *	unsigned short *
INT	int	int *	int *
UNSIGNED INT	unsigned int	unsigned int *	unsigned int *
LONG	long	long *	long *
UNSIGNED LONG	unsigned long	unsigned long *	unsigned long *
SIZE_T	size_t	size_t *	size_t *
SB1	sb1	sb1 *	sb1 *
UB1	ub1	ub1 *	ub1 *
SB2	sb2	sb2 *	sb2 *
UB2	ub2	ub2 *	ub2 *
SB4	sb4	sb4 *	sb4 *
UB4	ub4	ub4 *	ub4 *
FLOAT	float	float *	float *
DOUBLE	double	double *	double *
STRING	char *	char *	char *
RAW	unsigned char *	unsigned char *	unsigned char *
OCILOBLOCATOR	OCILobLocator *	OCILobLocator **	OCILobLocator **

Table 11–2 (Cont.) External Datatype Mappings

OCINUMBER	OCINumber *	OCINumber *	OCINumber *
OCISTRING	OCIString *	OCIString *	OCIString *
OCIRAW	OCIRaw *	OCIRaw *	OCIRaw *
OCIDATE	OCIDate *	OCIDate *	OCIDate *
OCICOLL	OCIColl * or OCIArray *, or OCITable *	OCIColl ** or OCIArray **, or OCITable **	OCIColl ** or OCIArray **, or OCITable **
OCITYPE	OCIType *	OCIType *	OCIType *
TDO	OCIType *	OCIType *	OCIType *
ADT	dvoid*	dvoid*	dvoid*

Composite object types are not self describing. Their description is stored in a **Type Descriptor Object** (TDO). Objects and indicator structs for objects have no predefined OCI datatype, but must use the datatypes generated by Oracle's **Object Type Translator** (OTT). The optional TDO argument for INDICATOR, and for composite objects, in general, has the C datatype, OCIType *.

OCICOLL for REF and collection arguments *is* optional and only exists for the sake of completeness. You can not map REFs or collections onto any other datatype and vice versa.

BY VALUE/REFERENCE for IN and IN OUT Parameter Modes

If you specify BY VALUE, then scalar IN and RETURN arguments are passed by value (which is also the default). Alternatively, you may have them passed by reference by specifying BY REFERENCE.

By default, or if you specify BY REFERENCE, then scalar IN OUT, and OUT arguments are passed by reference. Specifying BY VALUE for IN OUT, and OUT arguments is not supported for C. The usefulness of the BY REFERENCE/VALUE clause is restricted to external datatypes that are, by default, passed by value. This is true for IN, and RETURN arguments of the following external types:

```
[UNSIGNED] CHAR
[UNSIGNED] SHORT
[UNSIGNED] INT
[UNSIGNED] LONG
SIZE_T
```

```
SB1
SB2
SB4
UB1
UB2
UB4
FLOAT
DOUBLE
```

All IN and RETURN arguments of external types not on the above list, all IN OUT arguments, and all OUT arguments are passed by reference.

The PARAMETERS Clause

Generally, the PL/SQL subprogram that publishes an external routine declares a list of formal parameters, as the following example shows:

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE LIBRARY MathLib AS '/tmp/math.so';
```

```
CREATE OR REPLACE FUNCTION Interp_func (
/* Find the value of y at x degrees using Lagrange interpolation: */
   x    IN FLOAT,
   y    IN FLOAT)
RETURN FLOAT AS
   LANGUAGE C
   NAME "Interp_func"
   LIBRARY MathLib;
```

Each formal parameter declaration specifies a name, parameter mode, and PL/SQL datatype (which maps to the default external datatype). That might be all the information the external routine needs. If not, then you can provide more information using the PARAMETERS clause, which lets you specify the following:

- Non-default external datatypes
- The current and/or maximum length of a parameter
- NULL/NOT NULL indicators for parameters
- Characterset IDs and forms
- The position of parameters in the list

- How IN parameters are passed (by value or by reference)

If you decide to use the PARAMETERS clause, keep in mind:

- For every formal parameter, there must be a corresponding parameter in the PARAMETERS clause.
- If you include the WITH CONTEXT clause, then you must specify the parameter CONTEXT, which shows the position of the context pointer in the parameter list.
- If the external routine is a function, then you must specify the parameter RETURN, and it must be in the last position.

Overriding Default Datatype Mapping

In some cases, you can use the PARAMETERS clause to override the default datatype mappings. For example, you can re-map the PL/SQL datatype BOOLEAN from external datatype INT to external datatype CHAR.

Specifying Properties

You can also use the PARAMETERS clause to pass additional information about PL/SQL formal parameters and function results to an external routine. Do this by specifying one or more of the following properties:

```
INDICATOR [{STRUCT | TDO}]
LENGTH
MAXLEN
CHARSETID
CHARSETFORM
SELF
```

The following table shows the allowed and the default external datatypes, PL/SQL datatypes, and PL/SQL parameter modes allowed for a given property. Notice that MAXLEN (used to specify data returned from C back to PL/SQL) cannot be applied to an IN parameter.

Table 11–3 Property Datatype Mappings

Property	C Parameter		PL/SQL Parameter		
	Allowed External Types	**Default External Type**	**Allowed Types**	**Allowed Modes**	**Default Passing Method**
INDICATOR	SHORT	SHORT	all scalars	IN	BY VALUE
	INT			IN OUT	BY REFERENCE
	LONG			OUT	BY REFERENCE
				RETURN	BY REFERENCE
LENGTH	[UNSIGNED] SHORT	INT	CHAR	IN	BY VALUE
	[UNSIGNED] INT		LONG RAW	IN OUT	BY REFERENCE
	[UNSIGNED] LONG		RAW	OUT	BY REFERENCE
			VARCHAR2	RETURN	BY REFERENCE
MAXLEN	[UNSIGNED] SHORT	INT	CHAR	IN OUT	BY REFERENCE
	[UNSIGNED] INT		LONG RAW	OUT	BY REFERENCE
	[UNSIGNED] LONG		RAW	RETURN	BY REFERENCE
			VARCHAR2		
CHARSETID	[UNSIGNED] SHORT	[UNSIGNED] INT	CHAR	IN	BY VALUE
CHARSETFORM	[UNSIGNED] INT		CLOB	IN OUT	BY REFERENCE
	[UNSIGNED] LONG		VARCHAR2	OUT	BY REFERENCE
				RETURN	BY REFERENCE

In the following example, the PARAMETERS clause specifies properties for the PL/SQL formal parameters and function result:

```
CREATE OR REPLACE FUNCTION plsToCparse_func  (
   x   IN BINARY_INTEGER,
   Y   IN OUT CHAR)
RETURN CHAR AS LANGUAGE C
   LIBRARY c_utils
   NAME "C_parse"
   PARAMETERS (
      x,            -- stores value of x
      x INDICATOR,  -- stores null status of x
      y,            -- stores value of y
      y LENGTH,     -- stores current length of y
      y MAXLEN,     -- stores maximum length of y
      RETURN INDICATOR,
      RETURN);
```

With this PARAMETERS clause, the C prototype becomes:

```
char * C_parse(int x, short x_ind, char *y, int *y_len,
               int *y_maxlen, short *retind);
```

The additional parameters in the C prototype correspond to the INDICATOR **(for** x**),** LENGTH **(of** y**),** and MAXLEN **(of** y**]**, as well as the INDICATOR **for the function result** in the PARAMETERS clause. The parameter RETURN corresponds to the C function identifier, which stores the result value.

INDICATOR

An INDICATOR is a parameter whose value indicates whether or not another parameter is NULL. PL/SQL does not need indicators, because the RDBMS concept of nullity is built into the language. However, an external routine might need to know if a parameter or function result is NULL. Also, an external routine might need to signal the server that a returned value is actually a NULL, and should be treated accordingly.

In such cases, you can use the property INDICATOR to associate an indicator with a formal parameter. If the PL/SQL subprogram is a function, then you can also associate an indicator with the function result, as shown above.

To check the value of an indicator, you can use the constants OCI_IND_NULL and OCI_IND_NOTNULL. If the indicator equals OCI_IND_NULL, then the associated parameter or function result is NULL. If the indicator equals OCI_IND_NOTNULL, then the parameter or function result is not NULL.

For IN parameters, which are inherently read-only, INDICATOR is passed by value (unless you specify BY REFERENCE) and is read-only (even if you specify BY REFERENCE). For OUT, IN OUT, and RETURN parameters, INDICATOR is passed by reference by default.

The INDICATOR can also have a STRUCT or TDO option. Because specifying INDICATOR as a property of an object is not supported, and because arguments of objects have complete indicator structs instead of INDICATOR scalars, you must specify this by using the STRUCT option. You must use the type descriptor object (TDO) option for composite objects and collections,

LENGTH and MAXLEN

In PL/SQL, there is no standard way to indicate the length of a RAW or string parameter. However, in many cases, you want to pass the length of such a parameter to and from an external routine. Using the properties LENGTH and MAXLEN, you can specify parameters that store the current length and maximum length of a formal parameter.

> **Note:** With a parameter of type RAW or LONG RAW, you must use the property LENGTH. Also, if that parameter is IN OUT and NULL or OUT and NULL, then you must set the length of the corresponding C parameter to zero.

For IN parameters, LENGTH is passed by value (unless you specify BY REFERENCE) and is read-only. For OUT, IN OUT, and RETURN parameters, LENGTH is passed by reference.

As mentioned above, MAXLEN does not apply to IN parameters. For OUT, IN OUT, and RETURN parameters, MAXLEN is passed by reference and is read-only.

CHARSETID and CHARSETFORM

Oracle provides national language support, which lets you process single-byte and multi-byte character data and convert between character sets. It also lets your applications run in different language environments.

The properties CHARSETID and CHARSETFORM identify the non-default character set from which the character data being passed was formed. With CHAR, CLOB, and VARCHAR2 parameters, you can use CHARSETID and CHARSETFORM to pass the character set ID and form to the external routine.

For IN parameters, CHARSETID and CHARSETFORM are passed by value (unless you specify BY REFERENCE) and are read-only (even if you specify BY REFERENCE). For OUT, IN OUT, and RETURN parameters, CHARSETID and CHARSETFORM are passed by reference and are read-only.

The OCI attribute names for these properties are OCI_ATTR_CHARSET_ID and OCI_ATTR_CHARSET_FORM.

> **See Also:** For more information about using NLS data with the OCI, see *Oracle Call Interface Programmer's Guide* and the *Oracle8i National Language Support Guide*.

Repositioning Parameters

Remember, each formal parameter of the external routine must have a corresponding parameter in the PARAMETERS clause. Their positions can differ, because PL/SQL associates them by name, not by position. However, the PARAMETERS clause and the C prototype for the external routine must have the same number of parameters, and they must be in the same order.

Using SELF

SELF is the always-present argument of an object type's member function or procedure, namely the object instance itself. In most cases, this argument is implicit and is not listed in the argument list of the PL/SQL procedure. However, SELF must be explicitly specified as an argument of the PARAMETERS clause.

For example, assume that a user wants to create a Person object, consisting of a person's name and date of birth, and then further a table of this object type. The user would eventually like to determine the age of each Person in this table.

Note: You may need to set up data structures similar to the following for certain examples to work:

```
CONNECT system/manager
GRANT CONNECT,RESOURCE,CREATE LIBRARY TO scott IDENTIFIED BY
tiger;
CONNECT scott/tiger
CREATE OR REPLACE LIBRARY agelib UNTRUSTED IS
  '/tmp/scott1.so';.
```

This example is only for Solaris; other libraries and include paths might be needed for other platforms.

In SQL*Plus, the Person object type can be created by:

```
CREATE OR REPLACE TYPE Person1_typ AS OBJECT
( Name      VARCHAR2(30),
  B_date    DATE,
  MEMBER FUNCTION calcAge_func RETURN NUMBER,
  PRAGMA RESTRICT_REFERENCES(calcAge_func, WNDS)
);
```

Normally, the member function would be implemented in PL/SQL, but for this example, we make it an external procedure. To realize this, the body of the member function is declared as follows:

```
CREATE OR REPLACE TYPE BODY Person1_typ AS
  MEMBER FUNCTION calcAge_func RETURN NUMBER
  AS LANGUAGE C
  NAME "age"
  LIBRARY agelib
  WITH CONTEXT
  PARAMETERS
  ( CONTEXT,
```

```
    SELF,
    SELF INDICATOR STRUCT,
    SELF TDO,
    RETURN INDICATOR
  );
END;
```

Notice that the `calcAge_func` member function doesn't take any arguments, but only returns a number. A member function is always invoked on an instance of the associated object type. The object instance itself always is an implicit argument of the member function. To refer to the implicit argument, the `SELF` keyword is used. This is incorporated into the external procedure syntax by supporting references to `SELF` in the parameters clause.

Now the matching table is created and populated.

```
CREATE TABLE Person_tab OF Person1_typ;

INSERT INTO Person_tab VALUES
   ('SCOTT', TO_DATE('14-MAY-85'));

INSERT INTO Person_tab VALUES
   ('TIGER', TO_DATE('22-DEC-71'));
```

Finally, we retrieve the information of interest from the table.

```
SELECT p.name, p.b_date, p.calcAge_func() FROM Person_tab p;

NAME                           B_DATE    P.CALCAGE_
------------------------------ --------- ----------
SCOTT                          14-MAY-85          0
TIGER                          22-DEC-71          0
```

Sample C code, implementing the "external" member function, and the Object-Type-Translator (OTT)-generated struct definitions are included below.

```
#include <oci.h>

struct PERSON
{
    OCIString   *NAME;
    OCIDate      B_DATE;
};
typedef struct PERSON PERSON;

struct PERSON_ind
```

```
{
    OCIInd    _atomic;
    OCIInd    NAME;
    OCIInd    B_DATE;
};
typedef struct PERSON_ind PERSON_ind;

OCINumber *age (ctx, person_obj, person_obj_ind, tdo, ret_ind)
OCIExtProcContext *ctx;
PERSON         *person_obj;
PERSON_ind     *person_obj_ind;
OCIType        *tdo;
OCIInd         *ret_ind;
{
    sword      err;
    text       errbuf[512];
    OCIEnv    *envh;
    OCISvcCtx *svch;
    OCIError  *errh;
    OCINumber *age;
    int        inum = 0;
    sword      status;

    /* get OCI Environment */
    err = OCIExtProcGetEnv( ctx, &envh, &svch, &errh );

    /* initialize return age to 0 */
    age = (OCINumber *)OCIExtProcAllocCallMemory(ctx, sizeof(OCINumber));
    status = OCINumberFromInt(errh, &inum, sizeof(inum), OCI_NUMBER_SIGNED,
                              age);
    if (status != OCI_SUCCESS)
    {
      OCIExtProcRaiseExcp(ctx, (int)1476);
      return (age);
    }

    /* return NULL if the person object is null or the birthdate is null */
    if ( person_obj_ind->_atomic == OCI_IND_NULL ||
         person_obj_ind->B_DATE  == OCI_IND_NULL )
    {
        *ret_ind = OCI_IND_NULL;
        return (age);
    }

    /* The actual implementation to calculate the age is left to the reader,
```

```
       but an easy way of doing this is a callback of the form:
            select trunc(months_between(sysdate, person_obj->b_date) / 12)
            from dual;
    */
    *ret_ind = OCI_IND_NOTNULL;
    return (age);
}
```

Passing Parameters by Reference

In C, you can pass IN scalar parameters by value (the value of the parameter is passed) or by reference (a pointer to the value is passed). When an external routine expects a pointer to a scalar, specify BY REFERENCE phrase to pass the parameter by reference:

```
CREATE OR REPLACE PROCEDURE findRoot_proc (
   x IN REAL)
AS LANGUAGE C
   LIBRARY c_utils
   NAME "C_findRoot"
   PARAMETERS (
      x BY REFERENCE);
```

In this case, the C prototype would be:

```
void C_findRoot(float *x);
```

This is rather than the default, which would be used when there is no PARAMETERS clause:

```
void C_findRoot(float x);
```

WITH CONTEXT

By including the WITH CONTEXT clause, you can give an external routine access to information about parameters, exceptions, memory allocation, and the user environment. The WITH CONTEXT clause specifies that a context pointer will be passed to the external routine. For example, if you write the following PL/SQL function:

```
CREATE OR REPLACE FUNCTION getNum_func (
   x IN REAL)
RETURN BINARY_INTEGER AS LANGUAGE C
   LIBRARY c_utils
   NAME "C_getNum"
   WITH CONTEXT
```

```
   PARAMETERS (
      CONTEXT,
      x BY REFERENCE,
      RETURN INDICATOR);
```

Then, the C prototype would be:

```
int C_getNum(
   OCIExtProcContext *with_context,
   float *x,
   short *retind);
```

The context data structure is opaque to the external routine; but, is available to service routines called by the external routine.

If you also include the PARAMETERS clause, then you must specify the parameter CONTEXT, which shows the position of the context pointer in the parameter list. If you omit the PARAMETERS clause, then the context pointer is the first parameter passed to the external routine.

Inter-Language Parameter Mode Mappings

PL/SQL supports the IN, IN OUT, and OUT parameter modes, as well as the RETURN clause for routines returning values.

See Also: *Oracle8i Java Stored Procedures Developer's Guide*

Rules for PL/SQL and C Parameter Modes are listed above.

Executing External Routines: the CALL Statement

Now that your Java class method, or external C routine, has been published, you are ready to invoke it.

Do not call an external routine directly. Instead, call the PL/SQL subprogram that published the external routine. Such calls, which you code in the usual way, can appear in the following:

- Anonymous blocks
- Stand-alone and packaged subprograms
- Methods of an object type
- Database triggers

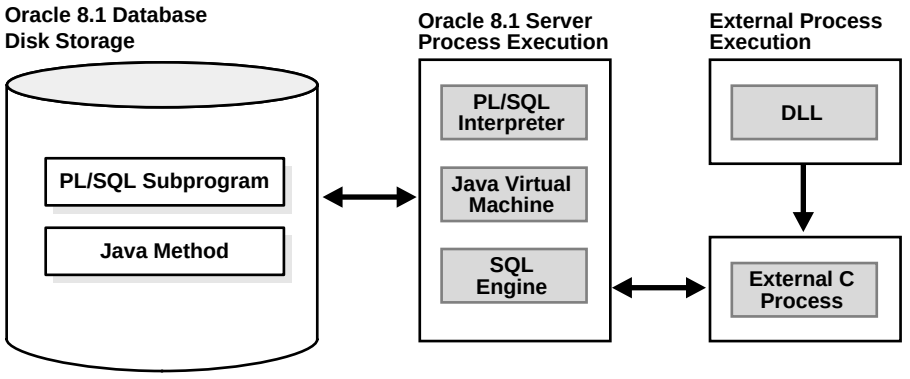
- SQL statements (calls to packaged functions only).

Although the CALL statement, described below, is confined to SELECTs, it can appear in either the WHERE clause or the SELECT list.

> **Note:** To call a packaged function from SQL statements, you must use the pragma RESTRICT_REFERENCES, which asserts the purity level of the function (the extent to which the function is free of side effects). PL/SQL cannot check the purity level of the corresponding external routine. Therefore, make sure that the routine does not violate the pragma. Otherwise, you might get unexpected results.

Any PL/SQL block or subprogram executing on the server side, or on the client side, (for example, in a tool such as Oracle Forms) can call an external procedure. On the server side, the external procedure runs in a separate process address space, which safeguards your database. Figure 11–1 shows how Oracle8 and external routines interact.

Figure 11–1 Oracle8 and External Routines



Preliminaries

Before you call your external routine, you might want to make sure you understand the execution environment. Specifically, you might be interested in privileges, permissions, and synonyms.

Privileges

When external routines are called via CALL specification's, they execute with *definer's privileges*, rather than with the privileges of their invoker.

An invoker's-privileges program is not bound to a particular schema. It executes at the calling site and accesses database items (such as tables and views) with the caller's visibility and permissions. However, a definer's privileges program is bound to the schema in which it is defined. It executes at the defining site, in the definer's schema, and accesses database items with the definer's visibility and permissions.

Managing Permissions

Note: You may need to set up the following data structures for certain examples to work:

```
CONNECT system/manager
GRANT CREATE ANY DIRECTORY to scott;
CONNECT scott/tiger
CREATE OR REPLACE DIRECTORY bfile_dir AS '/tmp';
CREATE OR REPLACE JAVA RESOURCE NAMED "appImages" USING BFILE
(bfile_dir,'bfile_audio');
```

To call external routines, a user must have the EXECUTE privilege on the call specification and on any resources used by the routine.

In SQL*Plus, you can use the GRANT and REVOKE data control statements to manage permissions. For example:

```
GRANT EXECUTE ON plsToJ_demoExternal_proc TO Public;
REVOKE EXECUTE ON plsToJ_demoExternal_proc FROM Public;
GRANT EXECUTE ON JAVA RESOURCE "appImages" TO Public;
GRANT EXECUTE ON plsToJ_demoExternal_proc TO Scott;
REVOKE EXECUTE ON plsToJ_demoExternal_proc FROM Scott;
```

See Also:

- *Oracle8i SQL Reference*
- *Oracle8i Java Stored Procedures Developer's Guide*

Creating Synonyms

For convenience, you or your DBA can create synonyms for external routines using the CREATE [PUBLIC] SYNONYM statement. In the example below, your DBA creates a public synonym, which is accessible to all users. If PUBLIC is not specified, then the synonym is private and accessible only within its schema.

```
CREATE PUBLIC SYNONYM Rfac FOR Scott.RecursiveFactorial;
```

CALL Statement Syntax

Invoke the external routine by means of the SQL CALL statement. You can execute the CALL statement interactively from SQL*Plus. The syntax is:

```
CALL [schema.][{object_type_name | package_name}]routine_name[@dblink_name]
   [(parameter_list)] [INTO :host_variable][INDICATOR][:indicator_variable];
```

This is essentially the same as executing a routine foo() using a SQL statement of the form "SELECT foo(...) FROM dual," except that the overhead associated with performing the SELECT is not incurred.

For example, here is an anonymous PL/SQL block which uses dynamic SQL to call plsToC_demoExternal_proc, which we published above. PL/SQL passes three parameters to the external C routine C_demoExternal_proc.

```
DECLARE
   xx NUMBER(4);
   yy VARCHAR2(10);
   zz DATE;
 BEGIN
    EXECUTE IMMEDIATE 'CALL plsToC_demoExternal_proc(:xxx, :yyy, :zzz)' USING
xx,yy,zz;
 END;
```

The semantics of the CALL statement is identical to the that of an equivalent BEGIN..END block.

Note: CALL is the only SQL statement that cannot be put, by itself, in a PL/SQL BEGIN...END block. It can be part of an EXECUTE IMMEDIATE statement within a BEGIN...END block.

Calling Java Class Methods

Here is how you would call the J_calcFactorial class method published earlier. First, declare and initialize two SQL*Plus host variables, as follows:

```
VARIABLE x NUMBER
VARIABLE y NUMBER
EXECUTE :x := 5;
```

Now, call J_calcFactorial:

```
CALL J_calcFactorial(:x) INTO :y;
PRINT y
```

The result:

```
Y
------
   120
```

See Also: *Oracle8i Java Stored Procedures Developer's Guide*

Calling External C Routines

To call an external C routine, PL/SQL must know in which DLL it resides. To do this, the PL/SQL engine looks in the data dictionary for the library alias mentioned in the AS LANGUAGE clause. Oracle looks for the filename associated with the DLL contained in that library.

Next, PL/SQL alerts a Listener process which, in turn, spawns a session-specific agent named extproc. The Listener hands over the connection to extproc, and PL/SQL passes to extproc the name of the DLL, the name of the external routine, and any parameters.

Then, extproc loads the DLL and runs the external routine. Also, extproc handles service calls (such as raising an exception) and callbacks to the Oracle server. Finally, extproc passes to PL/SQL any values returned by the external routine.

> **Note:** Although some DLL caching takes place, there is no guarantee that your DLL will remain in the cache; therefore, do not store global variables in your DLL.

After the external routine completes, `extproc` remains active throughout your Oracle session; when you log off, `extproc` is killed. Consequently, you incur the cost of launching `extproc` only once, no matter how many calls you make. Still, you should call an external routine only when the computational benefits outweigh the cost.

> **Note:** The Listener, using the information in the `tnsnames.ora` and `listener.ora` files, must start `extproc` on the machine that runs the Oracle server. Starting `extproc` on a different machine is not supported.

Here, we call PL/SQL function `plsCallsCdivisor_func`, which we published above, from an anonymous block. PL/SQL passes the two integer parameters to external function `Cdivisor_func`, which returns their greatest common divisor.

```
DECLARE
   g    BINARY_INTEGER;
   a    BINARY_INTEGER;
   b    BINARY_INTEGER;
CALL plsCallsCdivisor_func(a, b);
IF g IN (2,4,8) THEN ...
```

Errors and Exceptions

Generic Compile Time Call specification Errors

The PL/SQL compiler raises compile time errors if the following conditions are detected in the syntax:

- An AS EXTERNAL call specification is found in a TYPE or PACKAGE specification.

Java Exception Handling

See Also: *Oracle8i Java Stored Procedures Developer's Guide*

C Exception Handling

C programs can raise exceptions through the `OCIExtproc...` functions.

Using Service Routines with External C Routines

When called from an external routine, a service routine can raise exceptions, allocate memory, and invoke OCI handles for callbacks to the server. To use a **service routine**, you must specify the `WITH CONTEXT` clause, which lets you pass a context structure to the external routine. The context structure is declared in header file `ociextp.h` as follows:

```
typedef struct OCIExtProcContext OCIExtProcContext;
```

> **Note:** `ociextp.h` is located in `$ORACLE_HOME/plsql/public` on UNIX.

OCIExtProcAllocCallMemory

This service routine allocates *n* bytes of memory for the duration of the external routine call. Any memory allocated by the function is freed automatically as soon as control returns to PL/SQL.

> **Note:** The external routine does not need to (and should not) call the C function `free()` to free memory allocated by this service routine as this is handled automatically.

The C prototype for this function is as follows:

```
dvoid *OCIExtProcAllocCallMemory(
   OCIExtProcContext *with_context,
   size_t amount);
```

The parameters `with_context` and `amount` are the context pointer and number of bytes to allocate, respectively. The function returns an untyped pointer to the allocated memory. A return value of zero indicates failure.

In SQL*Plus, suppose you publish external function plsToC_concat_func, as follows:

Note: You may need to set up data structures similar to the following for certain examples to work:

```
CONNECT system/manager
DROP USER y CASCADE;
GRANT CONNECT,RESOURCE,CREATE LIBRARY TO y IDENTIFIED BY y;
CONNECT y/y
CREATE LIBRARY stringlib AS
'/private/varora/ilmswork/Cexamples/john2.so';
```

```
CREATE OR REPLACE FUNCTION plsToC_concat_func (
   str1 IN VARCHAR2,
   str2 IN VARCHAR2)
RETURN VARCHAR2 AS LANGUAGE C
NAME "concat"
LIBRARY stringlib
WITH CONTEXT
PARAMETERS (
CONTEXT,
str1   STRING,
str1   INDICATOR short,
str2   STRING,
str2   INDICATOR short,
RETURN INDICATOR short,
RETURN LENGTH short,
RETURN STRING);
```

When called, C_concat concatenates two strings, then returns the result:

select plsToC_concat_func('hello ', 'world') from dual;

```
PLSTOC_CONCAT_FUNC('HELLO','WORLD')
--------------------------------------------------------------------------------
hello world
```

If either string is NULL, then the result is also NULL. As the following example shows, C_concat uses OCIExtProcAllocCallMemory to allocate memory for the result string:

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
```

```
#include <oci.h>
#include <ociextp.h>

char *concat(ctx, str1, str1_i, str2, str2_i, ret_i, ret_l)
OCIExtProcContext *ctx;
char   *str1;
short  str1_i;
char   *str2;
short  str2_i;
short  *ret_i;
short  *ret_l;
{
  char *tmp;
  short len;
  /* Check for null inputs. */
  if ((str1_i == OCI_IND_NULL) || (str2_i == OCI_IND_NULL))
  {
      *ret_i = (short)OCI_IND_NULL;
      /* PL/SQL has no notion of a NULL ptr, so return a zero-byte string. */
      tmp = OCIExtProcAllocCallMemory(ctx, 1);
      tmp[0] = '\0';
      return(tmp);
  }
  /* Allocate memory for result string, including NULL terminator. */
  len = strlen(str1) + strlen(str2);
  tmp = OCIExtProcAllocCallMemory(ctx, len + 1);

  strcpy(tmp, str1);
  strcat(tmp, str2);

  /* Set NULL indicator and length. */
  *ret_i = (short)OCI_IND_NOTNULL;
  *ret_l = len;
  /* Return pointer, which PL/SQL frees later. */
  return(tmp);
}

#ifdef LATER
static void checkerr (/*_ OCIError *errhp, sword status _*/);

void checkerr(errhp, status)
OCIError *errhp;
sword status;
{
  text errbuf[512];
```

```
  sb4 errcode = 0;

  switch (status)
  {
  case OCI_SUCCESS:
    break;
  case OCI_SUCCESS_WITH_INFO:
    (void) printf("Error - OCI_SUCCESS_WITH_INFO\n");
    break;
  case OCI_NEED_DATA:
    (void) printf("Error - OCI_NEED_DATA\n");
    break;
  case OCI_NO_DATA:
    (void) printf("Error - OCI_NODATA\n");
    break;
  case OCI_ERROR:
    (void) OCIErrorGet((dvoid *)errhp, (ub4) 1, (text *) NULL, &errcode,
                       errbuf, (ub4) sizeof(errbuf), OCI_HTYPE_ERROR);
    (void) printf("Error - %.*s\n", 512, errbuf);
    break;
  case OCI_INVALID_HANDLE:
    (void) printf("Error - OCI_INVALID_HANDLE\n");
    break;
  case OCI_STILL_EXECUTING:
    (void) printf("Error - OCI_STILL_EXECUTE\n");
    break;
  case OCI_CONTINUE:
    (void) printf("Error - OCI_CONTINUE\n");
    break;
  default:
    break;
  }
}

char *concat(ctx, str1, str1_i, str2, str2_i, ret_i, ret_l)
OCIExtProcContext *ctx;
char   *str1;
short  str1_i;
char   *str2;
short  str2_i;
short  *ret_i;
short  *ret_l;
{
  char *tmp;
  short len;
```

```
  /* Check for null inputs. */
  if ((str1_i == OCI_IND_NULL) || (str2_i == OCI_IND_NULL))
  {
      *ret_i = (short)OCI_IND_NULL;
      /* PL/SQL has no notion of a NULL ptr, so return a zero-byte string. */
      tmp = OCIExtProcAllocCallMemory(ctx, 1);
      tmp[0] = '\0';
      return(tmp);
  }
  /* Allocate memory for result string, including NULL terminator. */
  len = strlen(str1) + strlen(str2);
  tmp = OCIExtProcAllocCallMemory(ctx, len + 1);

  strcpy(tmp, str1);
  strcat(tmp, str2);

  /* Set NULL indicator and length. */
  *ret_i = (short)OCI_IND_NOTNULL;
  *ret_l = len;
  /* Return pointer, which PL/SQL frees later. */
  return(tmp);
}

/*=============================================================================*/
int main(char *argv, int argc)
{
  OCIExtProcContext *ctx;
  char           *str1;
  short          str1_i;
  char           *str2;
  short          str2_i;
  short          *ret_i;
  short          *ret_l;
  /* OCI Handles */
  OCIEnv        *envhp;
  OCIServer     *srvhp;
  OCISvcCtx     *svchp;
  OCIError      *errhp;
  OCISession    *authp;
  OCIStmt       *stmthp;
  OCILobLocator *clob, *blob;
  OCILobLocator *Lob_loc;

  /* Initialize and Logon */
  (void) OCIInitialize((ub4) OCI_DEFAULT, (dvoid *)0,
```

```
                    (dvoid * (*)(dvoid *, size_t)) 0,
                    (dvoid * (*)(dvoid *, dvoid *, size_t))0,
                    (void (*)(dvoid *, dvoid *)) 0 );

(void) OCIEnvInit( (OCIEnv **) &envhp,
                   OCI_DEFAULT, (size_t) 0,
                   (dvoid **) 0 );

(void) OCIHandleAlloc( (dvoid *) envhp, (dvoid **) &errhp, OCI_HTYPE_ERROR,
                  (size_t) 0, (dvoid **) 0);

/* Server contexts */
(void) OCIHandleAlloc( (dvoid *) envhp, (dvoid **) &srvhp, OCI_HTYPE_SERVER,
                  (size_t) 0, (dvoid **) 0);

/* Service context */
(void) OCIHandleAlloc( (dvoid *) envhp, (dvoid **) &svchp, OCI_HTYPE_SVCCTX,
                  (size_t) 0, (dvoid **) 0);

/* Attach to Oracle */
(void) OCIServerAttach( srvhp, errhp, (text *)"", strlen(""), 0);

/* Set attribute server context in the service context */
(void) OCIAttrSet ((dvoid *) svchp, OCI_HTYPE_SVCCTX,
                   (dvoid *)srvhp, (ub4) 0,
                   OCI_ATTR_SERVER, (OCIError *) errhp);

(void) OCIHandleAlloc((dvoid *) envhp,
                      (dvoid **)&authp, (ub4) OCI_HTYPE_SESSION,
                      (size_t) 0, (dvoid **) 0);

(void) OCIAttrSet((dvoid *) authp, (ub4) OCI_HTYPE_SESSION,
                (dvoid *) "samp", (ub4)4,
                (ub4) OCI_ATTR_USERNAME, errhp);

(void) OCIAttrSet((dvoid *) authp, (ub4) OCI_HTYPE_SESSION,
                (dvoid *) "samp", (ub4) 4,
                (ub4) OCI_ATTR_PASSWORD, errhp);

/* Begin a User Session */
checkerr(errhp, OCISessionBegin ( svchp,  errhp, authp, OCI_CRED_RDBMS,
                        (ub4) OCI_DEFAULT));

(void) OCIAttrSet((dvoid *) svchp, (ub4) OCI_HTYPE_SVCCTX,
                  (dvoid *) authp, (ub4) 0,
```

```
                    (ub4) OCI_ATTR_SESSION, errhp);

  /* ----------------------User Logged In-----------------------------*/
  printf ("user logged in \n");

  /* allocate a statement handle */
  checkerr(errhp, OCIHandleAlloc( (dvoid *) envhp, (dvoid **) &stmthp,
           OCI_HTYPE_STMT, (size_t) 0, (dvoid **) 0));

  checkerr(errhp, OCIDescriptorAlloc((dvoid *)envhp, (dvoid **) &Lob_loc,
                                     (ub4) OCI_DTYPE_LOB,
                                     (size_t) 0, (dvoid **) 0));

  /* ------- subroutine called  here----------------------*/
  printf ("calling concat...\n");
  concat(ctx, str1, str1_i, str2, str2_i, ret_i, ret_l);

  return 0;
}

#endif
```

OCIExtProcRaiseExcp

This service routine raises a predefined exception, which must have a valid Oracle error number in the range 1...32767. After doing any necessary cleanup, your external must return immediately. (No values are assigned to OUT or IN OUT parameters.) The C prototype for this function follows:

```
int OCIExtProcRaiseExcp(
   OCIExtProcContext *with_context,
   size_t errnum);
```

The parameters with_context and error_number are the context pointer and Oracle error number. The return values OCIEXTPROC_SUCCESS and OCIEXTPROC_ERROR indicate success or failure.

In SQL*Plus, suppose you publish external routine plsTo_divide_proc, as follows:

```
CREATE OR REPLACE PROCEDURE plsTo_divide_proc (
   dividend IN BINARY_INTEGER,
   divisor  IN BINARY_INTEGER,
   result   OUT FLOAT)
AS LANGUAGE C
   NAME "C_divide"
```

```
   LIBRARY MathLib
   WITH CONTEXT
   PARAMETERS (
      CONTEXT,
      dividend INT,
      divisor  INT,
      result   FLOAT);
```

When called, `C_divide` finds the quotient of two numbers. As the following example shows, if the divisor is zero, `C_divide` uses `OCIExtProcRaiseExcp` to raise the predefined exception `ZERO_DIVIDE`:

```
void C_divide (ctx, dividend, divisor, result)
OCIExtProcContext *ctx;
int    dividend;
int    divisor;
float  *result;
{
  /* Check for zero divisor. */
  if (divisor == (int)0)
  {
    /* Raise exception ZERO_DIVIDE, which is Oracle error 1476. */
    if (OCIExtProcRaiseExcp(ctx, (int)1476) == OCIEXTPROC_SUCCESS)
    {
      return;
    }
    else
    {
      /* Incorrect parameters were passed. */
      assert(0);
    }
  }
  *result = (float)dividend / (float)divisor;
}
```

OCIExtProcRaiseExcpWithMsg

This service routine raises a user-defined exception and returns a user-defined error message. The C prototype for this function follows:

```
int OCIExtProcRaiseExcpWithMsg(
   OCIExtProcContext *with_context,
   size_t  error_number,
   text   *error_message,
   size_t  len);
```

The parameters `with_context`, `error_number`, and `error_message` are the context pointer, Oracle error number, and error message text. The parameter `len` stores the length of the error message. If the message is a null-terminated string, then `len` is zero. The return values `OCIEXTPROC_SUCCESS` and `OCIEXTPROC_ERROR` indicate success or failure.

In the previous example, we published external routine `plsTo_divide_proc`. In the example below, you use a different implementation. With this version, if the divisor is zero, then `C_divide` uses `OCIExtProcRaiseExcpWithMsg` to raise a user-defined exception:

```
void C_divide (ctx, dividend, divisor, result)
OCIExtProcContext *ctx;
int    dividend;
int    divisor;
float  *result;
  /* Check for zero divisor. */
  if (divisor == (int)0)
  {
    /* Raise a user-defined exception, which is Oracle error 20100,
       and return a null-terminated error message. */
    if (OCIExtProcRaiseExcpWithMsg(ctx, (int)20100,
          "divisor is zero", 0) == OCIEXTPROC_SUCCESS)
    {
      return;
    }
    else
    {
      /*  Incorrect parameters were passed. */
      assert(0);
    }
  }
  *result = dividend / divisor;

}
```

Doing Callbacks with External C Routines

OCIExtProcGetEnv

This service routine enables OCI callbacks to the database during an external routine call. It is only used for callbacks, and, furthermore, it is the only callback routine used. If you use the OCI handles obtained by this function for standard OCI

calls, then the handles establish a new connection to the database and cannot be used for callbacks in the same transaction. In other words, during an external routine call, you can use OCI handles for callbacks or a new connection but not for both.

The C prototype for this function follows:

```
sword OCIExtProcGetEnv ( OCIExtProcContext *with_context,
   OCIEnv envh,
   OCISvcCtx svch,
   OCIError errh )
```

The parameter `with_context` is the context pointer, and the parameters `envh`, `svch`, and `errh` are the OCI environment, service, and error handles, respectively. The return values `OCIEXTPROC_SUCCESS` and `OCIEXTPROC_ERROR` indicate success or failure.

Both External C routines and Java class methods can call-back to the database to do SQL operations. For a working example, see "Demo Program" on page 11-48.

Java exceptions:

> **See Also:** *Oracle8i Java Stored Procedures Developer's Guide*

Note: Callbacks are not necessarily a same-session phenomenon; you may execute an SQL statement in a different session via `OCIlogon`.

An external C routine executing on the Oracle server can call a service routine to obtain OCI environment and service handles. With the OCI, you can use callbacks to execute SQL statements and PL/SQL subprograms, fetch data, and manipulate `LOB`s. Moreover, callbacks and external routines operate in the same user session and transaction context, and so have the same user privileges.

In SQL*Plus, suppose you run the following script:

```
CREATE TABLE Emp_tab (empno NUMBER(10))

CREATE PROCEDURE plsToC_insertIntoEmpTab_proc (
   empno BINARY_INTEGER)
AS LANGUAGE C
   NAME "C_insertEmpTab"
   LIBRARY insert_lib
```

```
   WITH CONTEXT
   PARAMETERS (
      CONTEXT,
      empno LONG);
```

Later, you might call service routine `OCIExtProcGetEnv` from external routine `plsToC_insertIntoEmpTab_proc`, as follows:

```
#include <stdio.h>
#include <stdlib.h>
#include <oratypes.h>
#include <oci.h>   /* includes ociextp.h */
...
void C_insertIntoEmpTab (ctx, empno)
OCIExtProcContext *ctx;
long empno;
{
  OCIEnv    *envhp;
  OCISvcCtx *svchp;
  OCIError  *errhp;
  int        err;
  ...
  err = OCIExtProcGetEnv(ctx, &envhp, &svchp, &errhp);
  ...
}
```

If you do not use callbacks, you do not need to include `oci.h`; instead, just include `ociextp.h`.

Object Support for OCI Callbacks

To execute object-related callbacks from your external routines, the OCI environment in the `extproc` agent is now fully initialized in object mode. You retrieve handles to this environment with the `OCIExtProcGetEnv`() routine.

The object runtime environment lets you use static, as well as dynamic, object support provided by OCI. To utilize static support, use the OTT to generate C structs for the appropriate object types, and then use conventional C code to access the objects' attributes.

For those objects whose types are unknown at external procedure creation time, an alternative, dynamic, way of accessing objects is first to invoke `OCIDescribeAny`() to obtain attribute and method information about the type. Then,

OCIObjectGetAttr() and OCIObjectSetAttr() can be called to retrieve and set attribute values.

Because the current external routine model is stateless, OCIExtProcGetEnv() must be called in every external routine that wants to execute callbacks, or invoke OCIExtProc...() service routines. After every external routine invocation, the callback mechanism is cleaned up and all OCI handles are freed.

Restrictions on Callbacks

With callbacks, the following SQL commands and OCI routines are not supported:

- Transaction control commands such as COMMIT
- Data definition commands such as CREATE
- The following object-oriented OCI routines:

```
OCIObjectNew
OCIObjectPin
OCIObjectUnpin
OCIObjectPinCountReset
OCIObjectLock
OCIObjectMarkUpdate
OCIObjectUnmark
OCIObjectUnmarkByRef
OCIObjectAlwaysLatest
OCIObjectNotAlwaysLatest
OCIObjectMarkDeleteByRef
OCIObjectMarkDelete
OCIObjectFlush
OCIObjectFlushRefresh
OCIObjectGetTypeRef
OCIObjectGetObjectRef
OCIObjectExists
OCIObjectIsLocked
OCIObjectIsDirtied
OCIObjectIsLoaded
OCIObjectRefresh
OCIObjectPinTable
OCIObjectArrayPin
OCICacheFlush,
OCICacheFlushRefresh,
OCICacheRefresh
OCICacheUnpin
OCICacheFree
```

```
OCICacheUnmark
OCICacheGetObjects
OCICacheRegister
```

- Polling-mode OCI routines such as `OCIGetPieceInfo`
- The following OCI routines:

```
OCIEnvInit
OCIInitialize
OCIPasswordChange
OCIServerAttach
OCIServerDetach
OCISessionBegin
OCISessionEnd
OCISvcCtxToLda
OCITransCommit
OCITransDetach
OCITransRollback
OCITransStart
```

Also, with OCI routine `OCIHandleAlloc`, the following handle types are not supported:

```
OCI_HTYPE_SERVER
OCI_HTYPE_SESSION
OCI_HTYPE_SVCCTX
OCI_HTYPE_TRANS
```

Debugging External Routines

See Also: *Oracle8i Java Stored Procedures Developer's Guide*

Usually, when an external routine fails, its prototype is faulty. In other words, the prototype does not match the one generated internally by PL/SQL. This can happen if you specify an incompatible C datatype. For example, to pass an `OUT` parameter of type `REAL`, you must specify `float *`. Specifying `float`, `double *`, or any other C datatype will result in a mismatch.

In such cases, you might get:

```
lost RPC connection to external routine agent
```

This error, which means that agent `extproc` terminated abnormally because the external routine caused a core dump. To avoid errors when declaring C prototype parameters, refer to the tables above.

Using Package DEBUG_EXTPROC

To help you debug external routines, PL/SQL provides the utility package `DEBUG_EXTPROC`. To install the package, run the script `dbgextp.sql` which you can find in the PL/SQL demo directory. (For the location of the directory, see your Oracle Installation or User's Guide.)

To use the package, follow the instructions in `dbgextp.sql`. Your Oracle account must have `EXECUTE` privileges on the package and `CREATE LIBRARY` privileges.

Note: `DEBUG_EXTPROC` works only on platforms with debuggers that can attach to a running process.

Demo Program

Also in the PL/SQL demo directory is the script `extproc.sql`, which demonstrates the calling of an external routine. The companion file `extproc.c` contains the C source code for the external routine.

To run the demo, follow the instructions in `extproc.sql`. You must use the `SCOTT/TIGER` account, which must have `CREATE LIBRARY` privileges.

Guidelines for External C Routines

Handling Global And Static Variables

Global Variables A global variable is declared outside of a function, and its value is shared by all functions of a program. In case of external routines, this means that all functions in a DLL share the value of the global. The usage of global variables is discouraged for two reasons:

- **Threading**: In the current non-threaded configuration of the *extproc* process, there is only one function active at a time. In the future, however, Oracle might thread the extproc process, which would mean that multiple functions can be active at the same time. In that case, it is possible that two or more functions concurrently would try to access the global variable with unsuccessful results.

- **DLL caching**: Global variables are also used to store data that is intended to persist beyond the lifetime of a function. For example, consider two functions *func1*() and *func2*() trying to pass data to each other. Because of the DLL caching feature, it is possible that after *func1*()'s completion, the DLL will be unloaded, which results in all global variables losing their values. When *func2*() is executed, the DLL is reloaded, and all globals are initialized to 0, which will be inconsistent with their values at the completion of *func1*().

Static Variables There are two types of static variables: external and internal. An external static variable is a special case of a global variable, so its usage is discouraged for the above two reasons. Internal static variables are local to a particular function, but remain in existence rather than coming and going each time the function is activated. Therefore, they provide private, permanent storage within a single function. These variables are used to pass on data to subsequent invocation of the same function. But, because of the DLL caching feature mentioned above, the DLL might be unloaded and reloaded between invocations, which means that the internal static variable would lose its value.

> **See Also:** For help in creating a dynamic link library, look in the RDBMS subdirectory */public*, where a template *makefile* can be found.

Call specification and CALLing Guidelines

When calling external routines:

- Never write to `IN` parameters or overflow the capacity of `OUT` parameters. (PL/SQL does no run time checks for these error conditions.)
- Never read an `OUT` parameter or a function result.
- Always assign a value to `IN OUT` and `OUT` parameters and to function results. Otherwise, your external routine will not return successfully.
- If you include the `WITH CONTEXT` and `PARAMETERS` clauses, then you must specify the parameter `CONTEXT`, which shows the position of the context pointer in the parameter list.
- If you include the `PARAMETERS` clause, and if the external routine is a function, then you must specify the parameter `RETURN` in the last position.
- For every formal parameter, there must be a corresponding parameter in the `PARAMETERS` clause. Also, make sure that the datatypes of parameters in the `PARAMETERS` clause are compatible with those in the C prototype, because no implicit conversions are done.

- With a parameter of type RAW or LONG RAW, you must use the property LENGTH. Also, if that parameter is IN OUT or OUT and null, then you must set the length of the corresponding C parameter to zero.

Restrictions on External C Routines

Currently, the following restrictions apply to external routines:

- This feature is available only on platforms that support DLLs.
- Only C routines and routines callable from C code are supported.
- You cannot pass PL/SQL cursor variables, records, collections, or instances of an object type to an external routine.
- In the LIBRARY subclause, you cannot use a database link to specify a remote library.
- The Listener must start agent extproc on the machine that runs the Oracle server. Starting extproc on a different machine is not supported.
- The maximum number of parameters that you can pass to a external routine is 128. However, if you pass float or double parameters by value, then the maximum is less than 128. How much less depends on the number of such parameters and your operating system. To get a rough estimate, count each float or double passed by value as two parameters.

12

Establishing Security Policies

This chapter discusses and provides guidance on developing security policies.

> **Note:** If you are using Trusted Oracle, then see the *Trusted Oracle* documentation for additional information about establishing an overall system security policy.

This chapter discusses the elements you can incorporate into security policies:

About Security Policies

There are many types of mechanisms available to maintain the security of an Oracle database. In addition to requirements unique to your environment, you should design and implement a discretionary security policy to determine, for example:

- The level of security at the application level
- System and object privileges
- Database roles
- How to grant and revoke privileges and roles
- How to create, alter, and drop roles
- How to control role use
- Level of granularity of access control
- Which user attributes govern a user's access to the database

This chapter discusses three elements you can use in establishing security policies:

Application Security:	Attach privileges and roles to each application, while making sure that users do not misuse those roles and privileges when they are not actually using the application.
Application Context:	Use this feature to set up session-based attributes securely. For example, you can securely store such user attributes as the user name, her role, the application she is using, the books she is authorized to access, and her position in the management hierarchy. You can then retrieve that information later in the session.
Fine-Grained Access Control:	Use this feature to implement security policies at a low level of granularity. Do this by creating security policy functions attached to the table or view on which you have based your application. Then, when a user enters a DML statement on that object, Oracle modifies that statement dynamically and transparently to the user.

Application Security

Draft a security policy for each database application. For example, each developed database application should have one or more application roles that provide different levels of security when executing the application. The application roles can be granted to user roles or directly to specific usernames.

Applications that potentially allow unrestricted SQL statement execution (such as SQL*Plus) also need security policies that prevent malicious access to confidential or important schema objects.

Application Administrators

In large database systems with many database applications, it may be desirable to have application administrators. An application administrator is responsible for the following:

- Creating roles for an application and managing the privileges of each application role
- Creating and managing the objects used by a database application
- Maintaining and updating the application code and Oracle procedures and packages as necessary

Roles and Application Privilege Management

Because most database applications involve many different privileges on many different schema objects, keeping track of which privileges are required for each application can be complex. In addition, authorizing users to run an application can involve many `GRANT` operations. To simplify application privilege management, create a role for each application and grant that role all the privileges a user needs to run the application. In fact, an application might have a number of roles, each granted a specific subset of privileges that allow fewer or more capabilities while running the application.

For example, suppose that every administrative assistant uses the Vacation application to record vacation taken by members of the department. You should:

1. Create a `VACATION` role.
2. Grant all privileges required by the Vacation application to the `VACATION` role.
3. Grant the `VACATION` role to all administrative assistants or to a role named `ADMIN_ASSISTS` (if previously defined).

Grouping application privileges in a role aids privilege management. Consider the following administrative options:

- You can grant the role, rather than many individual privileges, to those users who run the application. Then, as employees change jobs, you need to grant or revoke only one role, rather than many privileges.
- You can change the privileges associated with an application by modifying only the privileges granted to the role, rather than the privileges held by all users of the application.
- You can determine which privileges are necessary to run a particular application by querying the ROLE_TAB_PRIVS and ROLE_SYS_PRIVS data dictionary views.
- You can determine which users have privileges on which applications by querying the DBA_ROLE_PRIVS data dictionary view.

Enabling Application Roles

A single user can use many applications and associated roles. However, you should allow a user to have only the privileges associated with the currently running application role. For example, consider the following scenario:

- The ORDER role (for the ORDER application) contains the UPDATE privilege for the INVENTORY table.
- The INVENTORY role (for the INVENTORY application) contains the SELECT privilege for the INVENTORY table.
- Several order entry clerks have been granted both the ORDER and INVENTORY roles.

In this scenario, an order entry clerk, who has been granted both roles, can presumably use the privileges of the ORDER role when running the INVENTORY application to update the INVENTORY table. The problem is that updating the INVENTORY table is not an authorized action when using the INVENTORY application, but only when using the ORDER application.

To avoid such problems, consider using either the SET ROLE command or the SET ROLE procedure as explained below.

SET ROLE Command

Use a SET ROLE statement at the beginning of each application to automatically enable its associated role and, consequently, disable all others. By using the SET ROLE command, each application dynamically enables particular privileges for a user only when required.

The SET ROLE statement facilitates privilege management because, in addition to letting you control what information a user can access, it allows you to control when a user can access it. In addition, the SET ROLE statement keeps users operating in a well defined privilege domain.

If a user gets all privileges from roles, then the user cannot combine them to perform unauthorized operations.

See Also: "Enabling and Disabling Roles" on page 12-12

SET_ROLE Procedure

The DBMS_SESSIONS.SET_ROLE procedure behaves similarly to the SET ROLE statement and can be accessed from PL/SQL. You cannot call SET_ROLE from a stored procedure. This restriction prevents a stored procedure from changing its security domain during its execution. A stored procedure executes under the security domain of the creator of the procedure.

DBMS_SESSION.SET_ROLE is callable only from the following:

- Anonymous PL/SQL blocks
- Invoker's rights stored procedures (except those invoked from within definer's rights procedures).

Because PL/SQL does the security check on SQL when an anonymous block is compiled, SET_ROLE will not affect the security role (in other words, it will not affect the roles enabled) for embedded SQL statements or procedure calls.

For example, suppose you have a role named ACCT that has been granted privileges allowing you to select from table FINANCE in the JOE schema. In this case, the following block fails:

Note: You may need to set up data structures for certain examples to work, such as:

```
CONNECT system/manager
DROP USER joe CASCADE;
CREATE USER joe IDENTIFIED BY joe;
GRANT CREATE SESSION, RESOURCE, UNLIMITED TABLESPACE TO joe;
GRANT CREATE SESSION, RESOURCE, UNLIMITED TABLESPACE TO scott;
DROP ROLE acct;
CREATE ROLE acct;
GRANT acct TO scott;

CONNECT joe/joe;
CREATE TABLE finance (empno NUMBER);
GRANT SELECT ON finance TO acct;
CONNECT scott/tiger
```

```
DECLARE
    n NUMBER;
BEGIN
    SYS.DBMS_SESSION.SET_ROLE('acct');
    SELECT empno INTO n FROM JOE.FINANCE;
END;
```

This block fails because the security check that verifies that you have the SELECT privilege on table JOE.FINANCE happens at compile time. At compile time, you do not have the ACCT role enabled yet. The role is not enabled until the block is executed.

The DBMS_SQL package, however, is not subject to this restriction. When you use this package, the security checks are performed at runtime. Thus, a call to SET_ROLE would affect the SQL executed using calls to the DBMS_SQL package. The following block is, therefore, successful:

```
CREATE OR REPLACE PROCEDURE dynSQL_proc IS
   n NUMBER;
BEGIN
   SYS.DBMS_SESSION.SET_ROLE('acct');
   EXECUTE IMMEDIATE 'select empno from joe.finance' INTO n;
    --other calls to SYS.DBMS_SQL
END;
```

Restricting Application Roles from Tool Users

Prebuilt database applications explicitly control the potential actions of a user, including the enabling and disabling of the user's roles while using the application. Alternatively, ad hoc query tools, such as SQL*Plus, allow a user to submit any SQL statement (which may or may not succeed), including the enabling and disabling of any granted role. This can pose a serious security problem: A user of an application could exercise the privileges attached to that application to issue destructive SQL statements against database tables by using an ad hoc tool.

For example, consider the following scenario:

- The Vacation application has a corresponding `VACATION` role.
- The `VACATION` role includes the privileges to issue `SELECT`, `INSERT`, `UPDATE`, and `DELETE` statements against the `EMP_TAB` table.
- The Vacation application controls the use of the privileges obtained via the `VACATION` role (the application controls when statements are issued).

Now, consider a user who has been granted the `VACATION` role. Suppose, instead of using the Vacation application, the user executes SQL*Plus. At this point, the user is restricted only by the privileges granted to him explicitly or via roles, including the `VACATION` role. Because SQL*Plus is an ad hoc query tool, the user is not restricted to a set of predefined actions, as with designed database applications. The user can query or modify data in the `EMP_TAB` table as he or she chooses.

To avoid potential problems like the one above, consider the following possible policies for application roles, each of which is explained more fully below:

- Enable the proper role when the application starts, and disable it when the application terminates
- Encapsulate privileges in stored procedures and grant the user execute privileges rather than raw privileges
- Grant privileges through roles that require a password unknown to the user
- Use application context

Enable the proper role when the application starts, and disable it when the application terminates

- Give each application distinct roles:
  - One role should contain *all* privileges necessary to use the application successfully. Depending on the situation, there might be several roles that contain more or fewer privileges to provide tighter or less restrictive

security while executing the application. Each application role should be protected by a password (or by operating system authentication) to prevent unauthorized use.

  - Another role should contain only non-destructive privileges associated with the application (SELECT privileges for specific tables or views associated with the application). The read-only role allows the application user to generate custom reports using ad hoc tools, such as SQL*Plus. However, this role does not allow the application user to modify table data outside the application itself. A role designed for an ad hoc query tool may or may not be protected by a password (or operating system authentication).

- At startup, each application should use the SET ROLE command to enable one of the application roles associated with that application. If a password is used to authorize the role, then the password must be included in the SET ROLE statement within the application (encrypted by the application, if possible); if the role is authorized by the operating system, then the system administrator must have set up user accounts and applications so that application users get the appropriate operating system privileges when using the application.
- At termination, each application should disable the previously enabled application role.
- Application users should be granted application roles, as required. The administrator can prohibit a user from using application data with ad hoc tools by not granting the non-destructive role to the user.

Using this configuration, each application enables the proper role when the application is started, and disables the role when the application terminates. If an application user decides to use an ad hoc tool, then the user can enable only the non-destructive role intended for that tool.

Additionally, you can

- Specify the roles to enable when a user starts SQL*Plus, using the PRODUCT_USER_PROFILE table. This functionality is similar to that of a precompiler or Oracle Call Interface (OCI) application that issues a SET ROLE statement to enable specific roles upon application startup.
- Disable the use of the SET ROLE command for SQL*Plus users with the PRODUCT_USER_PROFILE table. This allows a SQL*Plus user only the privileges associated with the roles enabled when the user started SQL*Plus.

Other ad hoc query and reporting tools can also make use of the PRODUCT_USER_PROFILE table to restrict the roles and commands that each user can use while running that product.

See Also: See the appropriate tool manual.

Encapsulate privileges in stored procedures and grant the user execute privileges rather than raw privileges

Another way to restrict users from exercising application privileges by way of ad hoc query tools is to encapsulate privileges into stored procedures, rather than issuing direct privilege grants to users. This allows users to exercise privileges only in the context of well-formed business applications. For example, consider authorizing users to update a table only by executing a stored procedure, rather than by updating the table directly. By doing this, you avoid the problem of the user having the SELECT privilege and using it outside the application.

See Also: For an example of encapsulating privileges in stored procedures, see "Example 3: Human Resources Application #2" on page 12-35.

Grant privileges through roles that require a password unknown to the user

In this scenario, you enable the roles by a password *known only by the creator of the role*. Use the application to issue a SET ROLE command. Because the user does not have the password, either embed the password in the application, or use a stored procedure to retrieve the role password from a database table.

Use application context

In this scenario, you establish a security policy by securely setting session-based attributes.

See Also: "Application Context" on page 12-22

Schemas

A *schema* is a security domain that can contain database objects. The privileges granted to each user or role controls access to these database objects.

Most schemas can be thought of as usernames — the accounts set up to allow users to connect to a database and access the database's objects. However, *unique schemas* do not allow connections to the database, but are used to contain a related set of objects. Schemas of this sort are created as normal users, yet not granted the CREATE SESSION system privilege (either explicitly or via a role). However, you

must temporarily grant the CREATE SESSION privilege to such schemas, if you want to use the CREATE SCHEMA command to create multiple tables and views in a single transaction.

For example, the schema objects for a specific application might be owned by a schema. Application users can connect to the database using typical database usernames and use the application and the corresponding object, if they have the privileges to do so. However, no user can connect to the database using the schema set up for the application, thereby preventing access to the associated objects via this schema. This security configuration provides another layer of protection for schema objects.

> **See Also:** "Renaming the Schema" on page 3-48 in Chapter 3, "Managing Schema Objects"

Managing Privileges and Roles

As part of designing your application, you need to determine the types of users who will be working with the application and the level of access that they must be granted to accomplish their designated tasks. You must categorize these users into role groups, and then determine the privileges that must be granted to each role.

Typically, end users are granted object privileges. An object privilege allows a user to perform a particular action on a specific table, view, sequence, procedure, function, or package. Depending on the type of object, there are different types of object privileges. Table 12–1 summarizes the object privileges available for each type of object.

Table 12–1 Object Privileges

Object Privilege	Table	View	Sequence	Procedure (1)
ALTER	3		3	
DELETE	3	3		
EXECUTE				3
INDEX	3 (2)			
INSERT	3	3		
REFERENCES	3 (2)			
SELECT	3	3 (3)	3	
UPDATE	3	3		

- "Procedure (1)"—stand-alone stored procedures, functions, and public package constructs
- "2"—privilege that cannot be granted to a role
- "3"—can also be granted for snapshots

Table 12–2 lists the SQL statements permitted by the object privileges listed in Table 12–1.

As you implement and test your application, you should create each of these roles, and test the usage scenario for each role to be certain that the users of your application will have proper access to the database. After completing your tests, you should coordinate with the administrator of the application that each user is assigned the proper roles.

Table 12–2 SQL Statements Permitted by Database Object Privileges

Object Privilege	SQL Statements Permitted
ALTER	ALTER object (table or sequence)
	CREATE TRIGGER ON object (tables only)
DELETE	DELETE FROM object (table or view)
EXECUTE	EXECUTE object (procedure or function)
	References to public package variables
INDEX	CREATE INDEX ON object (table or view)
INSERT	INSERT INTO object (table or view)
REFERENCES	CREATE or ALTER TABLE statement defining a FOREIGN KEY integrity constraint on object (tables only)
SELECT	SELECT...FROM object (table, view, or snapshot) SQL statements using a sequence

Creating a Role

The use of a role can be protected by an associated password. For example:

```
CREATE ROLE Clerk IDENTIFIED BY Bicentennial;
```

If you are granted a role protected by a password, then you can enable or disable the role only by supplying the proper password for the role using a SET ROLE command.

> **See Also:** "Explicitly Enabling Roles" on page 12-14

Alternatively, roles can be created, so that role use is authorized using information from the operating system or from a network authentication service.

> **See Also:** *Oracle8i Administrator's Guide*
>
> For information about network authentication services, see *Oracle Advanced Security Administrator's Guide.*

If a role is created without any protection, then any grantee can enable or disable it.

Database applications usually use the role authorization feature to specifically enable an application role, and disable all other roles of a user. This way, the user cannot use privileges (from a role) intended for another application. With ad hoc query tools, such as SQL*Plus or Enterprise Manager, users can explicitly enable only the roles for which they are authorized (in other words, they know the password or are authorized by the operating system).

> **See Also:** "Restricting Application Roles from Tool Users" on page 12-7

When you create a new role, the name that you use must be unique among existing usernames and role names of the database. Roles are not contained in the schema of any user.

Immediately after creation, a role has no privileges associated with it. To associate privileges with a new role, you must grant privileges or other roles to the newly created role.

Privileges Required to Create Roles To create a role, you must have the CREATE ROLE system privilege.

Enabling and Disabling Roles

Although a user can be granted a role, the role must be enabled before the privileges associated with it become available in the user's current session. Some, all, or none of the user's roles can be enabled or disabled. The following sections discuss when roles should be enabled and disabled, and the different ways that a user can have roles enabled or disabled.

When to Enable Roles In general, a user's security domain should always permit the user to perform the current task at hand, yet limit the user from having unnecessary

privileges for the current job. For example, a user should have all the privileges to work with the database application currently in use, but not have any privileges required for any other database applications. Having too many privileges might allow users to access information through unintended methods.

Privileges granted directly to a user are always available to the user; therefore, directly granted privileges cannot be selectively enabled and disabled, depending on a user's current task. Alternatively, privileges granted to a role can be selectively made available for any user granted the role. The enabling of roles **never** affects privileges explicitly granted to a user. The following sections explain how a user's roles can be selectively enabled (and disabled).

Default Roles A default role is one that is automatically enabled for a user when the user creates a session. A user's list of default roles should include those roles that correspond to his or her typical job function.

Each user has a list of zero, or one or more default roles. Any role directly granted to a user can potentially be a default role of the user; an indirectly granted role (a role that is granted to a role) cannot be a default role; only directly granted roles can be default roles of a user.

The number of default roles for a user should not exceed the maximum number of enabled roles that are allowed per user (as specified by the initialization parameter MAX_ENABLED_ROLES); if the number of default roles for a user exceeds this maximum, then errors are returned when the user attempts a connection, and the user's connection is not allowed.

Note: A default role is automatically enabled for a user when the user creates a session. Placing a role in a user's list of default roles bypasses authentication for the role, whether it is authorized using a password or the operating system.

A user's list of default roles can be set and altered using the SQL command ALTER USER. If the user's list of default roles is specified as ALL, then every role granted to a user is automatically added to the user's list of default roles. Only subsequent modification of a user's default role list can remove newly granted roles from a user's list of default roles.

Modifications to a user's default role list only apply to sessions created after the alteration or role grant; neither method applies to a session in progress at the time of the user alteration or role grant.

Explicitly Enabling Roles A user (or application) can explicitly enable a role using the SQL command SET ROLE. A SET ROLE statement enables all specified roles, provided that they have been granted to the user. All roles granted to the user that are not explicitly specified in a SET ROLE statement are disabled, including any roles previously enabled.

When you enable a role that contains other roles, all the indirectly granted roles are specifically enabled. Each indirectly granted role can be explicitly enabled or disabled for a user.

If a role is protected by a password, then the role can only be enabled by indicating the role's password in the SET ROLE statement. If the role is not protected by a password, then the role can be enabled with a simple SET ROLE statement. For example, assume that Morris' security domain is as follows:

- He is granted three roles:
  - PAYROLL_CLERK (password BICENTENNIAL)
  - ACCTS_PAY (password GARFIELD)
  - ACCTS_REC (identified externally).

  The PAYROLL_CLERK role includes the indirectly granted role PAYROLL_REPORT (identified externally).
- His only default role is PAYROLL_CLERK.

Morris' currently enabled roles can be changed from his default role, PAYROLL_CLERK, to ACCTS_PAY and ACCTS_REC, by the following statements:

Note: You may need to set up the following data structures for certain examples to work, such as:

```
GRANT PAYROLL_CLERK TO hr;
GRANT ACCTS_PAY TO hr;
GRANT ACCTS_REC TO hr;
```

```
SET ROLE accts_pay IDENTIFIED BY garfield;
SET ROLE accts_pay IDENTIFIED BY accts_rec;
```

Notice that in the first statement, multiple roles can be enabled in a single SET ROLE statement. The ALL and ALL EXCEPT options of the SET ROLE command also allow several roles granted directly to the user to be enabled in one statement:

Note: You may need to set up the following data structures for certain examples to work, such as:

```
CREATE ROLE Payroll_clerk;
CREATE ROLE Payroll_report;
```

```
SET ROLE ALL EXCEPT Payroll_clerk;
```

This statement shows the use of the ALL EXCEPT option of the SET ROLE command. Use this option when you want to enable most of a user's roles and only disable one or more. Similarly, all of Morris' roles can be enabled by the following statement:

```
SET ROLE ALL;
```

When using the ALL or ALL EXCEPT options of the SET ROLE command, all roles to be enabled either must not require a password, or must be authenticated using the operating system. If a role requires a password, then the SET ROLE ALL or ALL EXCEPT statement is rolled back and an error is returned.

A user can also explicitly enable any indirectly granted roles granted to him or her via an explicit grant of another role. For example, Morris can issue the following statement:

```
SET ROLE Payroll_report;
```

Privileges Required to Explicitly Enable Roles Any user can use the SET ROLE command to enable any granted roles, provided the grantee supplies role passwords, when necessary.

Enabling and Disabling Roles When OS_ROLES=TRUE If OS_ROLES is set to TRUE, then any role granted by the operating system can be dynamically enabled using the SET ROLE command. However, any role not identified in a user's operating system account cannot be specified in a SET ROLE statement (it is ignored), even if a role has been granted using a GRANT statement.

When OS_ROLES is set to TRUE, a user can enable as many roles as specified by the initialization parameter MAX_ENABLED_ROLES.

> **See Also:** For more information about use of the operating system for role authorization, see *Oracle8i Administrator's Guide.*

Dropping Roles

When you drop a role, the security domains of all users and roles granted that role are immediately changed to reflect the absence of the dropped role's privileges. All indirectly granted roles of the dropped role are also removed from affected security domains. Dropping a role automatically removes the role from all users' default role lists.

Because the creation of objects is not dependent upon the privileges received via a role, no cascading effects regarding objects need to be considered when dropping a role (for example, tables or other objects are not dropped when a role is dropped).

Drop a role using the SQL command DROP ROLE. For example:

```
DROP ROLE clerk;
```

Privileges Required to Drop Roles To drop a role, you must have the DROP ANY ROLE system privilege or have been granted the role with the ADMIN OPTION.

Granting and Revoking Privileges and Roles

The following sections explain how to grant and revoke system privileges, roles, and schema object privileges.

Granting System Privileges and Roles System privileges and roles can be granted to other roles or users using the SQL command GRANT, as shown in the following example:

Note: You may need to set up the following data structures for certain examples to work, such as:

```
CONNECT sys/change_on_install AS sysdba;
CREATE USER jward IDENTIFIED BY jward;
CREATE USER tsmith IDENTIFIED BY tsmith;
CREATE USER finance IDENTIFIED BY finance;
CREATE USER michael IDENTIFIED BY michael;
CREATE ROLE Payroll_report;
GRANT CREATE TABLE, Accts_rec TO finance IDENTIFIED BY finance;
GRANT CREATE TABLE, Accts_rec TO tsmith IDENTIFIED BY tsmith;
GRANT REFERENCES ON Dept_tab TO jward;
CONNECT scott/tiger
CREATE VIEW Salary AS SELECT Empno,Sal from Emp_tab;
```

```
GRANT CREATE SESSION, Accts_pay TO jward, finance;
```

Schema object privileges cannot be granted along with system privileges and roles in the same GRANT statement.

The ADMIN OPTION—A system privilege or role can be granted with the ADMIN OPTION. (This option is not valid when granting a role to another role.) A grantee with this option has several expanded capabilities:

- The grantee can grant or revoke the system privilege or role to or from *any* user or other role in the database. (A user cannot revoke a role from himself.)
- The grantee can further grant the system privilege or role with the ADMIN OPTION.
- The grantee of a role can alter or drop the role.

A grantee without the ADMIN OPTION cannot perform the above operations.

When a user creates a role, the role is automatically granted to the creator with the ADMIN OPTION.

Assume that you grant the NEW_DBA role to MICHAEL with the following statement:

```
GRANT New_dba TO michael WITH ADMIN OPTION;
```

The user MICHAEL cannot only use all of the privileges implicit in the NEW_DBA role, but can grant, revoke, or drop the NEW_DBA role, as necessary.

Privileges Required to Grant System Privileges or Roles—To grant a system privilege or role, the grantor requires the ADMIN OPTION for all system privileges and roles being granted. Additionally, any user with the GRANT ANY ROLE system privilege can grant any role in a database.

Granting Schema Object Privileges Grant schema object privileges to roles or users using the SQL command GRANT. The following statement grants the SELECT, INSERT, and DELETE object privileges for all columns of the EMP_TAB table to the users JWARD and TSMITH:

```
GRANT SELECT, INSERT, DELETE ON Emp_tab TO jward, tsmith;
```

To grant the INSERT object privilege for only the ENAME and JOB columns of the EMP_TAB table to the users JWARD and TSMITH, enter the following statement:

```
GRANT INSERT(Ename, Job) ON Emp_tab TO jward, tsmith;
```

To grant all schema object privileges on the SALARY view to the user WALLEN, use the ALL short cut. For example:

```
GRANT ALL ON Salary TO wallen;
```

System privileges and roles cannot be granted along with schema object privileges in the same GRANT statement.

The GRANT OPTION—A schema object privilege can be granted to a user with the GRANT OPTION. This special privilege allows the grantee several expanded privileges:

- The grantee can grant the schema object privilege to any user or any role in the database.
- The grantee can also grant the schema object privilege to other users, with or without the GRANT OPTION.
- If the grantee receives schema object privileges for a table with the GRANT OPTION, and the grantee has the CREATE VIEW or the CREATE ANY VIEW system privilege, then the grantee can create views on the table and grant the corresponding privileges on the view to any user or role in the database.

The user whose schema contains an object is automatically granted all associated schema object privileges with the GRANT OPTION.

> **Note:** The GRANT OPTION is not valid when granting a schema object privilege to a role. Oracle prevents the propagation of schema object privileges via roles, so that grantees of a role cannot propagate object privileges received via roles.

Privileges Required to Grant Schema Object Privileges—To grant a schema object privilege, the grantor must either

- Be the owner of the schema object being specified, or
- Have been granted the schema object privileges being granted with the GRANT OPTION

Revoking System Privileges and Roles System privileges and roles can be revoked using the SQL command REVOKE. For example:

```
REVOKE CREATE TABLE, Accts_rec FROM tsmith, finance;
```

The ADMIN OPTION for a system privilege or role cannot be selectively revoked; the privilege or role must be revoked, and then the privilege or role is regranted without the ADMIN OPTION.

Privileges Required to Revoke System Privileges and Roles—Any user with the ADMIN OPTION for a system privilege or role can revoke the privilege or role from any other database user or role (the user does not have to be the user that originally granted the privilege or role). Additionally, any user with the GRANT ANY ROLE can revoke *any* role.

Revoking Schema Object Privileges Schema object privileges can be revoked using the SQL command REVOKE. For example, assuming you are the original grantor, to revoke the SELECT and INSERT privileges on the EMP_TAB table from the users JWARD and TSMITH, enter the following statement:

```
REVOKE SELECT, INSERT ON Emp_tab FROM jward, tsmith;
```

A grantor could also revoke all privileges on the table DEPT_TAB (even if only one privilege was granted) that he or she granted to the role HUMAN_RESOURCES by entering the following statement:

```
REVOKE ALL ON Dept_tab FROM human_resources;
```

This statement would only revoke the privileges that the grantor authorized, not the grants made by other users. The GRANT OPTION for a schema object privilege cannot be selectively revoked; the schema object privilege must be revoked and then regranted without the GRANT OPTION. A user cannot revoke schema object privileges from him or herself.

Revoking Column-Selective Schema Object Privileges—Recall that column-specific INSERT, UPDATE, and REFERENCES privileges can be granted for tables or views; however, it is not possible to revoke column-specific privileges selectively with a similar REVOKE statement. Instead, the grantor must first revoke the schema object privilege for all columns of a table or view, and then selectively grant the new column-specific privileges again.

For example, assume the role HUMAN_RESOURCES has been granted the UPDATE privilege on the DEPTNO and DNAME columns of the table DEPT_TAB. To revoke the UPDATE privilege on just the DEPTNO column, enter the following two statements:

```
REVOKE UPDATE ON Dept_tab FROM human_resources;
GRANT UPDATE (Dname) ON Dept_tab TO human_resources;
```

The REVOKE statement revokes the UPDATE privilege on all columns of the DEPT_TAB table from the role HUMAN_RESOURCES. The GRANT statement regrants the UPDATE privilege on the DNAME column to the role HUMAN_RESOURCES.

Revoking the REFERENCES Schema Object Privilege—If the grantee of the REFERENCES object privilege has used the privilege to create a foreign key constraint (that currently exists), then the grantor can only revoke the privilege by specifying the CASCADE CONSTRAINTS option in the REVOKE statement:

```
REVOKE REFERENCES ON Dept_tab FROM jward CASCADE CONSTRAINTS;
```

Any foreign key constraints currently defined that use the revoked REFERENCES privilege are dropped when the CASCADE CONSTRAINTS option is specified.

Privileges Required to Revoke Schema Object Privileges—To revoke a schema object privilege, the revoker must be the original grantor of the object privilege being revoked.

Cascading Effects of Revoking Privileges Depending on the type of privilege, there may or may not be cascading effects if a privilege is revoked. The following sections explain several cascading effects.

System Privileges—There are no cascading effects when revoking a system privilege related to DDL operations, regardless of whether the privilege was granted with or without the ADMIN OPTION. For example, assume the following:

1. You grant the CREATE TABLE system privilege to JWARD with the WITH ADMIN OPTION.
2. JWARD creates a table.
3. JWARD grants the CREATE TABLE system privilege to TSMITH.
4. TSMITH creates a table.
5. You revoke the CREATE TABLE privilege from JWARD.
6. JWARD's table continues to exist. TSMITH continues to have the CREATE TABLE system privilege, and his table still exists.

Cascading effects can be observed when revoking a system privilege related to a DML operation. For example, if SELECT ANY TABLE is granted to a user, and if that user has created any procedures, then all procedures contained in the user's schema must be reauthorized before they can be used again (after the revoke).

Schema Object Privileges—Revoking a schema object privilege can have several types of cascading effects that should be investigated before a REVOKE statement is issued:

- Schema object definitions that depend on a DML object privilege can be affected if the DML object privilege is revoked. For example, assume the procedure body of the TEST procedure includes a SQL statement that queries data from the EMP_TAB table. If the SELECT privilege on the EMP_TAB table is revoked from the owner of the TEST procedure, then the procedure can no longer be executed successfully.
- Schema object definitions that require the ALTER and INDEX DDL object privileges are not affected, if the ALTER or INDEX object privilege is revoked. For example, if the INDEX privilege is revoked from a user that created an index on someone else's table, then the index continues to exist after the privilege is revoked.
- When a REFERENCES privilege for a table is revoked from a user, any foreign key integrity constraints defined by the user that require the dropped REFERENCES privilege are automatically dropped. For example, assume that the user JWARD is granted the REFERENCES privilege for the DEPTNO column of the DEPT_TAB table and creates a foreign key on the DEPTNO column in the EMP_TAB table that references the DEPTNO column. If the REFERENCES privilege on the DEPTNO column of the DEPT_TAB table is revoked, then the foreign key constraint on the DEPTNO column of the EMP_TAB table is dropped in the same operation.
- The schema object privilege grants propagated using the GRANT OPTION are revoked, if a grantor's object privilege is revoked. For example, assume that USER1 is granted the SELECT object privilege with the GRANT OPTION, and grants the SELECT privilege on EMP_TAB to USER2. Subsequently, the SELECT privilege is revoked from USER1. This revoke is cascaded to USER2 as well. Any schema objects that depended on USER1's and USER2's revoked SELECT privilege can also be affected.

Granting to, and Revoking from, the User Group PUBLIC Privileges and roles can also be granted to and revoked from the user group PUBLIC. Because PUBLIC is accessible to every database user, all privileges and roles granted to PUBLIC are accessible to every database user.

You should only grant a privilege or role to PUBLIC if every database user requires the privilege or role. This recommendation restates the general rule that at any given time, each database user should only have the privileges required to successfully accomplish the current task.

Revokes from PUBLIC can cause significant cascading effects, depending on the privilege that is revoked. If any privilege related to a DML operation is revoked from PUBLIC (for example, SELECT ANY TABLE, UPDATE ON EMP_TAB), then all procedures in the database (including functions and packages) must be reauthorized before they can be used again. Therefore, use caution when granting DML-related privileges to PUBLIC.

When Do Grants and Revokes Take Effect? Depending upon what is granted or revoked, a grant or revoke takes effect at different times:

- All grants / revokes of privileges (system and schema object) to users, roles, or PUBLIC are immediately observed.
- All grants / revokes of roles to users, other roles, or PUBLIC are observed only when a current user session issues a SET ROLE statement to re-enable the role after the grant / revoke, or when a new user session is created after the grant / revoke.

How Do Grants Affect Dependent Objects? Issuing a GRANT statement against a schema object causes the "last DDL time" attribute of the object to change. This can invalidate any dependent schema objects, in particular PL / SQL package bodies that refer to the schema object. These then must be recompiled.

Application Context

Application context allows you to write applications on certain aspects of a user's session information. This is especially useful in developing secure applications based on a user's access privileges. For example, suppose a user is running the Oracle Human Resource application. Part of the application's initialization process is to determine the kind of responsibility that the user may assume based on the user's identity. This responsibility ID becomes part of the Oracle Human Resource application context; it will affect what data the user can access throughout the session.

Features of Application Context

Application context provides security tailored to the attributes you specify for each application. It also provides security through validation.

Security Tailored to the Attributes You Specify for Each Application

Each application can have its own context with its own attributes. For example, suppose you have three applications: General Ledger, Order Entry, and Human Resources. You can specify different attributes for each application. Thus,

- For the General Ledger application context, you can specify the attributes `BOOK` and `TITLE`
- For the Order Entry application context, you can specify the attribute `CUSTOMER_NUMBER`

  and

- For the Human Resources application context, you can specify the attributes `ORGANIZATION_ID`, `POSITION`, and `COUNTRY`.

In each case, you can adapt the application context to your precise security needs.

Security through Validation

Suppose you have a General Ledger application, which has access control based on sets of books. If a user accessing this application changes the set of books he is working on from *01* to *02*, the application context can ensure that:

- *02* is a valid set of books
- The user has privileges to access set of books *02*

The validation function can check application metadata tables to make this determination and ensure that the attributes in combination are in line with the overall security policy. To restrict a user from changing a context attribute without the above security validation, Oracle verifies that only the designated package implementing the context changes the attribute.

Using Application Context

In very basic terms, when you use application context, you perform the following two tasks, each of which is described below.

- Create a PL/SQL package with functions that set the context for your application
- Create a unique context and associate it with the PL/SQL package you created

Create a PL/SQL package with functions that set the context for your application

See Also: See *Oracle8i Supplied Packages Reference*

The following example creates the package `app_security_context`.

```
CREATE OR REPLACE PACKAGE App_security_context IS
   PROCEDURE Set_empno;
END;

CREATE OR REPLACE PACKAGE BODY App_security_context IS
   PROCEDURE Set_empno
   IS
   Emp_id NUMBER;
   BEGIN
    SELECT Empno INTO Emp_id FROM Emp_tab
       WHERE Ename = SYS_CONTEXT('USERENV',
                                 'SESSION_USER');
    DBMS_SESSION.SET_CONTEXT('app_context', 'empno', Emp_id);
   END;
END;
```

About the SYS_CONTEXT function The syntax for this function is

```
SYS_CONTEXT ('namespace', 'attribute')
```

and it returns the value of `attribute` as defined in the package currently associated with the context namespace. It is evaluated once for each statement execution, and is treated like a constant during type checking for optimization. You can use the pre-defined namespace USERENV to access primitive contexts such as userid and NLS parameters.

See Also: See *Oracle8i SQL Reference*

Create a unique context and associate it with the PL/SQL package you created

To do this, you use the CREATE CONTEXT command. Each context must have a unique attribute and belong to a namespace. Contexts are always owned by the schema SYS.

For example:

```
CREATE CONTEXT App_context USING APP_SECURITY_CONTEXT;
```

where `app_context` is the context namespace, and `app_security_context` is the trusted package that can set attributes in the context namespace.

After you have created the context, you can set or reset the context attributes by using the DBMS_SESSION.SET_CONTEXT package. The values of the attributes you set remain either until you reset them or until the user ends the session.

You can set the context attributes inside only the trusted procedure you named in the CREATE CONTEXT command.

Fine-Grained Access Control

Fine-grained access control allows you to build applications that enforce security policies at a low level of granularity. You can use it, for example, to restrict a customer who is accessing an Oracle server to see only his own account, a physician to see only the records of her own patients, or a manager to see only the records of employees who work for him.

When you use fine-grained access control, you create security policy functions attached to the table or view on which you have based your application. Then, when a user enters a DML statement (SELECT, INSERT, UPDATE, or DELETE) on that object, Oracle dynamically modifies that user's statement—transparently to the user—so that the statement implements the correct access control.

Features of Fine-Grained Access Control

Fine-grained access control provides the following capabilities.

Table- or view-based security policies

Attaching security policies to tables or views, rather than to applications, provides greater security, simplicity, and flexibility.

Security — Attaching a policy to a table or view overcomes a potentially serious application security problem. Suppose a user is authorized to use an application, and then, drawing on the privileges associated with that application, wrongfully modifies the database by using an ad hoc query tool, such as SQL*Plus. By attaching security policies to tables or views, fine-grained access control ensures that the same security is in force, no matter how a user accesses the data.

Simplicity — Adding the security policy to the table or view means that you make the addition only once, rather than repeatedly adding it to each of your table- or view-based applications.

Flexibility — You can have one security policy for SELECT statements, another for INSERT statements, and still others for UPDATE and DELETE statements. For example, you might want to enable a Human Resources clerk to SELECT all employee records in her division, but to UPDATE only salaries for those employees in her division whose last names begin with "A" through "F."

Multiple policies for each table or view

You can establish several policies for the same table or view. For example, suppose you have a base application for Order Entry, and each division of your company has its own special rules for data access. You can add a division-specific policy function to a table without having to rewrite the policy function of the base application.

High performance

With fine-grained access control, each policy function for a given query is evaluated only once, namely, at statement parse time. Moreover, the entire dynamically modified query is optimized and the parsed statement can be shared and reused. This means that rewritten queries can take advantage of the high performance features of Oracle such as dictionary caching and shared cursors.

Note: For performance reasons, parsed static SQL statements in instantiated PL/SQL packages may not get re-parsed. If you want to force the re-evaluation of the policy function, Oracle recommends that you use dynamic SQL.

Example of a Dynamically Modified Statement

Suppose you want to attach to the ORDERS_TAB table the following security policy: "Customers can see only their own orders." The process would be as follows.

1. You create a package to add a predicate to a user's DML statement.

   Note: A predicate is the WHERE clause and, more explicitly, a selection criteria clause based on one of the operators (=, !=, IS, IS NOT, >, >=).

   In this case, you might create a package that adds the following predicate:

   ```
   Cust_no = (SELECT Custno FROM Customers WHERE Custname =
              SYS_CONTEXT ('userenv','session_user'))
   ```

2. A user enters the statement:

   ```
   SELECT * FROM Orders_tab
   ```

3. The Oracle server calls the package you created to implement the security policy.

4. The package dynamically modifies the user's statement to read:

```
SELECT * FROM Orders_tab WHERE Custno = (
   SELECT Custno FROM Customers
       WHERE Custname = SYS_CONTEXT('userenv', 'session_user'))
```

5. The Oracle server executes the dynamically modified statement.
6. Upon execution, the package uses the username returned by `SYS_CONTEXT ('userenv','session_user')` to look up the corresponding customer and to limit the data returned from the `ORDERS_TAB` table to that customer's data only.

See Also: For more information on using Fine-grained access control, see "Examples" on page 12-29 and *Oracle8i Supplied Packages Reference*

Using Application Context within a Fine-Grained Access Control Package

To make the implementation of a security policy easier, you have the option of using application context within a fine-grained access control package.

Using Application Context as a Secure Data Cache

Accessing an application context inside your fine-grained access control policy function is like writing down an often-used phone number and posting it next to your phone, where you can find it easily, rather than looking it up every time you need it.

For example, suppose you base access to the `ORDERS_TAB` table on customer number. Rather than querying the customer number for a logged-in user each time you need it, you could store it in the application context. This way, the customer number is available when you need it.

Designing a Fine-Grained Access Control Policy to Return a Specific Predicate for an Attribute

Suppose an attribute of the Order Entry context is `position`. You can return different predicates depending on that attribute. Thus, you can enable a user in the `Clerk` position to retrieve all orders, but a user in the `Customer` position to see his own records only.

To design a fine-grained access control policy to return a specific predicate for an attribute, access the application context within the package that implements the policy. For example, to limit customers to seeing their own records only, use fine-grained access control to dynamically modify the user's query from this:

```
SELECT * FROM Orders_tab
```

to this:

```
SELECT * FROM Orders_tab
   WHERE Custno = SYS_CONTEXT ('order_entry', 'cust_num');
```

See Also: "Application Context" on page 12-22 and "Examples" on page 12-29.

Examples

This section provides three examples, each using application context within a fine-grained access control package.

Example 1: Order Entry Application

This simple example uses application context to implement the policy: 'Customers can see their own orders only.' This example guides you through the following tasks in building the application:

- Create a PL/SQL package which sets the context for the application
- Create an application context
- Access the application context inside the package that implements the security policy on the database object
- Create the new security policy

See Also: Compare and contrast this example, which uses an application context within the dynamically generated predicate, with "Example of a Dynamically Modified Statement" on page 12-27, which uses a subquery in the predicate.

The procedure in this example:

- Assumes a one-to-one relationship between users and customers
- Finds the user's customer number (`Cust_num`)

- Caches the customer number in the application context

You can later refer to the `cust_num` attribute of your order entry context (`order_entry_ctx`) inside the security policy package.

Note: You could use a logon trigger to set the initial context.

See Also: Chapter 13, "Using Triggers"

Create a PL/SQL package which sets the context for the application

```
CREATE OR REPLACE PACKAGE apps.oe_ctx AS
   PROCEDURE set_cust_num ;
END;

CREATE OR REPLACE PACKAGE BODY apps.oe_ctx AS
   PROCEDURE set_cust_num IS
     custnum NUMBER;
   BEGIN
      SELECT cust_no INTO custnum FROM customers WHERE username =
         SYS_CONTEXT('USERENV', 'session_user');
     /* SET cust_num attribute in 'order_entry' context */
         DBMS_SESSION.SET_CONTEXT('order_entry', 'cust_num', custnum);
         DBMS_SESSION.SET_CONTEXT('order_entry', 'cust_num', custnum);
   END set_cust_num;
 END;
```

Note: This example does not treat error handling.

You can access session primitives—such as session user—by using `SYS_CONTEXT('USERENV', desired session primitive)`.

For more information, see *Oracle8i SQL Reference.*

Create an application context

```
CREATE CONTEXT Order_entry USING Apps.Oe_ctx;
```

Access the application context inside the package that implements the security policy on the database object

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE PACKAGE Oe_security AS
FUNCTION Custnum_sec (D1 VARCHAR2, D2 VARCHAR2)
RETURN VARCHAR2;
END;
```

The package body appends a dynamic predicate to SELECT statements on the ORDERS_TAB table. This predicate limits the orders returned to those of the user's customer number by accessing the cust_num context attribute, instead of a subquery to the customers table.

```
CREATE OR REPLACE PACKAGE BODY Oe_security AS

/* limits select statements based on customer number: */
FUNCTION Custnum_sec (D1 VARCHAR2, D2 VARCHAR2) RETURN VARCHAR2
IS
    D_predicate VARCHAR2 (2000)
    BEGIN
     D_predicate = 'cust_no = SYS_CONTEXT("order_entry", "cust_num")';
     RETURN D_predicate;
    END Custnum_sec;
END Oe_security;
```

Create the new security policy

Note: You may need to set up the following data structures for certain examples to work:

```
CONNECT sys/change_on_install AS sysdba;
CREATE USER secusr IDENTIFIED BY secusr;
```

```
DBMS_RLS.ADD_POLICY ('scott', 'orders_tab', 'oe_policy', 'secusr',
                     'oe_security.custnum_sec', 'select')
```

This statement adds a policy named OE_POLICY to the ORDERS_TAB table for viewing in schema SCOTT. The SECUSR.OE_SECURITY.CUSTNUM_SEC function

implements the policy, is stored in the SECUSR schema, and applies to SELECT statements only.

Now, any select statement by a customer on the ORDERS_TAB table automatically returns only that customer's orders. In other words, the dynamic predicate modifies the user's statement from this:

```
SELECT * FROM Orders_tab;
```

to this:

```
SELECT * FROM Orders_tab
   WHERE Custno = SYS_CONTEXT('order_entry','cust_num');
```

Note the following with regard to this example:

- In reality, you might have several predicates based on a user's position. For example, a sales rep would be able to see records for all his customers, and an order entry clerk would be able to see any customer order. You could expand the custnum_sec function to return different predicates based on the user's position context value.
- The use of application context in a fine-grained access control package effectively gives you a bind variable in a parsed statement. For example:

  ```
  SELECT * FROM Orders_tab
     WHERE Custno = SYS_CONTEXT('order_entry', 'cust_num')
  ```

  This is fully parsed and optimized, but the evaluation of the user's CUST_NUM attribute value for the ORDER_ENTRY context takes place at execution. This means that you get the benefit of an optimized statement which executes differently for each user executing the statement.

  Note: You can improve the performance of the function in this example even more by indexing CUST_NO.

- You could set your context attributes based on data from a database table or tables, or from a directory server using LDAP (Lightweight Directory Access Protocol).

Example 2: Human Resources Application #1

This example uses application context to control user access by way of a Human Resources application. It guides you through the following three tasks, each of which is described more fully below.

- Create a PL/SQL package with a number of functions that sets the context for the application
- Create the context and associate it with the package
- Create the initialization script for the application

In this example, assume that the application context for the Human Resources application is assigned to the HR_CTX namespace.

Create a PL/SQL package with a number of functions that sets the context for the application

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE OR REPLACE PACKAGE apps.hr_sec_ctx IS
   PROCEDURE set_resp_id (respid NUMBER);
   PROCEDURE set_org_id (orgid NUMBER);
  /* PROCEDURE validate_respid (respid NUMBER); */
  /* PROCEDURE validate_org_id (orgid NUMBER); */
END hr_sec_ctx;
```

APPS is the schema owning the package.

```
CREATE OR REPLACE PACKAGE BODY apps.hr_sec_ctx IS
/* function to set responsibility id */
PROCEDURE set_resp_id (respid NUMBER) IS
BEGIN

/* validate respid based on primitive and other context */
/*    validate_respid (respid); */

/* set resp_id attribute under namespace 'hr_ctx'*/
    DBMS_SESSION.SET_CONTEXT('hr_ctx', 'resp_id', respid);
END set_resp_id;

/* function to set organization id */
PROCEDURE set_org_id (orgid NUMBER) IS
```

```
BEGIN
/* validate organization ID */
/*    validate_org_id(orgid); /*
/* set org_id attribute under namespace 'hr_ctx' */
    DBMS_SESSION.SET_CONTEXT('hr_ctx', 'org_id', orgid);
END set_org_id;

/* more functions to set other attributes for the HR application */
END hr_sec_ctx;
```

Create the context and associate it with the package

```
CREATE CONTEXT Hr_ctx USING Apps.Hr_sec_ctx;
```

Create the initialization script for the application

Suppose that the execute privilege on the package HR_SEC_CTX has been granted to the schema running the application. Part of the script will make calls to set various attributes of the HR_CTX context. Here, we do not show how the context is determined. Normally, it is based on the primitive context or other derived context.

```
APPS.HR_SEC_CTX.SET_RESP_ID(1);
APPS.HR_SEC_CTX.SET_ORG_ID(101);
```

The SYS_CONTEXT function can be used for data access control based on this application context. For example, the base table HR_ORGANIZATION_UNIT can be secured by a view that restricts access to rows based on attribute ORG_ID:

Caution: You may need to set up data structures for certain examples to work:

```
CREATE TABLE hr_organization_unit (organization_id NUMBER);
```

```
CREATE VIEW Hr_organization_secv AS
   SELECT * FROM hr_organization_unit
      WHERE Organization_id = SYS_CONTEXT('hr_ctx','org_id');
```

Example 3: Human Resources Application #2

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE TABLE Payroll(
   Srate  NUMBER,
   Orate  NUMBER,
   Acctno NUMBER,
   Empno  NUMBER,
   Name   VARCHAR2(20));
CREATE TABLE Directory_u(
   Empno NUMBER,
   Mgrno NUMBER,
   Rank  NUMBER);
CREATE SEQUENCE Empno_seq
CREATE SEQUENCE Rank_seq
```

This example illustrates the use of the following security features in Oracle8*i* release 8.1.4:

- Event triggers
- Application context
- Fine-grained access control
- Encapsulation of privileges in stored procedures

In this example, we associate a security policy with the table called DIRECTORY which has the following columns:

- EMPNO—identification number for each employee
- MGRID—employee identification number for the manager of each employee
- RANK—position of the employee in the corporate hierarchy

The security policy associated with this table has two elements:

- All users can find the MGRID for a specific EMPNO.

  To implement this, we create a definer's right package in the Human Resources schema (HR) to do SELECT on the table

- Managers can update the positions in the corporate hierarchy of only their direct subordinates. To do this they must use only the designated application.

To implement this:

* Define fine-grained access policies on the table based on EMPNO and application context.
* Set EMPNO by using a logon trigger.
* Set the application context by using the designated package for processing the updates (event triggers and application context).

Note: In this example, we grant UPDATE privileges on the table to public, because fine-grained access control prevents an unauthorized user from wrongly modifying a given row.

```
CONNECT system/manager AS sysdba
GRANT CONNECT,RESOURCE,UNLIMITED TABLESPACE,CREATE ANY CONTEXT, CREATE
PROCEDURE, CREATE ANY TRIGGER TO HR IDENTIFIED BY HR;
CONNECT hr/hr;
CREATE TABLE Directory (Empno   NUMBER(4) NOT NULL,
                        Mgrno   NUMBER(4) NOT NULL,
                        Rank    NUMBER(7,2) NOT NULL);

CREATE TABLE Payroll (Empno  NUMBER(4) NOT NULL,
                      Name   VARCHAR(30) NOT NULL );

/* seed the tables with a couple of managers: */
INSERT INTO Directory VALUES (1, 1, 1.0);
INSERT INTO Payroll VALUES (1, 'KING');
INSERT INTO Directory VALUES (2, 1, 5);
INSERT INTO Payroll VALUES (2, 'CLARK');

/* Create the sequence number for EMPNO: */
CREATE SEQUENCE Empno_seq START WITH 5;

/* Create the sequence number for RANK:  */
CREATE SEQUENCE Rank_seq START WITH 100;

CREATE OR REPLACE CONTEXT Hr_app USING Hr.Hr0_pck;
CREATE OR REPLACE CONTEXT Hr_sec USING Hr.Hr1_pck;

CREATE or REPLACE PACKAGE Hr0_pck IS
PROCEDURE adjustrankby1(Empno NUMBER);
END;
```

```
CREATE or REPLACE PACKAGE BODY Hr0_pck IS
/* raise the rank of the empno by 1:  */
PROCEDURE Adjustrankby1(Empno NUMBER)
IS
   Stmt   VARCHAR2(100);
   BEGIN

   /*Set context to indicate application state */
   DBMS_SESSION.SET_CONTEXT('hr_app','adjstate',1);
   /* Now we can issue DML statement:  */
   Stmt := 'UPDATE SET Rank := Rank +1 FROM Directory d WHERE d.Empno = '
   || Empno;
   EXECUTE IMMEDIATE STMT;

/* Re-set application state: */
   DBMS_SESSION.SET_CONTEXT('hr_app','adjstate',0);
   END;
END;

CREATE or REPLACE PACKAGE hr1_pck IS PROCEDURE setid;
END;
/
/* Based on userid, find EMPNO, and set it in application context */

CREATE or REPLACE PACKAGE BODY Hr1_pck IS
PROCEDURE setid
  IS
  id NUMBER;
  BEGIN
    SELECT Empno INTO id FROM Payroll WHERE Name =
      SYS_CONTEXT('userenv','session_user') ;
    DBMS_SESSION.SET_CONTEXT('hr_sec','empno',id);
    DBMS_SESSION.SET_CONTEXT('hr_sec','appid',id);
  EXCEPTION
    /* For purposes of demonstration insert into payroll table
    /  so that user can continue on and run example. */
    WHEN NO_DATA_FOUND THEN
      INSERT INTO Payroll (Empno, Name)
         VALUES (Empno_seq.NEXTVAL, SYS_CONTEXT('userenv','session_user'));
      INSERT INTO Directory (Empno, Mgrno, Rank)
         VALUES (Empno_seq.CURRVAL, 2, Rank_seq.NEXTVAL);
      SELECT Empno INTO id FROM Payroll WHERE Name =
        sys_context('userenv','session_user') ;
      DBMS_SESSION.SET_CONTEXT('hr_sec','empno',id);
      DBMS_SESSION.SET_CONTEXT('hr_sec','appid',id);
```

```
    WHEN OTHERS THEN
      NULL;
    /* If this is to be fired via a "logon" trigger,
    /  you need to handle exceptions if you want the user to continue
    /  logging into the database. */
  END;
END;

GRANT EXECUTE ON Hr1_pck TO public;

CONNECT system/manager AS sysdba

CREATE OR REPLACE TRIGGER Databasetrigger

AFTER LOGON
ON DATABASE
BEGIN
   hr.Hr1_pck.Setid;
END;

/* Creates the package for finding the MGRID for a particular EMPNO
using definer's right (encapsulated privileges). Note that users are
granted EXECUTE privileges only on this package, and not on the table
(DIRECTORY) it is querying. */

CREATE or REPLACE PACKAGE hr2_pck IS
   FUNCTION Findmgr(Empno NUMBER) RETURN NUMBER;
END;

CREATE or REPLACE PACKAGE BODY hr2_pck IS
   /* insert a new employee record: */
   FUNCTION findmgr(empno number) RETURN NUMBER IS
   Mgrid NUMBER;
   BEGIN
      SELECT mgrno INTO mgrid FROM directory WHERE mgrid = empno;
   RETURN mgrid;
   END;
END;

CREATE or REPLACE FUNCTION secure_updates(ns varchar2,na varchar2)
  RETURN VARCHAR2 IS
     Results VARCHAR2(100);
    BEGIN
       /* Only allow updates when designated application has set the session
        state to indicate we are inside it. */
```

```
      IF (sys_context('hr_sec','adjstate') = 1)
         THEN results := 'mgr = SYS_CONTEXT("hr_sec","empno")';
      ELSE results := '1=2';
     END IF;
     RETURN Results;
  END;

/* Attaches fine-grained access policy to all update operations on
hr.directory */

CONNECT system/manager AS sysdba;
BEGIN
   DBMS_RLS.ADD_POLICY('hr','directory_u','secure_update','hr',
                       'secure_updates','update',TRUE,TRUE);
END;
```

Part III

The Active Database

Part III contains the following chapters:

13

Using Triggers

Triggers are procedures that are stored in the database and implicitly run, or *fired*, when something happens.

Traditionally, triggers supported the execution of a PL/SQL block when an `INSERT`, `UPDATE`, or `DELETE` occurred on a table or view. With Oracle8*i*, triggers support system and other data events on `DATABASE` and `SCHEMA`. Oracle also supports the execution of a PL/SQL or Java procedure.

This chapter discusses DML triggers, `INSTEAD OF` triggers, and system triggers (triggers on `DATABASE` and `SCHEMA`). Topics include:

Designing Triggers

Use the following guidelines when designing your triggers:

- Use triggers to guarantee that when a specific operation is performed, related actions are performed.
- Do not define triggers that duplicate the functionality already built into Oracle. For example, do not define triggers to enforce data integrity rules that can be easily enforced using declarative integrity constraints.
- Limit the size of triggers. If the logic for your trigger requires much more than 60 lines of PL/SQL code, then it is better to include most of the code in a stored procedure and call the procedure from the trigger.
- Use triggers only for centralized, global operations that should be fired for the triggering statement, regardless of which user or database application issues the statement.
- **Do not create recursive triggers.** For example, creating an AFTER UPDATE statement trigger on the `Emp_tab` table that itself issues an UPDATE statement on `Emp_tab`, causes the trigger to fire recursively until it has run out of memory.
- Use triggers on DATABASE judiciously. They are executed for *every* user *every* time the event occurs on which the trigger is created.

Creating Triggers

Triggers are created using the CREATE TRIGGER statement. This statement can be used with any interactive tool, such as SQL*Plus or Enterprise Manager. When using an interactive tool, a single slash (/) on the last line is necessary to activate the CREATE TRIGGER statement.

The following statement creates a trigger for the Emp_tab table:

```
CREATE OR REPLACE TRIGGER Print_salary_changes
BEFORE DELETE OR INSERT OR UPDATE ON Emp_tab
FOR EACH ROW
WHEN (new.Empno > 0)
DECLARE
    sal_diff number;
BEGIN
    sal_diff  := :new.sal  - :old.sal;
    dbms_output.put('Old salary: ' || :old.sal);
    dbms_output.put('  New salary: ' || :new.sal);
    dbms_output.put_line('  Difference ' || sal_diff);
END;
/
```

If you enter a SQL statement, such as the following:

```
UPDATE Emp_tab SET sal = sal + 500.00 WHERE deptno = 10;
```

Then, the trigger fires once for each row that is updated, and it prints the new and old salaries, and the difference.

The CREATE (or CREATE OR REPLACE) statement fails if any errors exist in the PL/SQL block.

Note: The size of the trigger cannot be more than 32K.

The following sections use this example to illustrate the way that parts of a trigger are specified.

> **See Also:** For more realistic examples of CREATE TRIGGER statements, see "Examples of Trigger Applications" on page 13-34.

Prerequisites for Creating Triggers

Before creating any triggers, run the CATPROC.SQL script while connected as SYS. This script automatically runs all of the scripts required for, or used within, the procedural extensions to the Oracle Server.

> **See Also:** The location of this file is operating system dependent; see your platform-specific Oracle documentation.

Types of Triggers

A trigger is either a stored PL/SQL block or a PL/SQL, C, or Java procedure associated with a table, view, schema, or the database itself. Oracle automatically executes a trigger when a specified event takes place, which may be in the form of a system event or a DML statement being issued against the table.

Triggers can be:

- DML triggers on tables.
- INSTEAD OF triggers on views.

> **Note:** With Oracle8*i* release 8.1.5, INSTEAD OF triggers are only available with the Enterprise Edition. This may change in future releases.

- System triggers on DATABASE or SCHEMA: With DATABASE, triggers fire for each event for all users; with SCHEMA, triggers fire for each event for that specific user.

> **See Also:** *Oracle8i SQL Reference* explains the syntax for creating triggers.

Overview of System Events

You can create triggers to be fired on any of the following:

- DML statements (DELETE, INSERT, UPDATE)
- DDL statements (CREATE, ALTER, DROP)
- Database operations (SERVERERROR, LOGON, LOGOFF, STARTUP, SHUTDOWN)

System Event Publication Attributes

You can obtain certain event-specific attributes when the trigger is fired.

> **See Also:** Chapter 14, "Working With System Events".

Creating a trigger on DATABASE implies that the triggering event is outside the scope of a user (for example, database STARTUP and SHUTDOWN), and it applies to all users (for example, a trigger created on LOGON event by the DBA).

Creating a trigger on SCHEMA implies that the trigger is created in the current user's schema and is fired only for that user.

For each trigger, publication can be specified on DML and system events.

> **See Also:** "Triggering Event Publication" on page 13-54 and "Event Attribute Functions" in Chapter 14, "Working With System Events"

Naming Triggers

Trigger names must be unique with respect to other triggers in the same schema. Trigger names do not need to be unique with respect to other schema objects, such as tables, views, and procedures. For example, a table and a trigger can have the same name (however, to avoid confusion, this is not recommended).

Triggering Statement

The triggering statement specifies the following:

- The type of SQL statement or the system event, database event, or DDL event that fires the trigger body. The options include DELETE, INSERT, and UPDATE. One, two, or all three of these options can be included in the triggering statement specification.
- The table, view, DATABASE, or SCHEMA associated with the trigger.

> **Note:** Exactly one table or view can be specified in the triggering statement. If the INSTEAD OF option is used, then the triggering statement may only specify a view; conversely, if a view is specified in the triggering statement, then only the INSTEAD OF option may be used.

For example, the PRINT_SALARY_CHANGES trigger fires after any DELETE, INSERT, or UPDATE on the Emp_tab table. Any of the following statements trigger the PRINT_SALARY_CHANGES trigger given in the previous example:

```
DELETE FROM Emp_tab;
INSERT INTO Emp_tab VALUES ( . . . );
INSERT INTO Emp_tab SELECT . . . FROM . . . ;
UPDATE Emp_tab SET . . . ;
```

INSERT Trigger Behavior

INSERT triggers will fire during import and during SQL*Loader conventional loads. (For direct loads, triggers are disabled before the load.)

For example, you have three tables: A, B, and C. You also have an INSERT trigger on table A which looks from table B and inserts into table C. If you import table A, then table C is also updated.

Note: The IGNORE parameter determines whether triggers will be fired during import. If IGNORE=N (default), then import does not load an already existing table, so no pre-existing triggers will fire. If the table did not exist, then import creates and loads it before any triggers are defined, so again, they do not fire. If IGNORE=Y, then import loads rows into existing tables. Triggers will fire, and indexes will be maintained.

Column List for UPDATE

If a triggering statement specifies UPDATE, then an optional list of columns can be included in the triggering statement. If you include a column list, then the trigger is fired on an UPDATE statement only when one of the specified columns is updated. If you omit a column list, then the trigger is fired when any column of the associated table is updated. A column list cannot be specified for INSERT or DELETE triggering statements.

The previous example of the PRINT_SALARY_CHANGES trigger could include a column list in the triggering statement. For example:

```
. . . BEFORE DELETE OR INSERT OR UPDATE OF ename ON Emp_tab . . .
```

Usage Notes

- You cannot specify a column list for UPDATE with INSTEAD OF triggers.
- If the column specified in the UPDATE OF clause is an object column, then the trigger is also fired if any of the attributes of the object are modified.
- You cannot specify UPDATE OF clauses on collection columns.

BEFORE and AFTER Options

The BEFORE or AFTER option in the CREATE TRIGGER statement specifies exactly when to fire the trigger body in relation to the triggering statement that is being run. In a CREATE TRIGGER statement, the BEFORE or AFTER option is specified just before the triggering statement. For example, the PRINT_SALARY_CHANGES trigger in the previous example is a BEFORE trigger.

Note: AFTER row triggers are slightly more efficient than BEFORE row triggers. With BEFORE row triggers, affected data blocks must be read (logical read, not physical read) once for the trigger and then again for the triggering statement.

Alternatively, with AFTER row triggers, the data blocks must be read only once for both the triggering statement and the trigger.

INSTEAD OF Triggers

The INSTEAD OF option can also be used in triggers. INSTEAD OF triggers provide a transparent way of modifying views that cannot be modified directly through UPDATE, INSERT, and DELETE statements. These triggers are called INSTEAD OF triggers because, unlike other types of triggers, Oracle fires the trigger *instead* of executing the triggering statement. The trigger performs UPDATE, INSERT, or DELETE operations directly on the underlying tables.

You can write normal UPDATE, INSERT, and DELETE statements against the view, and the INSTEAD OF trigger works invisibly in the background to make the right actions take place.

INSTEAD OF triggers can only be activated for each row.

See Also: "FOR EACH ROW Option" on page 13-12

Usage Notes

- With Oracle8*i* release 8.1.5, INSTEAD OF triggers are only available with the Enterprise Edition. This may also be available in the Standard Edition in future releases.
- The INSTEAD OF option can *only* be used for triggers created over views.
- The BEFORE and AFTER options *cannot* be used for triggers created over views.
- The CHECK option for views is not enforced when inserts or updates to the view are done using INSTEAD OF triggers. The INSTEAD OF trigger body must enforce the check.

Views That Are Not Modifiable

A view cannot be modified by UPDATE, INSERT, or DELETE statements if the view query contains any of the following constructs:

- Set operators
- Group functions
- GROUP BY, CONNECT BY, or START WITH clauses
- The DISTINCT operator
- Joins (a subset of join views are updatable)

If a view contains pseudocolumns or expressions, then you can only update the view with an UPDATE statement that does not refer to any of the pseudocolumns or expressions.

INSTEAD OF Trigger Example

Note: You may need to set up the following data structures for this example to work:

```
CREATE TABLE Project_tab (
   Prj_level NUMBER,
   Projno    NUMBER,
   Resp_dept NUMBER);
CREATE TABLE Emp_tab (
   Empno     NUMBER NOT NULL,
   Ename     VARCHAR2(10),
   Job       VARCHAR2(9),
   Mgr       NUMBER(4),
   Hiredate  DATE,
   Sal       NUMBER(7,2),
   Comm      NUMBER(7,2),
   Deptno    NUMBER(2) NOT NULL);

CREATE TABLE Dept_tab (
   Deptno    NUMBER(2) NOT NULL,
   Dname     VARCHAR2(14),
   Loc       VARCHAR2(13),
   Mgr_no    NUMBER,
   Dept_type NUMBER);
```

The following example shows an INSTEAD OF trigger for inserting rows into the MANAGER_INFO view.

```
CREATE OR REPLACE VIEW manager_info AS
    SELECT e.ename, e.empno, d.dept_type, d.deptno, p.prj_level,
       p.projno
        FROM   Emp_tab e, Dept_tab d, Project_tab p
        WHERE  e.empno =  d.mgr_no
        AND    d.deptno = p.resp_dept;

CREATE OR REPLACE TRIGGER manager_info_insert
INSTEAD OF INSERT ON manager_info
REFERENCING NEW AS n                -- new manager information

FOR EACH ROW
DECLARE
   rowcnt number;
```

```
BEGIN
   SELECT COUNT(*) INTO rowcnt FROM Emp_tab WHERE empno = :n.empno;
   IF rowcnt = 0  THEN
       INSERT INTO Emp_tab (empno,ename) VALUES (:n.empno, :n.ename);
   ELSE
      UPDATE Emp_tab SET Emp_tab.ename = :n.ename
         WHERE Emp_tab.empno = :n.empno;
   END IF;
   SELECT COUNT(*) INTO rowcnt FROM Dept_tab WHERE deptno = :n.deptno;
   IF rowcnt = 0 THEN
      INSERT INTO Dept_tab (deptno, dept_type)
         VALUES(:n.deptno, :n.dept_type);
   ELSE
      UPDATE Dept_tab SET Dept_tab.dept_type = :n.dept_type
         WHERE Dept_tab.deptno = :n.deptno;
   END IF;
   SELECT COUNT(*) INTO rowcnt FROM Project_tab
      WHERE Project_tab.projno = :n.projno;
   IF rowcnt = 0 THEN
      INSERT INTO Project_tab (projno, prj_level)
         VALUES(:n.projno, :n.prj_level);
   ELSE
      UPDATE Project_tab SET Project_tab.prj_level = :n.prj_level
         WHERE Project_tab.projno = :n.projno;
   END IF;
END;
```

The actions shown for rows being inserted into the MANAGER_INFO view first test to see if appropriate rows already exist in the base tables from which MANAGER_INFO is derived. The actions then insert new rows or update existing rows, as appropriate. Similar triggers can specify appropriate actions for UPDATE and DELETE.

Object Views and INSTEAD OF Triggers

INSTEAD OF triggers provide the means to modify object view instances on the client-side through OCI calls.

> **See Also:** *Oracle Call Interface Programmer's Guide*

To modify an object materialized by an object view in the client-side object cache and flush it back to the persistent store, you must specify INSTEAD OF triggers, unless the object view is modifiable. If the object is read only, then it is not necessary to define triggers to pin it.

Triggers on Nested Table View Columns

INSTEAD OF triggers can also be created over nested table view columns. These triggers provide a way of updating elements of the nested table. They fire for each nested table element being modified. The row correlation variables inside the trigger correspond to the nested table element. This type of trigger also provides an additional correlation name for accessing the parent row that contains the nested table being modified.

Note: These triggers:

- Can only be defined over nested table columns in views.
- Fire only when the nested table elements are modified using the THE() or TABLE() clauses. They do not fire when a DML statement is performed on the view.

For example, consider a department view that contains a nested table of employees.

```
CREATE OR REPLACE VIEW Dept_view AS
SELECT d.Deptno, d.Dept_type, d.Dept_name,
   CAST (MULTISET ( SELECT e.Empno, e.Empname, e.Salary
      FROM Emp_tab e
      WHERE e.Deptno = d.Deptno) AS Amp_list_ Emplist
FROM Dept_tab d;
```

The CAST (MULTISET..) operator creates a multi-set of employees for each department. Now, if you want to modify the emplist column, which is the nested table of employees, then you can define an INSTEAD OF trigger over the column to handle the operation.

The following example shows how an insert trigger might be written:

```
CREATE OR REPLACE TRIGGER Dept_emplist_tr
   INSTEAD OF INSERT ON NESTED TABLE Emplist OF Dept_view
   REFERENCING NEW AS Employee
      PARENT AS Department
   FOR EACH ROW
BEGIN
-- The insert on the nested table is translated to an insert on the base table:
   INSERT INTO Emp_tab VALUES (
      :Employee.Empno, :Employee.Empname,:Employee.Salary, :Department.Deptno);
END;
```

Any INSERT into the nested table fires the trigger, and the Emp_tab table is filled with the correct values. For example:

```
INSERT INTO TABLE (SELECT d.Emplist FROM Dept_view d WHERE Deptno = 10)
   VALUES (1001, 'John Glenn', 10000)
```

The :department.deptno correlation variable in this example would have a value of 10.

FOR EACH ROW Option

The FOR EACH ROW option determines whether the trigger is a *row* trigger or a *statement* trigger. If you specify FOR EACH ROW, then the trigger fires once for each row of the table that is affected by the triggering statement. The absence of the FOR EACH ROW option indicates that the trigger fires only once for each applicable statement, but not separately for each row affected by the statement.

For example, you define the following trigger:

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE TABLE Emp_log (
   Emp_id     NUMBER,
   Log_date   DATE,
   New_salary NUMBER,
   Action     VARCHAR2(20));
```

```
CREATE OR REPLACE TRIGGER Log_salary_increase
AFTER UPDATE ON Emp_tab
FOR EACH ROW
WHEN (new.Sal > 1000)
BEGIN
    INSERT INTO Emp_log (Emp_id, Log_date, New_salary, Action)
       VALUES (:new.Empno, SYSDATE, :new.SAL, 'NEW SAL');
END;
```

Then, you enter the following SQL statement:

```
UPDATE Emp_tab SET Sal = Sal + 1000.0
    WHERE Deptno = 20;
```

If there are five employees in department 20, then the trigger fires five times when this statement is entered, because five rows are affected.

The following trigger fires only once for each UPDATE of the Emp_tab table:

```
CREATE OR REPLACE TRIGGER Log_emp_update
AFTER UPDATE ON Emp_tab
BEGIN
    INSERT INTO Emp_log (Log_date, Action)
        VALUES (SYSDATE, 'Emp_tab COMMISSIONS CHANGED');
END;
```

See Also: For the order of trigger firing, see *Oracle8i Concepts*.

The statement level triggers are useful for performing validation checks for the entire statement.

Note: You can only specify the FOR EACH ROW option for INSTEAD OF triggers.

WHEN Clause

Optionally, a trigger restriction can be included in the definition of a row trigger by specifying a Boolean SQL expression in a WHEN clause.

Note: A WHEN clause cannot be included in the definition of a statement trigger.

If included, then the expression in the WHEN clause is evaluated for each row that the trigger affects.

If the expression evaluates to TRUE for a row, then the trigger body is fired on behalf of that row. However, if the expression evaluates to FALSE or NOT TRUE for a row (unknown, as with nulls), then the trigger body is not fired for that row. The evaluation of the WHEN clause does not have an effect on the execution of the triggering SQL statement (in other words, the triggering statement is not rolled back if the expression in a WHEN clause evaluates to FALSE).

For example, in the PRINT_SALARY_CHANGES trigger, the trigger body is not run if the new value of Empno is zero, NULL, or negative. In more realistic examples, you might test if one column value is less than another.

The expression in a WHEN clause of a row trigger can include correlation names, which are explained below. The expression in a WHEN clause must be a SQL expression, and it cannot include a subquery. You cannot use a PL/SQL expression (including user-defined functions) in the WHEN clause.

Note: You cannot specify the WHEN clause for INSTEAD OF triggers.

The Trigger Body

The trigger body is a CALL procedure or a PL/SQL block that can include SQL and PL/SQL statements. The CALL procedure can be either a PL/SQL or a Java procedure that is encapsulated in a PL/SQL wrapper. These statements are run if the triggering statement is entered and if the trigger restriction (if included) evaluates to TRUE.

The trigger body for row triggers has some special constructs that can be included in the code of the PL/SQL block: correlation names and the REFERENCEING option, and the conditional predicates INSERTING, DELETING, and UPDATING.

Note: The INSERTING, DELETING, and UPDATING conditional predicates cannot be used for the CALL procedures; they can only be used in a PL/SQL block.

Example 1 This example illustrates how a DBA can monitor all users logging on:

Note: You may need to set up data structures similar to the following for certain examples to work:

```
CONNECT system/manager
GRANT ADMINISTER DATABASE TRIGGER TO scott;
CONNECT scott/tiger
CREATE TABLE audit_table (
   seq number,
   user_at  VARCHAR2(10),
   time_now DATE,
   term     VARCHAR2(10),
   job      VARCHAR2(10),
   proc     VARCHAR2(10),
   enum     NUMBER);
```

```
CREATE OR REPLACE PROCEDURE foo (c VARCHAR2) AS
   BEGIN
      INSERT INTO Audit_table (user_at) VALUES(c);
   END;

CREATE OR REPLACE TRIGGER logontrig AFTER LOGON ON DATABASE
CALL foo (sys.login_user)
/
```

Example 2 This example illustrates a trigger invoking a Java procedure:

```
CREATE OR REPLACE PROCEDURE Before_delete (Id IN NUMBER, Ename VARCHAR2)
IS language Java
name 'thjvTriggers.beforeDelete (oracle.sql.NUMBER, oracle.sql.CHAR)';

CREATE OR REPLACE TRIGGER Pre_del_trigger BEFORE DELETE ON Tab
FOR EACH ROW
CALL Before_delete (:old.Id, :old.Ename)
```

thjvTriggers.java

```
import java.sql.*
import java.io.*
import oracle.sql.*
import oracle.oracore.*
public class thjvTriggers
{
public state void
beforeDelete (NUMBER old_id, CHAR old_name)
Throws SQLException, CoreException
   {
   Connection conn = JDBCConnection.defaultConnection();
   Statement stmt = conn.CreateStatement();
   String sql = "insert into logtab values
   ("+ old_id.intValue() +", '"+ old_ename.toString() + ", BEFORE DELETE');
   stmt.exectueUpdate (sql);
   stmt.close();
   return;
   }
}
```

Accessing Column Values in Row Triggers

Within a trigger body of a row trigger, the PL/SQL code and SQL statements have access to the old and new column values of the current row affected by the

triggering statement. Two correlation names exist for every column of the table being modified: one for the old column value, and one for the new column value. Depending on the type of triggering statement, certain correlation names might not have any meaning.

- A trigger fired by an INSERT statement has meaningful access to new column values only. Because the row is being created by the INSERT, the old values are null.
- A trigger fired by an UPDATE statement has access to both old and new column values for both BEFORE and AFTER row triggers.
- A trigger fired by a DELETE statement has meaningful access to :old column values only. Because the row no longer exists after the row is deleted, the :new values are NULL. However, you cannot modify :new values: ORA-4084 is raised if you try to modify :new values.

The new column values are referenced using the new qualifier before the column name, while the old column values are referenced using the old qualifier before the column name. For example, if the triggering statement is associated with the Emp_tab table (with the columns SAL, COMM, etc.), then you can include statements in the trigger body. For example:

```
IF :new.Sal > 10000 . . .
IF :new.Sal < :old.Sal . . .
```

Old and new values are available in both BEFORE and AFTER row triggers. A new column value can be assigned in a BEFORE row trigger, but not in an AFTER row trigger (because the triggering statement takes effect before an AFTER row trigger is fired). If a BEFORE row trigger changes the value of new.column, then an AFTER row trigger fired by the same statement sees the change assigned by the BEFORE row trigger.

Correlation names can also be used in the Boolean expression of a WHEN clause. A colon must precede the old and new qualifiers when they are used in a trigger's body, but a colon is not allowed when using the qualifiers in the WHEN clause or the REFERENCING option.

INSTEAD OF Triggers on Nested Table View Columns

In the case of INSTEAD OF triggers on nested table view columns, the new and old qualifiers correspond to the new and old nested table elements. The parent row corresponding to this nested table element can be accessed using the parent qualifier. The parent correlation name is meaningful and valid only inside a nested table trigger.

REFERENCING Option

The REFERENCING option can be specified in a trigger body of a row trigger to avoid name conflicts among the correlation names and tables that might be named old or new. Because this is rare, this option is infrequently used.

For example, assume you have a table named new with columns field1 (number) and field2 (character). The following CREATE TRIGGER example shows a trigger associated with the new table that can use correlation names and avoid naming conflicts between the correlation names and the table name:

Note: You may need to set up the following data structures for certain examples to work:

```
CREATE TABLE new (
   field1     NUMBER,
   field2     VARCHAR2(20));
```

```
CREATE OR REPLACE TRIGGER Print_salary_changes
BEFORE UPDATE ON new
REFERENCING new AS Newest
FOR EACH ROW
BEGIN
   :Newest.Field2 := TO_CHAR (:newest.field1);
END;
```

Notice that the new qualifier is renamed to newest using the REFERENCING option, and it is then used in the trigger body.

Conditional Predicates

If more than one type of DML operation can fire a trigger (for example, ON INSERT OR DELETE OR UPDATE OF Emp_tab), then the trigger body can use the conditional predicates INSERTING, DELETING, and UPDATING to run specific blocks of code, depending on the type of statement that fires the trigger. Assume this is the triggering statement:

```
INSERT OR UPDATE ON Emp_tab
```

Within the code of the trigger body, you can include the following conditions:

```
IF INSERTING THEN . . . END IF;
IF UPDATING THEN . . . END IF;
```

The first condition evaluates to TRUE only if the statement that fired the trigger is an INSERT statement; the second condition evaluates to TRUE only if the statement that fired the trigger is an UPDATE statement.

In an UPDATE trigger, a column name can be specified with an UPDATING conditional predicate to determine if the named column is being updated. For example, assume a trigger is defined as the following:

```
CREATE OR REPLACE TRIGGER . . .
. . . UPDATE OF Sal, Comm ON Emp_tab . . .
BEGIN

. . . IF UPDATING ('SAL') THEN . . . END IF;

END;
```

The code in the THEN clause runs only if the triggering UPDATE statement updates the SAL column. The following statement fires the above trigger and causes the UPDATING (sal) conditional predicate to evaluate to TRUE:

```
UPDATE Emp_tab SET Sal = Sal + 100;
```

Error Conditions and Exceptions in the Trigger Body

If a predefined or user-defined error condition or exception is raised during the execution of a trigger body, then all effects of the trigger body, as well as the triggering statement, are rolled back (unless the error is trapped by an exception handler). Therefore, a trigger body can prevent the execution of the triggering statement by raising an exception. User-defined exceptions are commonly used in triggers that enforce complex security authorizations or integrity constraints.

The only exception to this is when the event under consideration is database STARTUP, SHUTDOWN, or LOGIN when the user logging in is SYSTEM. In these scenarios, only the trigger action is rolled back.

Triggers and Handling Remote Exceptions

A trigger that accesses a remote site cannot do remote exception handling if the network link is unavailable. For example:

```
CREATE OR REPLACE TRIGGER Example
AFTER INSERT ON Emp_tab
FOR EACH ROW
BEGIN
  INSERT INTO Emp_tab@Remote     -- <- compilation fails here
  VALUES ('x');                  --    when dblink is inaccessible
EXCEPTION
  WHEN OTHERS THEN
    INSERT INTO Emp_log
    VALUES ('x');
END;
```

A trigger is compiled when it is created. Thus, if a remote site is unavailable when the trigger must compile, then Oracle cannot validate the statement accessing the remote database, and the compilation fails. The previous example exception statement cannot run, because the trigger does not complete compilation.

Because stored procedures are stored in a compiled form, the work-around for the above example is as follows:

```
CREATE OR REPLACE TRIGGER Example
AFTER INSERT ON Emp_tab
FOR EACH ROW
BEGIN
   Insert_row_proc;
END;

CREATE OR REPLACE PROCEDURE Insert_row_proc AS
BEGIN
    INSERT INTO Emp_tab@Remote
    VALUES ('x');
EXCEPTION
   WHEN OTHERS THEN
       INSERT INTO Emp_log
       VALUES ('x');
END;
```

The trigger in this example compiles successfully and calls the stored procedure, which already has a validated statement for accessing the remote database; thus, when the remote INSERT statement fails because the link is down, the exception is caught.

Restrictions on Creating Triggers

Coding triggers requires some restrictions that are not required for standard PL/SQL blocks. The following sections discuss these restrictions.

Trigger Size The size of a trigger cannot be more than 32K.

Valid SQL Statements in Trigger Bodies The body of a trigger can contain DML SQL statements. It can also contain SELECT statements, but they must be SELECT... INTO... statements or the SELECT statement in the definition of a cursor.

DDL statements are not allowed in the body of a trigger. Also, no transaction control statements are allowed in a trigger. ROLLBACK, COMMIT, and SAVEPOINT cannot be used.For system triggers, {CREATE/ALTER/DROP} TABLE statements and ALTER...COMPILE are allowed.

> **Note:** A procedure called by a trigger cannot run the above transaction control statements, because the procedure runs within the context of the trigger body.

Statements inside a trigger can reference remote schema objects. However, pay special attention when calling remote procedures from within a local trigger. If a timestamp or signature mismatch is found during execution of the trigger, then the remote procedure is not run, and the trigger is invalidated.

LONG, LONG RAW, and LOB Datatypes LONG, LONG RAW, and LOB datatypes in triggers are subject to the following restrictions:

- A SQL statement within a trigger can insert data into a column of LONG or LONG RAW datatype.
- If data from a LONG or LONG RAW column can be converted to a constrained datatype (such as CHAR and VARCHAR2), then a LONG or LONG RAW column can be referenced in a SQL statement within a trigger. The maximum length for these datatypes is 32000 bytes.
- Variables cannot be declared using the LONG or LONG RAW datatypes.
- :NEW and :PARENT cannot be used with LONG or LONG RAW columns.
- LOB values for :NEW variables cannot be modified in the trigger body. For example:

```
:NEW.Column := ...
```

This is not allowed if column is of LOB datatype.

Note: Previously, column, in this example, would not have been allowed if it was an object, a varray, or a nested table. This restriction has been lifted in release 8.1.5.

References to Package Variables If an UPDATE or DELETE statement detects a conflict with a concurrent UPDATE, then Oracle performs a transparent ROLLBACK to SAVEPOINT and restarts the update. This can occur many times before the statement completes successfully. Each time the statement is restarted, the BEFORE statement trigger is fired again. The rollback to savepoint does not undo changes to any package variables referenced in the trigger. The package should include a counter variable to detect this situation.

Row Evaluation Order A relational database does not guarantee the order of rows processed by a SQL statement. Therefore, do not create triggers that depend on the order in which rows are processed. For example, do not assign a value to a global package variable in a row trigger if the current value of the global variable is dependent on the row being processed by the row trigger. Also, if global package variables are updated within a trigger, then it is best to initialize those variables in a BEFORE statement trigger.

When a statement in a trigger body causes another trigger to be fired, the triggers are said to be *cascading*. Oracle allows up to 32 triggers to cascade at any one time. However, you can effectively limit the number of trigger cascades using the initialization parameter OPEN_CURSORS, because a cursor must be opened for every execution of a trigger.

Trigger Evaluation Order Although any trigger can run a sequence of operations either in-line or by calling procedures, using multiple triggers of the same type enhances database administration by permitting the modular installation of applications that have triggers on the same tables.

Oracle executes all triggers of the same type before executing triggers of a different type. If you have multiple triggers of the same type on a single table, then Oracle chooses an arbitrary order to execute these triggers.

> **See Also:** *Oracle8i Concepts* has more information on the firing order of triggers.

Each subsequent trigger sees the changes made by the previously fired triggers. Each trigger can see the old and new values. The old values are the original values, and the new values are the current values, as set by the most recently fired UPDATE or INSERT trigger.

To ensure that multiple triggered actions occur in a specific order, you must consolidate these actions into a single trigger (for example, by having the trigger call a series of procedures).

You cannot open a database that contains multiple triggers of the same type if you are using any version of Oracle before release 7.1. You also cannot open such a database if your COMPATIBLE initialization parameter is set to a version earlier than 7.1.0. For system triggers, compatibility must be 8.1.0.

Mutating and Constraining Tables A *mutating* table is a table that is currently being modified by an UPDATE, DELETE, or INSERT statement, or it is a table that might need to be updated by the effects of a declarative DELETE CASCADE referential integrity constraint.

A *constraining* table is a table that a triggering statement might need to read either directly, for a SQL statement, or indirectly, for a declarative referential integrity constraint. A table is mutating or constraining only to the session that issued the statement in progress.

Tables are never considered mutating or constraining *for statement triggers* unless the trigger is fired as the result of a DELETE CASCADE. Views are not considered mutating or constraining in INSTEAD OF triggers.

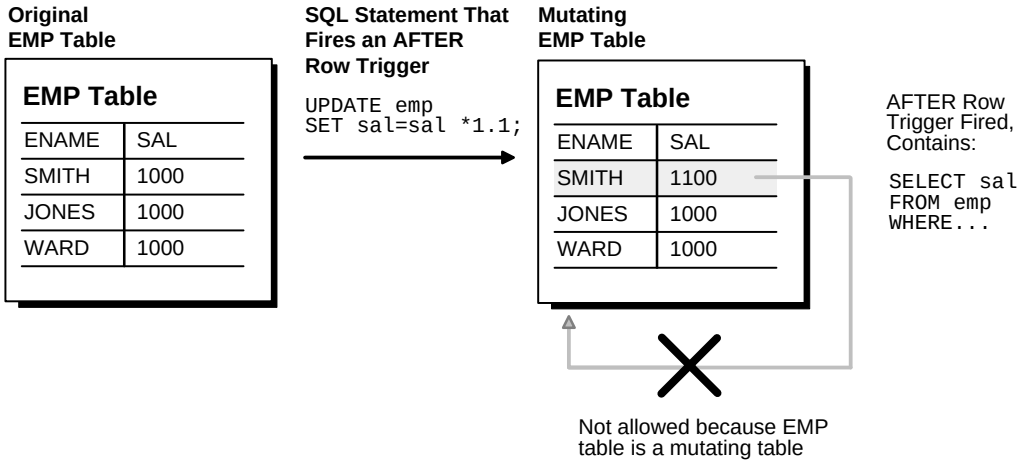
For all row triggers, or for statement triggers that were fired as the result of a DELETE CASCADE, there are two important restrictions regarding mutating and constraining tables. These restrictions prevent a trigger from seeing an inconsistent set of data.

- The SQL statements of a trigger cannot read from (query) or modify a mutating table of the triggering statement.
- The statements of a trigger cannot change the PRIMARY, FOREIGN, or UNIQUE KEY columns of a constraining table of the triggering statement.

  There is an exception to this restriction: For a single row INSERT, constraining tables are mutating for AFTER row triggers, but not for BEFORE row triggers. INSERT statements that involve more than one row, such as INSERT INTO Emp_tab SELECT..., are not considered single row inserts, even if they only result in one row being inserted.

Figure 13–1 illustrates the restriction placed on mutating tables.

Figure 13–1 Mutating Tables



Notice that the SQL statement is run for the first row of the table, and then an AFTER row trigger is fired. In turn, a statement in the AFTER row trigger body attempts to query the original table. However, because the EMP table is mutating, this query is not allowed by Oracle. If attempted, then a runtime error occurs, the effects of the trigger body and triggering statement are rolled back, and control is returned to the user or application.

Consider the following trigger:

```
CREATE OR REPLACE TRIGGER Emp_count
AFTER DELETE ON Emp_tab
FOR EACH ROW
DECLARE
    n INTEGER;
BEGIN
    SELECT COUNT(*) INTO n FROM Emp_tab;
    DBMS_OUTPUT.PUT_LINE(' There are now ' || n ||
        ' employees.');
END;
```

If the following SQL statement is entered:

```
DELETE FROM Emp_tab WHERE Empno = 7499;
```

Then, the following error is returned:

```
ORA-04091: table SCOTT.Emp_tab is mutating, trigger/function may not see it
```

Oracle returns this error when the trigger fires, because the table is mutating when the first row is deleted. (Only one row is deleted by the statement, because Empno is a primary key, but Oracle has no way of knowing that.)

If you delete the line "FOR EACH ROW" from the trigger above, then the trigger becomes a statement trigger, the table is not mutating when the trigger fires, and the trigger does output the correct data.

If you need to update a mutating or constraining table, then you could use a temporary table, a PL/SQL table, or a package variable to bypass these restrictions. For example, in place of a single AFTER row trigger that updates the original table, resulting in a mutating table error, you may be able to use two triggers—an AFTER row trigger that updates a temporary table, and an AFTER statement trigger that updates the original table with the values from the temporary table.

Declarative integrity constraints are checked at various times with respect to row triggers.

> **See Also:** *Oracle8i Concepts* has information about the interaction of triggers and integrity constraints.

Because declarative referential integrity constraints are currently not supported between tables on different nodes of a distributed database, the constraining table restrictions do not apply to triggers that access remote nodes. These restrictions are also not enforced among tables in the same database that are connected by loop-back database links. A loop-back database link makes a local table appear remote by defining a Net8 path back to the database that contains the link.

You should not use loop-back database links to circumvent the trigger restrictions. Such applications might behave unpredictably.

System Trigger Restrictions

Nature of the Event Depending on the event, the publication functionality imposes different restrictions. It may not be possible for the server to impose all restrictions. The restrictions that cannot be fully enforced are clearly documented. For example, certain DDL operations may not be allowed on DDL events.

Only committed triggers are fired. For example, if you create a trigger that should be fired after all CREATE events, then the trigger itself does not fire after the

creation, because the correct information about this trigger was not committed at the time when the trigger on CREATE events was fired. On the other hand, if you DROP a trigger that should be fired *before* all DROP events, then the trigger fires before the DROP.

For example, if you execute the following SQL statement:

```
CREATE OR REPLACE TRIGGER Foo AFTER CREATE ON DATABASE
BEGIN null;
END;
```

Then, trigger `foo` is not fired after the creation of `foo`. Oracle does not fire a trigger that is not committed.

See Also: For other restrictions, see "List of Events" on page 14-4.

Foreign Function Callouts All restrictions on foreign function callouts will also apply.

Who Is the Trigger User?

If you enter the following statement:

```
SELECT Username FROM USER_USERS;
```

Then, in a trigger, the name of the owner of the trigger is returned, not the name of user who is updating the table.

Privileges

Privileges to Create Triggers

To create a trigger in your schema, you must have the CREATE TRIGGER system privilege, and either:

- Own the table specified in the triggering statement, or
- Have the ALTER privilege for the table in the triggering statement, or
- Have the ALTER ANY TABLE system privilege

To create a trigger in another user's schema, you must have the CREATE ANY TRIGGER system privilege. With this privilege, the trigger can be created in any schema and can be associated with any user's table. In addition, the user creating the trigger must also have EXECUTE privilege on the referenced procedures, functions, or packages.

To create a trigger on DATABASE, you must have the ADMINISTER DATABASE TRIGGER privilege. If this privilege is later revoked, then you can drop the trigger, but not alter it.

Privileges for Referenced Schema Objects

The object privileges to the schema objects referenced in the trigger body must be granted to the trigger's owner explicitly (not through a role). The statements in the trigger body operate under the privilege domain of the trigger's owner, not the privilege domain of the user issuing the triggering statement. This is similar to stored procedures.

Compiling Triggers

Triggers are similar to PL/SQL anonymous blocks with the addition of the :new and :old capabilities, but their compilation is different. A PL/SQL anonymous block is compiled each time it is loaded into memory. Compilation involves three stages:

1. Syntax checking: PL/SQL syntax is checked, and a parse tree is generated.
2. Semantic checking: Type checking and further processing on the parse tree.
3. Code generation: The pcode is generated.

Triggers, in contrast, are fully compiled when the CREATE TRIGGER statement is entered, and the pcode is stored in the data dictionary. Hence, firing the trigger no longer requires the opening of a shared cursor to run the trigger action. Instead, the trigger is executed directly.

If errors occur during the compilation of a trigger, then the trigger is still created. If a DML statement fires this trigger, then the DML statement fails. (Runtime that trigger errors always cause the DML statement to fail.) You can use the SHOW ERRORS statement in SQL*Plus or Enterprise Manager to see any compilation errors when you create a trigger, or you can SELECT the errors from the USER_ERRORS view.

Dependencies

Compiled triggers have dependencies. They become invalid if a depended-on object, such as a stored procedure or function called from the trigger body, is modified. Triggers that are invalidated for dependency reasons are recompiled when next invoked.

You can examine the ALL_DEPENDENCIES view to see the dependencies for a trigger. For example, the following statement shows the dependencies for the triggers in the SCOTT schema:

```
SELECT NAME, REFERENCED_OWNER, REFERENCED_NAME, REFERENCED_TYPE
    FROM ALL_DEPENDENCIES
    WHERE OWNER = 'SCOTT' and TYPE = 'TRIGGER';
```

Triggers may depend on other functions or packages. If the function or package specified in the trigger is dropped, then the trigger is marked invalid. An attempt is made to validate the trigger on occurrence of the event. If the trigger cannot be validated successfully, then it is marked VALID WITH ERRORS, and the event fails.

Note:

- There is an exception for STARTUP events: STARTUP events succeed even if the trigger fails. There are also exceptions for SHUTDOWN events and for LOGON events if you login as SYSTEM.
- Because the DBMS_AQ package is used to enqueue a message, dependency between triggers and queues cannot be maintained.

Recompiling Triggers

Use the ALTER TRIGGER statement to recompile a trigger manually. For example, the following statement recompiles the PRINT_SALARY_CHANGES trigger:

```
ALTER TRIGGER Print_salary_changes COMPILE;
```

To recompile a trigger, you must own the trigger or have the ALTER ANY TRIGGER system privilege.

Migration Issues

Non-compiled triggers cannot be fired under compiled trigger releases (such as Oracle 7.3 and Oracle8). If you are upgrading from a non-compiled trigger release to a compiled trigger release, then all existing triggers must be compiled. The upgrade script `cat73xx.sql` invalidates all triggers, so that they are automatically recompiled when first run. (The *xx* stands for a variable minor release number.)

Downgrading from Oracle 7.3 or later to a release prior to 7.3 requires that you run the `cat73xxd.sql` downgrade script. This handles portability issues between stored and non-stored trigger releases.

Modifying Triggers

Like a stored procedure, a trigger cannot be explicitly altered: It must be replaced with a new definition. (The ALTER TRIGGER statement is used only to recompile, enable, or disable a trigger.)

When replacing a trigger, you must include the OR REPLACE option in the CREATE TRIGGER statement. The OR REPLACE option is provided to allow a new version of an existing trigger to replace the older version, without affecting any grants made for the original version of the trigger.

Alternatively, the trigger can be dropped using the DROP TRIGGER statement, and you can rerun the CREATE TRIGGER statement.

To drop a trigger, the trigger must be in your schema, or you must have the DROP ANY TRIGGER system privilege.

Debugging Triggers

You can debug a trigger using the same facilities available for stored procedures.

See Also: "Debugging" on page 10-49

Enabling and Disabling Triggers

A trigger can be in one of two distinct modes:

Enabled	An enabled trigger executes its trigger body if a triggering statement is entered and the trigger restriction (if any) evaluates to TRUE.
Disabled	A disabled trigger does not execute its trigger body, even if a triggering statement is entered and the trigger restriction (if any) evaluates to TRUE.

Enabling Triggers

By default, a trigger is automatically enabled when it is created; however, it can later be disabled. After you have completed the task that required the trigger to be disabled, re-enable the trigger, so that it fires when appropriate.

Enable a disabled trigger using the ALTER TRIGGER statement with the ENABLE option. To enable the disabled trigger named REORDER of the INVENTORY table, enter the following statement:

```
ALTER TRIGGER Reorder ENABLE;
```

All triggers defined for a specific table can be enabled with one statement using the ALTER TABLE statement with the ENABLE clause with the ALL TRIGGERS option. For example, to enable all triggers defined for the INVENTORY table, enter the following statement:

```
ALTER TABLE Inventory
    ENABLE ALL TRIGGERS;
```

Disabling Triggers

You might temporarily disable a trigger if:

- An object it references is not available.
- You need to perform a large data load, and you want it to proceed quickly without firing triggers.
- You are reloading data.

By default, triggers are enabled when first created. Disable a trigger using the ALTER TRIGGER statement with the DISABLE option.

For example, to disable the trigger named REORDER of the INVENTORY table, enter the following statement:

```
ALTER TRIGGER Reorder DISABLE;
```

All triggers associated with a table can be disabled with one statement using the ALTER TABLE statement with the DISABLE clause and the ALL TRIGGERS option. For example, to disable all triggers defined for the INVENTORY table, enter the following statement:

```
ALTER TABLE Inventory
    DISABLE ALL TRIGGERS;
```

Listing Information About Triggers

The following data dictionary views reveal information about triggers:

- USER_TRIGGERS
- ALL_TRIGGERS
- DBA_TRIGGERS

The new column, BASE_OBJECT_TYPE, specifies whether the trigger is based on DATABASE, SCHEMA, table, or view. The old column, TABLE_NAME, is null if the base object is not table or view.

The column ACTION_TYPE specifies whether the trigger is a call type trigger or a PL/SQL trigger.

The column TRIGGER_TYPE includes two additional values: BEFORE EVENT and AFTER EVENT, applicable only to system events.

The column TRIGGERING_EVENT includes all system and DML events.

> **See Also:** The *Oracle8i Reference* provides a complete description of these data dictionary views.

For example, assume the following statement was used to create the REORDER trigger:

Caution: You may need to set up data structures for certain examples to work:

```
CREATE OR REPLACE TRIGGER Reorder
AFTER UPDATE OF Parts_on_hand ON Inventory
FOR EACH ROW
WHEN(new.Parts_on_hand < new.Reorder_point)
DECLARE
   x NUMBER;
BEGIN
   SELECT COUNT(*) INTO x
      FROM Pending_orders
      WHERE Part_no = :new.Part_no;
   IF x = 0  THEN
      INSERT INTO Pending_orders
         VALUES (:new.Part_no, :new.Reorder_quantity,
                 sysdate);
   END IF;
END;
```

The following two queries return information about the REORDER trigger:

```
SELECT Trigger_type, Triggering_event, Table_name
   FROM USER_TRIGGERS
   WHERE Trigger_name = 'REORDER';

TYPE             TRIGGERING_STATEMENT       TABLE_NAME
---------------- -------------------------- ------------
AFTER EACH ROW   UPDATE                     INVENTORY

SELECT Trigger_body
   FROM USER_TRIGGERS
   WHERE Trigger_name = 'REORDER';

TRIGGER_BODY
-------------------------------------------
DECLARE
   x NUMBER;
BEGIN
   SELECT COUNT(*) INTO x
      FROM Pending_orders
      WHERE Part_no = :new.Part_no;
   IF x = 0
      THEN INSERT INTO Pending_orders
         VALUES (:new.Part_no, :new.Reorder_quantity,
            sysdate);
   END IF;
END;
```

Examples of Trigger Applications

You can use triggers in a number of ways to customize information management in an Oracle database. For example, triggers are commonly used to:

- Provide sophisticated auditing
- Prevent invalid transactions
- Enforce referential integrity (either those actions not supported by declarative integrity constraints or across nodes in a distributed database)
- Enforce complex business rules
- Enforce complex security authorizations
- Provide transparent event logging
- Automatically generate derived column values
- Enable building complex views that are updatable
- Track system events

This section provides an example of each of the above trigger applications. These examples are not meant to be used exactly as written: They are provided to assist you in designing your own triggers.

Auditing with Triggers

Triggers are commonly used to supplement the built-in auditing features of Oracle. Although triggers can be written to record information similar to that recorded by the `AUDIT` statement, triggers should be used only when more detailed audit information is required. For example, use triggers to provide value-based auditing on a per-row basis tables.

Sometimes, the Oracle `AUDIT` statement is considered a *security* audit facility, while triggers can provide *financial* audit facility.

When deciding whether to create a trigger to audit database activity, consider what Oracle's auditing features provide, compared to auditing defined by triggers.

DML and DDL Auditing	Standard auditing options permit auditing of DML and DDL statements regarding all types of schema objects and structures. Comparatively, *triggers* permit auditing of DML statements entered against tables, and DDL auditing at SCHEMA or DATABASE level.
Centralized Audit Trail	All database audit information is recorded centrally and automatically using the auditing features of Oracle.
Declarative Method	Auditing features enabled using the standard Oracle features are easier to declare and maintain, and less prone to errors, when compared to auditing functions defined by triggers.
Auditing Options can be Audited	Any changes to existing auditing options can also be audited to guard against malicious database activity.
Session and Execution time Auditing	Using the database auditing features, records can be generated once every time an audited statement is entered (BY ACCESS) or once for every session that enters an audited statement (BY SESSION). Triggers cannot audit by session; an audit record is generated each time a trigger-audited table is referenced.
Auditing of Unsuccessful Data Access	Database auditing can be set to audit when unsuccessful data access occurs. However, unless autonomous transactions are used, any audit information generated by a trigger is rolled back if the triggering statement is rolled back. For more information on autonomous transactions, see *Oracle8i Concepts*.
Sessions can be Audited	Connections and disconnections, as well as session activity (physical I/Os, logical I/Os, deadlocks, etc.), can be recorded using standard database auditing.

When using triggers to provide sophisticated auditing, AFTER triggers are normally used. By using AFTER triggers, auditing information is recorded after the triggering statement is subjected to any applicable integrity constraints, preventing cases where the audit processing is carried out unnecessarily for statements that generate exceptions to integrity constraints.

When to use AFTER row vs. AFTER statement triggers depends on the information being audited. For example, row triggers provide value-based auditing on a per-row basis for tables. Triggers can also require the user to supply a "reason code" for issuing the audited SQL statement, which can be useful in both row and statement-level auditing situations.

The following example demonstrates a trigger that audits modifications to the Emp_tab table on a per-row basis. It requires that a "reason code" be stored in a global package variable before the update. This shows how triggers can be used to provide value-based auditing and how to use public package variables.

Note: You may need to set up the following data structures for the examples to work:

```
CREATE OR REPLACE PACKAGE Auditpackage AS
   Reason VARCHAR2(10);
PROCEDURE Set_reason(Reason VARCHAR2);
END;
CREATE TABLE Emp99 (
   Empno               NOT NULL   NUMBER(4)
   Ename               VARCHAR2(10)
   Job                 VARCHAR2(9)
   Mgr                 NUMBER(4)
   Hiredate            DATE
   Sal                 NUMBER(7,2)
   Comm                NUMBER(7,2)
   Deptno              NUMBER(2)
   Bonus               NUMBER
   Ssn                 NUMBER
   Job_classification  NUMBER);

CREATE TABLE Audit_employee (
   Oldssn              NUMBER
   Oldname             VARCHAR2(10)
   Oldjob              VARCHAR2(2)
   Oldsal              NUMBER
   Newssn              NUMBER
   Newname             VARCHAR2(10)
   Newjob              VARCHAR2(2)
   Newsal              NUMBER
   Reason              VARCHAR2(10)
   User1               VARCHAR2(10)
   Systemdate          DATE);
```

```
CREATE OR REPLACE TRIGGER Audit_employee
AFTER INSERT OR DELETE OR UPDATE ON Emp99
FOR EACH ROW
BEGIN
/* AUDITPACKAGE is a package with a public package
   variable REASON.  REASON could be set by the
   application by a command such as EXECUTE
   AUDITPACKAGE.SET_REASON(reason_string). Note that a
   package variable has state for the duration of a
   session and that each session has a separate copy of
   all package variables. */

IF Auditpackage.Reason IS NULL THEN
   Raise_application_error(-20201, 'Must specify reason'
      || ' with AUDITPACKAGE.SET_REASON(Reason_string)');
END IF;

/* If the above conditional evaluates to TRUE, the
   user-specified error number and message is raised,
   the trigger stops execution, and the effects of the
   triggering statement are rolled back.  Otherwise, a
   new row is inserted into the predefined auditing
   table named AUDIT_EMPLOYEE containing the existing
   and new values of the Emp_tab table and the reason code
   defined by the REASON variable of AUDITPACKAGE.  Note
   that the "old" values are NULL if triggering
   statement is an INSERT and the "new" values are NULL
   if the triggering statement is a DELETE. */

INSERT INTO Audit_employee VALUES
   (:old.Ssn, :old.Ename, :old.Job_classification, :old.Sal,
   :new.Ssn, :new.Ename, :new.Job_classification, :new.Sal,
   auditpackage.Reason, User, Sysdate );
END;
```

Optionally, you can also set the reason code back to NULL if you wanted to force the reason code to be set for every update. The following simple AFTER statement trigger sets the reason code back to NULL after the triggering statement is run:

```
CREATE OR REPLACE TRIGGER Audit_employee_reset
AFTER INSERT OR DELETE OR UPDATE ON Emp_tab
BEGIN
   auditpackage.set_reason(NULL);
END;
```

Notice that the previous two triggers are both fired by the same type of SQL statement. However, the AFTER row trigger is fired once for each row of the table affected by the triggering statement, while the AFTER statement trigger is fired only once after the triggering statement execution is completed.

Another example of using triggers to do auditing is shown below. This trigger tracks changes made to the Emp_tab table and stores this information in AUDIT_TABLE and AUDIT_TABLE_VALUES.

Note: You may need to set up the following data structures for the example to work:

```
CREATE TABLE Audit_table (
   Seq      NUMBER,
   User_at  VARCHAR2(10),
   Time_now DATE,
   Term     VARCHAR2(10),
   Job      VARCHAR2(10),
   Proc     VARCHAR2(10),
   enum     NUMBER);
CREATE SEQUENCE Audit_seq;
CREATE TABLE Audit_table_values (
   Seq      NUMBER,
   Dept     NUMBER,
   Dept1    NUMBER,
   Dept2    NUMBER);
```

```
CREATE OR REPLACE TRIGGER Audit_emp
   AFTER INSERT OR UPDATE OR DELETE ON Emp_tab
   FOR EACH ROW
   DECLARE
      Time_now DATE;
      Terminal CHAR(10);
   BEGIN
      -- get current time, and the terminal of the user:
      Time_now := SYSDATE;
      Terminal := USERENV('TERMINAL');
      -- record new employee primary key
      IF INSERTING THEN
         INSERT INTO Audit_table
            VALUES (Audit_seq.NEXTVAL, User, Time_now,
               Terminal, 'Emp_tab', 'INSERT', :new.Empno);
      -- record primary key of the deleted row:
      ELSIF DELETING THEN
         INSERT INTO Audit_table
            VALUES (Audit_seq.NEXTVAL, User, Time_now,
               Terminal, 'Emp_tab', 'DELETE', :old.Empno);
      -- for updates, record the primary key
      -- of the row being updated:
      ELSE
         INSERT INTO Audit_table
            VALUES (audit_seq.NEXTVAL, User, Time_now,
               Terminal, 'Emp_tab', 'UPDATE', :old.Empno);
         -- and for SAL and DEPTNO, record old and new values:
         IF UPDATING ('SAL') THEN
            INSERT INTO Audit_table_values
               VALUES (Audit_seq.CURRVAL, 'SAL',
                  :old.Sal, :new.Sal);

         ELSIF UPDATING ('DEPTNO') THEN
            INSERT INTO Audit_table_values
               VALUES (Audit_seq.CURRVAL, 'DEPTNO',
                  :old.Deptno, :new.DEPTNO);
         END IF;
      END IF;
END;
```

Integrity Constraints and Triggers

Triggers and declarative integrity constraints can both be used to constrain data input. However, triggers and integrity constraints have significant differences.

Declarative integrity constraints are statements about the database that are always true. A constraint applies to existing data in the table and any statement that manipulates the table.

See Also: Chapter 5, "Maintaining Data Integrity"

Triggers constrain what a transaction can do. A trigger does not apply to data loaded before the definition of the trigger; therefore, it is not known if all data in a table conforms to the rules established by an associated trigger.

Although triggers can be written to enforce many of the same rules supported by Oracle's declarative integrity constraint features, triggers should only be used to enforce complex business rules that cannot be defined using standard integrity constraints. The declarative integrity constraint features provided with Oracle offer the following advantages when compared to constraints defined by triggers:

Centralized Integrity Checks	All points of data access must adhere to the global set of rules defined by the integrity constraints corresponding to each schema object.
Declarative Method	Constraints defined using the standard integrity constraint features are much easier to write and are less prone to errors, when compared with comparable constraints defined by triggers.

While most aspects of data integrity can be defined and enforced using declarative integrity constraints, triggers can be used to enforce complex business constraints not definable using declarative integrity constraints. For example, triggers can be used to enforce:

- UPDATE and DELETE SET NULL, and UPDATE and DELETE SET DEFAULT referential actions.
- Referential integrity when the parent and child tables are on different nodes of a distributed database.
- Complex check constraints not definable using the expressions allowed in a CHECK constraint.

Referential Integrity Using Triggers

Many cases of referential integrity can be enforced using triggers. However, only use triggers when you want to enforce the UPDATE and DELETE SET NULL (when referenced data is updated or deleted, all associated dependent data is set to NULL), and UPDATE and DELETE SET DEFAULT (when referenced data is updated or deleted, all associated dependent data is set to a default value) referential actions, or when you want to enforce referential integrity between parent and child tables on different nodes of a distributed database.

When using triggers to maintain referential integrity, declare the PRIMARY (or UNIQUE) KEY constraint in the parent table. If referential integrity is being maintained between a parent and child table in the same database, then you can also declare the foreign key in the child table, but disable it; this prevents the corresponding PRIMARY KEY constraint from being dropped (unless the PRIMARY KEY constraint is explicitly dropped with the CASCADE option).

To maintain referential integrity using triggers:

- A trigger must be defined for the child table that guarantees values inserted or updated in the foreign key correspond to values in the parent key.
- One or more triggers must be defined for the parent table. These triggers guarantee the desired referential action (RESTRICT, CASCADE, or SET NULL) for values in the foreign key when values are updated or deleted in the parent key. No action is required for inserts into the parent table (no dependent foreign keys exist).

The following sections provide examples of the triggers necessary to enforce referential integrity. The Emp_tab and Dept_tab table relationship is used in these examples.

Several of the triggers include statements that lock rows (SELECT... FOR UPDATE). This operation is necessary to maintain concurrency as the rows are being processed.

Foreign Key Trigger for Child Table The following trigger guarantees that before an INSERT or UPDATE statement affects a foreign key value, the corresponding value exists in the parent key. The mutating table exception included in the example below allows this trigger to be used with the UPDATE_SET_DEFAULT and UPDATE_CASCADE triggers. This exception can be removed if this trigger is used alone.

```
CREATE OR REPLACE TRIGGER Emp_dept_check
BEFORE INSERT OR UPDATE OF Deptno ON Emp_tab
FOR EACH ROW WHEN (new.Deptno IS NOT NULL)

-- Before a row is inserted, or DEPTNO is updated in the Emp_tab
-- table, fire this trigger to verify that the new foreign
-- key value (DEPTNO) is present in the Dept_tab table.
DECLARE
   Dummy              INTEGER;  -- used for cursor fetch below
   Invalid_department EXCEPTION;
   Valid_department   EXCEPTION;
   Mutating_table     EXCEPTION;
   PRAGMA EXCEPTION_INIT (Mutating_table, -4091);

-- Cursor used to verify parent key value exists.  If
-- present, lock parent key's row so it can't be
-- deleted by another transaction until this
-- transaction is committed or rolled back.
  CURSOR Dummy_cursor (Dn NUMBER) IS
   SELECT Deptno FROM Dept_tab
      WHERE Deptno = Dn
         FOR UPDATE OF Deptno;
BEGIN
   OPEN Dummy_cursor (:new.Deptno);
   FETCH Dummy_cursor INTO Dummy;

   -- Verify parent key.  If not found, raise user-specified
   -- error number and message.  If found, close cursor
   -- before allowing triggering statement to complete:
   IF Dummy_cursor%NOTFOUND THEN
      RAISE Invalid_department;
   ELSE
      RAISE valid_department;
   END IF;
   CLOSE Dummy_cursor;
EXCEPTION
   WHEN Invalid_department THEN
      CLOSE Dummy_cursor;
      Raise_application_error(-20000, 'Invalid Department'
         || ' Number' || TO_CHAR(:new.deptno));
   WHEN Valid_department THEN
      CLOSE Dummy_cursor;
   WHEN Mutating_table THEN
      NULL;
END;
```

UPDATE and DELETE RESTRICT Trigger for Parent Table The following trigger is defined on the DEPT_TAB table to enforce the UPDATE and DELETE RESTRICT referential action on the primary key of the DEPT_TAB table:

```
CREATE OR REPLACE TRIGGER Dept_restrict
BEFORE DELETE OR UPDATE OF Deptno ON Dept_tab
FOR EACH ROW

-- Before a row is deleted from Dept_tab or the primary key
-- (DEPTNO) of Dept_tab is updated, check for dependent
-- foreign key values in Emp_tab; rollback if any are found.
DECLARE
   Dummy                INTEGER;      -- used for cursor fetch below
   Employees_present    EXCEPTION;
   employees_not_present EXCEPTION;

   -- Cursor used to check for dependent foreign key values.
   CURSOR Dummy_cursor (Dn NUMBER) IS
      SELECT Deptno FROM Emp_tab WHERE Deptno = Dn;

BEGIN
   OPEN Dummy_cursor (:old.Deptno);
   FETCH Dummy_cursor INTO Dummy;
   -- If dependent foreign key is found, raise user-specified
   -- error number and message.  If not found, close cursor
   -- before allowing triggering statement to complete.
   IF Dummy_cursor%FOUND THEN
      RAISE Employees_present;     -- dependent rows exist
   ELSE
      RAISE Employees_not_present; -- no dependent rows
   END IF;
   CLOSE Dummy_cursor;

EXCEPTION
   WHEN Employees_present THEN
      CLOSE Dummy_cursor;
      Raise_application_error(-20001, 'Employees Present in'
         || ' Department ' || TO_CHAR(:old.DEPTNO));
   WHEN Employees_not_present THEN
      CLOSE Dummy_cursor;
END;
```

Caution: This trigger does not work with self-referential tables (tables with both the primary/unique key and the foreign key). Also, this trigger does not allow triggers to cycle (such as, A fires B fires A).

UPDATE and DELETE SET NULL Triggers for Parent Table The following trigger is defined on the DEPT_TAB table to enforce the UPDATE and DELETE SET NULL referential action on the primary key of the DEPT_TAB table:

```
CREATE OR REPLACE TRIGGER Dept_set_null
AFTER DELETE OR UPDATE OF Deptno ON Dept_tab
FOR EACH ROW

-- Before a row is deleted from Dept_tab or the primary key
-- (DEPTNO) of Dept_tab is updated, set all corresponding
-- dependent foreign key values in Emp_tab to NULL:
BEGIN
   IF UPDATING AND :OLD.Deptno != :NEW.Deptno OR DELETING THEN
      UPDATE Emp_tab SET Emp_tab.Deptno = NULL
         WHERE Emp_tab.Deptno = :old.Deptno;
   END IF;
END;
```

DELETE Cascade Trigger for Parent Table The following trigger on the DEPT_TAB table enforces the DELETE CASCADE referential action on the primary key of the DEPT_TAB table:

```
CREATE OR REPLACE TRIGGER Dept_del_cascade
AFTER DELETE ON Dept_tab
FOR EACH ROW

-- Before a row is deleted from Dept_tab, delete all
-- rows from the Emp_tab table whose DEPTNO is the same as
-- the DEPTNO being deleted from the Dept_tab table:
BEGIN
   DELETE FROM Emp_tab
      WHERE Emp_tab.Deptno = :old.Deptno;
END;
```

> **Note:** Typically, the code for DELETE CASCADE is combined with the code for UPDATE SET NULL or UPDATE SET DEFAULT to account for both updates and deletes.

UPDATE Cascade Trigger for Parent Table The following trigger ensures that if a department number is updated in the Dept_tab table, then this change is propagated to dependent foreign keys in the Emp_tab table:

```
-- Generate a sequence number to be used as a flag for
-- determining if an update has occurred on a column:
CREATE SEQUENCE Update_sequence
    INCREMENT BY 1 MAXVALUE 5000
    CYCLE;

CREATE OR REPLACE PACKAGE Integritypackage AS
   Updateseq NUMBER;
END Integritypackage;

CREATE OR REPLACE PACKAGE BODY Integritypackage AS
END Integritypackage;
-- create flag col:
ALTER TABLE Emp_tab ADD Update_id NUMBER;   .

CREATE OR REPLACE TRIGGER Dept_cascade1 BEFORE UPDATE OF Deptno ON Dept_tab
DECLARE
   Dummy NUMBER;

-- Before updating the Dept_tab table (this is a statement
-- trigger), generate a new sequence number and assign
-- it to the public variable UPDATESEQ of a user-defined
-- package named INTEGRITYPACKAGE:
BEGIN
   SELECT Update_sequence.NEXTVAL
      INTO Dummy
      FROM dual;
   Integritypackage.Updateseq := Dummy;
END;

CREATE OR REPLACE TRIGGER Dept_cascade2 AFTER DELETE OR UPDATE
   OF Deptno ON Dept_tab FOR EACH ROW

-- For each department number in Dept_tab that is updated,
-- cascade the update to dependent foreign keys in the
```

```
-- Emp_tab table.  Only cascade the update if the child row
-- has not already been updated by this trigger:
BEGIN
   IF UPDATING THEN
      UPDATE Emp_tab
         SET Deptno = :new.Deptno,
         Update_id = Integritypackage.Updateseq   --from 1st
         WHERE Emp_tab.Deptno = :old.Deptno
         AND Update_id IS NULL;
         /* only NULL if not updated by the 3rd trigger
            fired by this same triggering statement */
   END IF;
   IF DELETING THEN

   -- Before a row is deleted from Dept_tab, delete all
   -- rows from the Emp_tab table whose DEPTNO is the same as
   -- the DEPTNO being deleted from the Dept_tab table:
      DELETE FROM Emp_tab
      WHERE Emp_tab.Deptno = :old.Deptno;
   END IF;
END;
CREATE OR REPLACE TRIGGER Dept_cascade3 AFTER UPDATE OF Deptno ON Dept_tab
BEGIN  UPDATE Emp_tab
   SET Update_id = NULL
   WHERE Update_id = Integritypackage.Updateseq;
END;
```

Note: Because this trigger updates the `Emp_tab` table, the `Emp_dept_check` trigger, if enabled, is also fired. The resulting mutating table error is trapped by the `Emp_dept_check` trigger. You should carefully test any triggers that require error trapping to succeed to ensure that they always work properly in your environment.

Complex Check Constraints

Triggers can enforce integrity rules other than referential integrity. For example, this trigger performs a complex check before allowing the triggering statement to run.

Note: You may need to set up the following data structures for the example to work:

```
CREATE TABLE Salgrade (
   Grade                NUMBER,
   Losal                NUMBER,
   Hisal                NUMBER,
   Job_classification   NUMBER)
```

```
CREATE OR REPLACE TRIGGER Salary_check
BEFORE INSERT OR UPDATE OF Sal, Job ON Emp99
FOR EACH ROW
DECLARE
   Minsal               NUMBER;
   Maxsal               NUMBER;
   Salary_out_of_range  EXCEPTION;
BEGIN

/* Retrieve the minimum and maximum salary for the
   employee's new job classification from the SALGRADE
   table into MINSAL and MAXSAL: */

SELECT Minsal, Maxsal INTO Minsal, Maxsal FROM Salgrade
   WHERE Job_classification = :new.Job;


/* If the employee's new salary is less than or greater
   than the job classification's limits, the exception is
   raised.  The exception message is returned and the
   pending INSERT or UPDATE statement that fired the
   trigger is rolled back:*/

   IF (:new.Sal < Minsal OR :new.Sal > Maxsal) THEN
      RAISE Salary_out_of_range;
   END IF;
EXCEPTION
   WHEN Salary_out_of_range THEN
      Raise_application_error (-20300,
         'Salary '||TO_CHAR(:new.Sal)||' out of range for '
```

```
         ||'job classification '||:new.Job
         ||' for employee '||:new.Ename);
   WHEN NO_DATA_FOUND THEN
      Raise_application_error(-20322,
         'Invalid Job Classification '
         ||:new.Job_classification);
END;
```

Complex Security Authorizations and Triggers

Triggers are commonly used to enforce complex security authorizations for table data. Only use triggers to enforce complex security authorizations that cannot be defined using the database security features provided with Oracle. For example, a trigger can prohibit updates to salary data of the `Emp_tab` table during weekends, holidays, and non-working hours.

When using a trigger to enforce a complex security authorization, it is best to use a BEFORE statement trigger. Using a BEFORE statement trigger has these benefits:

- The security check is done before the triggering statement is allowed to run, so that no wasted work is done by an unauthorized statement.
- The security check is performed only once for the triggering statement, not for each row affected by the triggering statement.

This example shows a trigger used to enforce security.

> **Note:** You may need to set up the following data structures for the example to work:
>
> ```
> CREATE TABLE Company_holidays (Day DATE);
> ```

```
CREATE OR REPLACE TRIGGER Emp_permit_changes
BEFORE INSERT OR DELETE OR UPDATE ON Emp99
DECLARE
   Dummy             INTEGER;
   Not_on_weekends   EXCEPTION;
   Not_on_holidays   EXCEPTION;
   Non_working_hours EXCEPTION;
BEGIN
   /* check for weekends: */
   IF (TO_CHAR(Sysdate, 'DY') = 'SAT' OR
      TO_CHAR(Sysdate, 'DY') = 'SUN') THEN
      RAISE Not_on_weekends;
   END IF;
```

```
   /* check for company holidays:*/
   SELECT COUNT(*) INTO Dummy FROM Company_holidays
      WHERE TRUNC(Day) = TRUNC(Sysdate);
      /* TRUNC gets rid of time parts of dates: */
   IF dummy > 0 THEN
      RAISE Not_on_holidays;
   END IF;
   /* Check for work hours (8am to 6pm): */
   IF (TO_CHAR(Sysdate, 'HH24') < 8 OR
       TO_CHAR(Sysdate, 'HH24') > 18) THEN
       RAISE Non_working_hours;
   END IF;
EXCEPTION
   WHEN Not_on_weekends THEN
      Raise_application_error(-20324,'May not change '
         ||'employee table during the weekend');
   WHEN Not_on_holidays THEN
      Raise_application_error(-20325,'May not change '
         ||'employee table during a holiday');
   WHEN Non_working_hours THEN
      Raise_application_error(-20326,'May not change '
      ||'Emp_tab table during non-working hours');
END;
```

Transparent Event Logging and Triggers

Triggers are very useful when you want to transparently perform a related change in the database following certain events.

The REORDER trigger example shows a trigger that reorders parts as necessary when certain conditions are met. (In other words, a triggering statement is entered, and the PARTS_ON_HAND value is less than the REORDER_POINT value.)

Derived Column Values and Triggers

Triggers can derive column values automatically, based upon a value provided by an INSERT or UPDATE statement. This type of trigger is useful to force values in specific columns that depend on the values of other columns in the same row. BEFORE row triggers are necessary to complete this type of operation for the following reasons:

- The dependent values must be derived before the INSERT or UPDATE occurs, so that the triggering statement can use the derived values.
- The trigger must fire for each row affected by the triggering INSERT or UPDATE statement.

The following example illustrates how a trigger can be used to derive new column values for a table whenever a row is inserted or updated.

Note: You may need to set up the following data structures for the example to work:

```
ALTER TABLE Emp99 ADD(
   Uppername   VARCHAR2(20),
   Soundexname VARCHAR2(20));
```

```
CREATE OR REPLACE TRIGGER Derived
BEFORE INSERT OR UPDATE OF Ename ON Emp99

/* Before updating the ENAME field, derive the values for
   the UPPERNAME and SOUNDEXNAME fields. Users should be
   restricted from updating these fields directly: */
FOR EACH ROW
BEGIN
   :new.Uppername := UPPER(:new.Ename);
   :new.Soundexname := SOUNDEX(:new.Ename);
END;
```

Building Complex Updatable Views

Views are an excellent mechanism to provide logical windows over table data. However, when the view query gets complex, the system implicitly cannot translate the DML on the view into those on the underlying tables. INSTEAD OF triggers help solve this problem. These triggers can be defined over views, and they fire *instead* of the actual DML.

Consider a library system where books are arranged under their respective titles. The library consists of a collection of book type objects. The following example explains the schema.

```
CREATE OR REPLACE TYPE Book_t AS OBJECT
(
   Booknum   NUMBER,
   Title     VARCHAR2(20),
   Author    VARCHAR2(20),
   Available CHAR(1)
);
CREATE OR REPLACE TYPE Book_list_t AS TABLE OF Book_t;
```

Assume that the following tables exist in the relational schema:

```
Table Book_table (Booknum, Section, Title, Author, Available)
```

Booknum	Section	Title	Author	Available
121001	Classic	Iliad	Homer	Y
121002	Novel	Gone With the Wind	Mitchell M	N

Library consists of `library_table(section)`.

Section
Geography
Classic

Now you can define a complex view over these tables to create a logical view of the library with sections and a collection of books in each section.

```
CREATE OR REPLACE VIEW Library_view AS
SELECT i.Section, CAST (MULTISET (
   SELECT b.Booknum, b.Title, b.Author, b.Available
   FROM Book_table b
   WHERE b.Section = i.Section) AS Book_list_t) BOOKLIST
FROM Library_table i;
```

Make this view updatable by defining an `INSTEAD OF` trigger over the view.

```
CREATE OR REPLACE TRIGGER Library_trigger INSTEAD OF INSERT ON Library_view FOR
EACH ROW
   Bookvar BOOK_T;
   i       INTEGER;
```

```
BEGIN
   INSERT INTO Library_table VALUES (:NEW.Section);
   FOR i IN 1..:NEW.Booklist.COUNT LOOP
      Bookvar := Booklist(i);
      INSERT INTO book_table
         VALUES ( Bookvar.booknum, :NEW.Section, Bookvar.Title, Bookvar.Author,
bookvar.Available);
   END LOOP;
END;
/
```

Now, the `library_view` is an updatable view, and any `INSERT`s on the view are handled by the trigger that gets fired automatically. For example:

```
INSERT INTO Library_view VALUES ('History', book_list_t(book_t(121330,
'Alexander', 'Mirth', 'Y');
```

Similarly, you can also define triggers on the nested table `booklist` to handle modification of the nested table element.

Tracking System Events

Fine-Grained Access Control System triggers can be used to set application context. Application context is an Oracle8*i* feature which enhances your ability to implement fine-grained access control. Application context is a secure session cache, and it can be used to store session-specific attributes.

In the example that follows, procedure `set_ctx` sets the application context based on the user profile. The trigger `setexpensectx` ensures that the context is set for every user.

```
CONNECT secdemo/secdemo

CREATE OR REPLACE CONTEXT Expenses_reporting USING Secdemo.Exprep_ctx;

REM ================================================================
REM Creation of the package which implements the context:
REM ================================================================

CREATE OR REPLACE PACKAGE Exprep_ctx AS
 PROCEDURE Set_ctx;
END;

SHOW ERRORS
```

```
CREATE OR REPLACE PACKAGE BODY Exprep_ctx IS
   PROCEDURE Set_ctx IS
      Empnum   NUMBER;
      Countrec NUMBER;
      Cc       NUMBER;
      Role     VARCHAR2(20);
   BEGIN

      -- SET emp_number:
      SELECT Employee_id INTO Empnum FROM Employee
         WHERE Last_name = SYS_CONTEXT('userenv', 'session_user');

      DBMS_SESSION.SET_CONTEXT('expenses_reporting','emp_number', Empnum);

      -- SET ROLE:
      SELECT COUNT (*) INTO Countrec FROM Cost_center WHERE Manager_id=Empnum;
      IF (countrec > 0) THEN
         DBMS_SESSION.SET_CONTEXT('expenses_reporting','exp_role','MANAGER');
      ELSE
         DBMS_SESSION.SET_CONTEXT('expenses_reporting','exp_role','EMPLOYEE');
      END IF;

      -- SET cc_number:
      SELECT Cost_center_id INTO Cc FROM Employee
         WHERE Last_name = SYS_CONTEXT('userenv','session_user');
      DBMS_SESSION.SET_CONTEXT(expenses_reporting','cc_number',Cc);
   END;
END;
```

CALL Syntax

```
CREATE OR REPLACE TRIGGER Secdemo.Setexpseetx
AFTER LOGON ON DATABASE
CALL Secdemo.Exprep_etx.Set_otx
```

Triggering Event Publication

Oracle's system event publication lets applications subscribe to database events, just like they subscribe to messages from other applications.

See Also: Chapter 14, "Working With System Events"

Oracle's system events publication framework includes the following features:

- Infrastructure for publish / subscribe, by making the database an active publisher of events.
- Integration of data cartridges in the server: The system events publication can be used to notify cartridges of state changes in the server.
- Integration of fine-grained access control in the server.

Publication Framework

The Oracle framework allows declarative definition of system event publication. This enables triggers to support database events, and users can specify a procedure that is to be run when the event occurs. DML events are supported on tables, and system events are supported on `DATABASE` and `SCHEMA`.

The system event publication subsystem tightly integrates with the Advanced Queueing publish / subscribe engine. The `DBMS_AQ.ENQUEUE()` procedure is used by publish / subscribe applications, and callouts are used by non-publish / subscribe applications, like cartridges.

Users or administrators can enable publication of system events by creating triggers specifying the publication attributes. By default, a trigger (and, therefore, publication of events specified in the trigger) is enabled. Users can also disable publication of these events by disabling the trigger, using the `ALTER TRIGGER` statement.

See Also: *Oracle8i SQL Reference*

For details on how to subscribe to published events and how to specify the delivery of these published events, see *Oracle8i Application Developer's Guide - Advanced Queuing* and *Oracle Call Interface Programmer's Guide*

Event Publication

When events are detected by the server, the trigger mechanism executes the action specified in the trigger. As part of this action, you can use the DBMS_AQ package to publish the event to a queue, which then enables subscribers to get notifications.

> **Note:** Detection of an event is predefined for a given release of the server. There is no user-specified event detection mechanism.

When an event occurs, all triggers that are enabled on that event are fired. More than one trigger can be created on an object; therefore, it is possible that more than one publication is made in response to the same event, and there should be no publication ordering assumptions. The publications are made in the order in which the system events transpire.

Publication Context When an event is published, certain runtime context and attributes, as specified in the parameter list, are passed to the callout procedure. A set of functions called event attribute functions are provided.

> **See Also:** For event-specific attributes, see "Event Attribute Functions" on page 14-2.

For each system event supported, event-specific attributes are identified and predefined for the event. You can choose the parameter list to be any of these attributes, along with other simple expressions. For callouts, these are passed as IN arguments.

Error Handling Return status from publication callout functions for all events are ignored. For example, with SHUTDOWN events, the server cannot do anything with the return status.

> **See Also:** For details on return status, see "List of Events" on page 14-4.

Execution Model Traditionally, triggers execute as the definer of the trigger. The trigger action of an event is executed as the definer of the action (as the definer of the package or function in callouts, or as owner of the trigger in queues). Because the owner of the trigger must have EXECUTE privileges on the underlying queues, packages, or procedure, this behavior is consistent.

14

Working With System Events

System events, like LOGON and SHUTDOWN, provide a mechanism for tracking system changes. With Oracle, this tracking can be combined with database event notification. Database event notification provides a simple and elegant method of delivering asynchrononous messaging to an application.

This chapter includes descriptions of the various events on which triggers can be created. It also provides the list of event attribute functions.

See Also: Chapter 13, "Using Triggers"

Event Attribute Functions

You can obtain certain event-specific attributes when a trigger is fired. These attributes can be used as standalone functions.

Usage Notes

- To make these attributes available, you must first run the CATPROC.SQL script.
- The trigger dictionary object maintains metadata about events that will be published and their corresponding attributes.

Table 14–1 System Defined Event Attributes

Attribute	Type	Description	Example
sysevent	VARCHAR2(20)	System event firing the trigger: Event name is same as that in the syntax.	`INSERT INTO event_table (sys.sysevent);`
instance_num	NUMBER	Instance number.	`IF (instance_num = 1) THEN INSERT INTO event_table ('1'); END IF;`
database_name	VARCHAR2(50)	Database name.	`DECLARE db_name VARCHAR2(50); BEGIN db_name := database_name; END;`
server_error	NUMBER	Given a position(1 for top of stack), it returns the error number at that position on error stack	`INSERT INTO event_table ('top stack error ' || sys.server_error(1));`
is_servererror	BOOLEAN	Returns TRUE if given error is on error stack, FALSE otherwise.	`IF (is_servererror(error_number)) THEN INSERT INTO event_table ('Server error!!'); END IF;`
login_user	VARCHAR2(30)	Login user name.	`SELECT sys.login_user FROM dual;`
dictionary_obj_type	VARCHAR(20)	Type of the dictionary object on which the DDL operation occurred.	`INSERT INTO event_table ('This object is a ' || sys.dictionary_obj_type);`

Table 14–1 System Defined Event Attributes (Cont.)

Attribute	Type	Description	Example
dictionary_obj_name	VARCHAR(30)	Name of the dictionary object on which the DDL operation occurred.	INSERT INTO event_table ('Changed object is ' || sys.dictionary_obj_name');
dictionary_obj_owner	VARCHAR(30)	Owner of the dictionary object on which the DDL operation occurred.	INSERT INTO event_table ('object owner is' || sys.dictionary_obj.owner');
des_encrypted_password	VARCHAR(2)	The DES encrypted password of the user being created or altered.	IF (dictionary_obj_type = 'USER') THEN INSERT INTO event_table (sys.des_encypted_password); END IF;

List of Events

Resource Manager Events

Resource manager events are related to instance startup and shutdown.Triggers created on resource manager events must be associated with the database object.

Table 14–2 contains a list of resource manager events.

Table 14–2 Resource Manager Events

Event	Description	Conditions	Restrictions	Transaction	Attributes
STARTUP	This event is fired when the database is open.	None allowed	No database operations allowed Return status ignored.	Starts a separate transaction and commits it after firing the triggers.	sysevent login_user instance_num database_name
SHUTDOWN	This event is fired just before the server starts the shutdown of an instance. This lets the cartridge shutdown completely. For abnormal instance shutdown, this event may not be fired.	None allowed	No database operations allowed Return status ignored.	Starts a separate transaction and commits it after firing the triggers.	sysevent login_user instance_num database_name
SERVERERROR	This event is fired when the error eno occurs. If no condition is given, then this event fires when any error occurs.	ERRNO = eno	Depends on the error Return status ignored.	Starts a separate transaction and commits it after firing the triggers.	sysevent login_user instance_num database_name server_error is_servererror

Client Events

Client events are the events related to user logon / logoff, DML, and DDL operations. For example:

```
CREATE OR REPLACE TRIGGER On_Logon
  AFTER LOGON
  ON The_user.Schema
BEGIN
  Do_Something;
END;
```

Table 14–3 contains a list of client events.

Table 14–3 Client Events

Event	Description	Conditions	Restrictions	Transaction	Attributes
LOGON	These events are fired after a successful logon of a user.	Simple conditions on USERID() and USERNAME()	None Return status ignored.	Starts a separate transaction and commits it after firing the triggers.	sysevent login_user instance_num database_name
LOGOFF	These events are fired at the start of a user logoff	Simple conditions on USERID() and USERNAME()	None Return status ignored.	Fires the triggers in the existing user transaction.	sysevent login_user instance_num database_name

Table 14–3 Client Events

Event	Description	Conditions	Restrictions	Transaction	Attributes
BEFORE CREATE AFTER CREATE	These events are fired when a catalog object is created.	Simple conditions on the type and name of the object; functions like USERID() and USERNAME()	Cannot drop the object being created.	Fires the triggers in the existing user transaction.	sysevent login_user instance_num database_name dictionary_obj_type dictionary_obj_name dictionary_obj_owner
BEFORE ALTER AFTER ALTER	These events are fired when a catalog object is altered.	Simple conditions on the type and name of the object; functions like USERID() and USERNAME()	Cannot drop the object being altered.	Fire the triggers in the existing user transaction.	sysevent login_user instance_num database_name dictionary_obj_type dictionary_obj_name dictionary_obj_owner
DROP BEFORE DROP AFTER DROP	These events are fired when a catalog object is dropped.	Simple conditions on the type and name of the object; functions like USERID() and USERNAME()	Cannot alter the object being dropped.	Fire the triggers in the existing user transaction.	sysevent login_user instance_num database_name dictionary_obj_type dictionary_obj_name dictionary_obj_owner

15

Using Publish-Subscribe

Because the database is the most significant resource of information within the enterprise, Oracle created a publish-subscribe solution for enterprise information delivery and messaging to complement this role. Topics in this chapter include:

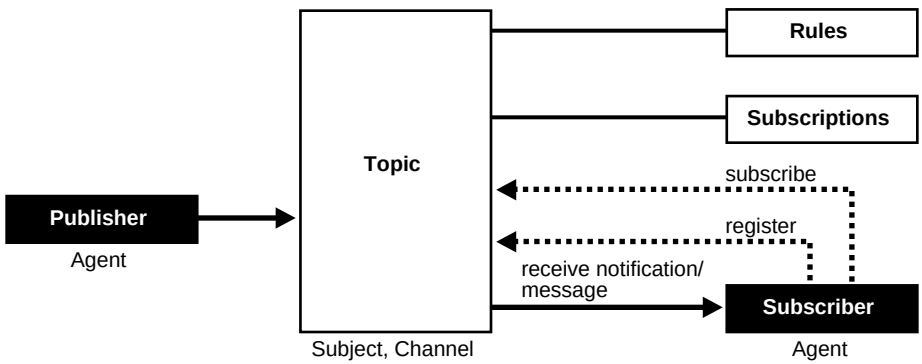
Introduction to Publish-Subscribe

Networking technologies and products now enable a high degree of connectivity across a large number of computers, applications, and users. In these environments, it is important to provide asynchronous communications for the class of distributed systems that operate in a loosely-coupled and autonomous fashion, and which require operational immunity from network failures. This requirement has been filled by various middleware products that are characterized as messaging, message oriented middleware (MOM), message queuing, or publish-subscribe.

Applications which communicate through a publish and subscribe paradigm require the sending applications (publishers) to publish messages without explicitly specifying recipients or having knowledge of intended recipients. Similarly, receiving applications (subscribers) must receive only those messages that the subscriber has registered an interest in.

This decoupling between senders and recipients is usually accomplished by an intervening entity between the publisher and the subscriber, which serves as a level of indirection. This intervening entity is a queue which is used to represent a subject or channel. Figure 15–1 illustrates publish and subscribe functionality.

Figure 15–1 Oracle Publish-Subscribe Functionality



A subscriber subscribes to a queue by expressing interest in messages enqueued to that queue and by using a subject- or content-based rule as a filter. This results in a set of rule-based subscriptions associated with a given queue.

At runtime, publishers post messages to various queues. The queue (in other words, the delivery mechanisms of the underlying infrastructure) then delivers messages that match the various subscriptions to the appropriate subscribers.

Publish-Subscribe Infrastructure

Oracle includes the following infrastructure and features to support database-enabled publish-subscribe messaging:

- Database Events
- Advanced Queuing
- Client Notifications

Database Events

Database events support declarative definitions for publishing database events, detection, and run-time publication of such events. This feature enables active publication of information to end-users in an event-driven manner, to complement the traditional pull-oriented approaches to accessing information.

See Also: Chapter 14, "Working With System Events"

Advanced Queuing

Oracle Advanced Queuing supports a queue-based publish-subscribe paradigm. Database queues serve as a durable store for messages, along with capabilities to allow publish and subscribe based on queues. A rules-engine and subscription service dynamically route messages to recipients based on expressed interest. This allows decoupling of addressing between senders and receivers to complement the existing explicit sender-receiver message addressing.

See Also: *Oracle8i Application Developer's Guide - Advanced Queuing*

Client Notifications

Client notifications support asynchronous delivery of messages to interested subscribers. This enables database clients to register interest in certain queues, and it enables these clients to receive notifications when publications on such queues occur. Asynchronous delivery of messages to database clients is in contrast to the traditional polling techniques used to retrieve information.

See Also: *Oracle Call Interface Programmer's Guide*

Publish-Subscribe Concepts

This section describes various concepts related to publish-subscribe.

Queues

A queue is an entity that supports the notion of named subjects of interest. Queues can be characterized as:

Non-Persistent Queues (Lightweight Queues) The underlying queue infrastructure pushes the messages published to connected clients in a lightweight, at-best-once, manner.

Persistent Queues Queues serve as durable containers for messages. Messages are delivered in a deferred and reliable mode.

Agent

Publishers and subscribers are internally represented as agents. There is a distinction between an agent and a client.

An *agent* is a persistent logical subscribing entity that expresses interest in a queue via a subscription. An agent has properties, such as an associated subscription, an address, and a delivery mode for messages. In this context, an agent is an electronic proxy for a publisher or subscriber.

A *client* is a transient physical entity. The attributes of a client include the physical process where the client programs run, the node name, and the client application logic. There could be several clients acting on behalf of a single agent. Also, the same client, if authorized, can act on behalf of multiple agents.

Rules

A rule on a queue is specified as a conditional expression using a predefined set of operators on the message format attributes or on the message header attributes. Each queue has an associated message content format that describes the structure of the messages represented by that queue. The message format may be unstructured (RAW) or it may have a well-defined structure (ADT). This allows both subject- or content-based subscriptions.

Subscriber

Subscribers (agents) may specify subscriptions on a queue using a rule. Subscribers are durable and are stored in a catalog.

Database Event Publication Framework

The database represents a significant source for publishing information. An event framework is proposed to allow declarative definition of database event publication. As these pre-defined events occur, the framework detects and publishes such events. This allows active delivery of information to end-users in an event-driven manner as part of the publish-subscribe capability.

Registration

Registration is the process of associated delivery information by a given client, acting on behalf of an agent. There is an important distinction between the subscription and registration related to the agent/client separation.

Subscription indicates an interest in a particular queue by an agent. It does not specify where and how delivery must occur. Delivery information is a physical property that is associated with a client, and it is a transient manifestation of the logical agent; i.e., the subscriber. A specific client process acting on behalf of an agent registers delivery information by associating a host and port, indicating *where* the delivery should be done, and a callback, indicating *how* there delivery should be done.

Publish Message

Publishers publish messages to queues by using the appropriate queuing interfaces. The interfaces may depend on which model the queue is implemented on. For example, an enqueue call represents the publishing of a message.

Rules Engine

When a message is posted or published to a given queue, a rules engine extracts the set of candidate rules from all rules defined on that queue that match the published message.

Subscription Services

Corresponding to the list of candidate rules on a given queue, the set of subscribers that match the candidate rules can be evaluated. In turn, the set of agents corresponding to this subscription list can be determined and notified.

Posting

The queue notifies all registered clients of the appropriate published messages. This concept is called *posting*. When the queue needs to notify all interested clients, it posts the message to all registered clients.

Receive Message

A subscriber may receive messages via any of the following mechanisms:

- A client process acting on behalf of the subscriber specifies a callback using the registration mechanism. The posting mechanism then asynchronously invokes the callback when a message matches the subscriber's subscription. The message content may be passed to the callback function (non-persistent queues only).
- A client process acting on behalf of the subscriber specifies a callback using the registration mechanism. The posting mechanism then asynchronously invokes the callback function, but without the full message content. This serves as a notification to the client, which subsequently retrieves the message content in a pull fashion (persistent queues only).
- A client process acting on behalf of the subscriber simply retrieves messages from the queue in a periodic, or some other appropriate, manner. While the messages are deferred, there is no asynchronous delivery to the end-client.

Examples

Note: You may need to set up data structures, similar to the following, for certain examples to work:

```
CONNECT system/manager
DROP USER pubsub CASCADE;
CREATE USER pubsub IDENTIFIED BY pubsub;
GRANT CONNECT, RESOURCE TO pubsub;
GRANT EXECUTE ON DBMS_AQ to pubsub;
GRANT EXECUTE ON DBMS_AQADM to pubsub;
GRANT AQ_ADMINISTRATOR_ROLE TO pubsub;
CONNECT pubsub/pubsub
```

Scenario: This example shows how system events, client notification, and AQ work together to implement publish-subscribe.

- Create under the user schema, pubsub, with all objects necessary to support a publish-subscribe mechanism. In this particular code, the Agent snoop subscribe to messages that are published at logon events. Note that the user pubsub needs AQ_ADMINISTRATOR_ROLE privileges to use AQ functionalities.
-

```
Rem ------------------------------------------------------
REM create queue table for persistent multiple consumers:
Rem ------------------------------------------------------

CONNECT pubsub/pubsub;

Rem  Create or replace a queue table
BEGIN
DBMS_AQADM.CREATE_QUEUE_TABLE(
   Queue_table        =>  'Pubsub.Raw_msg_table',
   Multiple_consumers =>   TRUE,
   Queue_payload_type =>  'RAW',
   Compatible         =>  '8.1');
END;
/
Rem ------------------------------------------------------
Rem  Create a persistent queue for publishing messages:
Rem ------------------------------------------------------

Rem  Create a queue for logon events
begin
BEGIN
   DBMS_AQADM.CREATE_QUEUE(
         Queue_name     =>   'Pubsub.Logon',
         Queue_table    =>   'Pubsub.Raw_msg_table',
         Comment        =>   'Q for error triggers');
END;
/

Rem ------------------------------------------------------
Rem  Start the queue:
Rem ------------------------------------------------------

BEGIN
   DBMS_AQADM.START_QUEUE('pubsub.logon');
END;
/
```

```
Rem ----------------------------------------------------
Rem  define new_enqueue for convenience:
Rem ----------------------------------------------------

CREATE OR REPLACE PROCEDURE New_enqueue(
               Queue_name      IN VARCHAR2,
               Payload         IN RAW ,
               Correlation     IN VARCHAR2 := NULL,
               Exception_queue IN VARCHAR2 := NULL)
AS

Enq_ct     DBMS_AQ.Enqueue_options_t;
Msg_prop   DBMS_AQ.Message_properties_t;
Enq_msgid  RAW(16);
Userdata   RAW(1000);

BEGIN
   Msg_prop.Exception_queue := Exception_queue;
   Msg_prop.Correlation := Correlation;
   Userdata := Payload;

DBMS_AQ.ENQUEUE(Queue_name, Enq_ct, Msg_prop, Userdata, Enq_msgid);
END;
/

Rem ----------------------------------------------------
Rem  add subscriber with rule based on current user name,
Rem  using correlation_id
Rem ----------------------------------------------------


DECLARE
Subscriber Sys.Aq$_agent;
BEGIN
   Subscriber := sys.aq$_agent('SNOOP', NULL, NULL);
DBMS_AQADM.ADD_SUBSCRIBER(
    Queue_name         => 'Pubsub.logon',
    Subscriber         => subscriber,
    Rule               => 'CORRID = ''SCOTT'' ');
END;
/

Rem ----------------------------------------------------
Rem  create a trigger on logon on database:
Rem ----------------------------------------------------
```

```
Rem  create trigger on after logon:
CREATE OR REPLACE TRIGGER pubsub.Systrig2
   AFTER LOGON
   ON DATABASE
   BEGIN
      New_enqueue('Pubsub.Logon', HEXTORAW('9999'), Dbms_standard.login_user);
   END;
/
```

- After subscriptions are created, the next step is for the client to register for notification using callback functions. This is done using the Oracle Call Interface (OCI). The code below performs necessary steps for registration. The initial steps of allocating and initializing session handles are omitted here for sake of clarity.

```
ub4 namespace = OCI_SUBSCR_NAMESPACE_AQ;

/* callback function for notification of logon of user 'scott' on database: */

ub4 notifySnoop(ctx, subscrhp, pay, payl, desc, mode)
dvoid *ctx;
OCISubscription *subscrhp;
dvoid *pay;
ub4 payl;
dvoid *desc;
ub4 mode;
{
    printf("Notification : User Scott Logged on\n");
}

int main()
{
    OCISession *authp = (OCISession *) 0;
    OCISubscription *subscrhpSnoop = (OCISubscription *)0;

    /*************************************************
       Initialize OCI Process/Environment
       Initialize Server Contexts
       Connect to Server
       Set Service Context
    *************************************************/

    /* Registration Code Begins */
```

```
    /* Each call to initSubscriptionHn allocates
           and Initialises a Registration Handle */


    initSubscriptionHn(    &subscrhpSnoop,    /* subscription handle */
        "ADMIN:PUBSUB.SNOOP", /* subscription name */
                  /* <agent_name>:<queue_name> */
        (dvoid*)notifySnoop); /* callback function */

     /*************************************************
       The Client Process does not need a live Session for Callbacks
       End Session and Detach from Server
      *************************************************/

    OCISessionEnd ( svchp,  errhp, authp, (ub4) OCI_DEFAULT);

    /* detach from server */
    OCIServerDetach( srvhp, errhp, OCI_DEFAULT);

    while (1)     /* wait for callback */
        sleep(1);

}

void initSubscriptionHn (subscrhp,
subscriptionName,
func)

OCISubscription **subscrhp;
char* subscriptionName;
dvoid * func;
{

    /* allocate subscription handle: */

    (void) OCIHandleAlloc((dvoid *) envhp, (dvoid **)subscrhp,
        (ub4) OCI_HTYPE_SUBSCRIPTION,
        (size_t) 0, (dvoid **) 0);

    /* set subscription name in handle: */

    (void) OCIAttrSet((dvoid *) *subscrhp, (ub4) OCI_HTYPE_SUBSCRIPTION,
        (dvoid *) subscriptionName,
        (ub4) strlen((char *)subscriptionName),
```

```
        (ub4) OCI_ATTR_SUBSCR_NAME, errhp);

    /* set callback function in handle: */

    (void) OCIAttrSet((dvoid *) *subscrhp, (ub4) OCI_HTYPE_SUBSCRIPTION,
        (dvoid *) func, (ub4) 0,
        (ub4) OCI_ATTR_SUBSCR_CALLBACK, errhp);

    (void) OCIAttrSet((dvoid *) *subscrhp, (ub4) OCI_HTYPE_SUBSCRIPTION,
        (dvoid *) 0, (ub4) 0,
        (ub4) OCI_ATTR_SUBSCR_CTX, errhp);

    /* set namespace in handle: */

    (void) OCIAttrSet((dvoid *) *subscrhp, (ub4) OCI_HTYPE_SUBSCRIPTION,
        (dvoid *) &namespace, (ub4) 0,
        (ub4) OCI_ATTR_SUBSCR_NAMESPACE, errhp);

    checkerr(errhp, OCISubscriptionRegister(svchp, subscrhp, 1, errhp,

        OCI_DEFAULT));
}
```

Now, if user SCOTT logged on to the database, the client is notified, and the call back function notifySnoop is called.

Part IV

The Object-Relational Database Management System

Part IV contains the following chapters:

16

User-Defined Datatypes

This chapter has an extended example of how to use user-defined datatypes (Oracle objects). The example shows how a relational model might be transformed into an object-relational model that better represents the real-world entities that are managed by an application.

This chapter contains the following sections:

Introduction

User-defined types are schema objects in which users formalize the data structures and operations that appear in their applications.

> **See Also:** *Oracle8i Concepts* for an introduction to user-defined types and instructions on how to use them.

The example in this chapter illustrates the most important aspects of defining and using user-defined types. One important aspect of using user-defined types is creating methods that perform operations on objects. In the example, definitions of object type methods use the PL/SQL language. Other aspects of using user-defined types, such as defining a type, use SQL.

> **See Also:** *Oracle8i SQL Reference* for a complete description of SQL syntax and usage for user-defined types.

PL/SQL and Java provide additional capabilities beyond those illustrated in this chapter, especially in the area of accessing and manipulating the elements of collections.

> **See Also:** *PL/SQL User's Guide and Reference* for a complete discussion of PL/SQL capabilities, and *Oracle8i Java Stored Procedures Developer's Guide* for a complete discussion of Java.

Client applications that use the Oracle Call Interface (OCI), Pro*C/C++, or Oracle Objects for OLE (OO4O) can take advantage of its extensive facilities for accessing objects and collections, and manipulating them on clients.

> **See Also:** *Oracle Call Interface Programmer's Guide*, *Pro*C/C++ Precompiler Programmer's Guide*o and *Oracle Objects for OLE/ActiveX Programmer's Guide* for more information.

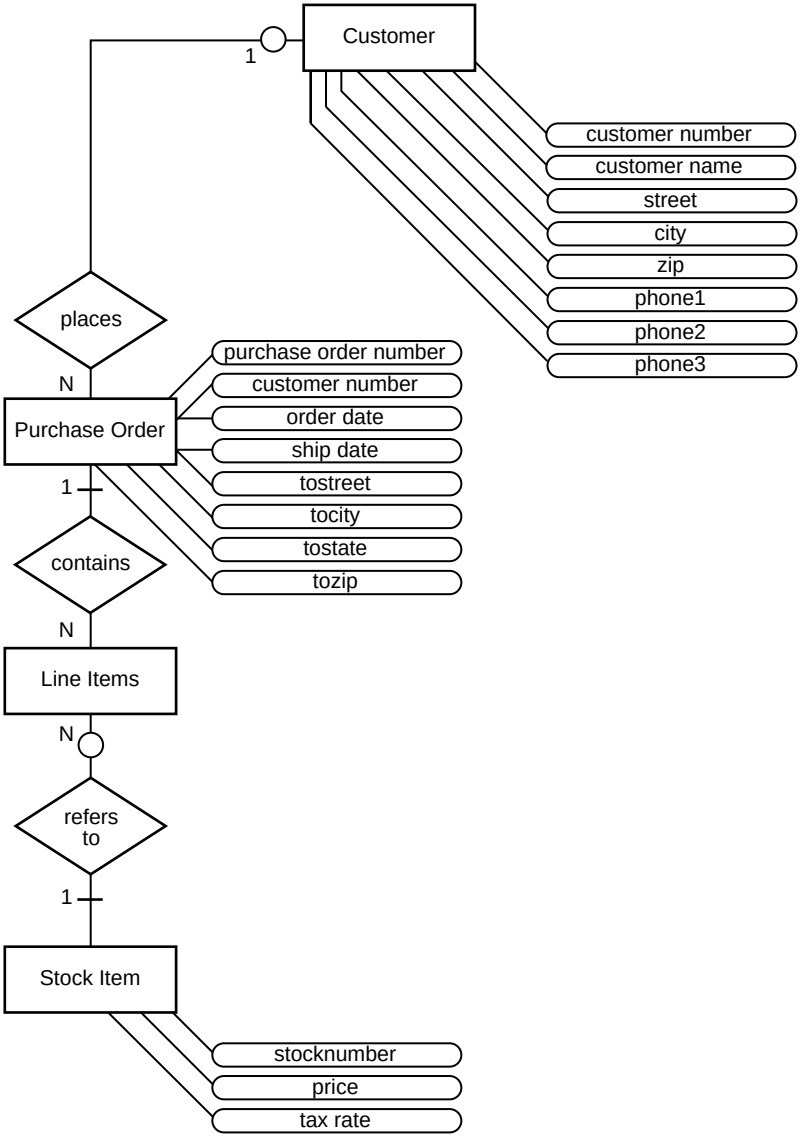
A Purchase Order Example

This example is based on a simple business activity: managing customer orders. The hypothetical application is presented utilizing three different approaches.

- The first approach — **Implementing the Application Under The Relational Model** — implements the schema using only Oracle's built-in datatypes. In this approach, you create tables and use well-known relational techniques to store, access, and modify the data.
- The second approach —**Implementing the Application Under The Object-Relational Model** — uses Oracle's *object types* to translate the entities and their relationships into schema objects that more closely represent their existence in the real world of the application domain. It uses *object-relational tables* to hold the underlying data, and encapsulates the behavior of objects with their data as *operations* which can then be used to access and modify the data in addition to the traditional DML.
- The third approach — **Using Object Views** — uses the relational tables created in the first approach. Rather than building object-relational tables, it uses object views to represent virtual object tables. This approach is described in Chapter 17.

Implementing the Application Under The Relational Model

Figure 16–1 Entity-Relationship Diagram for Purchase Order Application



Entities and Relationships

The basic entities in this example are:

- Customers
- The stock of products for sale
- Purchase orders

As you can see from Figure 16–1, a customer has contact information, so that the address and set of telephone numbers is exclusive to that customer. In other words, the application does not allow for different customers to be associated with the same address or telephone numbers. Also, if a customer changes her address, then the previous address ceases to exist; or, if someone ceases to be a customer, then the associated address disappears.

A customer has a one-to-many relationship with a purchase order, because a customer can place many orders, but a given purchase order is placed by a single customer. However, the relationship is optional rather than mandatory, because a person or company be defined as a customer before placing an order.

A purchase order has a many-to-many relationship with a stock item, because a purchase order can contain many stock items, and a stock item can appear on many purchase orders. Because this relationship does not show which stock items appear on which purchase orders, the entity-relationship has the notion of a line item. As pictured in the diagram, a purchase order must contain one or more line items. Each line item is associated only with a single purchase order.

The relationship between line item and stock item is that a particular stock item can appear on none or many line items, but each line item must refer to one and only one stock item.

Creating Tables Under the Relational Model

The relational approach normalizes entities and their attributes, and structures customers, purchase orders, and stock item into tables. The table names are `Customer_reltab`, `PurchaseOrder_reltab`, and `Stock_reltab`.

Taking the relational approach means breaking addresses into their standard parts and allocating these to columns in the `Customer_reltab` table. A side-effect of structuring telephone numbers as columns is that doing so sets an arbitrary limit on the number of telephone numbers a customer can have.

The relational approach separates line items from their purchase orders and puts each into its own table, named `PurchaseOrder_reltab` and `LineItems_reltab`. As depicted in Figure 16–1, a line item has a relationship to both a purchase order and a stock item. Under the relational model, these are implemented as columns in `LineItems_reltab` table with foreign keys to `PurchaseOrder_reltab` and `Stock_reltab`.

Note: We have adopted a convention in this section of the chapter of adding the suffix `_reltab` to the names of tables created under the relational model. It is always useful to develop a notation that allows you to keep track of your coding design and allows those that come after to you to understand your intentions.

You may find it useful to make distinctions between tables (`_tab`) and types (`_typ`), particularly while you are learning the technology. However, we are not suggesting that using our conventions is an integral part of working with object-relational technology. Indeed, one of the main advantages of object-relational methods is that the names you give to software entities can closely model real-world objects.

The relational approach results in the following tables:

Customer_reltab

The `Customer_reltab` table has the following definition:

```
CREATE TABLE Customer_reltab (
  CustNo               NUMBER NOT NULL,
  CustName             VARCHAR2(200) NOT NULL,
  Street               VARCHAR2(200) NOT NULL,
  City                 VARCHAR2(200) NOT NULL,
  State                CHAR(2) NOT NULL,
  Zip                  VARCHAR2(20) NOT NULL,
  Phone1               VARCHAR2(20),
  Phone2               VARCHAR2(20),
  Phone3               VARCHAR2(20),
  PRIMARY KEY (CustNo)
  ) ;
```

This table, `Customer_reltab`, stores all the information about customers, which means that it fully contains information that is intrinsic to the customer (defined with the `NOT NULL` constraint) and information that is not as essential. According to

this definition of the table, the application requires that every customer have a shipping address.

Our Entity-Relationship (E-R) diagram showed a customer placing an order, but the table does not make allowance for any relationship between the customer and the purchase order. This suggests that the relationship must be managed by the purchase order.

PurchaseOrder_reltab

The `PurchaseOrder_reltab` table has the following definition:

```
CREATE TABLE PurchaseOrder_reltab (
   PONo        NUMBER, /* purchase order no */
   Custno      NUMBER references Customer_reltab, /*  Foreign KEY referencing
                                                      customer */
   OrderDate   DATE, /*  date of order */
   ShipDate    DATE, /* date to be shipped */
   ToStreet    VARCHAR2(200), /* shipto address */
   ToCity      VARCHAR2(200),
   ToState     CHAR(2),
   ToZip       VARCHAR2(20),
   PRIMARY KEY(PONo)
   ) ;
```

As expected, `PurchaseOrder_reltab` manages the relationship between the customer and the purchase order by means of the foreign key (FK) column `CustNo`, which references the `CustNo` key of the `PurchaseOrder_reltab`. Because the table makes no allowance for the relationship between the purchase order and its line items, the list of line items must handle this.

LineItems_reltab

The `LineItems_reltab` table has the following definition:

```
CREATE TABLE LineItems_reltab (
  LineItemNo           NUMBER,
  PONo                 NUMBER REFERENCES PurchaseOrder_reltab,
  StockNo              NUMBER REFERENCES Stock_reltab,
  Quantity             NUMBER,
  Discount             NUMBER,
  PRIMARY KEY (PONo, LineItemNo)
  ) ;
```

Note: The `Stock_reltab` table, describe in "Stock_reltab" on page 16-8, must be created before creating the `LineItems_reltab` table.

The table name is in the plural form `LineItems_reltab` as opposed to the singular `LineItems_reltab` to emphasize that the table will serve as a collection of line items. Of course, the table name has no effect on the behavior of the table, but it is a useful naming convention because it helps you keep in mind that, while every table is a collection, this is not the same as requiring a table to serve as a collection.

As shown in the E-R diagram, the list of line items has relationships with both the purchase order and the stock item. These relationships are managed by `LineItems_reltab` by means of two FK columns:

- `PONo`, which references the `PONo` column in `PurchaseOrder_reltab`
- `StockNo`, which references the `StockNo` column in `Stock_reltab`

Stock_reltab

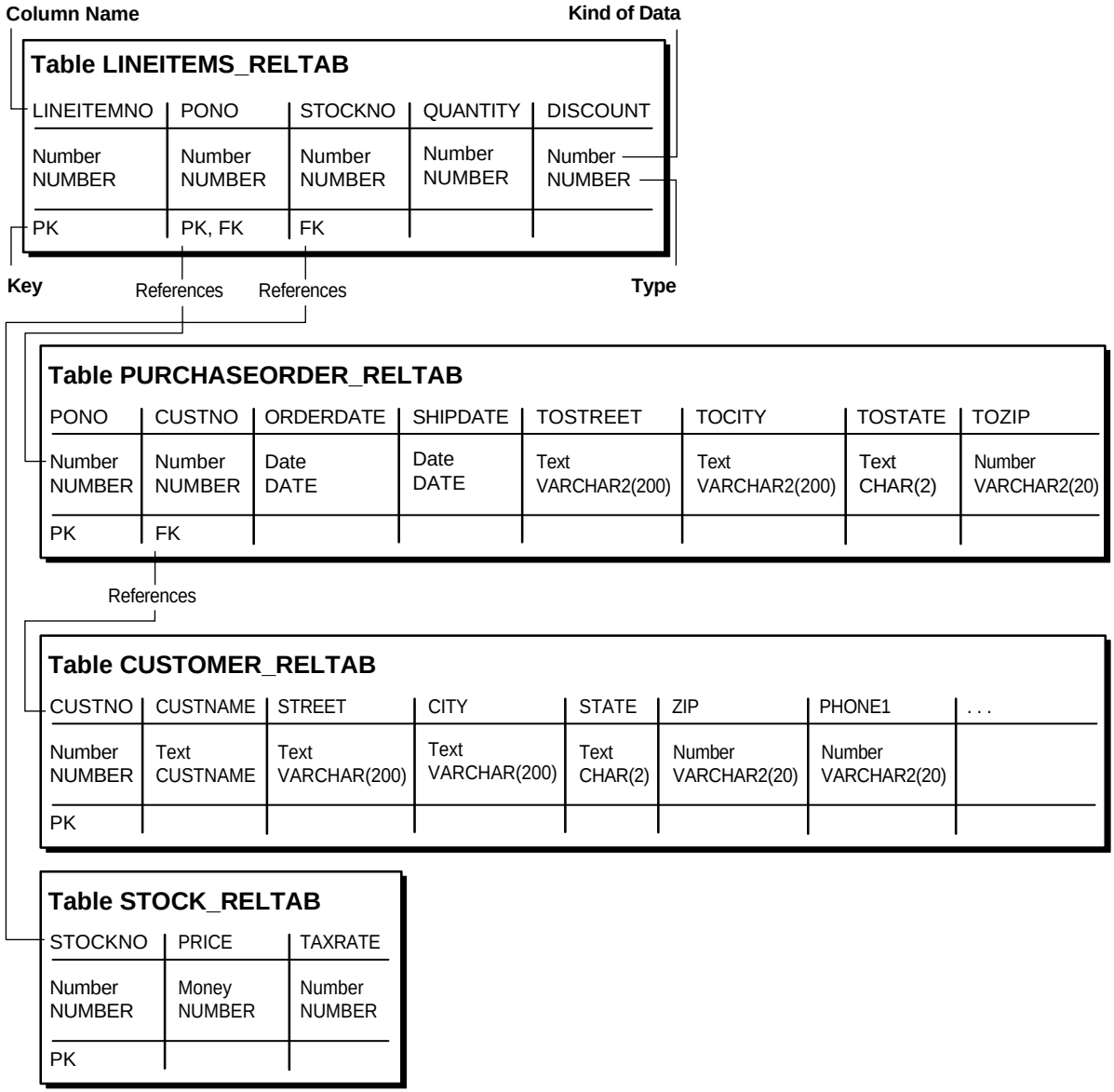
The `Stock_reltab` table has the following definition:

```
CREATE TABLE Stock_reltab (
  StockNo      NUMBER PRIMARY KEY,
  Price        NUMBER,
  TaxRate      NUMBER
  ) ;
```

Schema Plan Under the Relational Model

The following drawing is a graphical representation of the relationships between the tables. It is similar to the E-R diagram (Figure 16–1) because it tries to describe the model for the total application. It differs from the E-R diagram because it pictures an implementation of the first approach we are considering — the relational approach.

Figure 16–2 Schema Plan for a Purchase Order Application Under the Relational Model



Inserting Values Under the Relational Model

In an application based on the tables defined in the previous section, statements similar to the following insert data into the tables.

Establish Inventory

```
INSERT INTO Stock_reltab VALUES(1004, 6750.00, 2) ;
INSERT INTO Stock_reltab VALUES(1011, 4500.23, 2) ;
INSERT INTO Stock_reltab VALUES(1534, 2234.00, 2) ;
INSERT INTO Stock_reltab VALUES(1535, 3456.23, 2) ;
```

Register Customers

```
INSERT INTO Customer_reltab
  VALUES (1, 'Jean Nance', '2 Avocet Drive',
         'Redwood Shores', 'CA', '95054',
         '415-555-1212', NULL, NULL) ;

INSERT INTO Customer_reltab
  VALUES (2, 'John Nike', '323 College Drive',
         'Edison', 'NJ', '08820',
         '609-555-1212', '201-555-1212', NULL) ;
```

Place Orders

```
INSERT INTO PurchaseOrder_reltab
  VALUES (1001, 1, SYSDATE, '10-MAY-1997',
          NULL, NULL, NULL, NULL) ;

INSERT INTO PurchaseOrder_reltab
  VALUES (2001, 2, SYSDATE, '20-MAY-1997',
         '55 Madison Ave', 'Madison', 'WI', '53715') ;
```

Detail Line Items

```
INSERT INTO LineItems_reltab VALUES(01, 1001, 1534, 12,  0) ;
INSERT INTO LineItems_reltab VALUES(02, 1001, 1535, 10, 10) ;
INSERT INTO LineItems_reltab VALUES(01, 2001, 1004,  1,  0) ;
INSERT INTO LineItems_reltab VALUES(02, 2001, 1011,  2,  1) ;
```

Querying Data Under The Relational Model

Assuming that values have been inserted into these tables in the usual way, your application could execute queries similar to the following to retrieve the necessary information from the stored data.

Get Customer and Line Item Data for a Specific Purchase Order

```
SELECT   C.CustNo, C.CustName, C.Street, C.City, C.State,
         C.Zip, C.phone1, C.phone2, C.phone3,
         P.PONo, P.OrderDate,
         L.StockNo, L.LineItemNo, L.Quantity, L.Discount
 FROM    Customer_reltab C,
         PurchaseOrder_reltab P,
         LineItems_reltab L
 WHERE   C.CustNo = P.CustNo
  AND    P.PONo = L.PONo
  AND    P.PONo = 1001 ;
```

Get the Total Value of Purchase Orders

```
SELECT     P.PONo, SUM(S.Price * L.Quantity)
 FROM      PurchaseOrder_reltab P,
           LineItems_reltab L,
           Stock_reltab S
 WHERE     P.PONo = L.PONo
  AND      L.StockNo = S.StockNo
 GROUP BY P.PONo ;
```

Get the Purchase Order and Line Item Data for those LineItems that Use a Stock Item Identified by a Specific Stock Number

```
SELECT    P.PONo, P.CustNo,
          L.StockNo, L.LineItemNo, L.Quantity, L.Discount
 FROM     PurchaseOrder_reltab P,
          LineItems_reltab     L
 WHERE    P.PONo = L.PONo
   AND    L.StockNo = 1004 ;
```

Updating Data Under The Relational Model

Given the schema objects described above, you could execute statements similar to the following to update the stored data:

Update the Quantity for Purchase Order 1001 and Stock Item 1534

```
UPDATE LineItems_reltab
   SET      Quantity = 20
   WHERE    PONo     = 1001
   AND      StockNo  = 1534 ;
```

Deleting Data Under The Relational Model

In an application based on the tables defined earlier, you could execute statements similar to the following to delete stored data:

Delete Purchase Order 1001

```
DELETE
   FROM   LineItems_reltab
   WHERE  PONo = 1001 ;

DELETE
   FROM   PurchaseOrder_reltab
   WHERE  PONo = 1001 ;
```

Limitations of a Purely Relational Model

The Relational Database Management System (RDBMS) is a very powerful and efficient form of information management. Why then should you even consider another approach? If you examine the application as developed under the relational model in comparison to the real world of the application domain, then certain shortcomings become evident.

Limitation in Encapsulating Data (Structure) with Operations (Behavior)

Database tables are excellent for modeling a structure of relationships, but they fail to capture the way that objects in the real world are naturally bundled with operations on the data. For example, when you operate on a purchase order in the real world, you expect to be able to sum the line items to find the total cost to the customer. Similarly, you expect that you should be able to retrieve information about the customer who placed the order — such as name, reference number, address, and so on. More complexly, you may want to determine the customer's buying history and payment pattern.

An RDBMS provides very sophisticated structures for storing and retrieving data, but each application developer must craft the operations needed for each application. This means that you must recode operations often, even though they may be very similar to operations already coded for applications within the same enterprise.

Limitation in Dealing with Composition

Relational tables do not capture compositions. For example, an address may be a composite of number, street, city, state, and zip code, but in a relational table, the notion of an address as a structure composed of the individual columns is not captured.

Limitation in Dealing with Aggregation

Relational tables have difficulty dealing with complex part-whole relationships. A piston and an engine have the same status as columns in the `Stock_reltab`, but there is no easy way to describe the fact that pistons are part of engines, except by creating multiple tables with primary key-foreign key relationships. Similarly, there is no easy way to implement the complex interrelationships between collections.

Limitation in Dealing with Generalization-Specialization

There is no easy way to capture the relationship of generalization-specification (inheritance). If we abstract the base requirements of a purchase order and build a complex technology to capture the relationships, then there is no way to develop purchase orders that use this basic functionality and then further specialize the functionality for different domains. Instead, we will have built the base functionality into every implementation of a purchase order.

The Evolution of the Object-Relational Database System

So why not create applications using a third-generation language (3GL)?

First, an RDBMS provides functionality that would take millions of person-hours to replicate.

Second, one of the problems of information management using 3GLs is that they are not persistent; or, if they are persistent, then they sacrifice security to obtain the necessary performance by way of locating the application logic and the data logic in the same address space. Neither trade-off is acceptable to users of an RDBMS, for whom both persistence and security are basic requirements.

This leaves the application developer working under the relational model with the problem of simulating complex types by some form of mapping into SQL. Apart from the many person-hours required, this approach involves serious problems of implementation. You must:

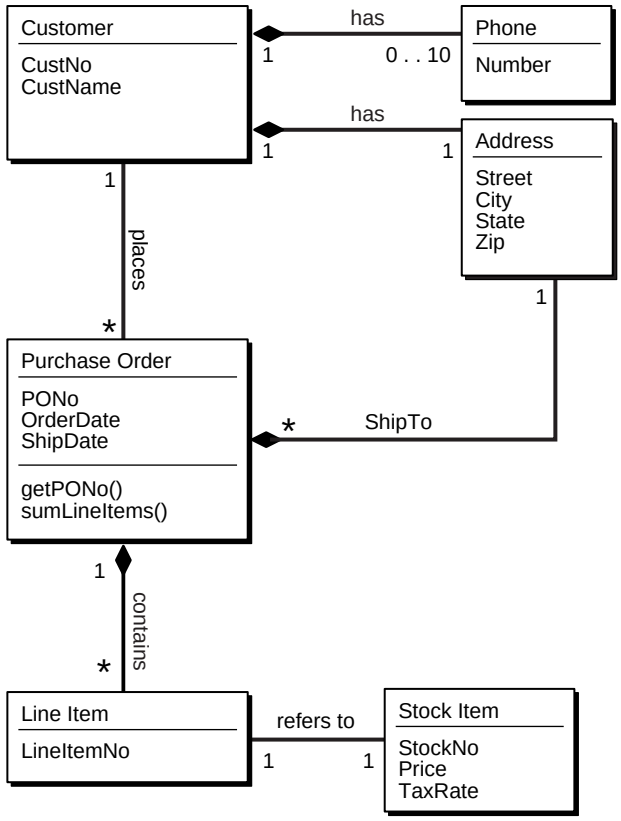
- Translate from application logic into data logic on 'write', and then
- Perform the reverse process on 'read' (and vice versa).

Obviously, there is heavy traffic back and forth between the client address space and that of the server, with the accompanying decrement in performance. And, if client and server are on different machines, then the toll on performance from network roundtrips may be considerable.

Object-relational (O-R) technology solves these problems. This chapter and the following chapter present examples that implement this new functionality.

Implementing the Application Under The Object-Relational Model

Figure 16–3 Class Diagram for Purchase Order Application



The O-R approach to the previous relational example begins with the same entity relationships outlined in "Entities and Relationships" on page 16-5. However, viewing these from the object-oriented perspective portrayed in the class diagram above allows us to define user-defined types that make it possible to translate more of the real-world structure into the database schema.

Rather than breaking up addresses or the customer's contact phones into unrelated columns in relational tables, the O-R approach defines types to represent them; rather than breaking line items out into a separate table, the O-R approach allows them to stay with their respective purchase orders as nested tables.

In the O-R approach, the main entities — customers, stock, and purchase orders — become objects. Object references express the relationships between them. Collection types model their multi-valued attributes.

Given an O-R strategy, there are two approaches to implementation:

- Create and populate object tables.
- Use object views to represent virtual object tables from existing relational data.

The remainder of this chapter develops the O-R schema and shows how to implement it with object tables. Chapter 17, "Objects in Views" implements the same schema with object views.

Defining Types

The following statements set the stage:

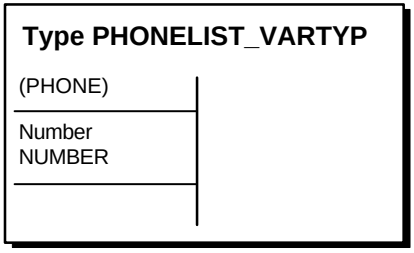
```
CREATE TYPE StockItem_objtyp
/

CREATE TYPE LineItem_objtyp
/

CREATE TYPE PurchaseOrder_objtyp
/
```

The preceding three statements define incomplete object types. The incomplete definitions notify Oracle that full definitions are coming later. Oracle allows types that refer to these types to compile successfully. Incomplete type declarations are like forward declarations in C and other programming languages.

The following statement defines an array type:

```
CREATE TYPE PhoneList_vartyp AS VARRAY(10) OF VARCHAR2(20)
/
```

Figure 16–4 Object Relational Representation of PhoneList_vartyp Type



The preceding statement defines the type `PhoneList_vartyp`. Any data unit of type `PhoneList_vartyp` is a varray of up to 10 telephone numbers, each represented by a data item of type VARCHAR2.

A list of phone numbers could occupy a varray or a nested table. In this case, the list is the set of contact phone numbers for a single customer. A varray is a better choice than a nested table for the following reasons:

- The order of the numbers might be important: varrays are ordered while nested tables are unordered.
- The number of phone numbers for a specific customer is small. Varrays force you to specify a maximum number of elements (10 in this case) in advance. They use storage more efficiently than nested tables, which have no special size limitations.
- There is no reason to query the phone number list, so the nested table format offers no benefit.

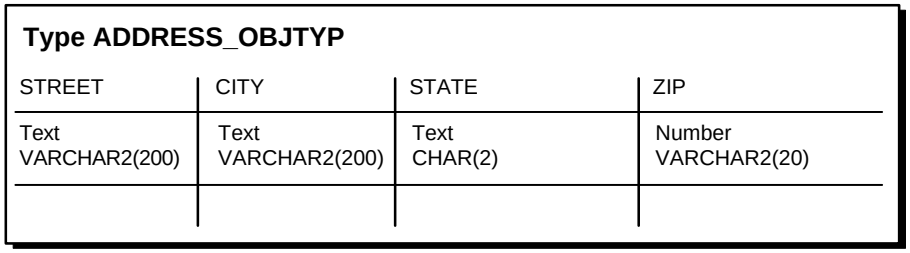
In general, if ordering and bounds are not important design considerations, then designers can use the following rule of thumb for deciding between varrays and nested tables: If you need to query the collection, then use nested tables; if you intend to retrieve the collection as a whole, then use varrays.

> **See Also:** Chapter 18, "Design Considerations for Oracle Objects" for more information about the design considerations for varrays and nested tables.

The following statement defines the object type `Address_objtyp` to represent addresses:

```
CREATE TYPE Address_objtyp AS OBJECT (
  Street         VARCHAR2(200),
  City           VARCHAR2(200),
  State          CHAR(2),
  Zip            VARCHAR2(20)
  )
/
```

Figure 16–5 Object Relational Representation of Address_objtyp Type



All of the attributes of an address are character strings, representing the usual parts of a simplified mailing address.

The following statement defines the object type `Customer_objtyp`, which uses other user-defined types as building blocks. This object type also has a comparison method.

```
CREATE TYPE Customer_objtyp AS OBJECT (
  CustNo           NUMBER,
  CustName         VARCHAR2(200),
  Address_obj      Address_objtyp,
  PhoneList_var    PhoneList_vartyp,

  ORDER MEMBER FUNCTION
    compareCustOrders(x IN Customer_objtyp) RETURN INTEGER,

  PRAGMA RESTRICT_REFERENCES (
    compareCustOrders,  WNDS, WNPS, RNPS, RNDS)
  )
/
```

Instances of the type `Customer_objtyp` are objects that represent blocks of information about specific customers. The attributes of a `Customer_objtyp` object are a number, a character string, an `Address_objtyp` object, and a varray of type `PhoneList_vartyp`.

Every `Customer_objtyp` object also has an associated order method, one of the two types of comparison methods. Whenever Oracle needs to compare two `Customer_objtyp` objects, it invokes the `compareCustOrders` method to do so.

Note: The statement does not include the actual PL/SQL program implementing the method `compareCustOrders`. That program appears in "The compareCustOrders Method" section on page 16-25.

The two types of comparison methods are map methods and order methods. This application uses one of each for purposes of illustration.

An `ORDER` method must be called for every two objects being compared, whereas a `MAP` method is called once per object. In general, when sorting a set of objects, the number of times an `ORDER` method is called is more than the number of times a `MAP` method would be called.

Because the system can perform scalar value comparisons very efficiently, coupled with the fact that calling a user-defined function is slower than calling a kernel implemented function, sorting objects using the `ORDER` method is relatively slow compared to sorting the mapped scalar values (returned by the `MAP` function).

See Also:

- *Oracle8i Concepts* for a discussion of `ORDER` and `MAP` methods.
- Chapter 18, "Design Considerations for Oracle Objects" for more information about design considerations for `ORDER` and `MAP` methods.
- *PL/SQL User's Guide and Reference* for details about how to use pragma declarations.

The following statement completes the definition of the incomplete object type `LineItem_objtyp` declared at the beginning of this section.

```
CREATE TYPE LineItem_objtyp AS OBJECT (
  LineItemNo   NUMBER,
  Stock_ref    REF StockItem_objtyp,
  Quantity     NUMBER,
  Discount     NUMBER
  )
/
```

Figure 16–6 Object Relational Representation of LineItem_objtyp Type

Type LINEITEM_OBJTYP

LINEITEMNO	STOCK_REF	QUANTITY	DISCOUNT
Number NUMBER	Reference STOCKITEM_OBJTYP	Number NUMBER	Number NUMBER

Instances of type `LineItem_objtyp` are objects that represent line items. They have three numeric attributes and one `REF` attribute. The `LineItem_objtyp` models the line item entity and includes an object reference to the corresponding stock object.

The following statement defines the nested table type `LineItemList_ntabtyp`:

```
CREATE TYPE LineItemList_ntabtyp AS TABLE OF LineItem_objtyp
/
```

A data unit of this type is a nested table, each row of which contains an object of type `LineItem_objtyp`. A nested table of line items is a better choice to represent the multivalued line item list of a purchase order than a varray of `LineItem_objtyp` objects would be, for the following reasons:

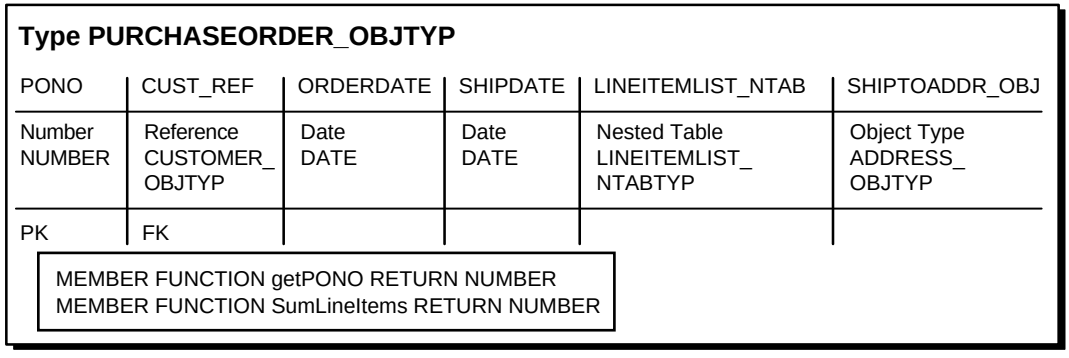
- Querying the contents of line items is likely to be a requirement for most applications. This is an inefficient operation for varrays because its storage representation is not the same as the table representation.
- Indexing on line item data may be a requirement in some applications. Nested tables allow this, but it is not possible with varrays.

- The order of line items is usually unimportant, and the line item number can be used to specify an order when necessary.
- There is no practical upper bound on the number of line items on a purchase order. Using a varray requires specifying an arbitrary upper bound on the number of elements.

The following statement completes the definition of the incomplete object type `PurchaseOrder_objtyp` declared at the beginning of this section:

```
CREATE TYPE PurchaseOrder_objtyp AUTHID CURRENT_USER AS OBJECT (
  PONo                 NUMBER,
  Cust_ref             REF Customer_objtyp,
  OrderDate            DATE,
  ShipDate             DATE,
  LineItemList_ntab    LineItemList_ntabtyp,
  ShipToAddr_obj       Address_objtyp,

  MAP MEMBER FUNCTION
    getPONo RETURN NUMBER,
    PRAGMA RESTRICT_REFERENCES (
      getPONo, WNDS, WNPS, RNPS, RNDS),

  MEMBER FUNCTION
    sumLineItems RETURN NUMBER,
    PRAGMA RESTRICT_REFERENCES (sumLineItems, WNDS, WNPS)
  )
/
```

Figure 16–7 Object Relational Representation of the PuchaseOrder_objtyp



The preceding statement defines the object type `PurchaseOrder_objtyp`. Instances of this type are objects representing purchase orders. They have six attributes, including a `REF` to `Customer_objtyp`, an `Address_objtyp` object, and a nested table of type `LineItemList_ntabtyp`, which is based on type `LineItem_objtyp`.

Objects of type `PurchaseOrder_objtyp` have two methods: `getPONo` and `sumLineItems`. One, `getPONo`, is a `MAP` method, one of the two kinds of comparison methods. A `MAP` method returns the relative position of a given record within the order of records within the object. So, whenever Oracle needs to compare two `PurchaseOrder_objtyp` objects, it implicitly calls the `getPONo` method to do so.

The two pragma declarations provide information to PL/SQL about what sort of access the two methods need to the database.

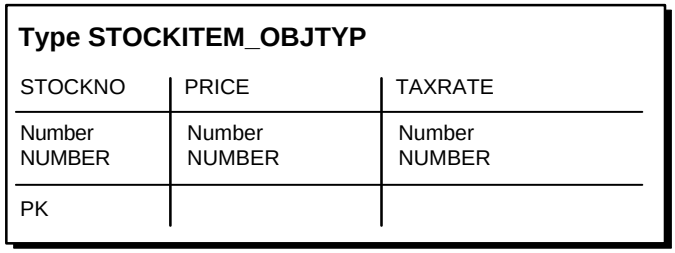
See Also: *PL/SQL User's Guide and Reference f*or complete details about how to use pragma declarations.

The statement does not include the actual PL/SQL programs implementing the methods `getPONo` and `sumLineItems`. That appears in "Method Definitions" on page 16-23.

The following statement completes the definition of `StockItem_objtyp`, the last of the three incomplete object types declared at the beginning of this section.

```
CREATE TYPE StockItem_objtyp AS OBJECT (
  StockNo    NUMBER,
  Price      NUMBER,
  TaxRate    NUMBER
  )
/
```

Figure 16–8 Object Relational Representation of the StockItem_objtyp



Instances of type `StockItem_objtyp` are objects representing the stock items that customers order. They have three numeric attributes.

Method Definitions

This section shows how to specify the methods of the `PurchaseOrder_objtyp` and `Customer_objtyp` object types. The following statement defines the body of the `PurchaseOrder_objtyp` object type (the PL/SQL programs that implement its methods):

```
CREATE OR REPLACE TYPE BODY PurchaseOrder_objtyp AS

MAP MEMBER FUNCTION getPONo RETURN NUMBER is
   BEGIN
      RETURN PONo;
   END;

MEMBER FUNCTION sumLineItems RETURN NUMBER is
      i             INTEGER;
      StockVal      StockItem_objtyp;
      Total         NUMBER := 0;

   BEGIN
      FOR i in 1..SELF.LineItemList_ntab.COUNT LOOP
         UTL_REF.SELECT_OBJECT(LineItemList_ntab(i).Stock_ref,StockVal);
         Total := Total + SELF.LineItemList_ntab(i).Quantity * StockVal.Price;
      END LOOP;
      RETURN Total;
   END;
END;
/
```

The getPONo Method

The `getPONo` method is simple; use it to return the purchase order number of its associated `PurchaseOrder_objtyp` object.

The sumLineItems Method

The `sumLineItems` method uses a number of O-R features:

- As already noted, the basic function of the `sumLineItems` method is to return the sum of the values of the line items of its associated `PurchaseOrder_objtyp` object. The keyword `SELF`, which is implicitly created as a parameter to every function, lets you refer to that object.
- The keyword `COUNT` gives the count of the number of elements in a PL/SQL table or array. Here, in combination with `LOOP`, the application iterates through all the elements in the collection — in this case, the items of the purchase order. In this way `SELF.LineItemList_ntab.COUNT` counts the number of elements in the nested table that match the `LineItemList_ntab` attribute of the `PurchaseOrder_objtyp` object, here represented by `SELF`.
- A `UTL_REF` package method is used in the implementation. The `UTL_REF` package methods are necessary because Oracle does not support implicit dereferencing of `REF`s within PL/SQL programs. The `UTL_REF` package provides methods that operate on object references. Here, the `SELECT_OBJECT` method is called to obtain the `StockItem_objtyp` object corresponding to the `Stock_ref`. Looking back to our data definition, you will see that `Stock_ref` is an attribute of the `LineItem_objtyp` object, which is itself an element of the `LineItemList_ntabtyp`. Recall that a purchase order (`PurchaseOrder_objtyp`) contains a list (`LineItemList_ntab`) of items (`LineItem_objtyp`), each of which contains a reference (`Stock_ref`) to information about the item (`StockItem_objtyp`). The operation that we have been considering simply fetches the required data by O-R means.
- The `AUTHID CURRENT_USER` syntax specifies that the `PurchaseOrder_objtyp` is defined invoker-rights. Therefore, the methods are executed under the rights of the current user, not under the rights of the user who defined the type.
- The PL/SQL variable `StockVal` is of type `StockItem_objtyp`. The `UTL_REF.SELECT_OBJECT` sets it to the object whose reference is the following:

  ```
  (LineItemList_ntab(i).Stock_ref)
  ```

  This object is the actual stock item referred to in the currently selected line item.

- Having retrieved the stock item in question, the next step is to compute its cost. The program refers to the stock item's cost as `StockVal.Price`, the `Price` attribute of the `StockItem_objtyp` object. But to compute the cost of the item, you also need to know the quantity of items ordered. In the application, the term `LineItemList_ntab(i).Quantity` represents the `Quantity` attribute of the currently selected `LineItem_objtyp` object.

The remainder of the method program is straightforward. The loop sums the extended values of the line items, and the method returns the total as its value.

The compareCustOrders Method

The following statement defines the `compareCustOrders` method of the `Customer_objtyp` object type.

```
CREATE OR REPLACE TYPE BODY Customer_objtyp AS
  ORDER MEMBER FUNCTION
  compareCustOrders (x IN Customer_objtyp) RETURN INTEGER IS
  BEGIN
    RETURN CustNo - x.CustNo;
  END;
END;
/
```

As mentioned earlier, the function of the `compareCustOrders` operation is to compare information about two customer orders. The mechanics of the operation are quite simple. The order method `compareCustOrders` takes another `Customer_objtyp` object as an input argument and returns the difference of the two `CustNo` numbers. Because it subtracts the `CustNo` of the other `Customer_objtyp` object from its own object's `CustNo`, the method returns one of the following:

- a negative number, if its own object has a smaller value of `CustNo`
- a positive number, if its own object has a larger value of `CustNo`
- zero, if the two objects have the same value of `CustNo`—in which case it is referring to itself.

If `CustNo` has some meaning in the real world (for example, lower numbers are created earlier in time than higher numbers), then the actual value returned by this function could be useful. If either of the input arguments (`SELF` and explicit) to an `ORDER` method is `NULL`, Oracle does not call the `ORDER` method and simply treats the result as `NULL`.

This completes the definition of the user-defined types used in the purchase order application. None of the declarations create tables or reserve data storage space.

Creating Object Tables

To this point, the example is the same whether you plan to create and populate object tables or implement the application with object views on top of the relational tables that appear in "Implementing the Application Under The Relational Model" on page 16-4. The remainder of this chapter continues the example using object tables. Chapter 17, "Objects in Views", picks up from this point and continues the example with object views.

Generally, you can think of the relationship between the "objects" and "object tables" in the following way:

- Classes, which represent entities, map to object tables
- Attributes map to columns
- Objects map to rows

Viewed in this way, each object table is an implicit type whose objects (specific rows) each have the same attributes (column values). The creation of explicit user-defined datatypes and object tables introduces a new level of functionality.

The Object Table Customer_objtab

The following statement defines an object table `Customer_objtab` to hold objects of type `Customer_objtyp`:

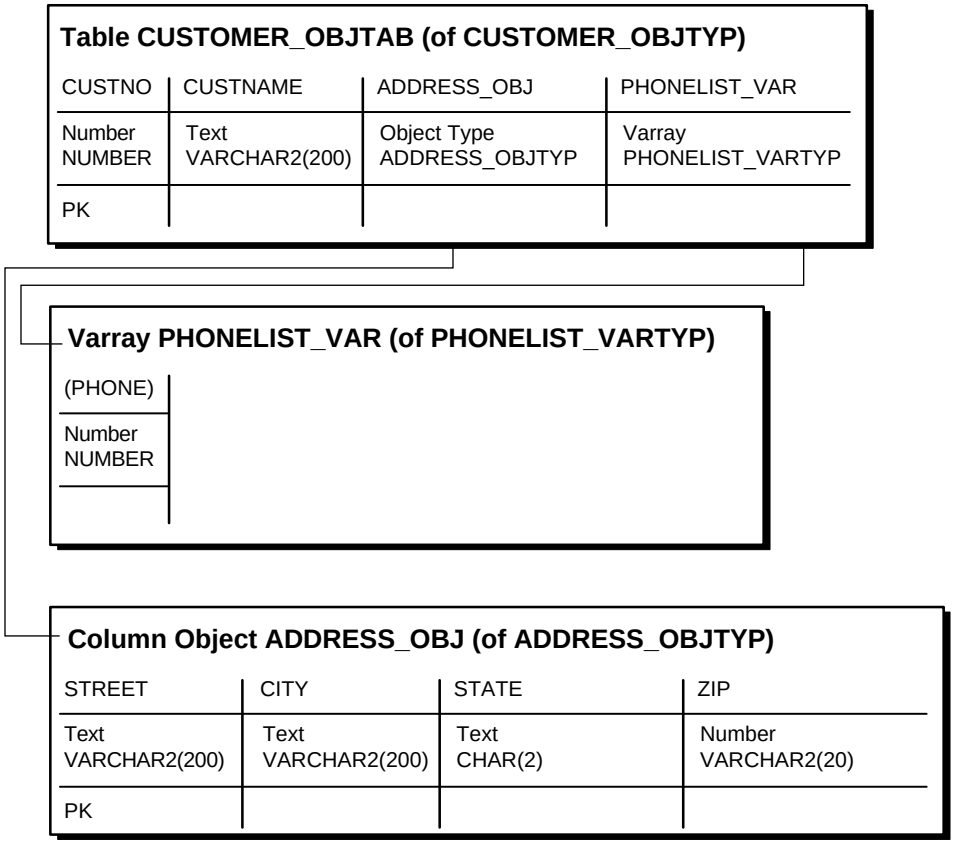
```
CREATE TABLE Customer_objtab OF Customer_objtyp (CustNo PRIMARY KEY)
   OBJECT ID PRIMARY KEY ;
```

As you can see, there is a syntactic difference in the definition of object tables as opposed to relational tables, namely the use of the term "`OF`" for object tables. You may recall that we earlier defined the attributes of `Customer_objtyp` objects as:

```
CustNo          NUMBER
CustName        VARCHAR2(200)
Address_obj     Address_objtyp
PhoneList_var   PhoneList_vartyp
```

This means that the object table `Customer_objtab` has columns of `CustNo`, `CustName`, `Address_obj`, and `PhoneList_var`, and that each row is an object of type `Customer_objtyp`. As you will see, this notion of *row object* offers a significant advance in functionality.

Figure 16–9 Object Relational Representation of Table Customer_objtab



Object Datatypes as a Template for Object Tables

Because there is a type `Customer_objtyp`, you could create numerous object tables of type `Customer_objtyp`. For example, you could create an object table `Customer_objtab2` also of type `Customer_objtyp`. By contrast, without this ability, you would need to define each table individually.

Being able to create object tables of the same type does not mean that you cannot introduce variations. The statement that created `Customer_objtab` defined a primary key constraint on the `CustNo` column. This constraint applies only to this object table. Another object table of `Customer_objtyp` objects (for example, `Customer_objtab2`) does not need to satisfy this constraint.

Object Identifiers and References

Customer_objtab contains customer objects, represented as row objects. Oracle allows row objects to be referenceable, meaning that other row objects or relational rows may reference a row object using its object identifier (OID). For example, a purchase order row object may reference a customer row object using its object reference. The object reference is an opaque system-generated value represented by the type REF and is composed of the row object's unique OID.

Oracle requires every row object to have a unique OID. You may specify the unique OID value to be system-generated or specify the row object's primary key to serve as its unique OID. You indicate this when you execute the CREATE TABLE statement by specifying OBJECT ID PRIMARY KEY or OBJECT ID SYSTEM GENERATED, the latter serving as the default. The choice of primary key as the object identifier may be more efficient in cases where the primary key value is smaller than the default 16 byte system-generated identifier. For our example, the choice of primary key as the row object identifier has been made.

Object Tables with Embedded Objects

Examining the definition of Customer_objtab, you can see that the Address_obj column contains Address_objtyp objects. In other words, an object type may have attributes that are themselves object types. These embedded objects represent composite or structured values, and are also referred to as column objects. They differ from row objects because they are not referenceable and can be NULL.

Address_objtyp objects have attributes of built-in types, which means that they are leaf-level scalar attributes of Customer_objtyp. Oracle creates columns for Address_objtyp objects and their attributes in the object table Customer_objtab. You can refer to these columns using the dot notation. For example, if you want to build an index on the Zip column, then you can refer to it as Address.Zip.

The PhoneList column contains varrays of type PhoneList_vartyp. You may recall that we defined each object of type PhoneList_vartyp as a varray of up to 10 telephone numbers, each represented by a data item of type VARCHAR2. Here is the CREATE TYPE statement that created PhoneList_vartyp:

```
CREATE TYPE PhoneList_vartyp AS VARRAY(10) OF VARCHAR2(20)
/
```

Because each varray of type PhoneList_vartyp can contain no more than 200 characters (10 x 20), plus a small amount of overhead, Oracle stores the varray as a single data unit in the PhoneList_var column. Oracle stores varrays that exceed 4000 bytes in "inline" BLOBs, which means that a portion of the varray value could potentially be stored outside the table.

The Object Table Stock_objtab

The next statement creates an object table for StockItem_objtyp objects:

```
CREATE TABLE Stock_objtab OF StockItem_objtyp (StockNo PRIMARY KEY)
   OBJECT ID PRIMARY KEY ;
```

This statement does not introduce anything new. The statement creates the Stock_objtab object table. Each row of the table is a StockItem_objtyp object having three numeric attributes:

```
StockNo     NUMBER
Price       NUMBER
TaxRate     NUMBER
```

Oracle assigns a column for each attribute, and the CREATE TABLE statement places a primary key constraint on the StockNo column, and specifies that the primary key be used as the row object's identifier.

The Object Table PurchaseOrder_objtab

The next statement defines an object table for PurchaseOrder_objtyp objects:

```
CREATE TABLE PurchaseOrder_objtab OF PurchaseOrder_objtyp (  /* Line 1 */
   PRIMARY KEY (PONo), /*  Line 2  */
   FOREIGN KEY (Cust_ref) REFERENCES Customer_objtab) /* Line 3 */
   OBJECT ID PRIMARY KEY  /* Line 4 */
   NESTED TABLE LineItemList_ntab STORE AS PoLine_ntab ( /*  Line 5 */
     (PRIMARY KEY(NESTED_TABLE_ID, LineItemNo)) /* Line 6 */
     ORGANIZATION INDEX COMPRESS) /*  Line 7 */
   RETURN AS LOCATOR  /*  Line 8 */
/
```

The SCOPE FOR constraint on a REF is not allowed in a CREATE TABLE statement. Therefore, to specify that Stock_ref can reference only the object table Stock_objtab, issue the following ALTER TABLE statement on the PoLine_ntab storage table:

```
ALTER TABLE PoLine_ntab
   ADD (SCOPE FOR (Stock_ref) IS stock_objtab) ;
```

Note that this statement is executed on the storage table, not the parent table.

The preceding CREATE TABLE statement creates the PurchaseOrder_objtab object table. This statement requires some explanation; hence, it has been annotated with line numbers on the right:

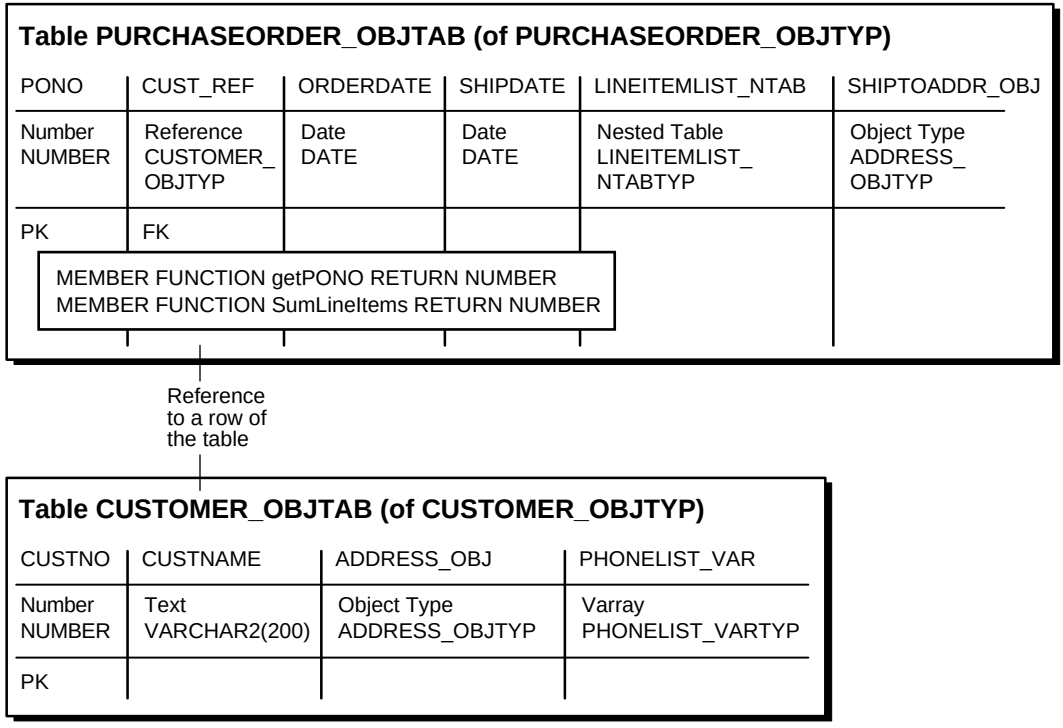
Line 1:

```
CREATE TABLE PurchaseOrder_objtab OF PurchaseOrder_objtyp (
```

This line indicates that each row of the table is a PurchaseOrder_objtyp object. Attributes of PurchaseOrder_objtyp objects are:

```
  PONo                NUMBER
  Cust_ref            REF Customer_objtyp
  OrderDate           DATE
  ShipDate            DATE
  LineItemList_ntab   LineItemList_ntabtyp
  ShipToAddr_obj      Address_objtyp
```

Figure 16–10 Object Relational Representation of Table PurchaseOrder_objtab



Line 2:

```
PRIMARY KEY (PONo),
```

This line specifies that the `PONo` attribute is the primary key for the table.

Line 3:

```
FOREIGN KEY (Cust_ref) REFERENCES Customer_objtab)
```

This line specifies a referential constraint on the `Cust_ref` column. This referential constraint is similar to those specified for relational tables. When there is no constraint, the `REF` column allows you to reference any row object. However, in this case, the `Cust_ref` `REF`s can refer only to row objects in the `Customer_objtab` object table.

Line 4:

```
OBJECT ID PRIMARY KEY
```

This line indicates that the primary key of the `PurchaseOrder_objtab` object table be used as the row's OID.

Line 5 - 8:

```
NESTED TABLE LineItemList_ntab STORE AS PoLine_ntab (
     (PRIMARY KEY(NESTED_TABLE_ID, LineItemNo))
     ORGANIZATION INDEX COMPRESS)
   RETURN AS LOCATOR
```

These lines pertain to the storage specification and properties of the nested table column, `LineItemList_ntab`. Recall from *Oracle8i Concepts* that the rows of a nested table are stored in a separate storage table. This storage table is not directly queryable by the user but can be referenced in DDL statements for maintenance purposes. A hidden column in the storage table, called the `NESTED_TABLE_ID`, matches the rows with their corresponding parent row. All the elements in the nested table belonging to a particular parent have the same `NESTED_TABLE_ID` value. For example, all the elements of the nested table of a given row of `PurchaseOrder_objtab` have the same value of `NESTED_TABLE_ID`. The nested table elements that belong to a different row of `PurchaseOrder_objtab` have a different value of `NESTED_TABLE_ID`.

In the `CREATE TABLE` example above, Line 5 indicates that the rows of `LineItemList_ntab` nested table are to be stored in a separate table (referred to as the storage table) named `PoLine_ntab`. The `STORE AS` clause also allows you to specify the constraint and storage specification for the storage table. In this example, Line 7 indicates that the storage table is an index-organized table (`IOT`). In general, storing nested table rows in an IOT is beneficial, because it provides clustering of rows belonging to the same parent. The specification of `COMPRESS` on the `IOT` saves storage space because, if you do not specify `COMPRESS`, the `NESTED_TABLE_ID` part of the `IOT`'s key is repeated for every row of a parent row object. If, however, you specify `COMPRESS`, the `NESTED_TABLE_ID` is stored only once for each row of a parent row object.

See Also: "Nested Table Storage" on page 18-16 for information about the benefits of organizing a nested table as and IOT and specifying nested table compression, and for more information about nested table storage.

In Line 6, the specification of NESTED_TABLE_ID and LineItemNo attribute as the primary key for the storage table serves two purposes: first, it serves as the key for the IOT; second, it enforces uniqueness of a column (LineItemNo) of a nested table within each row of the parent table. By including the LineItemNo column in the key, the statement ensures that the LineItemNo column contains distinct values within each purchase order.

Line 8 indicates that the nested table, LineItemList_ntab, is to be returned in the locator form when retrieved. If you do not specify LOCATOR, the default is VALUE, which indicates that the entire nested table is to be returned instead of just a locator to the nested table. When the cardinality of the nested table collection is high, it may not be very efficient to return the entire nested table whenever the containing row object or the column is selected.

Specifying that the nested table's locator is to be returned enables Oracle to send to the client only a locator to the actual collection value. An application may ascertain whether a fetched nested table is in the locator or value form by calling the OCICollIsLocator or UTL_COLL.IS_LOCATOR interfaces. Once it is determined that the locator has been returned, the application may query using the locator to fetch only the desired subset of row elements in the nested table. This locator-based retrieval of the nested table rows is based on the original statement's snapshot, to preserve the value or copy semantics of the nested table. That is, when the locator is used to fetch a subset of row elements in the nested table, the nested table snapshot reflects the nested table when the locator was first retrieved.

Recall the implementation of the sumLineItems method of PurchaseOrder_objtyp in "Method Definitions" on page 16-23. That implementation assumed that the LineItemList_ntab nested table would be returned as a VALUE. In order to handle large nested tables more efficiently, and to take advantage of the fact that the nested table in the PurchaseOrder_objtab is returned as a locator, the sumLineItems method would need to be rewritten as follows:

```
CREATE OR REPLACE TYPE BODY PurchaseOrder_objtyp AS

   MAP MEMBER FUNCTION getPONo RETURN NUMBER is
      BEGIN
         RETURN PONo;
      END;

   MEMBER FUNCTION sumLineItems RETURN NUMBER IS
      i          INTEGER;
      StockVal   StockItem_objtyp;
      Total      NUMBER := 0;
```

```
   BEGIN
      IF (UTL_COLL.IS_LOCATOR(LineItemList_ntab)) -- check for locator
         THEN
            SELECT SUM(L.Quantity * L.Stock_ref.Price) INTO Total
            FROM   TABLE(CAST(LineItemList_ntab AS LineItemList_ntabtyp)) L;
      ELSE
         FOR i in 1..SELF.LineItemList_ntab.COUNT LOOP
            UTL_REF.SELECT_OBJECT(LineItemList_ntab(i).Stock_ref,StockVal);
            Total := Total + SELF.LineItemList_ntab(i).Quantity *
                                                              StockVal.Price;
         END LOOP;
      END IF;
   RETURN Total;
   END;
END;
/
```

In the above implementation of `sumLineItems` method, a check is made to ascertain whether the nested table attribute, `LineItemList_ntab`, is returned as a locator using the `UTL_COLL.IS_LOCATOR` function. In the case where the condition evaluates to `TRUE`, the nested table locator is queried using the `TABLE` expression.

Note: The `CAST` expression is currently required in such `TABLE` expressions to communicate to the SQL compilation engine the actual type of the collection attribute (or parameter or variable) so that it can successfully compile the query.

The querying of the nested table locator results in a more efficient processing of the large line item list of a purchase order. The previous code segment of iterating over the `LineItemList_ntab` in the program is retained to deal with the case where the nested table is returned as a `VALUE`.

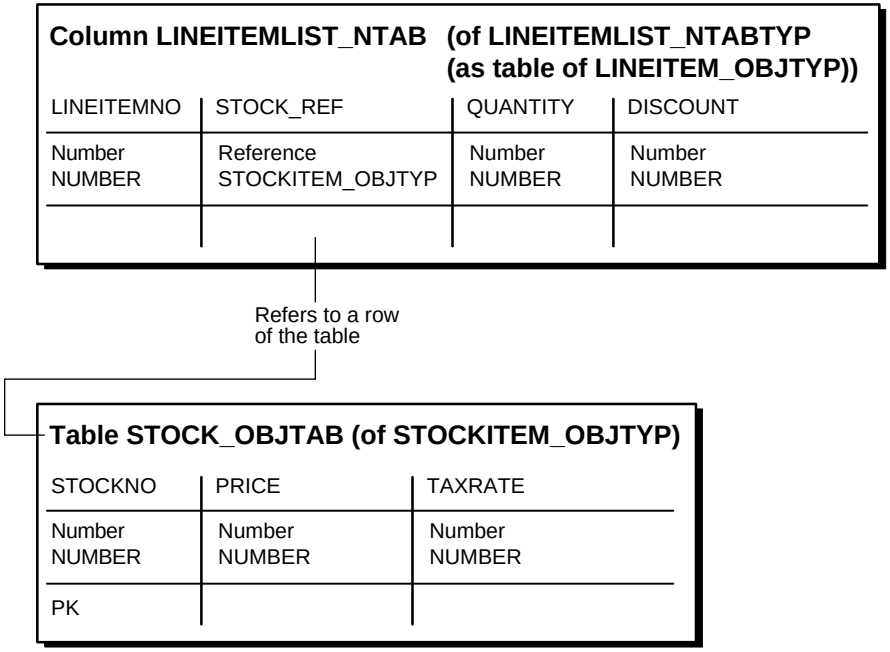
After the table is created, the following `ALTER TABLE` statement is issued:

```
ALTER TABLE PoLine_ntab
   ADD (SCOPE FOR (Stock_ref) IS stock_objtab);
```

This statement specifies that the `Stock_ref` column of the nested table is scoped to `Stock_objtab`. This indicates that the values stored in this column must be references to row objects in `Stock_objtab`. The `SCOPE` constraint is different from the referential constraint, because the `SCOPE` constraint has no implication on the referenced object. For example, any referenced row object in `Stock_objtab` may be deleted, even if it is referenced in the `Stock_ref` column of the nested table.

Such a deletion renders the corresponding reference in the nested table a DANGLING REF.

Figure 16–11 Object Relational Representation of Nested Table LineItemList_ntab

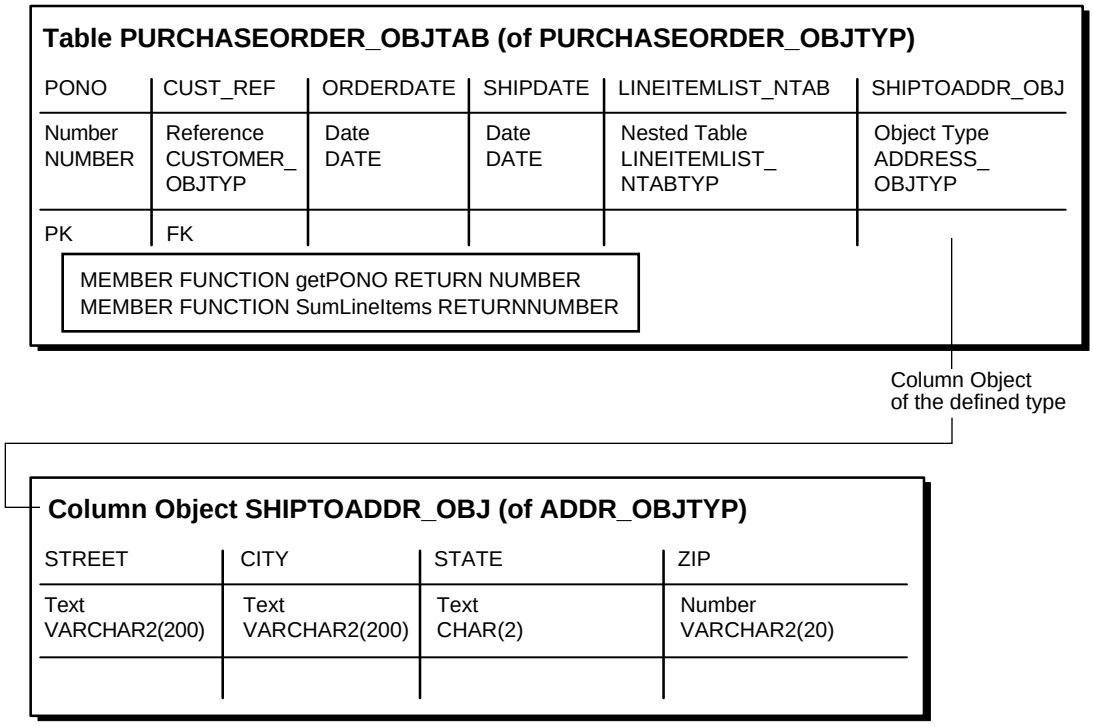


Oracle does not support referential constraint specification for storage tables. In this situation, specifying the SCOPE clause for a REF column is useful. In general, specifying scope or referential constraints for REF columns has a few benefits:

- It saves storage space because it allows Oracle to store just the row object's unique identifier as the REF value in the column.
- It enables an index to be created on the storage table's REF column.
- It allows Oracle to rewrite queries containing dereferences of these REFs as joins involving the referenced table.

At this point, all of the tables for the purchase order application are in place. The next section shows how to operate on these tables.

Figure 16–12 Object Relational Representation of Table PurchaseOrder_objtab



Inserting Values

The statements in this section show how to insert the same data into the object tables just created as the earlier statements inserted values into relational tables.

Stock_objtab

```
INSERT INTO Stock_objtab VALUES(1004, 6750.00, 2) ;
INSERT INTO Stock_objtab VALUES(1011, 4500.23, 2) ;
INSERT INTO Stock_objtab VALUES(1534, 2234.00, 2) ;
INSERT INTO Stock_objtab VALUES(1535, 3456.23, 2) ;
```

Customer_objtab

```
INSERT INTO Customer_objtab
  VALUES (
    1, 'Jean Nance',
    Address_objtyp('2 Avocet Drive', 'Redwood Shores', 'CA', '95054'),
    PhoneList_vartyp('415-555-1212')
    ) ;

INSERT INTO Customer_objtab
  VALUES (
    2, 'John Nike',
    Address_objtyp('323 College Drive', 'Edison', 'NJ', '08820'),
    PhoneList_vartyp('609-555-1212','201-555-1212')
    ) ;
```

PurchaseOrder_objtab

```
INSERT INTO PurchaseOrder_objtab
  SELECT  1001, REF(C),
          SYSDATE, '10-MAY-1999',
          LineItemList_ntabtyp(),
          NULL
   FROM   Customer_objtab C
   WHERE  C.CustNo = 1 ;
```

The preceding statement constructs a `PurchaseOrder_objtyp` object with the following attributes:

```
  PONo               1001
  Cust_ref           REF to customer number 1
  OrderDate          SYSDATE
  ShipDate           10-MAY-1999
  LineItemList_ntab  an empty LineItem_ntabtyp
  ShipToAddr_obj     NULL
```

The statement uses a query to construct a `REF` to the row object in the `Customer_objtab` object table that has a `CustNo` value of `1`.

The following statement uses a TABLE expression to identify the nested table as the target for the insertion, namely the nested table in the LineItemList_ntab column of the row object in the PurchaseOrder_objtab table that has a PONo value of 1001.

> **Note:** Oracle release 8.0 supports the "flattened subquery" or "THE (subquery)" expression to identify the nested table. This construct is being deprecated in release 8.1 in favor of the TABLE expression illustrated below.

```
INSERT INTO TABLE (
  SELECT  P.LineItemList_ntab
   FROM   PurchaseOrder_objtab P
   WHERE  P.PONo = 1001
  )
  SELECT  01, REF(S), 12, 0
   FROM   Stock_objtab S
   WHERE  S.StockNo = 1534 ;
```

The preceding statement inserts a line item into the nested table identified by the TABLE expression. The line item that it inserts contains a REF to the row object in the object table Stock_objtab that has a StockNo value of 1534.

The following statements are similar to the preceding two:

```
INSERT INTO PurchaseOrder_objtab
  SELECT  2001, REF(C),
          SYSDATE, '20-MAY-1997',
          LineItemList_ntabtyp(),
          Address_objtyp('55 Madison Ave','Madison','WI','53715')
   FROM   Customer_objtab C
   WHERE  C.CustNo = 2 ;

INSERT INTO TABLE (
  SELECT  P.LineItemList_ntab
   FROM   PurchaseOrder_objtab P
   WHERE  P.PONo = 1001
  )
  SELECT  02, REF(S), 10, 10
   FROM   Stock_objtab S
   WHERE  S.StockNo = 1535 ;
```

```
INSERT INTO TABLE (
  SELECT  P.LineItemList_ntab
   FROM   PurchaseOrder_objtab P
   WHERE  P.PONo = 2001
  )
  SELECT  10, REF(S), 1, 0
   FROM   Stock_objtab S
   WHERE  S.StockNo = 1004 ;

INSERT INTO TABLE (
  SELECT  P.LineItemList_ntab
   FROM   PurchaseOrder_objtab P
   WHERE  P.PONo = 2001
  )
  VALUES(11, (SELECT REF(S)
    FROM  Stock_objtab S
    WHERE S.StockNo = 1011), 2, 1) ;
```

Querying

The following query statement implicitly invokes a comparison method. It shows how Oracle uses the ordering of `PurchaseOrder_objtyp` object types that the comparison method defines:

```
SELECT  p.PONo
 FROM   PurchaseOrder_objtab p
 ORDER BY VALUE(p) ;
```

The preceding instruction causes Oracle to invoke the map method `getPONo` for each `PurchaseOrder_objtyp` object in the selection. Because that method simply returns the value of the object's `PONo` attribute, the result of the selection is a list of purchase order numbers in ascending numerical order.

The following queries correspond to the queries executed under the relational model.

Customer and Line Item Data for Purchase Order 1001

```
SELECT  DEREF(p.Cust_ref), p.ShipToAddr_obj, p.PONo,
        p.OrderDate, LineItemList_ntab
 FROM   PurchaseOrder_objtab p
 WHERE  p.PONo = 1001 ;
```

Total Value of Each Purchase Order

```
SELECT   p.PONo, p.sumLineItems()
 FROM    PurchaseOrder_objtab p ;
```

Purchase Order and Line Item Data Involving Stock Item 1004

```
SELECT   po.PONo, po.Cust_ref.CustNo,
         CURSOR (
           SELECT  *
            FROM   TABLE (po.LineItemList_ntab) L
            WHERE  L.Stock_ref.StockNo = 1004
           )
 FROM    PurchaseOrder_objtab po ;
```

The above query returns a nested cursor for the set of `LineItem_obj` objects selected from the nested table. The application can fetch from the nested cursor to obtain the individual `LineItem_obj` objects. The above query can be alternatively expressed by unnesting the nested set with respect to the outer result as follows:

```
SELECT   po.PONo, po.Cust_ref.CustNo, L.*
 FROM    PurchaseOrder_objtab po, TABLE (po.LineItemList_ntab) L
 WHERE   L.Stock_ref.StockNo = 1004 ;
```

The above query returns the result set as a "flattened" form (or First Normal Form). This type of query is useful when accessing Oracle collection columns from relational tools and APIs, such as ODBC. In the above unnesting example, only the rows of the `PurchaseOrder_objtab` object table that has any `LineItemList_ntab` rows are returned. If all rows of `PurchaseOrder_objtab` table are to be fetched, irrespective of the presence of any rows in their corresponding `LineItemList_ntab`, then the (+) operator is required as illustrated in the following query:

```
SELECT   po.PONo, po.Cust_ref.CustNo, L.*
 FROM    PurchaseOrder_objtab po, TABLE (po.LineItemList_ntab) (+) L
 WHERE   L.Stock_ref.StockNo = 1004 ;
```

Average Discount across all Line Items of all Purchase Orders

This request requires the rows of all nested tables, `LineItemList_ntab`, of all `PurchaseOrder_objtab` rows be queried. Again, unnesting is required for the following query:

```
SELECT   AVG(L.DISCOUNT)
 FROM    PurchaseOrder_objtab po, TABLE (po.LineItemList_ntab) L ;
```

Deleting

The following example has the same effect as the two deletions needed in the relational case (see "Deleting Data Under The Relational Model" on page 16-12). In this case, Oracle automatically deletes all line items belonging to the deleted purchase order. The relational case requires a separate step.

Delete Purchase Order 1001

```
DELETE
 FROM   PurchaseOrder_objtab
 WHERE  PONo = 1001 ;
```

This concludes the object table version of the purchase order example. The next chapter develops an alternative version of the example using relational tables and object views.

Partitioning Tables with Oracle Objects

Partitioning addresses the key problem of supporting very large tables and indexes by allowing you to decompose them into smaller and more manageable pieces called partitions. Oracle8*i* extends your partitioning capabilities by letting you partition tables that contain objects, REFs, varrays, and nested tables. Varrays stored in LOBs are equipartitioned in a way similar to LOBs.

The following example partitions the purchase order table along zip codes (`ToZip`), which is an attribute of the `ShipToAddr` embedded column object. For the purposes of this example, the `LineItemList` nested table was made a varray to illustrate storage for the partitioned varray.

Restriction: Nested tables are allowed in tables that are partitioned; however, the storage table associated with the nested table is not partitioned.

Assuming that the `LineItemList` is defined as a varray:

```
CREATE TYPE LineItemList_vartyp as varray(10000) of LineItem_objtyp
/

CREATE TYPE PurchaseOrder_typ AS OBJECT (
      PONo                NUMBER,
      Cust_ref            REF Customer_objtyp,
      OrderDate           DATE,
      ShipDate            DATE,
      OrderForm           BLOB,
      LineItemList        LineItemList_vartyp,
      ShipToAddr          Address_objtyp,

   MAP MEMBER FUNCTION
      ret_value RETURN NUMBER,
      PRAGMA RESTRICT_REFERENCES (
         ret_value, WNDS, WNPS, RNPS, RNDS),

   MEMBER FUNCTION
      total_value RETURN NUMBER,
      PRAGMA RESTRICT_REFERENCES (total_value, WNDS, WNPS)
  )
/

CREATE TABLE PurchaseOrders_tab of PurchaseOrder_typ
    LOB (OrderForm) store as (nocache logging)
    PARTITION BY RANGE (ShipToAddr.zip)
      (PARTITION PurOrderZone1_part
         VALUES LESS THAN ('59999')
         LOB (OrderForm) store as (
               storage (INITIAL 10 MINEXTENTS 10 MAXEXTENTS 100))
         VARRAY LineItemList store as LOB (
               storage (INITIAL 10 MINEXTENTS 10 MAXEXTENTS 100)),
    PARTITION PurOrderZone6_part
         VALUES LESS THAN ('79999')
         LOB (OrderForm) store as (
               storage (INITIAL 10 MINEXTENTS 10 MAXEXTENTS 100))
         VARRAY LineItemList store as LOB (
               storage (INITIAL 10 MINEXTENTS 10 MAXEXTENTS 100)),
    PARTITION PurOrderZoneO_part
       VALUES LESS THAN ('99999')
        LOB (OrderForm) store as (
               storage (INITIAL 10 MINEXTENTS 10 MAXEXTENTS 100))
        VARRAY LineItemList store as LOB (
               storage (INITIAL 10 MINEXTENTS 10 MAXEXTENTS 100))) ;
```

17

Objects in Views

This chapter contains an extended example of how to use object views. The chapter has the following major sections:

- Introduction
- Advantages of Using Views to Synthesize Objects
- Fundamental Elements of Using Objects in Views
- Extending the Purchase Order Example
- Using the OCI Object Cache

Introduction

The view mechanism has been extended to support objects: the view with row objects is called an object view. Why is this important? And how is it useful?

The need to maintain legacy applications, and a variety of other reasons, may require that the data be kept in relational format. The ability to create objects in views means that you can apply the object model to this data without changing its underlying structure. Just as you can define column objects and row objects (objects in object tables) in tables, you can define them in views. These column and row objects need not exist physically in the database and can simply be synthesized from relational data.

This makes objects in views a powerful object modeling tool to work with both relational and object data. For instance, using views for synthesizing objects can provide a stepping stone for "objectizing" relational data — prototyping the object model without modifying the storage structures. It also allows you to maintain co-existing relational and object applications.

This chapter deals with the various ways of defining and using such objects in views. We use the purchase-order example described in the previous chapters to show how to design the purchase-order object model. Specifically, we show how you would construct this model by using object views to synthesize objects from existing relational tables. We also show how complex views can be made "updatable" by using the `INSTEAD-OF` trigger mechanism.

See Also: *Oracle8i Concepts* for a discussion of object views and how to use them.

The example in this chapter illustrates the most important aspects of defining and using object views. The definitions of triggers use the PL/SQL language. The remainder of the example uses SQL.

See Also: *Oracle8i SQL Reference* for a complete description of SQL syntax and usage.

PL/SQL and Java provide additional capabilities beyond those illustrated in this chapter, especially in the area of accessing and manipulating the elements of collections.

> **See Also:** *PL/SQL User's Guide and Reference* for a complete discussion of PL/SQL capabilities, and *Oracle8i Java Stored Procedures Developer's Guide* for a complete discussion of Java.

Client applications that use the Oracle Call Interface (OCI) can take advantage of OCI's extensive facilities for accessing the objects and collections defined by object views and manipulating them on the client side.

> **See Also:** *Oracle Call Interface Programmer's Guide* for a complete discussion of those facilities.

Advantages of Using Views to Synthesize Objects

- Column objects and row objects in views can be synthesized from any data. The data may come from relational tables, object tables or data from any heterogeneous database.
- By synthesizing objects from relational data, we can extend the ways in which we can execute queries on the data. You can view data from multiple tables by using object de-referencing instead of writing complex joins with multiple tables.
- An object view provides a way of synthesizing row objects that have object identifiers and are capable of being referenced. By synthesizing such objects within the server, it endows the data with all the properties of objects — strong typing, structure (including multi-valued attributes), behavior (methods) and navigational access.
- Since the objects in the view are processed within the server, not on the client, this can result in significantly fewer SQL statements and much less network traffic.
- You can use views to provide security for existing object data. They can potentially expose only a subset of the attributes.
- Views can provide strong encapsulation of object data. By defining the view to be on the attribute accessor methods of the underlying object data, you can encapsulate the data and protect it against updates.
- You can deploy `INSTEAD-OF` triggers to update complex views since these triggers provide the logic of executing the actual DML. This allows you to

control the behavior of updates to complex object models and enforce security restrictions.

- The object data from object views can be pinned and used in the client side object cache. When you retrieve these synthesized objects in the object cache by means of specialized object retrieval mechanisms, you reduce network traffic.
- You gain great flexibility when you create an object model within a view in that you can continue to develop the model. If you need to alter an object type, you can simply replace the invalidated views with a new definition.
- Using objects in views does not place any restrictions on the characteristics of the underlying storage mechanisms. By the same token, you are not limited by the restrictions of current technology. For example, you can synthesize objects from relational tables which are parallelized and partitioned.
- You can create different complex data models from the same underlying data by means of object views. For example, you might wish to create one model of departments with embedded employees and another model in which department and employee objects mutually reference each other.
- You can also use objects views to model inverse relationships: you can use the same data to model one-to-one and one-to-many relationships as either embedded objects, or as collections of references to objects.

Fundamental Elements of Using Objects in Views

You need to understand the operation of a small number of basic elements in order to optimize your implementation of objects in views:

Objects in Columns

Column objects can be constructed by either selecting them from an underlying column object or by synthesizing them using the column's type constructor.

For example, consider the department table `dept` which has the following structure,

```
CREATE TABLE dept
(
    deptno       NUMBER PRIMARY KEY,
    deptname     VARCHAR2(20),
    deptstreet   VARCHAR2(20),
    deptcity     VARCHAR2(10),
    deptstate    CHAR(2),
    deptzip      VARCHAR2(10)
 );
```

Suppose you want to view all the departments and their addresses with the address as an object, you could do the following.

1. Create the type for the address object:

```
CREATE TYPE address_t AS OBJECT
(
   street   VARCHAR2(20),
    city    VARCHAR2(10),
    state   CHAR(2),
    zip     VARCHAR2(10)
);
/
```

2. Create the view containing the department number, name and address:

```
CREATE VIEW dept_view AS
  SELECT d.deptno, d.deptname,
              address_t(d.deptstreet,d.deptcity,d.deptstate,d.deptzip) AS
deptaddr
   FROM   dept d;
```

Now that the `deptaddr` column in the view is a structured object column, you can invoke member methods of the `address_t` object type on the objects synthesized in this column.

Atomic Nullness:

In the example shown above, the address object (`deptaddr`) can never be null (atomically null). In the relational department table we do not have a column that captures the nullness of the address for the department. If the nullness of the `deptstreet` column indicates that the whole address is null, then we can write a `DECODE`() expression to generate the atomic null object.

```
CREATE VIEW dept_view AS
  SELECT d.deptno, d.deptname,
        DECODE(d.deptstreet, NULL, NULL,
            address_t(d.deptstreet, d.deptcity, d.deptstate, d.deptzip)) AS
deptaddr
  FROM dept d;
```

We could also create functions other than the DECODE() expression to accomplish the same task. The drawback of these methods is that the deptaddr column becomes inherently "non-updatable" and so we would have to define an INSTEAD-OF trigger over the view to take care of updates to this column.

Collection Objects

Collections, both nested tables and VARRAYs, can be columns in views. You can select these collections from underlying collection columns or you can synthesize them using subqueries. The CAST-MULTISET operator provides a way of synthesizing such collections.

Taking the previous example as our starting point, let us represent each employee in an emp relational table with following structure:

```
CREATE TABLE emp
(
   empno    NUMBER PRIMARY KEY,
   empname  VARCHAR2(20),
   salary   NUMBER,
   deptno   NUMBER REFERENCES dept(deptno)
);
```

Using this relational table, we can construct a dept_view with the department number, name, address and a collection of employees belonging to the department.

1. Define a employee type and a nested table type for the employee type:

```
CREATE TYPE employee_t AS OBJECT
(
  eno NUMBER,
  ename VARCHAR2(20),
  salary  NUMBER
);
/
CREATE TYPE employee_list_t AS TABLE OF employee_t;
/
```

2. The dept_view can now be defined:

```
CREATE VIEW dept_view AS
  SELECT d.deptno, d.deptname,
         address_t(d.deptstreet,d.deptcity,d.deptstate,d.deptzip) AS deptaddr,
             CAST( MULTISET (
                          SELECT e.empno, e.empname, e.salary
                          FROM emp e
                          WHERE e.deptno = d.deptno)
                       AS employee_list_t)
                   AS emp_list
   FROM   dept d;
```

The SELECT subquery inside the CAST-MULTISET block selects the list of employees that belong to the current department. The MULTISET keyword indicates that this is a list as opposed to a singleton value. The CAST operator casts the result set into the appropriate type, in this case to the employee_list_t collection type.

A query on this view could give us the list of departments, with each department row containing the department number, name, the address object and a collection of employees belonging to the department.

Row Objects and Object Identifiers

The object view mechanism provides a way of creating row objects. Since the view data is not stored persistently, and therefore needs to be computed as required, utilizing object identifiers can become a tricky issue.

If the view is based on an object table or an object view, the row objects could take the same identifier as the underlying object entity. However, if the row object is synthesized from relational data, we do not have any object identifiers with which to work.

Oracle solves this problem by introducing primary key based object identifiers. The set of unique keys that identify the resultant row object is chosen to be the identifier for the object. This object identifier is itself synthesized using these key values. It is necessary for these values to be unique within the rows selected out of the view, since duplicates would lead to problems during navigation through object references.

The major benefits of defining these row objects are that they become capable of being referenced and can be pinned in the object cache.

Continuing with our department example, we can create a dept_view object view:

1. Define the object type for the row, in this case the dept_t department type:

```
CREATE TYPE dept_t AS OBJECT
(
  dno        NUMBER,
  dname      VARCHAR2(20),
  deptaddr   address_t,
  emplist    employee_list_t
);
/
```

In our case, the department table has deptno as the primary key. Consequently each department row will have a unique department number which can identify the row. This allows us to define the object view dept_view with the dno attribute (which maps to the deptno column value in the SELECT list of the view) as being the object identifier.

```
CREATE VIEW dept_view OF dept_t WITH OBJECT IDENTIFIER(dno)
   AS SELECT d.deptno, d.deptname,
                address_t(d.deptstreet,d.deptcity,d.deptstate,d.deptzip),
                CAST( MULTISET (
                          SELECT e.empno, e.empname, e.salary
                          FROM emp e
                          WHERE e.deptno = d.deptno)
                     AS employee_list_t)
   FROM   dept d;
```

If the object view is based on an object table or on another object view, the object identifiers need not be synthesized, and the object identifiers from the underlying table or view can be used provided that they still uniquely identify each object in this view. In that case, you either need not specify the WITH OBJECT IDENTIFIER clause, or you can specify WITH OBJECT IDENTIFIER DEFAULT to re-use the object identifiers from the underlying table or view source.

The object view created with the WITH OBJECT IDENTIFIER clause has a primary key based object identifier. If the WITH OBJECT IDENTIFIER DEFAULT clause is used during the creation of the view, the object identifier is either system generated or primary key based, depending on the underlying table or view definition.

Object References

In the example we have been developing, each object selected out of the dept_view view has a unique object identifier composed of the department number value. In the relational case, the foreign key deptno in the emp employee table matches the deptno primary key value in the dept department table. We used the primary key value for creating the object identifier in the dept_view. This allows

us to use the foreign key value in the emp_view in creating a reference to the primary key value in dept_view.

We accomplish this by using MAKE_REF operator to synthesize a primary key object reference. This takes the view or table name to which the reference points and a list of foreign key values to create the object identifier portion of the reference that will match with a particular object in the referenced view.

In order to create an emp_view view which has the employee's number, name, salary and a reference to the department in which she works, we need first to create the employee type emp_t and then the view based on that type

```
CREATE TYPE emp_t AS OBJECT
(
  eno      NUMBER,
  ename    VARCHAR2(20),
  salary   NUMBER,
  deptref  REF dept_t
);
/

CREATE VIEW emp_view OF emp_t WITH OBJECT IDENTIFIER(eno)
   AS SELECT e.empno, e.empname, e.salary,
                      MAKE_REF(dept_view, e.deptno)
         FROM emp e;
```

The deptref column in the view holds the department reference. We write the following simple query to determine all employees whose department is located in the city of San Francisco:

```
SELECT e.eno, e.salary, e.deptref.dno
FROM emp_view e
WHERE e.deptref.deptaddr.city = 'San Francisco';
```

Note that we could also have used the REF modifier to get the reference to the dept_view objects:

```
CREATE VIEW emp_view OF emp_t WITH OBJECT IDENTIFIER(eno)
   AS SELECT e.empno, e.empname, e.salary, REF(d)
         FROM emp e, dept_view d
          WHERE e.deptno = d.dno;
```

In this case we join the dept_view and the emp table on the deptno key. The advantage of using MAKE_REF operator instead of the REF modifier is that in using the former, we can create circular references. For example, we can create employee

view to have a reference to the department in which she works, and the department view can have a list of references to the employees who work in that department.

Note that if the object view has a primary key based object identifier, the reference to such a view is primary key based. On the other hand, a reference to a view with system generated object identifier will be a system generated object reference. This difference is only relevant when you create object instances in the OCI object cache and need to get the reference to the newly created objects. This is explained in a later section.

As with synthesized objects, we can also select persistently stored references as view columns and use them seamlessly in queries. However, the object references to view objects cannot be stored persistently.

Inverse Relationships

Views with objects can be used to model inverse relationships.

One-to-One Relationships

One-to-one relationships can be modeled with inverse object references. For example, let us say that each employee has a particular computer on her desk, and that the computer 'belongs' to that employee only. A relational model would capture this using foreign keys either from the computer table to the employee table, or in the reverse direction. Using views, we can model the objects so that we have an object reference from the employee to the computer object and also have a reference from the computer object to the employee.

One-to-Many and One-to-Many Relationships

One-to-many relationships (or many-to-many relationships) can be modeled either by using object references or by embedding the objects. One-to-many relationship can be modeled by having a collection of objects or object references. The many-to-one side of the relationship can be modeled using object references.

Consider the department-employee case. In the underlying relational model, we have the foreign key in the employee table. Using collections in views, we can model the relationship between departments and employees. The department view can have a collection of employees, and the employee view can have a reference to the department (or inline the department values). This gives us both the forward relation (from employee to department) and the inverse relation (department to list of employees). The department view can also have a collection of references to employee objects instead of embedding the employee objects.

Mutating Objects and Validation

INSTEAD-OF triggers provide a way of updating complex views which otherwise could not be updated. However, they can also be used to enforce constraints, check privileges and validate the DML. Using these triggers, you can control mutation of the objects created though an object view that might be caused by inserting, updating and deleting.

For instance, suppose we wanted to enforce the condition that the number of employees in a department cannot exceed 10. To enforce this, we can write an INSTEAD-OF trigger for the employee view. The trigger is not needed for doing the DML since the view can be updated, but we need it to enforce the constraint.

We implement the trigger by means of the following code:

```
CREATE TRIGGER emp_instr INSTEAD OF INSERT on emp_view
FOR EACH ROW
DECLARE
  dept_var dept_t;
  emp_count integer;
BEGIN
  -- Enforce the constraint..!
  -- First get the department number from the reference
  UTL_REF.SELECT_OBJECT(:NEW.deptref,dept_var);

  SELECT COUNT(*) INTO emp_count
  FROM emp
  WHERE deptno = dept_var.dno;

  IF emp_count < 9 THEN
       -- let us do the insert
      INSERT INTO emp VALUES (:NEW.eno,:NEW.ename,:NEW.salary,dept_var.dno);
  END IF;
END;
/
```

Extending the Purchase Order Example

In Chapter 16, "User-Defined Datatypes" we developed a purchase order example by following these steps:

1. Establish the entities and relationships.
2. Implement the entity-relationship structure by creating and populating the relational tables.

3. Define an object-relational schema of user-defined types to model the entity-relationship structure.
4. Implement the entity-relationship structure using the object-relational schema to create and populate object tables.

Using the mechanisms described in the previous section, let us redo the last step by creating an object-relational schema using views over relational tables.

Stock Object View

Stock objects are referenced from line item objects, and so we need to synthesize them from the `Stock_reltab` relational table. This mapping is straightforward as each attribute of the stock type directly maps to a column in the relational table. Since the stock number will uniquely identify each stock, we will use that for our object identifier. We define the stock object view as follows:

```
CREATE OR REPLACE VIEW Stock_objview OF StockItem_objtyp
   WITH OBJECT IDENTIFIER(StockNo)
    AS SELECT *
       FROM Stock_reltab;
```

Customer Object View

The customer object type (`Customer_objtyp`) includes an embedded address object (`Address_objtyp`) and a VARRAY (`PhoneList_vartyp`) of phone numbers. The relational table, `Customer_retab`, has three columns to store phone numbers. We can synthesize the VARRAY from these columns as show below,

```
CREATE OR REPLACE VIEW Customer_objview OF Customer_objtyp
   WITH OBJECT IDENTIFIER(Custno)
   AS SELECT c.Custno, C.custname,
             Address_objtyp(C.Street, C.City, C.State, C.Zip),
             PhoneList_vartyp(Phone1, Phone2, Phone3)
        FROM Customer_reltab c;
```

Again, the customer number forms the identifier for the customer object and the customer's address is synthesized using the default constructor of the `Address_objtyp`.

Purchase order view

The purchase order type uses a reference to the customer and has a collection of line item objects. The customer reference can be created using the `MAKE_REF` operator on the `Customer_objview` object view using the `Custno` foreign key in the

purchase order table. We can synthesize the line items from the line item table using a subquery to identify the line items corresponding to the particular purchase order. The line item type also includes a reference to the stock object which can be created using the MAKE_REF operator on the Stock_objview object view.

```
CREATE OR REPLACE VIEW PurchaseOrder_objview OF PurchaseOrder_objtyp
  WITH OBJECT IDENTIFIER(PONo)
   AS SELECT P.PONo,
             MAKE_REF(Customer_objview, P.Custno),
             P.OrderDate,
             P.ShipDate,
             CAST( MULTISET(
                    SELECT LineItem_objtyp( L.LineItemNo,
                                            MAKE_REF(Stock_objview,L.StockNo),
                                            L.Quantity, L.Discount)
                     FROM LineItems_reltab L
                     WHERE L.PONo = P.PONo)
                 AS LineItemList_ntabtyp),
          Address_objtyp(P.ToStreet,P.ToCity, P.ToState, P.ToZip)
         FROM PurchaseOrder_reltab P;
```

One minor point to note in the CAST-MULTISET operator is that we have used the base object type LineItem_objtyp in the SELECT list and constructed a list of line item objects and then cast them to the nested table type, LineItemList_ntabtyp. This is not necessary and we could have omitted the constructor and simply written the CAST-MULTISET part as

```
CAST( MULTISET (SELECT L.LineItemNo, MAKE_REF(..) …)
                              AS LineItemList_ntabtyp)
```

Oracle would automatically create the line item objects before creating the collection. However putting the constructor improves the readability of the CREATE-VIEW statement and forces a structural validation with the base type of the collection type specified in the CAST expression.

We have now created an object relational schema model using relational data and views. These views can be queried just like object tables.

Selecting

Objects synthesized using views will behave in the same way as native objects.

The following query statement implicitly invokes a comparison method. It shows how Oracle uses the ordering of PurchaseOrder_objtyp object types defined by the comparison method:

```
SELECT  p.PONo
 FROM   PurchaseOrder_objview p
 ORDER BY VALUE(p);
```

The preceding instruction causes Oracle to invoke the map method `getPONo` for each `PurchaseOrder_objtyp` object in the selection. Because that method returns the value of the object's `PONo` attribute, the result of the selection is a list of purchase order numbers in ascending numerical order. Remember that the object is constructed by the object view from underlying relational data.

The following queries correspond to the queries executed under the relational model.

Customer and Line Item Data for Purchase Order 1001

```
SELECT  DEREF(p.Cust_ref), p.ShipToAddr_obj, p.PONo,
        p.OrderDate, LineItemList_ntab
 FROM   PurchaseOrder_objview p
 WHERE  p.PONo = 1001 ;
```

Total Value of Each Purchase Order

```
SELECT   p.PONo, p.sumLineItems()
 FROM    PurchaseOrder_objview p ;
```

Purchase Order and Line Item Data Involving Stock Item 1004

```
SELECT   po.PONo, po.Cust_ref.CustNo,
         CURSOR (
              SELECT  *
              FROM    TABLE (po.LineItemList_ntab) L
              WHERE  L.Stock_ref.StockNo = 1004
           )
 FROM    PurchaseOrder_objview po ;
```

This query returns a nested cursor for the set of `LineItem_obj` objects selected from the nested table. The application can fetch from the nested cursor to obtain the individual `LineItem_obj` objects. You can implement the same query by unnesting the nested set with respect to the outer result:

```
SELECT   po.PONo, po.Cust_ref.CustNo, L.*
 FROM    PurchaseOrder_objview po, TABLE (po.LineItemList_ntab) L
 WHERE  L.Stock_ref.StockNo = 1004;
```

This query returns the result set as "flattened" in the First Normal Form form. This is useful when accessing Oracle collection columns from relational tools and APIs that cannot work with collections. In this example of unnesting, only the rows of the PurchaseOrder_objtab table which have any LineItemList_ntab rows are returned. If you need to fetch all rows of PurchaseOrder_objtab table irrespective of whether there are any rows in their corresponding LineItemList_ntab, an outer join (+) is required.

```
SELECT   po.PONo, po.Cust_ref.CustNo, L.*
 FROM    PurchaseOrder_objview  po, TABLE (po.LineItemList_ntab) (+) L
 WHERE  L.Stock_ref.StockNo = 1004;
```

Average Discount across all Line Items of all Purchase Orders

The following statement requires that the rows of all nested tables, LineItemList_ntab, of all PurchaseOrder_objview objects be queried. Again, unnesting is required for this query:

```
SELECT   AVG(L.DISCOUNT)
 FROM    PurchaseOrder_objview  po, TABLE (po.LineItemList_ntab) L;
```

As we have seen from the examples, views can help develop a good object model from any kind of data.

Updating Views

In the purchase-order model, the Stock_objview object view is a simple view and the system can translate any DML on the view into changes made to the underlying tables. However, in the case of the purchase order view (PurchaseOrder_objview), the task becomes complex and the view becomes inherently non-updatable. Such views (and any view) can be made updatable by defining INSTEAD-OF triggers for the view.

INSTEAD-OF triggers are triggers that fire upon an insert, delete or update of a row of a view on which they are defined and the body of the trigger contains the code for performing the DML. This means that when you create an INSTEAD-OF trigger, you specify the exact way to handle an update to the view.

As is the case with any other trigger, the new and old values of the row can be obtained through the respective qualifiers.

> **See Also:** Chapter 13, "Using Triggers" for more information about working with triggers.

For example, let us consider the `PurchaseOrder_objview` object view. Each row of the view contains a purchase order object with an embedded shipping address object, a reference to a customer object and a list of line items.

To translate an insert on this view into a change of the underlying data, we need to map the object attributes back to the relational tables from which we obtained those values. Specifically, we need to map the customer reference back to the customer number and map the line item list to the line item relational table.

INSTEAD-OF Trigger for PurchaseOrder_objview

```
CREATE OR REPLACE TRIGGER POView_instdinserttr
        INSTEAD OF INSERT on PurchaseOrder_objview
 DECLARE
  LineItems_ntab    LineItemList_ntabtyp;
  i                 INTEGER;
  CustVar_obj       Customer_objtyp;
  StockVar_obj      StockItem_objtyp;
  StockVarTemp_ref  REF StockItem_objtyp;

 BEGIN

   LineItems_ntab := :new.LineItemList_ntab;
   UTL_REF.SELECT_OBJECT(:new.Cust_ref, CustVar_obj);

   INSERT INTO PurchaseOrder_reltab
     VALUES(:new.PONo,CustVar_obj.Custno,:new.OrderDate,:new.ShipDate,
            :new.ShipToAddr_obj.Street,:new.ShipToAddr_obj.City,
            :new.ShipToAddr_obj.State,:new.ShipToAddr_obj.Zip) ;

   FOR i in 1..LineItems_ntab.count LOOP
     UTL_REF.SELECT_OBJECT(LineItems_ntab(i).Stock_ref, StockVar_obj);
     INSERT INTO LineItems_reltab
       VALUES(LineItems_ntab(i).LineItemNo,:new.PONo,StockVar_obj.StockNo,
              LineItems_ntab(i).Quantity,LineItems_ntab(i).Discount);
   END LOOP;

 END;
/
```

```
CREATE OR REPLACE TRIGGER POView_instddeletetr
        INSTEAD OF DELETE on PurchaseOrder_objview
  BEGIN

   DELETE FROM LineItems_reltab
   WHERE PONo = :old.PONo;

   DELETE FROM PurchaseOrder_reltab
   WHERE PONo = :old.PONo;

  END;
/
```

Note the use of the UTL_REF.SELECT_OBJECT function in the trigger. The UTL_REF package provides functions for pinning an object reference and selecting the object value. In the purchase order case, we need to get the object instances for the customer reference and the stock reference so that we can get the customer number and stock number to insert into the relational tables. You use the UTL_REF functions to accomplish this.

Any insert of the form,

```
INSERT INTO PurchaseOrder_objview
   SELECT 1001, REF(cust),,….
```

would fire the INSTEAD-OF trigger to perform the necessary action.

Similarly any deletes on the purchase order view would fire the POView_instddeletetr and delete the purchase order and the corresponding line items.

Inserting into the Nested Table

In the purchase order example, we might also want to be able to update the lineItemList collection elements directly:

```
INSERT INTO TABLE(SELECT e.lineItemList FROM PurchaseOrder_objview e
                                  WHERE e.PONo = 1001)
 VALUES (101,….);;
```

To do this we can define an INSTEAD-OF trigger over the nested table column to perform a similar action. These triggers are fired on DML statements that target the nested table using the TABLE<collection subquery>, and fire for each row of the collection being modified. The new and old qualifiers correspond to the new and old values of the collection element.

We can code the trigger in a similar way. One important difference is that the line item list object does not include the purchase order number which we need for inserting a row into the line item list table. However, we have this in the `parent` row corresponding to the collection entity being modified, and we can access this parent row's value through the `parent` qualifier.

The example below creates an instead-of trigger for the `LineItemList_ntab` nested table of object view, `PurchaseOrder_objview`.

```
CREATE OR REPLACE TRIGGER POLineItems_instdinsertr
  INSTEAD OF INSERT ON NESTED TABLE LineItemList_ntab OF PurchaseOrder_objview
DECLARE
  StockVar StockItem_objtyp;
BEGIN
  UTL_REF.SELECT_OBJECT(:NEW.Stock_ref, StockVar);
  INSERT INTO LineItems_reltab
   VALUES (:NEW.LineItemNo, :PARENT.PONo, StockVar.StockNo, :NEW.Quantity,
                       :NEW.Discount);
END;
/
CREATE OR REPLACE TRIGGER POLineItems_instddeltr
   INSTEAD OF DELETE ON NESTED TABLE LineItemList_ntab OF PurchaseOrder_objview
BEGIN
  DELETE FROM LineItems_reltab
    WHERE LineItemNo = :OLD.LineItemNo AND PONo = :PARENT.PONo;
END;
/
```

INSTEAD-OF Trigger for Customer_objview

In the `Customer_objview` case, we have an embedded object for the customer's address and a VARRAY of phone numbers. Our task is that we need to extract each element of the VARRAY and insert it into the phone columns in the base table.

```
CREATE OR REPLACE TRIGGER CustView_instdinserttr
       INSTEAD OF INSERT on Customer_objview
DECLARE
  Phones_var  PhoneList_vartyp;
  TPhone1 Customer_reltab.Phone1%TYPE := NULL;
  TPhone2 Customer_reltab.Phone2%TYPE := NULL;
  TPhone3 Customer_reltab.Phone3%TYPE := NULL;
BEGIN

   Phones_var := :new.PhoneList;
```

```
    IF Phones_var.COUNT > 2 then
     TPhone3 := Phones_var(3);
    END IF;
    IF Phones_var.COUNT > 1 then
     TPhone2 := Phones_var(2);
    END IF;
    IF Phones_var.COUNT > 0 then
     TPhone1 := Phones_var(1);
    END IF;

    INSERT INTO Customer_reltab
       VALUES(:new.Custno,:new.Custname,:new.Address.Street,
              :new.Address.City, :new.Address.State, :new.Address.Zip,
              TPhone1,TPhone2,TPhone3);
  END;
/
```

This trigger function updates the `Customer_reltab` table with the new information. Most of the program deals with updating the three phone number columns of the `Customer_reltab` table from the VARRAY of phone numbers. The `IF` statements assure that the program does not attempt to access elements with indexes greater than the specified number.

There is a slight mismatch between these two representations, because the VARRAY is defined hold up to ten numbers, while the customer table has only three phone number columns. The trigger program discards elements with indexes greater than three.

INSTEAD-OF Trigger for Stock_objview

The Stock_objview is a simple view which is inherently updatable. We do not have to define an `INSTEAD-OF` trigger for performing DML on it. However, we might want to enforce constraints on it, such as the `TaxRate` not being greater than 30%. We might also want to record this new Stock addition in the `Stock_archive_tab` which stores information on the stock purchase and depletion.

The `Stock_archive_tab` structure is shown below

```
CREATE TABLE Stock_archive_tab
(
   archive_date    DATE,
   StockNo         NUMBER,
   Price           NUMBER,
   TaxRate         NUMBER
);
```

```
CREATE OR REPLACE TRIGGER StockView_instdinsertr
        INSTEAD OF INSERT on Stock_objview
  BEGIN

    -- When the TaxRate is greater than 30% we can simply ignore the
    --  row or raise an exception.
    IF :new.TaxRate <= 30 THEN
      -- insert the values into the Stock table
      INSERT INTO Stock_reltab
         VALUES(:new.StockNo,:new.Cost,:new.TaxRate);

      --  Let us record this stock increase in the archive:
      INSERT INTO Stock_archive_tab
         VALUES (SYSDATE, :new.StockNo, :new.Cost, :new.TaxRate);

    END IF;
 END;
/
```

This trigger function updates the `Stock_reltab` table with the new information and also archives it. Similarly, we can implement delete and update triggers on the view which would both update the base table and also the archival table.

Inserting Values

The statements in this section show how to insert the same data into the object views created. Again, we have used the same examples as the last chapter to show how the synthesized objects in views behaves in the same way as native objects.

Stock_objview

```
INSERT INTO Stock_objview VALUES(1004, 6750.00, 2);
INSERT INTO Stock_objview VALUES(1011, 4500.23, 2);
INSERT INTO Stock_objview VALUES(1534, 2234.00, 2);
INSERT INTO Stock_objview VALUES(1535, 3456.23, 2);
```

The `INSTEAD-OF` trigger on the view would automatically record these insertions.

The following insert would not be recorded as our `StockView_instdinsertr` would prevent a stock object with `TaxRate` greater than 30% to be inserted.

```
INSERT INTO Stock_objview VALUES(1535, 3456.23, 32);
```

Customer_objview

Let us insert some customers in our system.

```
INSERT INTO Customer_objview
  VALUES (
     1, 'Jean Nance',
     Address_objtyp('2 Avocet Drive', 'Redwood Shores', 'CA', '95054'),
     PhoneList_vartyp('415-555-1212')
    ) ;

INSERT INTO Customer_objview
  VALUES (
     2, 'John Nike',
     Address_objtyp('323 College Drive', 'Edison', 'NJ', '08820'),
     PhoneList_vartyp('609-555-1212','201-555-1212')
    ) ;
```

PurchaseOrder_objview

```
INSERT INTO PurchaseOrder_objview
  VALUES ( 1001, ( SELECT REF(C)
                   FROM   Customer_objview C
                   WHERE  C.CustNo = 1),
            SYSDATE, '10-MAY-1997',
            LineItemList_ntabtyp(), NULL );
```

The preceding statement constructs a `PurchaseOrder_objtyp` object with the following attributes:

```
  PONo            1001
  Cust_ref        REF to customer number 1
  OrderDate       SYSDATE
  ShipDate        10-MAY-1997
  LineItemList    an empty LineItem_objtyp
  ShipToAddr      NULL
```

The statement uses a query to construct an object reference to the row object in the `Customer_objtab` object table that has a `CustNo` value of 1. Note the use of the subquery in the `VALUES` clause to construct an object reference to the customer. This query returns a single value.

We could also have used the `MAKE_REF` operator to construct the object reference with the same result,

```
INSERT INTO PurchaseOrder_objview
```

```
  VALUES( 1001,  MAKE_REF(Customer_objview, 1) ,
          SYSDATE,'10-MAY-1997', LineItemList_ntabtyp(), NULL);
```

The next statement uses a TABLE expression to identify the nested table as the target for the insertion. In this case, we are targeting the nested table in the LineItemList_ntab column of the row object in the PurchaseOrder_objview view that has a PONo value of 1001.

> **Note:** Oracle8.0 supports the "flattened subquery" or "THE(<subquery>)" expression to identify the nested table. This construct is being deprecated in favor of the TABLE expression illustrated below.

```
INSERT INTO TABLE (
    SELECT  P.LineItemList_ntab
    FROM    PurchaseOrder_objview P
    WHERE   P.PONo = 1001
   )
     SELECT  01, REF(S), 12, 0
     FROM    Stock_objview S
     WHERE   S.StockNo = 1534;
```

The preceding statement inserts a line item into the nested table identified by the TABLE expression. The line item that it inserts contains a reference to the row object in the object view Stock_objview that has a StockNo value of 1534. Remember that this will fire the POLineItems_instdinsertr trigger to insert the line item values into the LineItems_reltab relational table.

Deleting

The following example has the same effect as the deletions made in the relational case (see "Deleting Data Under The Relational Model" on page 16-12 in Chapter 16, "User-Defined Datatypes"). With views and INSTEAD-OF triggers, when a purchase order object is deleted, all line items belonging to the purchase order is automatically deleted. The relational case requires a separate step.

Delete Purchase Order 1001

```
DELETE
 FROM   PurchaseOrder_objview p
 WHERE  p.PONo = 1001 ;
```

This concludes the view version of the purchase order example.

Using the OCI Object Cache

We can pin and navigate objects synthesized from object views in the OCI Object Cache similar to the way we do this with object tables. We can also create new view objects, update them, delete them and flush them from the cache. The flush performs the appropriate DML on the view (such as insert for newly created objects and updates for any attribute changes). This would fire the `INSTEAD-OF` triggers if any on the view and the object would get stored persistently.

There is a minor difference between the two approaches with regard to getting the reference to a newly created instance in the object cache.

In the case of object views with primary key based reference, the attributes that make up the identifier for the object need to be initialized before the `OCIObjectGetObjectRef` call can be called on the object to get the object reference. For example, to create a new object in the OCI Object cache for the purchase order object, we need to take the following steps:

```
.. /* Initialize all the settings including creating a connection, getting a
      environment handle etc. We do not check for error conditions to make
      the example eaiser to read. */
OCIType *purchaseOrder_tdo = (OCIType *) 0; /* This is the type object for the
                                               purchase order */
dvoid * purchaseOrder_viewobj = (dvoid *) 0;   /* This is the view object */

/* The purchaseOrder struct is a structure that is defined to have the same
attributes as that of  PurchaseOrder_objtyp type. This can be created by the
user or generated automatically using  the OTT generator. */
purchaseOrder_struct *purchaseOrder_obj;

/* This is the null structure corresponding to the purchase order object's
attributes */
purchaseOrder_nullstruct *purchaseOrder_nullobj;

/* This is the variable containing the purchase order number that we need to
create */
int PONo = 1003;

/* This is the reference to the purchase order object */
OCIRef *purchaseOrder_ref = (OCIRef *)0;
```

```
/* Pin the object type first */
OCITypeByName( envhp, errhp, svchp,
                              (CONST text *) "",  (ub4) strlen( "") ,
                              (CONST text *) "PURCHASEORDER_OBJTYP" ,
                              (ub4) strlen("PURCHASEORDER_OBJTYP"),
                              (CONST char *) 0, (ub4)0,
                              OCI_DURATION_SESSION, OCI_TYPEGET_ALL,
&purchaseOrder_tdo);

/* Pin the table object - in this case it is the purchase order view */
OCIObjectPinObjectTable(envhp, errhp, svchp, (CONST text *) "",
                               (ub4) strlen( "" ),
                               (CONST text *) "PURCHASEORDER_OBJVIEW",
                               (ub4 ) strlen("PURCHASEORDER_OBJVIEW"),
                               (CONST OCIRef *) NULL,
                                OCI_DURATION_SESSION,
                                &purchaseOrder_viewobj);

/* Now create a new object in the cache. This is a purchase order object */
OCIObjectNew(envhp, errhp, svchp, OCI_TYPECODE_OBJECT, purchaseOrder_tdo,
                    purchaseOrder_viewobj, OCI_DURATION_DEFAULT, FALSE,
                    (dvoid **) *purchaseOrder_obj);

/* Now we can initialize this object, and use it as a regular object. But before
getting the reference to this object we need to initialize the PONo attribute of
the object which makes up its object identifier in the view */

/* Initialize the null identifiers */
OCIObjectGetInd( envhp, errhp, purchaseOrder_obj, purchaseOrder_nullobj);

purchaseOrder_nullobj->purchaseOrder = OCI_IND_NOTNULL;
purchaseOrder_nullobj->PONo = OCI_IND_NOTNULL;

/* This sets the PONo attribute */
OCINumberFromInt( errhp, (CONST dvoid *) &PoNo, sizeof(PoNo), OCI_NUMBER_SIGNED,
                                 &( purchaseOrder_obj->PONo));

/* Create an object reference */
OCIObjectNew( envhp, errhp, svchp, OCI_TYPECODE_REF, (OCIType *) 0,
                         (dvoid *) 0, (dvoid *) 0, OCI_DURATION_DEFAULT, TRUE,
                         (dvoid **) &purchaseOrder_ref);

/* Now get the reference to the newly created object */
OCIObjectGetObjectRef(envhp, errhp, (dvoid *) purchaseOrder_obj, purchaseOrder_
ref);
```

```
/* This reference may be used in the rest of the program ….. */
…
/* We can flush the changes to the disk and the newly instantiated purchase
order object in the object cache will become permanent. In the case of the
purchase order object, the insert will fire the INSTEAD-OF trigger defined over
the purchase order view to do the actual processing */

OCICacheFlush( envhp, errhp, svchp, (dvoid *) 0, 0, (OCIRef **) 0);
…
```

Views on Remote Tables

Views can be used to synthesize objects from remote tables.

Consider the case of a company which has three branches — one in Washington D.C., another in Seattle and a third in Chicago. Let us say that each of these sites has an employee table that is maintained separately by the respective IT departments. The headquarters in Washington has an department table that has the list of all the departments. Supposing that the CEO wants to get a total view of the entire organization, we can create views over the individual remote tables and then a overall view of the organization:-

Let us create the individual views first.

```
CREATE VIEW emp_washington_view (eno,ename,salary)
   AS SELECT e.empno, e.empname, e.salary
          FROM   emp@washington_link e;

CREATE VIEW emp_chicago_view
   AS SELECT e.eno, e.name, e.salary
          FROM   emp_tab@chicago_link e;

CREATE VIEW emp_seattle_view (eno,ename,salary)
   AS SELECT e.employeeno, e.employeename, e.employeesalary
          FROM   employeetab@seattle_link e;
```

We can now create the global view as follows:-

```
CREATE VIEW orgnzn_view  OF dept_t WITH OBJECT IDENTIFIER  (dno)
    AS SELECT d.deptno, d.deptname,
              address_t(d.deptstreet,d.deptcity,d.deptstate,d.deptzip),
              CAST( MULTISET (
                      SELECT e.eno, e.ename, e.salary
                      FROM emp_washington_view e)
```

```
                AS employee_list_t)
    FROM   dept d
    WHERE d.deptcity = 'Washington'
UNION ALL
    SELECT d.deptno, d.deptname,
           address_t(d.deptstreet,d.deptcity,d.deptstate,d.deptzip),
           CAST( MULTISET (
                    SELECT e.eno, e.name, e.salary
                    FROM emp_chicago_view e)
                 AS employee_list_t)
    FROM   dept d
    WHERE d.deptcity = 'Chicago'
UNION ALL
     SELECT d.deptno, d.deptname,
            address_t(d.deptstreet,d.deptcity,d.deptstate,d.deptzip),
            CAST( MULTISET (
                    SELECT e.eno, e.ename, e.salary
                    FROM emp_seattle_view e)
                AS employee_list_t)
    FROM   dept d
    WHERE d.deptcity = 'Seattle;
```

This view would now have list of all employees for each department. We use UNION ALL in this example since we cannot have two employees working in more than one department. If we had to deal with that eventuality, we could use a UNION of the rows. However, one caveat in using the UNION operator is that we need to introduce an ORDER BY operator within the CAST-MULTISET expressions so that the comparison of two collections is performed properly.

Partitioning Tables with Objects

Working with very large tables and indexes may lead you to decompose them into smaller and more manageable pieces called partitions. Since using objects in views does not affect the storage characteristics of the underlying tables, queries on objects with views can be optimized to take advantage of the partitions.

Parallel Query with Objects

Parallel query is supported on the objects synthesized from views.

To execute queries involving joins and sorts (using the ORDER BY, GROUP BY, and SET operations) in parallel, a MAP function is needed. In the absence of a MAP function, the query automatically becomes serial.

Parallel queries on nested table columns are not supported. Even in the presence of parallel hints or parallel attributes for the view, the query will be serial if it involves the nested table column.

Parallel DML is not supported on views with INSTEAD-OF trigger. However, the individual statements within the trigger may be parallelized.

Circular View References

You can define circular references to views using the MAKE_REF operator: view_A can refer to view_B which in turn can refer to view_A.

For example, in the case of the department and employee, the department object currently includes a list of employees. We may not want to materialize the entire list and instead opt to use references to employee objects. This may be necessary, for instance, if the employee object is large and we do not need all the employee objects to be materialized. We can pin the necessary employee references and extract the information later.

The employee object already has a reference to the department in which the employee works.

If we create object view over this model, we would get circular references between the department view and the employee view.

We can create circular references between object views in two different ways.

Method 1:

1. Create view A without including the reference to view B (that is, have a NULL value for the MAKE_REF column).
2. Create view B which includes the reference to view A.
3. Replace view A with a new definition which includes the reference to view B.

Method 2:

1. Create view A with the reference to view B using the FORCE keyword.
2. Create view B with reference to view A. When view A is used it is validated and re-compiled.

The advantage of Method 2 is that we do not have to repeat the creation of the view. But the disadvantage is other errors in the view creation may get masked because of the FORCE keyword. You need to use USER_ERRORS catalog view to get the errors

during the view creation in this case. Use this method only if you are sure that there are no errors in the view creation statement.

Also, if the views do not get automatically recompiled upon use because of errors, you would need to recompile them manually using the `ALTER VIEW COMPILE` command.

We will see the implementation for both the methods.

Creation of Tables and Types

Create the `emp` table to store the employee information.

```
CREATE TABLE emp
(
   empno    NUMBER PRIMARY KEY,
   empname  VARCHAR2(20),
   salary   NUMBER,
   deptno   NUMBER
);
```

Create the *emp_t* type with the reference to the department. Create a dummy department type so that the *emp_t* type creation does not result in any warnings or errors.

```
CREATE TYPE dept_t;
/
```

Create the employee type that includes a reference to the department.

```
CREATE TYPE emp_t AS OBJECT
(
  eno NUMBER,
  ename VARCHAR2(20),
  salary  NUMBER,
  deptref REF dept_t
);
/
```

Create the list of references to employee types.

```
CREATE TYPE employee_list_ref_t AS TABLE OF REF emp_t;
/
```

Create the department table.

```
CREATE TABLE dept
(
    deptno        NUMBER PRIMARY KEY,
    deptname      VARCHAR2(20),
```

```
    deptstreet    VARCHAR2(20),
    deptcity      VARCHAR2(10),
    deptstate     CHAR(2),
    deptzip       VARCHAR2(10)
 );
```

Create an address type to store the address information as an object.

```
CREATE TYPE address_t AS OBJECT
(
   street        VARCHAR2(20),
    city         VARCHAR2(10),
    state        CHAR(2),
    zip          VARCHAR2(10)
);
/
```

Create the department type. Note that we are replacing the existing department type.

```
CREATE OR REPLACE TYPE dept_t AS OBJECT
(
  dno           NUMBER,
  dname         VARCHAR2(20),
  deptaddr      address_t,
  empreflist    employee_list_ref_t
);
/
```

View Creation

Having created the necessary types with the underlying relational table definition, let us create the object views on top of them.

Method 1: Create the views without using the FORCE keyword.

Here we will first create the employee view without including the reference to the department view.

```
CREATE VIEW emp_view OF emp_t WITH OBJECT IDENTIFIER(eno)
   AS SELECT e.empno, e.empname, e.salary,
                        NULL
         FROM emp e;
```

The *deptref* column has a NULL value in it.

Next, we create the department view which includes references to the employee objects.

```
CREATE VIEW dept_view OF dept_t WITH OBJECT IDENTIFIER(dno)
   AS SELECT d.deptno, d.deptname,
                address_t(d.deptstreet,d.deptcity,d.deptstate,d.deptzip),
                CAST( MULTISET (
                           SELECT MAKE_REF(emp_view, e.empno)
                           FROM emp e
                           WHERE e.deptno = d.deptno)
                       AS employee_list_ref_t)
   FROM   dept d;
```

Here we have a created a list of references to employee objects in the department view instead of including the entire employee object. We can now proceed to re-create the employee view with the reference to the department view.

```
CREATE OR REPLACE VIEW emp_view OF emp_t WITH OBJECT IDENTIFIER(eno)
   AS SELECT e.empno, e.empname, e.salary,
                       MAKE_REF(dept_view, e.deptno)
         FROM emp e;
```

This creates the views.

Method 2: Creating the views with the FORCE keyword.

If we are sure that we do not have any syntax errors in the view creation statement, we can use the FORCE keyword to first force the creation of one of the views without the other view being present.

Let us first create an employee view which includes a reference to the department view. At this point, the department view has not been created and so the employee view is being forced into creation. This view cannot be queried until the department view is created properly.

```
CREATE FORCE VIEW emp_view OF emp_t WITH OBJECT IDENTIFIER(eno)
   AS SELECT e.empno, e.empname, e.salary,
                       MAKE_REF(dept_view, e.deptno)
         FROM emp e;
```

Next, we create the department view which includes references to the employee objects. We do not have to use the FORCE keyword here, since emp_view already exists.

```
CREATE VIEW dept_view OF dept_t WITH OBJECT IDENTIFIER(dno)
```

```
AS SELECT d.deptno, d.deptname,
            address_t(d.deptstreet,d.deptcity,d.deptstate,d.deptzip),
            CAST( MULTISET (
                        SELECT MAKE_REF(emp_view, e.empno)
                        FROM emp e
                        WHERE e.deptno = d.deptno)
                    AS employee_list_ref_t)
FROM   dept d;
```

This allows us to query the department view, getting the employee object by pinning the object reference.

We can retrieve the entire employee object by de-referencing the employee reference from the nested table `empreflist`.

```
SELECT DEREF(e.COLUMN_VALUE)
FROM TABLE( SELECT e.empreflist FROM dept_view e WHERE e.dno = 100) e;
```

The `COLUMN_VALUE` column is used to get to the scalar value in a scalar nested table. In this case, `COLUMN_VALUE` denotes the reference to the employee objects in the nested table `empreflist`.

We could also access only the employee number of all those employees whose name begins with “John”.

```
SELECT e.COLUMN_VALUE.eno
FROM TABLE(SELECT e.empreflist FROM dept_view e WHERE e.dno = 100) e
WHERE e.COLUMN_VALUE.ename like ‘John%’;
```

To get a tabular output, unnest the list of references:

```
SELECT d.dno, e.COLUMN_VALUE.eno, e.COLUMN_VALUE.ename
FROM dept_view d, TABLE(d.empreflist) e
WHERE e.COLUMN_VALUE.ename like ‘John%’
 AND   d.dno = 100;
```

Finally, we could rewrite the above query to use the `emp_view` instead of the `dept_view` in order to demonstrate the functionality of circular nature of the reference:

```
SELECT e.deptref.dno, DEREF(f.COLUMN_VALUE)
FROM emp_view e, TABLE(e.deptref.empreflist) f
WHERE e.deptref.dno = 100
AND f.COLUMN_VALUE.ename like 'John%';
```

18

Design Considerations for Oracle Objects

This chapter explains the implementation and performance characteristics of Oracle's object-relational model. The information in this chapter enables database designers to understand the advantages and disadvantages of various ways of mapping a logical data model into an Oracle physical implementation. This chapter also enables application developers to be aware of the various design issues to consider so that the they can use the features of Oracle objects effectively.

Specifically, this chapter covers the following topics:

- Object Types
- REFs
- Collections
- Methods
- Other Considerations

You should be familiar with the basic concepts behind Oracle objects before you read this chapter.

See Also: *Oracle8i Concepts* for conceptual information about Oracle objects, and see *Oracle8i SQL Reference* for information about the SQL syntax for using Oracle objects.

Object Types

Object types are abstractions of real-world entities, such as purchase orders, that interact with application programs. You can think of an object type as a template and a structured data unit that matches the template as an object. Object types can represent many different data structures; a few examples are line items, images, and spatial data.

You can use object types to map an object model directly to a database schema, instead of flattening the model to relational tables and columns. Objects enable you to bring related pieces of data together in a single unit, and object types allow you to store the behavior of data along with the data itself. Application code can retrieve and manipulate the data as objects.

Column Objects vs. Row Objects

You can store objects in columns of relational tables as column objects, or in object tables as row objects. Objects that have meaning outside of the relational database object in which they are contained, or objects that are shared among more than one relational database object, should be made referenceable as row objects. That is, such objects should be stored in an object table instead of in a column of a relational table.

For example, an object of object type `CUSTOMER` has meaning outside of any particular purchase order, and should be referenceable; therefore, `CUSTOMER` objects should be stored as row objects in an object table. An object of object type `ADDRESS`, however, has little meaning outside of a particular purchase order and can be one attribute within a purchase order; therefore, `ADDRESS` objects should be stored as column objects in columns of relational tables or object tables. So, `ADDRESS` might be a column object in the `CUSTOMER` row object.

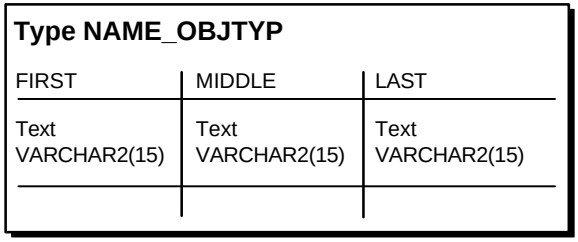
Column Object Storage

The storage of a column object is the same as the storage of an equivalent set of scalar columns that collectively make up the object. The only difference is that there is the additional overhead of maintaining the atomic null values of the object and its embedded object attributes. These values are called *null indicators* because, for every column object, a null indicator specifies whether the column object is null and whether each of its embedded object attributes is null. However, null indicators do not specify whether the scalar attributes of a column object are null. Oracle uses a different method to determine whether scalar attributes are null.

Consider a table that holds the identification number, name, address, and phone numbers of people within an organization. You can create three different object types to hold the name, address, and phone number. First, to create the `name_objtyp` object type, enter the following SQL statement:

```
CREATE TYPE name_objtyp AS OBJECT (
  first       VARCHAR2(15),
  middle      VARCHAR2(15),
  last        VARCHAR2(15))
/
```

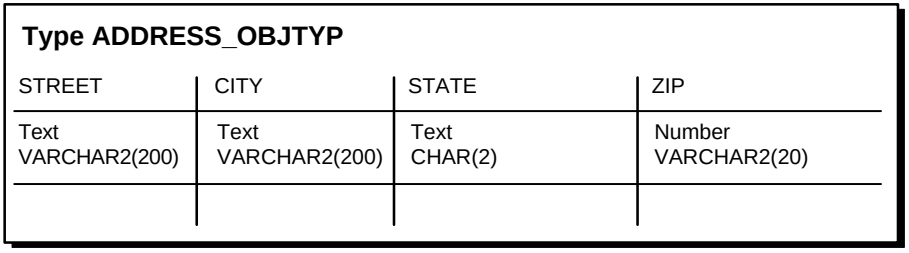
Figure 18–1 Object Relational Representation for the name_objtyp Type



Next, to create the `address_objtyp` object type, enter the following SQL statement:

```
CREATE TYPE address_objtyp AS OBJECT (
  street       VARCHAR2(200),
  city         VARCHAR2(200),
  state        CHAR(2),
  zipcode      VARCHAR2(20))
/
```

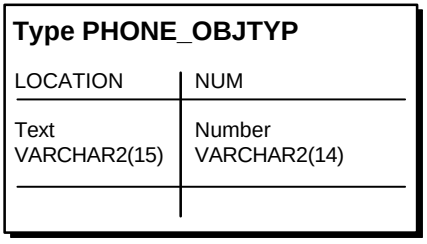
Figure 18–2 Object Relational Representation of the address_objtyp Type



Finally, to create the `phone_objtyp` object type, enter the following SQL statement:

```
CREATE TYPE phone_objtyp AS OBJECT (
  location     VARCHAR2(15),
  num          VARCHAR2(14))
/
```

Figure 18–3 Object Relational Representation of the phone_objtyp Type



Because each person may have more than one phone number, create a nested table type `phone_ntabtyp` based on the `phone_objtyp` object type:

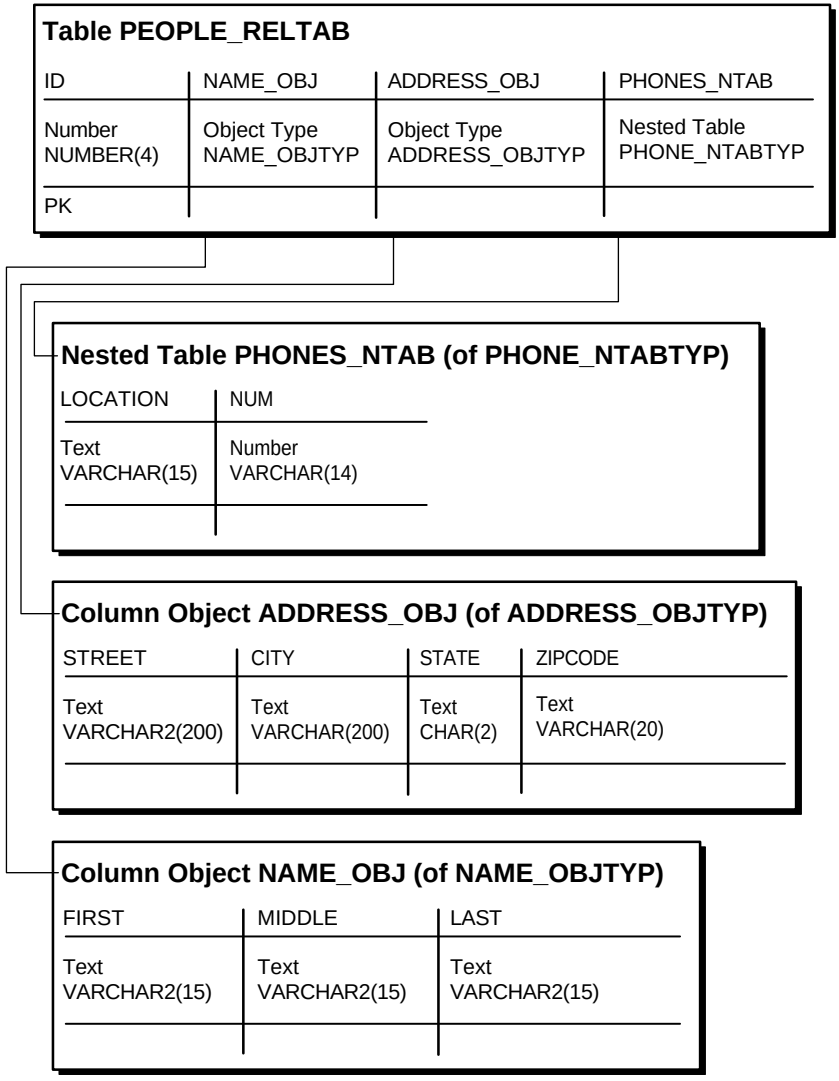
```
CREATE TYPE phone_ntabtyp AS TABLE OF phone_objtyp
/
```

> **See Also:** "Nested Tables" on page 18-16 for more information about nested tables.

Once all of these object types are in place, you can create a table to hold the information about the people in the organization with the following SQL statement:

```
CREATE TABLE people_reltab (
  id            NUMBER(4)   CONSTRAINT pk_people_reltab PRIMARY KEY,
  name_obj      name_objtyp,
  address_obj   address_objtyp,
  phones_ntab   phone_ntabtyp)
  NESTED TABLE  phones_ntab STORE AS phone_store_ntab;
```

Figure 18–4 Representation of the people_reltab Relational Table



The people_reltab table has three column objects: name_obj, address_obj, and phones_ntab. The phones_ntab column object is also a nested table.

> **Note:** The name_obj object, address_obj object, phones_ntab nested table, and people_reltab table are used in examples throughout this chapter.

The storage for each object stored in the people_reltab table is the same as that of the attributes of the object. For example, the storage required for a name_obj object is the same as the storage for the first, middle, and last attributes combined, except for the null indicator overhead.

If the COMPATIBLE parameter is set to 8.1.0 or higher, the null indicator for an object and its embedded object attributes occupy one bit each. Thus, an object with *n* embedded object attributes (including objects at all levels of nesting) has a storage overhead of CEIL(n/8) bytes. In the people_reltab table, for example, the overhead of the null information for each row is one byte because it translates to CEIL(3/8) or CEIL(.37), which rounds up to one byte. In this case, there are three objects in each row: name_obj, address_obj, and phones_ntab.

If, however, the COMPATIBLE parameter is set to a value below 8.1.0, such as 8.0.0, the storage is determined by the following calculation:

```
CEIL(n/8) + 6
```

Here, n is the total number of all attributes (scalar and object) within the object. Therefore, in the people_reltab table, for example, the overhead of the null information for each row is seven bytes because it translates to the following calculation:

```
CEIL(4/8) + 6 = 7
```

CEIL(4/8) is CEIL(.5), which rounds up to one byte. In this case, there are three objects in each row and one scalar.

Therefore, the storage overhead and performance of manipulating a column object is similar to that of the equivalent set of scalar columns. The storage for collection attributes are described in the "Collections" section on page 18-13.

> **See Also:** *Oracle8i SQL Reference* for more information about CEIL.

Row Object Storage in Object Tables

Row objects are stored in *object tables*. An object table is a special kind of table that holds objects and provides a relational view of the attributes of those objects. An object table is logically and physically similar to a relational table whose column types correspond to the top level attributes of the object type stored in the object table. The key difference is that an object table can optionally contain an additional *object identifier* (OID) column and index.

Object Identifier (OID) Storage and OID Index By default, Oracle assigns every row object a unique, immutable object identifier, called an OID. An OID allows the corresponding row object to be referred to from other objects or from relational tables. A built-in datatype called a REF represents such references. A REF encapsulates a reference to a row object of a specified object type.

By default, an object table contains a system-generated OID column, so that each row object is assigned a globally unique OID. This OID column is automatically indexed for efficient OID-based lookups. The OID column is the equivalent of having an extra 16-byte primary key column.

Primary-Key Based OIDs If a primary key column is available, you can avoid the storage and performance overhead of maintaining the 16-byte OID column and its index. Instead of using the system-generated OIDs, you can use a CREATE TABLE statement to specify that the system use the primary key column(s) as the OIDs of the objects in the table. Therefore, you can use existing columns as the OIDs of the objects or use application generated OIDs that are smaller than the 16-byte globally unique OIDs generated by Oracle.

Comparing Objects

You can compare objects by invoking the *map* or *order* methods defined on the object type. A map method converts objects into scalar values while preserving the ordering of the objects. Mapping objects into scalar values, if it can be done, is preferred because it allows the system to efficiently order objects once they are mapped.

The way objects are mapped has significant performance implications when sorting is required on the objects for ORDER BY or GROUP BY processing because an object may need to be compared to other objects many times, and it is much more efficient if the objects can be mapped to scalar values first. If the comparison semantics are extremely complex, or if the objects cannot be mapped into scalar values for comparison, you can define an order method that, given two objects, returns the ordering determined by the object implementor. Order methods are not as efficient

as map methods, so performance may suffer if you use order methods. In any one object type, you can implement either map or order methods, but not both.

Once again, consider an object type ADDRESS consisting of four character attributes: STREET, CITY, STATE, and ZIPCODE. Here, the most efficient comparison method is a map method because each object can be converted easily into scalar values. For example, you might define a map method that orders all of the objects by state.

On the other hand, suppose you want to compare binary objects, such as images. In this case, the comparison semantics may be too complex to use a map method; if so, you can use an order method to perform comparisons. For example, you could create an order method that compares images according to brightness or the number of pixels in each image.

If an object type does not have either a map or order method, only equality comparisons are allowed on objects of that type. In this case, Oracle performs the comparison by doing a field-by-field comparison of the corresponding object attributes, in the order they are defined. If the comparison fails at any point, a FALSE value is returned. If the comparison matches at every point, a TRUE value is returned. However, if an object has a collection of LOB attributes, then Oracle does not compare the object on a field-by-field basis. Such objects must have a map or order method to perform comparisons.

REFs

A REF is a logical "pointer" to a row object. REFs and collections of REFs model associations between objects and other objects. There are several scenarios in which REFs are useful in modelling relationships. For example, the relationship between a purchase order and a customer can be established using a REF attribute in the purchase order that references the customer. REFs provide an easy mechanism for navigating between objects. You can use the extended dot notation to follow the "pointers" without explicit joins.

Object Identifiers (OIDs)

REFs use object identifiers (OIDs) to point to objects. You can use either system-generated OIDs or primary-key based OIDs. The differences between these types of OIDs are outlined in "Row Object Storage in Object Tables" on page 18-8. If you use system-generated OIDs for an object table, Oracle maintains an index on the column that stores these OIDs. The index requires storage space, and each row object has a system-generated OID, which requires an extra 16 bytes of storage per row.

You can avoid these added storage requirements by using the primary key for the object identifiers, instead of system-generated OIDs. You can enforce referential integrity on columns that store references to these row objects in a way similar to foreign keys in relational tables.

However, if each primary key value requires more than 16 bytes of storage and you have a large number of REFs, using the primary key might require more space than system-generated OIDs because each REF is the size of the primary key. In addition, each primary-key based OID is locally (but not necessarily globally) unique. If you require a globally unique identifier, you must ensure that the primary key is globally unique or use system-generated OIDs.

Storage of REFs

A REF contains the following three logical components:

- OID of the object referenced. A system-generated OID is 16 bytes long. The size of a primary-key based OID depends on the size of the primary key column(s).
- OID of the table or view containing the object referenced, which is 16 bytes long.
- Rowid hint, which is 10 bytes long.

Constraints on REFs

Referential integrity constraints on REF columns ensure that there is a row object for the REF. Referential integrity constraints on REFs create the same relationship as specifying a primary key / foreign key relationship on relational data. In general, you should use referential integrity constraints wherever possible because they are the only way to ensure that the row object for the REF exists. However, you cannot specify referential integrity constraints on REFs that are in nested tables.

A *scoped REF* is constrained to contain only references to a specified object table. You can specify a scoped REF when you declare a column type, collection element, or object type attribute to be a REF. In general, you should use scoped REFs whenever possible instead of unscoped REFs because scoped REFs are stored more efficiently. Scoped REFs are stored on disk as just the OID, so each scoped REF is 16 bytes long. In addition to the smaller size, the optimizer often can optimize queries that dereference a scoped REF into efficient joins. This optimization is not possible for unscoped REFs because the optimizer cannot determine the containing table(s) for unscoped REFs at query optimization time.

However, unlike referential integrity constraints, scoped REFs do not ensure that the referenced row object exists; they only ensure that the referenced object table exists. Therefore, if you specify a scoped REF to a row object and then delete the row object, the scoped REF becomes a dangling REF because the referenced object no longer exists.

Note: Referential integrity constraints are scoped implicitly.

Unscoped REFs are useful if the application design requires that the objects referenced be scattered in multiple tables. Because rowid hints are ignored for scoped REFs, you should use unscoped REFs if the performance gain of the rowid hint, as explained below in the "WITH ROWID Option" section, outweighs the benefits of the storage saving and query optimization of using scoped REFs.

WITH ROWID Option

If the WITH ROWID option is specified for a REF column, Oracle maintains the rowid of the object referenced in the REF. Then, Oracle can find the object referenced directly using the rowid contained in the REF, without the need to fetch the rowid from the OID index. Therefore, you use the WITH ROWID option to specify a rowid hint. Maintaining the rowid requires more storage space because the rowid adds 16 bytes to the storage requirements of the REF.

Bypassing the OID index search improves the performance of REF traversal (navigational access) in applications. The actual performance gain may vary from application to application depending on the following factors:

- How large the OID indexes are
- Whether the OID indexes are cached in the buffer cache
- How many REF traversals an application does

The WITH ROWID option is only a hint because, when you use this option, Oracle checks the OID of the row object with the OID in the REF. If the two OIDs do not match, Oracle uses the OID index instead. The rowid hint is not supported for scoped REFs, for REFs with referential integrity constraints, or for primary key-based REFs.

Indexing REFs

You can build indexes on scoped REF columns using the CREATE INDEX command. Then, you can use the index to efficiently evaluate queries that dereference the scoped REFs. Such queries are turned into joins implicitly. For certain types of queries, Oracle can use an index on the scoped REF column to evaluate the join efficiently.

For example, suppose the object type address_objtyp is used to create an object table named address_objtab:

```
CREATE TABLE address_objtab OF address_objtyp ;
```

Then, a people_reltab2 table can be created that has the same definition as the people_reltab table discussed in "Column Object Storage" on page 18-2, except that a REF is used for the address:

```
CREATE TABLE people_reltab2 (
  id            NUMBER(4)   CONSTRAINT pk_people_reltab2 PRIMARY KEY,
  name_obj      name_objtyp,
  address_ref   REF address_objtyp SCOPE IS address_objtab, -- REF specified
  phones_ntab   phone_ntabtyp)
  NESTED TABLE  phones_ntab STORE AS phone_store_ntab2 ;
```

Now, an index can be created on the address_ref column:

```
CREATE INDEX address_ref_idx ON people_reltab2 (address_ref) ;
```

The following query dereferences the address_ref:

```
SELECT id FROM people_reltab2 p
   WHERE p.address_ref.state = 'CA' ;
```

When this query is executed, the address_ref_idx index is used to efficiently evaluate it. Here, address_ref is a scoped REF column that stores references to addresses stored in the address_objtab object table. Oracle implicitly transforms the above query into a query with a join:

```
SELECT p.id FROM people_reltab2 p, address_objtab a
   WHERE p.address_ref = ref(a) AND a.state = 'CA' ;
```

Oracle's optimizer might create a plan to perform a nested-loops join with address_objtab as the outer table and look up matching addresses using the index on the address_ref scoped REF column.

Collections

Collections model one-to-many relationships. For example, a purchase order has one or more line items; so, you may want to put the line items into a collection. Oracle supports two kinds of collections: varrays and nested tables.

There are two major differences between varrays and nested tables:

- Varrays are ordered and bounded collections, whereas nested tables are unordered and unbounded collections.
- Varrays are stored as opaque objects (that is, raw or BLOB), whereas nested tables are stored in a storage table with every element mapping to a row in the storage table.

Given these differences, if you want efficient queryability of collections, then you should use nested tables. On the other hand, if you constantly need to retrieve and manipulate the entire collection as a value, such as in a 3GL application, then varrays are a better choice. However, if the collections are very large, then you probably do not want the entire collection to be retrieved as a value and are likely to retrieve only subsets. In such cases, the collection should be modelled as a nested table and retrieved as a locator. For example, a purchase order object may have a nested table of line items, while a geometry object may contain a varray of coordinates.

Unnesting Queries

An unnesting query on a collection allows the data to be viewed in a flat (relational) form. You can execute unnesting queries on both nested tables and varrays. This section contains examples of unnesting queries.

Nested tables can be unnested for queries using the TABLE syntax, as in the following example:

```
SELECT p.name_obj, n.num
   FROM people_reltab p, TABLE(p.phones_ntab) n ;
```

Here, phones_ntab specifies the attributes of the phones_ntab nested table. To ensure that the parent rows with no children rows also are retrieved, use the outer join syntax as follows:

```
SELECT p.name_obj, n.num
   FROM people_reltab p, TABLE(p.phones_ntab) (+) n ;
```

In the first case, if the query does not refer to any columns from the parent table (other than the nested table column in the FROM clause), the query is optimized to execute only against the storage table.

You can also use the TABLE syntax to query varrays. For example, suppose the phones_ntab nested table is instead a varray named phones_var. In this case, you still can use the TABLE syntax to query the varray, as in the following example:

```
SELECT p.name_obj, n.num
   FROM people_reltab p, TABLE(p.phones_var) n ;
```

The unnesting query syntax is the same for varrays and nested tables.

Using Procedures and Functions in Unnesting Queries

You can create procedures and functions that you can then execute to perform unnesting queries. For example, you can create a function called home_phones() that returns only the phone numbers where location is 'home'. To create the home_phones() function, you enter code similar to the following:

```
CREATE OR REPLACE FUNCTION home_phones(allphones IN phone_ntabtyp)
         RETURN phone_ntabtyp IS
   homephones phone_ntabtyp := phone_ntabtyp();
   indx1      number;
   indx2      number := 0;
BEGIN
   FOR indx1 IN 1..allphones.count LOOP
      IF
         allphones(indx1).location = 'home'
      THEN
         homephones.extend;    -- extend the local collection
         indx2 := indx2 + 1;   -- extend the local collection
         homephones(indx2) := allphones(indx1);
      END IF;
   END LOOP;

   RETURN homephones;
END;
/
```

Now, to query for a list of people and their home phone numbers, enter the following:

```
SELECT p.name_obj, n.num
   FROM people_reltab p, table(
      CAST(home_phones(p.phones_ntab) AS phone_ntabtyp)) n ;
```

To query for a list of people and their home phone numbers, including those people who do not have a home phone number listed, enter the following:

```
SELECT p.name_obj, n.num
   FROM people_reltab p,
        TABLE(CAST(home_phones(p.phones_ntab) AS phone_ntabtyp))(+) n ;
```

> **See Also:** *Oracle8i SQL Reference* for more information about using the TABLE syntax.

Varrays

The following sections contain design considerations for using varrays.

Varray Storage

The size of a stored varray depends only on the current count of the number of elements in the varray and not on the maximum number of elements that it can hold. The storage of varrays incurs some overhead, such as null information. Therefore, the size of the varray stored may be slightly greater than the size of the elements multiplied by the count.

Varrays are stored in columns either as raw values or BLOBs. Oracle decides how to store the varray when the varray is defined, based on the maximum possible size of the varray computed using the LIMIT of the declared varray. If the size exceeds approximately 4000 bytes, then the varray is stored in BLOBs. Otherwise, the varray is stored in the column itself as a raw value. In addition, Oracle supports inline LOBs; therefore, elements that fit in the first 4000 bytes of a large varray (with some bytes reserved for the LOB locator) are stored in the column of the row itself.

Varray Access

If the entire collection is manipulated as a single unit in the application, varrays perform much better than nested tables. The varray is stored "packed" and requires no joins to retrieve the data, unlike nested tables.

Varray Querying

The unnesting syntax can be used to access varray columns similar to the way it is used to access nested tables.

> **See Also:** "Unnesting Queries" on page 18-13 for more information.

Varray Updates

Piece-wise updates of a varray value are not supported. Thus, when a varray is updated, the entire old collection is replaced by the new collection.

Nested Tables

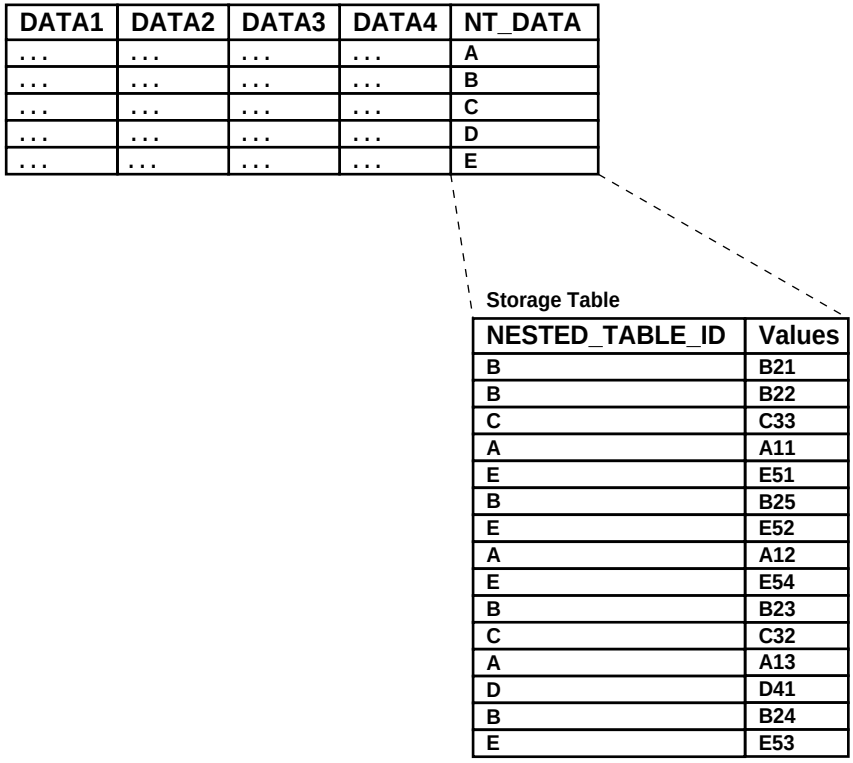
The following sections contain design considerations for using nested tables.

Nested Table Storage

Oracle stores the rows of a nested table in a separate storage table. A system generated `NESTED_TABLE_ID`, which is 16 bytes in length, correlates the parent row with the rows in its corresponding storage table.

Figure 18–5 shows how the storage table works. The storage table contains each value for each nested table in a nested table column. Each value occupies one row in the storage table. The storage table uses the `NESTED_TABLE_ID` to track the nested table for each value. So, in Figure 18–5, all of the values that belong to nested table `A` are identified, all of the values that belong to nested table `B` are identified, etc.

Figure 18–5 Nested Table Storage

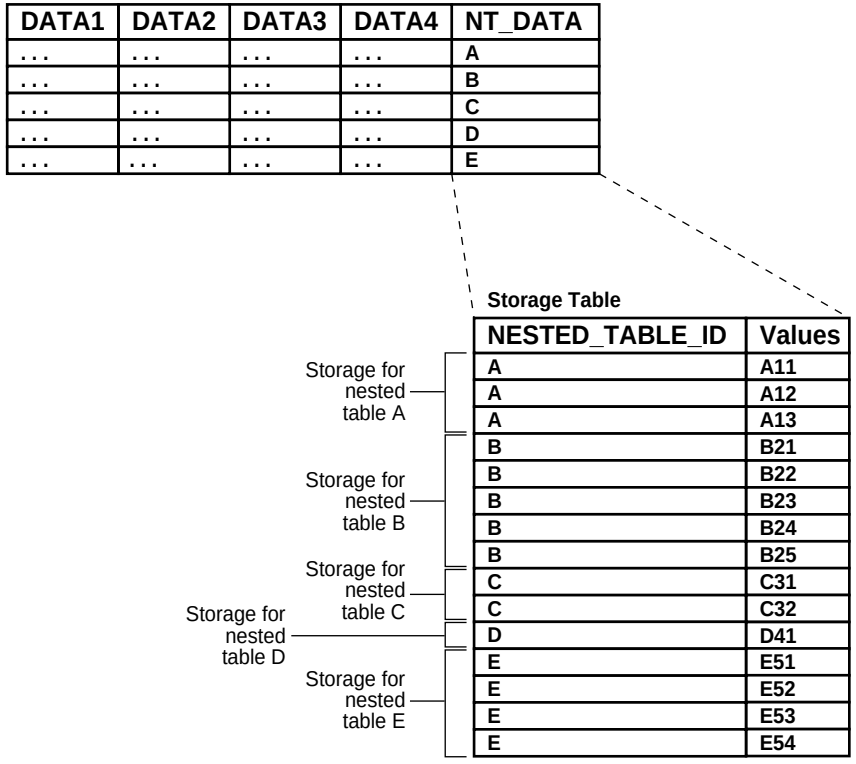


Nested Table in an Index-Organized Table (IOT)

If a nested table has a primary key, you can organize the nested table as an index-organized table (IOT). If the NESTED_TABLE_ID column is a prefix of the primary key for a given parent row, Oracle physically clusters its children rows together. So, when a parent row is accessed, all its children rows can be efficiently retrieved. When only parent rows are accessed, efficiency is maintained because the children rows are not inter-mixed with the parent rows.

Figure 18–6 shows how the storage table works when the nested table is in an IOT. The storage table groups the values for each nested table within a nested table column. In Figure 18–6, for each nested table in the NT_DATA column of the parent table, the data is grouped in the storage table. So, all of the values in nested table A are grouped together, all of the values in nested table B are grouped together, etc.

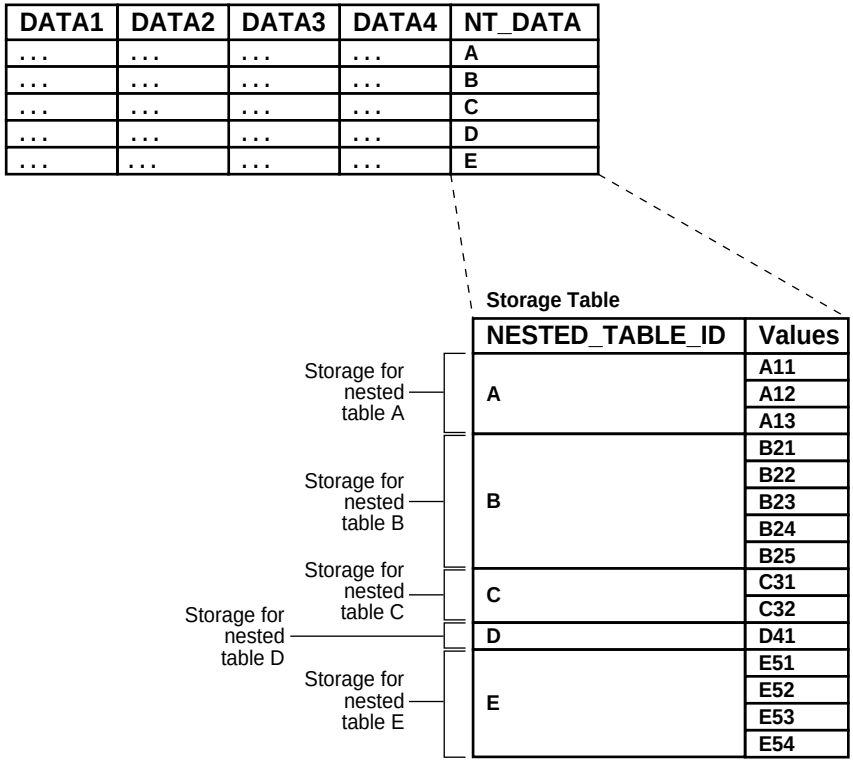
Figure 18–6 Nested Table in IOT Storage



In addition, the `COMPRESS` clause enables prefix compression on the IOT rows. It factors out the key of the parent in every child row. That is, the parent key is not repeated in every child row, thus providing significant storage savings.

In other words, if you specify nested table compression using the `COMPRESS` clause, the amount of space required for the storage table is reduced because the `NESTED_TABLE_ID` is not repeated for each value in a group. Instead, the `NESTED_TABLE_ID` is stored only once per group, as illustrated in Figure 18–7.

Figure 18–7 Nested Table in IOT Storage with Compression



In general, Oracle Corporation recommends that nested tables be stored in an IOT with the NESTED_TABLE_ID column as a prefix of the primary key. Further, prefix compression should be enabled on the IOT. However, if you usually do not retrieve the nested table as a unit and you do not want to cluster the child rows, do not store the nested table in an IOT and do not specify compression.

Nested Table Indexes

For nested tables stored in heap tables (as opposed to IOTs), you should create an index on the NESTED_TABLE_ID column of the storage table. The index on the corresponding ID column of the parent table is created by Oracle automatically when the table is created. Creating an index on the NESTED_TABLE_ID column enables Oracle to access the child rows of the nested table more efficiently, because Oracle must perform a join between the parent table and the nested table using the NESTED_TABLE_ID column.

Nested Table Locators

For large child-sets, the parent row and a locator to the child-set can be returned so that the children rows can be accessed on demand; the child-sets also can be filtered. Using nested table locators allows you to avoid unnecessary transporting of children rows for every parent.

You can perform either one of the following actions to access the children rows using the nested table locator:

- Call the OCI collection functions. This action occurs implicitly when you access the elements of the collection in the client-side code, such as *OCIColl** functions. The entire collection is retrieved implicitly on the first access.

  See Also: *Oracle Call Interface Programmer's Guide* for more information about OCI collection functions.

- Use SQL to retrieve the rows corresponding to the nested table. This action is described in the "The Object Table PurchaseOrder_objtab" section on page 16-29.

Optimizing Set Membership Queries

Set membership queries are useful when you want to search for a specific item in a nested table. For example, the following query tests the membership in a child-set; specifically, whether the location `home` is in the nested table `phones_ntab`, which is in the parent table `people_reltab`:

```
SELECT * FROM people_reltab p
   WHERE 'home' IN (SELECT location FROM TABLE(p.phones_ntab)) ;
```

Oracle can execute a query that tests the membership in a child-set more efficiently by transforming it internally into a semi-join. However, this optimization only happens if the `ALWAYS_SEMI_JOIN` initialization parameter is set. If you want to perform semi-joins, the valid values for this parameter are `MERGE` and `HASH`; these parameter values indicate which join method to use.

Note: In the example above, `home` and `location` are child set elements. If the child set elements are object types, they must have a map or order method to perform a set membership query.

DML Operations on Nested Tables

You can perform DML operations on nested tables. Rows can be inserted into or deleted from a nested table, and existing rows can be updated, by using the appropriate SQL command against the nested table. In these operations, the nested table is identified by a TABLE subquery. The following example inserts a new person into the people_reltab table, including phone numbers into the phones_ntab nested table:

```
INSERT INTO people_reltab values (
   0001,
   name_objtyp(
      'john', 'william', 'foster'),
   address_objtyp(
      '111 Maple Road', 'Fairfax', 'VA', '22033'),
   phone_ntabtyp(
      phone_objtyp('home', '650.331.1222'),
      phone_objtyp('work', '650.945.4389'))) ;
```

The following example inserts a phone number into the nested table phones_ntab for an existing person in the people_reltab table whose identification number is 0001:

```
INSERT INTO TABLE(SELECT p.phones_ntab FROM people_reltab p WHERE p.id = '0001')
   VALUES ('cell', '650.331.9337') ;
```

To drop a particular nested table, you can set the nested table column in the parent row to NULL, as in the following example:

```
UPDATE people_reltab SET phones_ntab = NULL WHERE id = '0001' ;
```

Once you drop a nested table, you cannot insert values into it until you recreate it. To recreate the nested table in the phones_ntab nested table column object for the person whose identification number is 0001, enter the following SQL statement:

```
UPDATE people_reltab SET phones_ntab = phone_ntabtyp() WHERE id = '0001' ;
```

You also can insert values into the nested table as you recreate it:

```
UPDATE people_reltab
   SET phones_ntab = phone_ntabtyp(phone_objtyp('home', '650.331.1222'))
   WHERE id = '0001' ;
```

DML operations on a nested table lock the parent row. Therefore, only one modification at a time can be made to the data in a particular nested table, even if the modifications are on different rows in the nested table. However, if only part of

the data in your nested table must support simultaneous modifications, while other data in the nested table does not require this support, you should consider using REFs to the data that requires simultaneous modifications.

For example, if you have an application that processes purchase orders, you might include customer information and line items in the purchase orders. In this case, the customer information does not change often and so you do not need to support simultaneous modifications for this data. Line items, on the other hand, might change very often. To support simultaneous updates on line items that are in the same purchase order, you can store the line items in a separate object table and reference them with REFs in the nested table.

Nesting Collections

An attribute of a collection cannot be a collection type (either varray or nested table). In other words, you cannot have collections within collections. Oracle allows only one level of direct nesting of collections. However, an attribute of a collection can be a reference to an object that has a collection attribute. Thus, you can have multiple levels of collections indirectly by using REFs.

For example, suppose you want to create a new object type called `person_objtyp` using the object types described in "Column Object Storage" on page 18-2, which are `name_objtyp`, `address_objtyp`, and `phone_ntabtyp`. Remember that the `phone_ntabtyp` object type is a nested table because each person may have more than one phone number.

To create the `person_objtyp` object type, issue the following SQL statement:

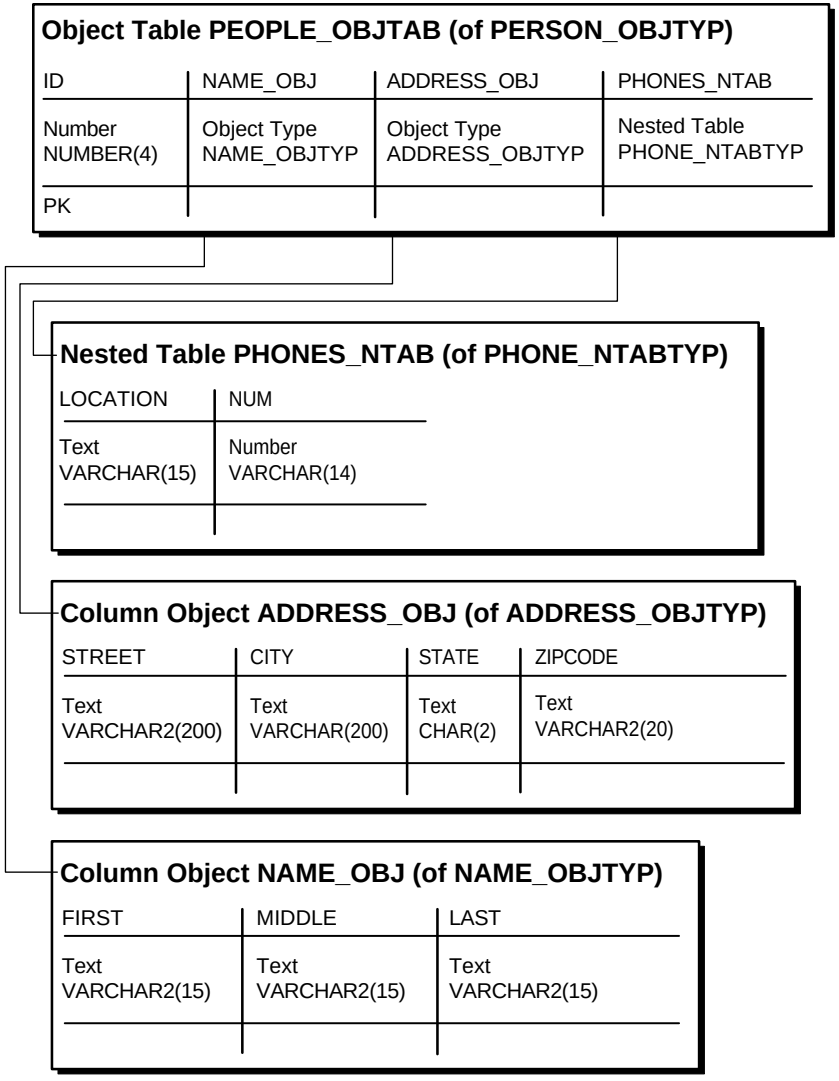
```
CREATE TYPE person_objtyp AS OBJECT (
   id            NUMBER(4),
   name_obj      name_objtyp,
   address_obj   address_objtyp,
   phones_ntab   phone_ntabtyp)
/
```

To create an object table called `people_objtab` of `person_objtyp` object type, issue the following SQL statement:

```
CREATE TABLE people_objtab OF person_objtyp (id PRIMARY KEY)
   NESTED TABLE phones_ntab STORE AS phones_store_ntab ;
```

The `people_objtab` table has the same attributes as the `people_reltab` table discussed in "Column Object Storage" on page 18-2. The difference is that the `people_objtab` is an object table with row objects, while the `people_reltab` table is a relational table with three column objects.

Figure 18–8 Object Relational Representation of the people_objtab Object Table



Now you can reference the row objects in the people_objtab object table from other tables. For example, suppose you want to create a projects_objtab table that contains the following:

- A project identification number for each project
- The title of each project
- The project lead for each project
- A description of each project
- Nested table collection of the team of people assigned to each project

You can use REFs to the people_objtab for the project leads, and you can use a nested table collection of REFs for the team. To begin, create a nested table object type called personref_ntabtyp based on the person_objtyp object type:

```
CREATE TYPE personref_ntabtyp AS TABLE OF REF person_objtyp
/
```

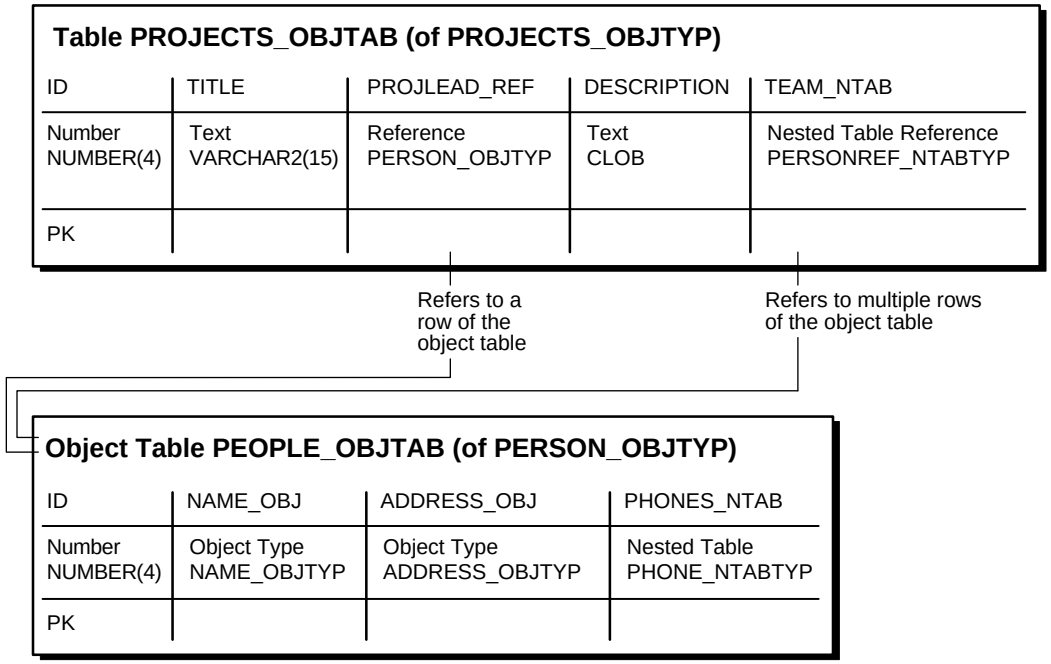
Now you are ready to create the object table projects_objtab. First, create the object type projects_objtyp by issuing the following SQL statement:

```
CREATE TYPE projects_objtyp AS OBJECT (
   id              NUMBER(4),
   title           VARCHAR2(15),
   proglead_ref    REF person_objtyp,
   description     CLOB,
   team_ntab       personref_ntabtyp)
/
```

Next, create the object table projects_objtab based on the projects_objtyp:

```
CREATE TABLE projects_objtab OF projects_objtyp (id PRIMARY KEY)
   NESTED TABLE team_ntab STORE AS team_store_ntab ;
```

Figure 18–9 Object Relational Representation of the projects_objtab Object Table



Once the `people_objtab` object table and the `projects_objtab` object table are in place, you indirectly have a nested collection. That is, the `projects_objtab` table contains a nested table collection of REFs that point to the people in the `people_objtab` table, and the people in the `people_objtab` table have a nested table collection of phone numbers.

You can insert values into the `people_objtab` table in the following way:

```
INSERT INTO people_objtab VALUES (
   0001,
   name_objtyp('JOHN', 'JACOB', 'SCHMIDT'),
   address_objtyp('1252 Maple Road', 'Fairfax', 'VA', '22033'),
   phone_ntabtyp(
      phone_objtyp('home', '650.339.9922'),
      phone_objtyp('work', '510.563.8792'))) ;
```

```
INSERT INTO people_objtab VALUES (
   0002,
   name_objtyp('MARY', 'ELLEN', 'MILLER'),
   address_objtyp('33 Spruce Street', 'McKees Rocks', 'PA', '15136'),
   phone_ntabtyp(
      phone_objtyp('home', '415.642.6722'),
      phone_objtyp('work', '650.891.7766'))) ;

INSERT INTO people_objtab VALUES (
   0003,
   name_objtyp('SARAH', 'MARIE', 'SINGER'),
   address_objtyp('525 Pine Avenue', 'San Mateo', 'CA', '94403'),
   phone_ntabtyp(
      phone_objtyp('home', '510.804.4378'),
      phone_objtyp('work', '650.345.9232'),
      phone_objtyp('cell', '650.854.9233'))) ;
```

Then, you can insert into the `projects_objtab` relational table by selecting from the `people_objtab` object table using a REF operator, as in the following examples:

```
INSERT INTO projects_objtab VALUES (
   1101,
   'Demo Product',
   (SELECT REF(p) FROM people_objtab p WHERE id = 0001),
   'Demo the product, show all the great features.',
   personref_ntabtyp(
      (SELECT REF(p) FROM people_objtab p WHERE id = 0001),
      (SELECT REF(p) FROM people_objtab p WHERE id = 0002),
      (SELECT REF(p) FROM people_objtab p WHERE id = 0003))) ;

INSERT INTO projects_objtab VALUES (
   1102,
   'Create PRODDB',
   (SELECT REF(p) FROM people_objtab p WHERE id = 0002),
   'Create a database of our products.',
   personref_ntabtyp(
      (SELECT REF(p) FROM people_objtab p WHERE id = 0002),
      (SELECT REF(p) FROM people_objtab p WHERE id = 0003))) ;
```

> **Note:** This example uses nested tables to store REFs, but you also can store REFs in varrays. That is, you can have a varray of REFs.

Methods

Methods are functions or procedures written in PL/SQL or Java and stored in the database, or written in a language such as C and stored externally. Methods implement operations the application can perform on the object.

Choosing a Language

Type methods can be implemented in any of the languages supported by Oracle, such as PL/SQL, Java, or C. Consider the following factors when you choose the language for a particular application:

- Ease of use
- SQL calls
- Speed of execution
- Same/different address space

In general, if the application performs intense computations, C is preferable, but if the application performs a relatively large number of database calls, PL/SQL or Java is preferable.

A method implemented in C executes in a separate process from the server using external routines. In contrast, a method implemented in Java or PL/SQL executes in the same process as the server.

See Also: Chapter 11, "External Routines"for information about using external routines.

Method Implementation Example

The example described in this section involves an object type whose methods are implemented in different languages. In the example, the object type `ImageType` has an `ID` attribute, which is a `NUMBER` that uniquely identifies it, and an `IMG` attribute, which is a `BLOB` that stores the raw image. The object type `ImageType` has the following methods:

- The method `get_name()` fetches the name of the image by looking it up in the database. This method is implemented in PL/SQL.
- The method `rotate()` rotates the image. This method is implemented in C.
- The method `clear()` returns a new image of the specified color. This method is implemented in Java.

For implementing a method in C, a LIBRARY object must be defined to point to the library that contains the external C routines. For implementing a method implemented in Java, this example assumes that the Java class with the method has been compiled and uploaded into Oracle.

> **See Also:** Chapter 11, "External Routines" and *Oracle8i Java Stored Procedures Developer's Guide* for more information.

Here is the object type specification and its methods:

```
CREATE TYPE ImageType AS OBJECT (
   id   NUMBER,
   img  BLOB,
   MEMBER FUNCTION get_name() return VARCHAR2,
   MEMBER FUNCTION rotate() return BLOB,
   STATIC FUNCTION clear(color NUMBER) return BLOB
   )
/

CREATE TYPE BODY ImageType AS
   MEMBER FUNCTION get_name() RETURN VARCHAR2
   AS
   imgname VARCHAR2(100);
   BEGIN
      SELECT name INTO imgname FROM imgtab WHERE imgid = id;
      RETURN imgname;
   END;

   MEMBER FUNCTION rotate() RETURN BLOB
   AS LANGUAGE C
   NAME "Crotate"
   LIBRARY myCfuncs;

   STATIC FUNCTION clear(color NUMBER) RETURN BLOB
   AS LANGUAGE JAVA
   NAME 'myJavaClass.clear(color oracle.sql.NUMBER) RETURN oracle.sql.BLOB';

END;
/
```

Restriction: Type methods can be mapped only to static Java methods.

See Also: Chapter 1, "Programmatic Environments" for more information about choosing a language.

Static Methods

Static methods differ from member methods in that the SELF value is not passed in as the first parameter. Methods in which the value of SELF is not relevant should be implemented as static methods. Static methods can be used for user-defined constructors.

The following example is a constructor-like method that constructs an instance of the type based on the explicit input parameters and inserts the instance into the specified table:

```
CREATE OR REPLACE TYPE atype AS OBJECT(a1 NUMBER,
   STATIC PROCEDURE newa (
      p1        NUMBER,
      tabname   VARCHAR2,
      schname   VARCHAR2))
/

CREATE OR REPLACE TYPE BODY atype AS
    STATIC PROCEDURE newa (p1 NUMBER, tabname VARCHAR2, schname VARCHAR2)
      IS
      sqlstmt VARCHAR2(100);
    BEGIN
      sqlstmt := 'INSERT INTO '||schname||'.'||tabname|| ' VALUES (atype(:1))';
      EXECUTE IMMEDIATE sqlstmt USING p1;
    END;
END;
/

CREATE TABLE atab OF atype;
   BEGIN
     atype.newa(1, 'atab', 'scott');
   END;
/
```

Invoker and Definer Rights

To create generic types that can be used in any schema, you must define the type to use invoker-rights. In general, use invoker-rights when both of the following conditions are true:

- There are type methods that access and manipulate data.
- Users who did not define these type methods must use them.

For example, you can grant user SARA execute privileges on type `atype` created by SCOTT in "Static Methods" on page 18-29, and then create table `atab` based on the type:

```
GRANT EXECUTE ON atype TO SARA ;
CONNECT SARA/TPK101 ;
CREATE TABLE atab OF scott.atype ;
```

Now, suppose user SARA tries to use `atype` in the following statement:

```
BEGIN
  scott.atype.newa(1, 'atab', 'SARA'); -- raises an error
END;
/
```

This statement raises an error because the definer of the type (SCOTT) does not have the privileges required to perform the insert in the `newa` procedure. You can avoid this error by defining `atype` using invoker-rights. Here, you first drop the `atab` table in both schemas and recreate `atype` using invoker-rights by specifying the AUTHID CURRENT_USER option:

```
DROP TABLE atab ;
CONNECT SCOTT/TIGER ;
DROP TABLE atab ;

CREATE OR REPLACE TYPE atype AUTHID CURRENT_USER AS OBJECT(a1 NUMBER,
   STATIC PROCEDURE newa(p1 NUMBER, tabname VARCHAR2, schname VARCHAR2))
/
```

```
CREATE OR REPLACE TYPE BODY atype AS
  STATIC PROCEDURE newa(p1 NUMBER, tabname VARCHAR2, schname VARCHAR2)
   IS
     sqlstmt VARCHAR2(100);
   BEGIN
      sqlstmt := 'INSERT INTO '||schname||'.'||tabname|| ' VALUES
         (scott.atype(:1))';
      EXECUTE IMMEDIATE sqlstmt USING p1;
   END;
END;
/
```

Now, if user SARA tries to use `atype` again, the statement executes successfully:

```
GRANT EXECUTE ON atype TO SARA ;
CONNECT SARA/TPK101 ;
CREATE TABLE atab OF scott.atype;

BEGIN
  scott.atype.newa(1, 'atab', 'SARA'); -- executes successfully
END;
/
```

The statement is successful this time because the procedure is executed under the privileges of the invoker (SARA), not the definer (SCOTT).

Invoker-rights also is useful when you are writing methods that operate on REFs and LOB locators. To access the data through the REF or the locator, you need to check that the invoker of the method (and not the type definer) has the necessary privileges.

Function-Based Indexes on the Return Values of Type Methods

You can create function-based indexes on the return values of type methods. The following example creates a function-based index on the method `afun()` of the type `atype2`:

```
CREATE TYPE atype2 AS OBJECT
(
  a NUMBER,
  MEMBER FUNCTION afun RETURN NUMBER DETERMINISTIC
)
/

CREATE OR REPLACE TYPE BODY atype2 IS
 MEMBER FUNCTION afun RETURN NUMBER IS
 BEGIN
  RETURN self.a * 100;
 END;
END;
/

CREATE TABLE atab2 OF atype2 ;
CREATE INDEX atab2_afun_idx ON atab2 x (x.afun()) ;
```

For some methods, you can use function-based indexes to improve the performance of method invocation in SQL.

Restriction: You cannot create an index on a type method that takes as input LOB, REF, nested table, or varray arguments, or on any object type that contains such attributes.

See Also: *Oracle8i SQL Reference* for detailed information about using function-based indexes.

Other Considerations

The following sections describe other factors you should consider when you implement Oracle objects.

New Object Format in Release 8.1

In release 8.1, objects are stored in a new format that uses less storage space and has better performance characteristics than the previous format. The performance also is improved due to a more efficient transport protocol. If the `COMPATIBLE` parameter is set to 8.1.0 or higher, all the new objects you create are automatically stored and transported in the release 8.1 format.

In order to convert the objects created in a release 8.0 database to the release 8.1 format, complete following steps:

1. Recreate the tables using a `CREATE TABLE...AS SELECT...` statement.
2. Export/import the data in the tables.

See Also: *Oracle8i Migration* for more information about compatibility and the `COMPATIBLE` initialization parameter.

Replication

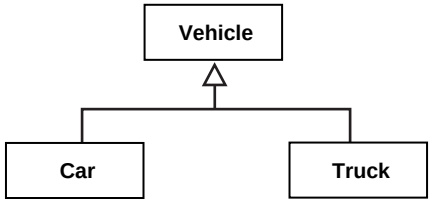
Replication of object columns and object tables is not yet supported. If replication is a requirement, then you can use object views and store the application objects in relational tables, which can be replicated. Using object views, both the object model and the data to be replicated can be preserved in the database.

Inheritance

Inheritance is a technique used in object-oriented development to create objects that contain generalized attributes and behavior for groups of related objects. The more general objects created using inheritance are referred to as a super-types. The objects that "inherit" from the super-types (that is, are more specific cases of the super-type) are called subtypes.

A common case of inheritance is that of `Person` and `Employee`. Some instances of person are employees. The more general case, `Person`, is the super-type and the special case, `Employee`, the sub-type. Another example could involve a `Vehicle` as super-type and `Car` and `Truck` as its subtypes.

Figure 18–10 Class Diagram: Vehicle as Super-type, Car and Truck as Subtypes



Inheritance Implementation Consequences

Inheritance can imply various levels of encapsulation for super-types. In cases where the super-type should not be exposed to other objects, a subtype should contain the methods and attributes necessary to make the super-type invisible. To understand the implementation consequences of the inheritance, it is also important to remember that Oracle8*i* is a strongly-typed system. A strongly-typed system requires that the type of an attribute is declared when the attribute is declared. Only values of the declared type may be stored in the attribute. For example, the Oracle8*i* collections are strongly-typed. Oracle8*i* does not allow the implementation of heterogeneous collections (collections of multiple types).

Simulating Inheritance

The Oracle type model does not support inheritance directly. However, you can map your current Oracle object types to Java classes and then leverage the inheritance features native to Java.

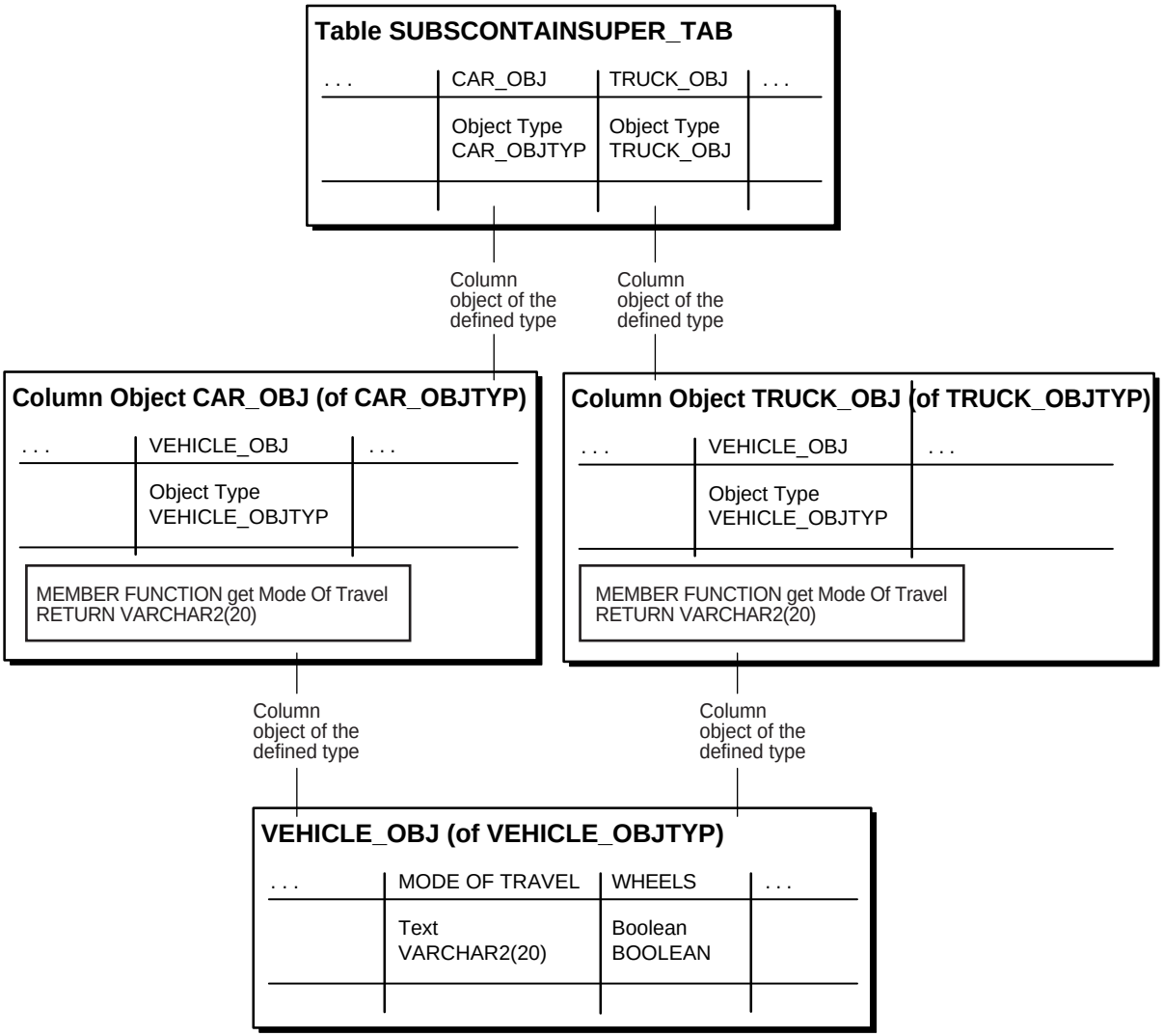
> **See Also:** *Oracle8i JDBC Developer's Guide and Reference* and *Oracle8i SQLJ Developer's Guide and Reference* for more information about mapping Oracle objects to Java classes.

In addition, inheritance can be simulated in Oracle. For example, you can use one of the following techniques to simulate inheritance:

- Subtype Contains Super-type
- Super-type Contains or References All Subtypes
- Dual Subtype / Super-type Reference

Subtype Contains Super-type

Figure 18–11 Object-Relational Schema — Subtype Contains Super-type



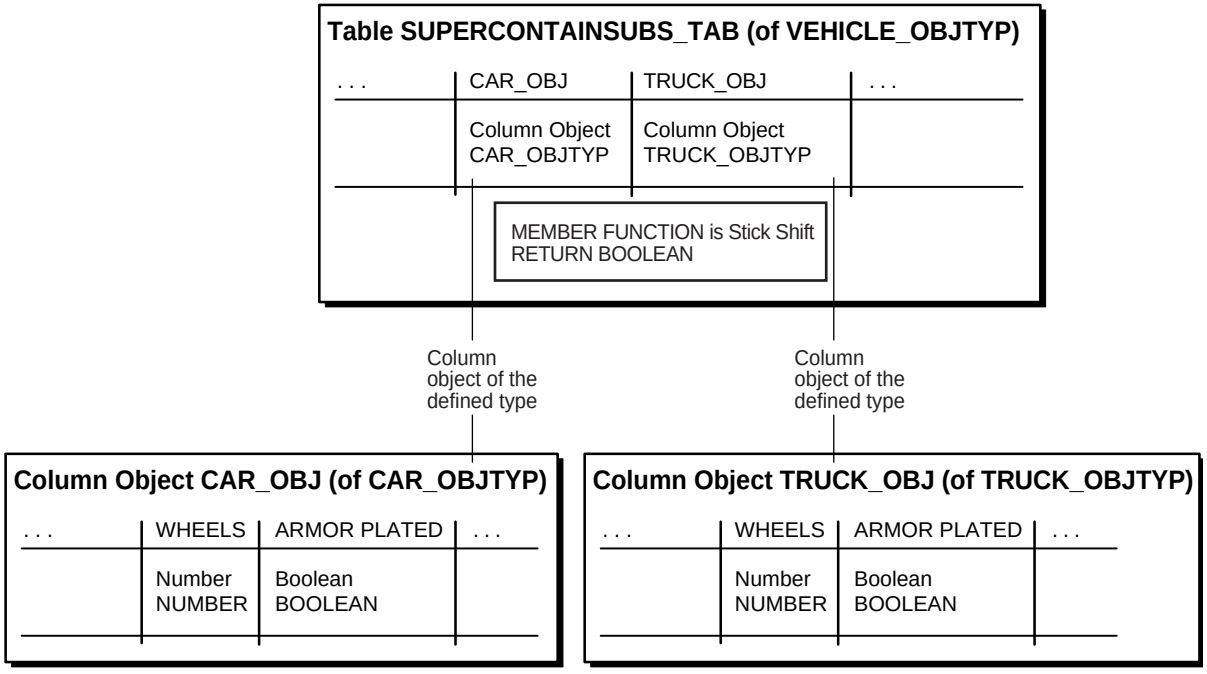
The Subtype Contains Super-type technique hides the implementation of the abstractions / generalizations for a subtype. Each of the subtypes are exposed to other types in the object model. The super-types are not exposed to other types. To simulate inheritance, the super-type in the design object model is created as an object type. The subtype is also created as an object type. The super-type is defined as an embedded attribute in the subtype. All of the methods that can be executed for the subtype and it's super-type must be defined in the subtype.

The Subtype Contains Super-type technique is used when each subtype has specific relationships to other objects in the object model. For example, a super-type of `Customer` may have subtypes of `Private Customer` and `Corporate Customer`. `Private Customers` have relationships with the `Personal Banking` objects, while `Corporate Customers` have relationships with the `Commercial Banking` objects. In this environment, the `Customer` super-type is not visible to the rest of the object model.

In the `Vehicle-Car / Truck` example, the `Vehicle` (super-type) is embedded in the sub-types `Car` and `Truck`.

Super-type Contains All Subtypes

Figure 18–12 Object-Relational Schema — Super-type Contains All Subtypes



The Super-type Contains All Subtypes technique hides the implementation of the subtypes and only exposes the super-type. To simulate inheritance, all of the subtypes for a given super-type in the design object model are created as object types. The super-type is created as an object type as well. The super-type declares an attribute for each subtype. The super-type also declares the constraints to enforce the one-and-only-one rules for the subtype attributes. All of the methods that can be executed for the subtype must defined in the super-type.

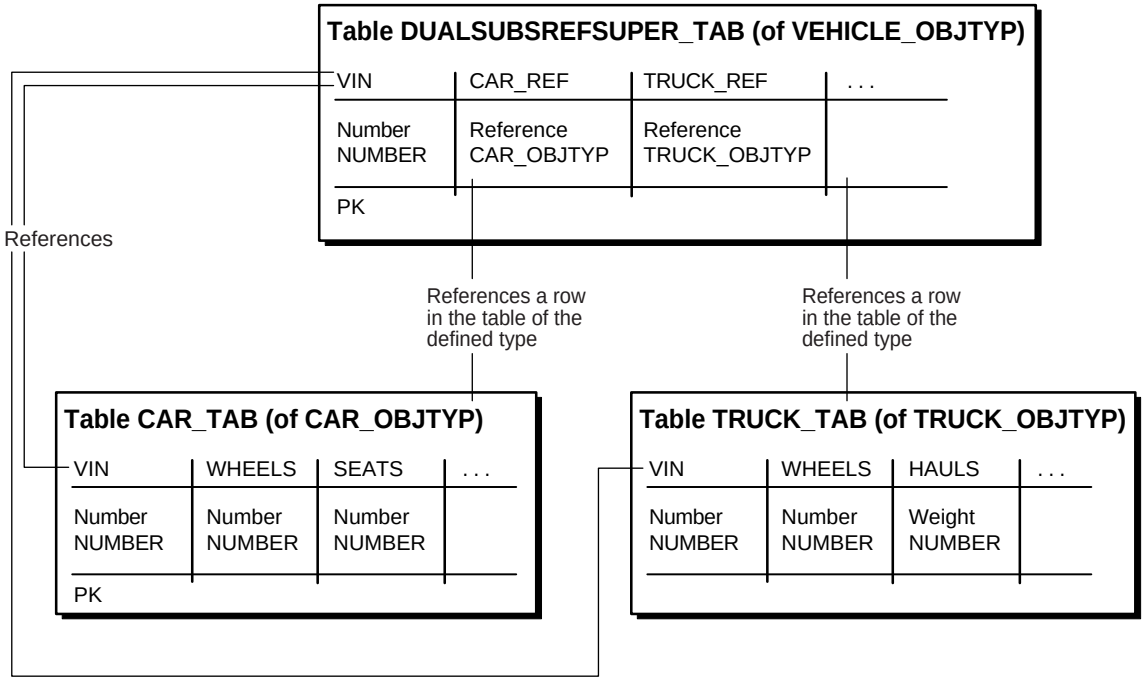
The Super-type Contains All Subtypes technique is used when objects have relationships with other objects that are predominately one-to-many in multiplicity. For example, a `Customer` can have many `Accounts` and a `Bank` can have many `Accounts`. The many relationships require a collection for each subtype if the *Subtype Contains Super-type* technique is used. If the `Account` is a super-type and `Checking` and `Savings` are subtypes, both `Bank` and `Customer` must implement a collection of `Checking` and `Savings` (4 collections). Adding a new account

subtype requires that both `Customer` and `Bank` add the collection to support the new account subtype (2 collections per addition). Using the *Super-type Contains All Subtype*s technique means that `Customer` and `Bank` have a collection of `Account`. Adding a subtype to `Accounts` means that only account changes.

In the case of the `Vehicle-Car / Truck`, the `Vehicle` is created with `Car` and `Truck` as embedded attributes of `Vehicle`.

Dual Subtype / Super-type Reference

Figure 18–13 Object-Relational Schema — Dual Subtype / Super-type Reference



In cases where the super-type is involved in multiple object-relationships with many for a multiplicity and the subtypes have specific relationships in the object model, the implementation of inheritance is a combination of the two inheritance techniques. The super-type is implemented as an object type. Each subtype is implemented as an object type. The super-type implements a referenced attribute for each subtype (zero referenced relationship). The super-type also implements an

or-association for the group of subtype attributes. Each subtype implements a referenced attribute for the super-type (one referenced relationship). In this way, both the super-type and sub-type are visible to the rest of the object model.

In the case of the `Vehicle-Car/Truck`, the `Vehicle` is created as a type. The `Car` and `Truck` are created as types. The `Vehicle` type implements a reference to both `Car` and `Truck`, with the or-constraint on the `Car` and `Truck` attributes. The `Car` implements an attribute that references `Vehicle`. The `Truck` implements an attribute that references `Vehicle`.

Constraints on Objects

Oracle does not support constraints and defaults in type specifications. However, you can specify the constraints and defaults when creating the tables:

```
CREATE OR REPLACE TYPE customer_type AS OBJECT(
   cust_id INTEGER)
/

CREATE OR REPLACE TYPE department_type AS OBJECT(
   deptno INTEGER)
/

CREATE TABLE customer_tab OF customer_type (
   cust_id default 1 NOT NULL) ;

CREATE TABLE department_tab OF department_type (
   deptno PRIMARY KEY) ;

CREATE TABLE customer_tab1 (
   cust customer_type DEFAULT customer_type(1)
   CHECK (cust.cust_id IS NOT NULL),
   some_other_column VARCHAR2(32)) ;
```

Type Evolution

You cannot change the definitions of types that have dependent data (in the form of column and / or row objects). However, you can modify tables with column objects by dropping and adding columns in a way similar to regular relational tables.

You cannot change tables containing row objects by dropping, adding, or modifying columns. If you need to modify tables containing row objects, a workaround is to perform the following steps:

1. Copy the table data into a temporary table, or export the table data.
2. Drop the table.
3. Recreate the type with the new definition.
4. Recreate the table.
5. Copy in the relevant data from temporary table, or import the data.

If type evolution is a requirement and this workaround is not acceptable, you should use object views defined over relational tables, instead of column objects or row objects. You can then change the definitions of object types and views.

Performance Tuning

See *Oracle8i Tuning* for details on measuring and tuning the performance of your application. In particular, some of the key performance factors are the following:

- `ANALYZE` command to collect statistics.
- `tkprof` to profile execution of SQL commands.
- `EXPLAIN PLAN` to generate the query plans.

See Also: *Oracle8i Tuning* describes these factors in detail.

Parallel Query with Oracle Objects

Oracle8*i* supports parallel query with objects. However, there are the following restrictions:

- To make queries involving joins and sorts parallel (using the ORDER BY, GROUP BY, and SET operations), a MAP function is required. In the absence of a MAP function, the query automatically becomes serial.
- Parallel queries on nested tables are not supported. Even if there are parallel hints or parallel attributes for the table, the query is serial.
- Parallel DML and parallel DDL are not supported with objects. DML and DDL are always performed in serial.

Support for Exporting, Importing, and Loading Oracle Objects

Oracle8*i* supports exporting Oracle objects using the Export utility, importing Oracle objects using the Import utility, and loading Oracle objects using SQL*Loader.

Objects that can be loaded with SQL*Loader include row objects, column objects, and objects with collections and references. However, SQL*Loader cannot perform direct path loading of objects. Therefore, use conventional path loading to load objects.

An alternative to conventional path loading is to first load the data into relational tables using direct path loading, and then create the object tables and tables with column objects using CREATE TABLE...AS SELECT commands. However, with this approach you need enough space to hold as much as twice the actual data.

See Also: *Oracle8i Utilities* for information about exporting, importing, and loading Oracle objects.

19

Programmatic Environments for Oracle Objects

In Oracle8*i*, the SQL data definition language (DDL) commands have been enhanced to support creation of object types and the SQL data manipulation language (DML) commands have been enhanced to manipulate objects. Also, Oracle's application programming environments have been enhanced to support objects. These environments include the Oracle Call Interface (OCI), Pro*C/C++, Oracle Objects for OLE, and Java. For each of these environments, an overview of object enhancements is provided.

This chapter covers the following topics:

Oracle Call Interface (OCI)

OCI is a set of C library functions that applications can use to manipulate data and schemas in an Oracle database. OCI supports both the associative style and the navigational style of data access.

See Also: *Oracle Call Interface Programmer's Guide* for more information about using objects with OCI.

Associative Access

Traditionally, 3GL programs have manipulated data stored in a relational database using the associative style of access. In associative access, data is manipulated by executing SQL statements and PL/SQL procedures, which allows applications to utilize the benefits of the SQL and PL/SQL languages. Also, in associative access, data may be manipulated on the server without incurring the cost of transporting the data to the client(s). OCI supports associative access to objects by providing an API for executing SQL statements that manipulate object data. Specifically, OCI supports the following object capabilities for associative access:

- Support for execution of SQL statements that manipulate object data and object type schema information
- Support for passing object instances, object references (REFs), and collections as input variables in SQL statements
- Support for receiving object instances, REFs, and collections as output of SQL statement fetches
- Support for describing the properties of SQL statements that return object instances, REFs, and collections
- Support for describing and executing PL/SQL procedures or functions with object parameters or results
- Enhancement of commit and rollback functions to synchronize object and relational functionality

Navigational Access

OCI also supports navigational access by object-oriented programs. In the object-oriented programming paradigm, applications model their real-world entities as a set of inter-related objects that form graphs of objects. The relationships between objects are implemented as references. An application processes objects by starting at some initial set of objects, using the references in these initial objects to traverse the remaining objects, and performing computations on each object. This style of access to objects is known as navigational access to objects. OCI provides an API for navigational access to objects. Specifically, OCI supports the following object capabilities for navigational access:

- A client side object cache for caching objects in memory
- Support for de-referencing an object reference and pinning the corresponding object in the object cache. The pinned object is transparently mapped in the host language representation.
- Support for notifying the cache when the pinned object is no longer needed
- Support for fetching a graph of related objects from the database into the client cache in one call
- Support for locking objects
- Support for creating, updating, and deleting objects in the cache
- Support for flushing changes made to objects in the client cache to the database

Object Cache

To support high-performance navigational access of objects, OCI runtime provides an object cache for caching objects in memory. The object cache supports references (REFs) to database objects in the object cache, the database objects can be identified (that is, pinned) through their references. Applications do not need to provide for allocation or freeing of memory when database objects are loaded into the cache, because the object cache provides transparent and efficient memory management for database objects.

Also, when database objects are loaded into the cache, they are transparently mapped into the host language representation. For example, in the C programming language, the database object is mapped to its corresponding C structure. The object cache maintains the association between the object copy in the cache and the corresponding database object. Upon transaction commit, changes made to the object copy in the cache are propagated automatically to the database.

The object cache maintains a fast look-up table for mapping REFs to objects. When an application de-references a REF and the corresponding object is not yet cached in the object cache, the object cache automatically sends a request to the server to fetch the object from the database and load it into the object cache. Subsequent de-references of the same REF are faster because they become local cache access and do not incur network round-trips. To notify the object cache that an application is accessing an object in the cache, the application pins the object; when it is finished with the object, it unpins it. The object cache maintains a pin count for each object in the cache. The count is incremented upon a pin call and decremented upon an unpin call. When the pin count goes to zero, it means the object is no longer needed by the application. The object cache uses a least-recently used (LRU) algorithm to manage the size of the cache. When the cache reaches the maximum size, the LRU algorithm frees candidate objects with a pin count of zero.

Building an OCI Program that Manipulates Objects

When you build an OCI program that manipulates objects, you must complete the following general steps:

1. Define the object types that correspond to the application objects.
2. Execute the SQL DDL statements to populate the database with the necessary object types.
3. Represent the object types in the host language format.

   For example, to manipulate instances of the object types in a C program, you must represent these types in the C host language format. You can do this by representing the object types as C *structs*. You can use a tool provided by Oracle called the Object Type Translator (OTT) to generate the C mapping of the object types. The OTT puts the equivalent C structs in header (*.h) files. You include these *.h files in the *.c files containing the C functions that implement the application.
4. Construct the application executable by compiling and linking the application's *.c files with the OCI library.

OCI Tips and Techniques

The following sections introduce tips and techniques for using OCI effectively by walking through common operations performed by an OCI program that uses objects.

Initializing Object Manipulation

To enable object manipulation, the OCI program must be initialized in *object mode*. The following OCI code initializes a program in object mode:

```
err = OCIInitialize(OCI_OBJECT, 0, 0, 0, 0);
```

When the program is initialized in object mode, the object cache is initialized. Memory for the cache is not allocated at this time; instead, it is allocated only on demand.

Controlling Object Cache Size

You can control the size of the object cache by using the following two OCI environment handle attributes:

- `OCI_ATTR_CACHE_MAX_SIZE` controls the maximum cache size
- `OCI_ATTR_CACHE_OPT_SIZE` controls the optimal cache size

You can get or set these OCI attributes using the *OCIAttrGet()* or *OCIAttrSet()* functions. Whenever memory is allocated in the cache, a check is made to determine whether the maximum cache size has been reached. If the maximum cache size has been reached, the cache automatically frees (ages out) the least-recently used objects with a pin count of zero. The cache continues freeing such objects until memory usage in the cache reaches the optimal size, or until it runs out of objects eligible for freeing. The object cache does not limit cache growth to the maximum cache size. The servicing of the memory allocation request could cause the cache to grow beyond the specified maximum cache size. The above two parameters allow the application to control the frequency of object aging from the cache.

Pinning and Unpinning Objects

Pinning is the process of retrieving an object from the server to the client cache, laying it in memory, providing a pointer to it for an application to manipulate, and marking the object as being in use. The *OCIObjectPin()* function de-references the given `REF` and pins the corresponding object in the cache. A pointer to the pinned object is returned to the caller and this pointer is valid as long as the object is pinned in the cache. This pointer *should not be used* after the object is unpinned

because the object may have aged out and therefore may no longer be in the object cache.

The following are examples of *OCIObjectPin()* and *OCIObjectUnpin()* calls:

```
status = OCIObjectPin(envh, errh, empRef,(OCIComplexObject*)0,
                      OCI_PIN_RECENT, OCI_DURATION_TRANSACTION,
                      OCI_LOCK_NONE, (dvoid**)&emp);
/* manipulate emp object */
status = OCIObjectUnpin(envh, errh, emp);
```

The `empRef` parameter passed in the pin call specifies the `REF` to the desired employee object. A pointer to the employee object in the cache is returned via the `emp` parameter.

You can use the *OCIObjectPinArray()* function to pin an array of objects in one call. This function de-references an array of `REF`s and pins the corresponding objects in the cache. Objects that are not already cached in the cache are retrieved from the server in one network round-trip. Therefore, calling *OCIObjectPinArray()* to pin an array of objects improves application performance. Also, the array of objects you are pinning can be of different types.

Pin Options When pinning an object, you can use the pin option argument to specify whether the recent version, latest version, or any version of the object is desired. The valid options are explained in more detail in the following list:

- The `OCI_PIN_RECENT` pin option instructs the object cache to return the object that is loaded into the cache in the current transaction; in other words, if the object was loaded prior to the current transaction, the object cache needs to refresh it with the latest version from the database. Succeeding pins of the object within the same transaction would return the cached copy and would not result in database access. In most cases, you should use this pin option.
- The `OCI_PIN_LATEST` pin option instructs the object cache to always get the latest copy of the object. If the object is already in the cache and not-locked, the object copy is refreshed with the latest copy from the database. On the other hand, if the object in the cache is locked, Oracle assumes that it is the latest copy, and the cached copy is returned. You should use this option for applications that must display the most recent copy of the object, such as applications that display stock quotes, current account balance, etc.

- The OCI_PIN_ANY pin option instructs the object cache to fetch the object in the most efficient manner; the version of the returned object does not matter. The pin any option is appropriate for objects which do not change often, such as product information, parts information, etc. The pin any option also is appropriate for read-only objects.

Pin Duration When pinning an object, you can specify the duration for which the object is pinned in the cache. When the duration expires, the object is unpinned automatically from the cache. The application should not use the object pointer after the object's pin duration has ended. An object can be unpinned prior to the expiration of its duration by explicitly calling the *OCIObjectUnpin()* function. Oracle supports two pre-defined pin durations:

- The session pin duration (OCI_DURATION_SESSION) lifetime is the duration of the database connection. Objects that are required in the cache at all times across transactions should be pinned with session duration.
- The transaction pin duration (OCI_DURATION_TRANS) lifetime is the duration of the database transaction. That is, the duration ends when the transaction is rolled back or committed.

Lock Options When pinning an object, the caller can specify whether the object should be locked via *lock options.* When an object is locked, a server-side lock is acquired, which prevents any other user from modifying the object. The lock is released when the transaction commits or rolls back. The following list describes the available lock options:

- The OCI_LOCK_NONE lock option instructs the cache to pin the object without locking.
- The OCI_LOCK_X lock option instructs the cache to pin the object only after acquiring a lock. If the object is currently locked by another user, the pin call with this option waits until it can acquire the lock before returning to the caller. Using the OCI_LOCK_X lock option is equivalent to executing a SELECT FOR UPDATE statement.
- The OCI_LOCK_X_NOWAIT lock option instructs the cache to pin the object only after acquiring a lock. Unlike the OCI_LOCK_X option, the pin call with OCI_LOCK_X_NOWAIT option will not wait if the object is currently locked by another user. Using the OCI_LOCK_X_NOWAIT lock option is equivalent to executing a SELECT FOR UPDATE WITH NOWAIT statement.

Using Complex Object Retrieval (COR)

Complex Object Retrieval (COR) can significantly improve the performance of applications that manipulate graphs of objects. COR allows applications to pre-fetch a set of related objects in one network round-trip, thereby improving performance. When pinning the root object(s) using *OCIObjectPin()* or *OCIObjectPinArray()*, you can specify the related objects to be pre-fetched along with the root. The pre-fetched objects are not pinned in the cache; instead, they are put in the LRU list. Subsequent pin calls on these objects result in a cache hit, thereby avoiding a round-trip to the server.

The application specifies the set of related objects to be pre-fetched by providing the following information:

- A REF to the root object
- One or more pairs of object type and depth information to specify the content and boundary of objects to be pre-fetched. The type information indicates which REF attributes should be de-referenced and which resulting object should be pre-fetched. The depth defines the boundary of objects pre-fetched. The depth level is the shortest number of references that need to be traversed from the root object to a related object.

For example, consider a purchase order system with the following properties:

- Each purchase order object includes a purchase order number, a REF to a customer object, and a collection of REFs that point to line item objects.
- Each customer object includes information about the customer, such as the customer's name and address.
- Each line item object includes a reference to a stock item and the quantity of the order.
- Each stock item object includes the name of the item, its price, and other information about the item.

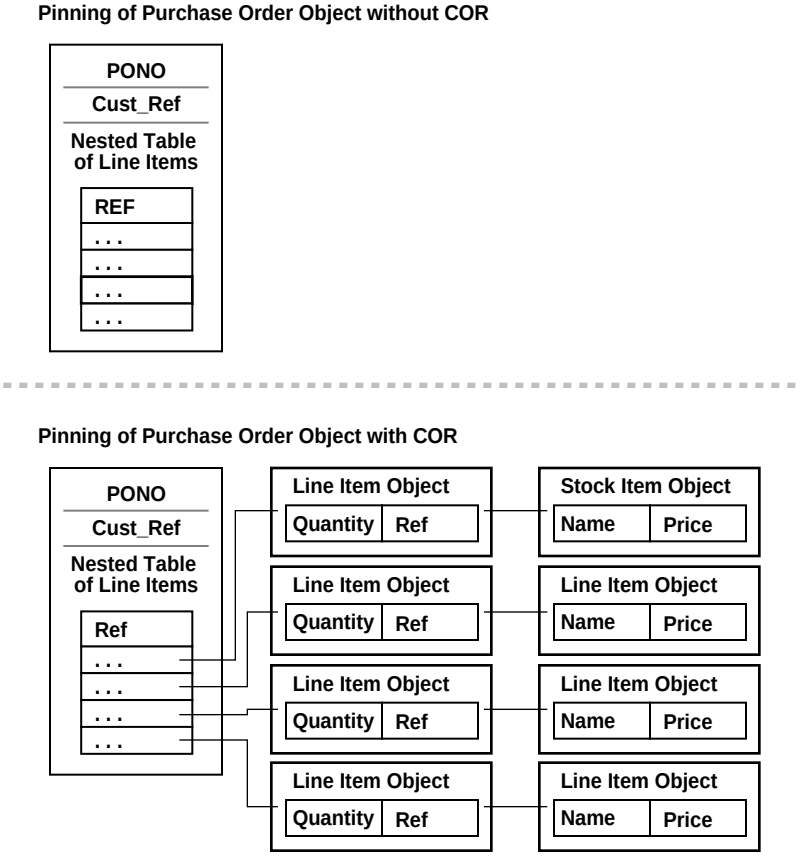
Suppose you want to calculate the total cost of a particular purchase order. To maximize efficiency, you want to fetch only the objects necessary for the calculation from the server to the client cache, and you want to fetch these objects with the least number of calls to the server possible.

If you do not use COR, your application must make several server calls to retrieve all of the necessary objects. However, if you use COR, you can specify the objects that you want to retrieve and exclude other objects that are not required. To calculate the total cost of a purchase order, you need the purchase order object, the

related line item objects, and the related stock item objects, but you do not need the customer objects.

Therefore, as shown in Figure 19–1, COR enables you to retrieve the required information for the calculation in the most efficient way possible. When pinning the purchase order object without COR, only that object is retrieved. When pinning it with COR, the purchase order and the related line item objects and stock item objects are retrieved. However, the related customer object is not retrieved because it is not required for the calculation.

Figure 19–1 Difference Between Retrieving an Object Without COR and With COR



Creating a New Object

The *OCIObjectNew()* function creates transient or persistent objects. A transient object's lifetime is the duration of the session in which it was created. A persistent object is an object that is stored in an object table in the database. The *OCIObjectNew()* function returns a pointer to the object created in the cache, and the application should initialize the new object by setting the attribute values directly. The object is not created in the database yet; it will be created and stored in the database when it is flushed from the cache.

When *OCIObjectNew()* creates an object in the cache, it sets all the attributes to NULL. The attribute null indicator information is recorded in the parallel null

indicator structure. If the application sets the attribute values, but fails to set the null indicator information in the parallel null structure, then upon object flush the object attributes will be set to NULL in the database.

In Oracle8*i*, if you want to set all of the attributes to NOT NULL during object creation instead, you can use the OCI_OBJECT_NEW_NOTNULL attribute of the environment handle using the *OCIAttrSet()* function. When set, this attribute creates a non-null object. That is, all the attributes are set to default values provided by Oracle and their null status information in the parallel null indicator structure is set to NOT NULL. Using this attribute eliminates the additional step of changing the indicator structure. You cannot change the default values provided by Oracle. Instead, you can populate the object with your own default values immediately after object creation.

When *OCIObjectNew()* is used to create a persistent object, the caller must identify the database table into which the newly created object is to be inserted. The caller identifies the table using a *table object*. Given the schema name and table name, the *OCIObjectPinTable()* function returns a pointer to the table object. Each call to *OCIObjectPinTable()* results in a call to the server to fetch the table object information. The call to the server happens even if the required table object has been previously pinned in the cache. When the application is creating multiple objects to be inserted into the same database table, Oracle Corporation recommends that the table object be pinned once and the pointer to the table object be saved for future use. Doing so improves performance of the application.

Updating an Object

Before you can update an object, the object must be pinned in the cache. After pinning the object, the application can update the desired attributes directly. You must make a call to the *OCIObjectMarkUpdate()* function to indicate that the object has been updated. Objects which have been marked as updated are placed in a dirty list and are flushed to the server upon cache flush or when the transaction is committed.

Deleting an Object

You can delete an object by calling the *OCIObjectMarkDelete()* function or the *OCIObjectMarkDeleteByRef()* function.

Locking an Object

The object cache supports both a pessimistic locking scheme and an optimistic locking scheme.

In the pessimistic locking scheme, objects are locked up-front prior to modifying the object in the cache, ensuring that no other user can modify the object till the transaction owning the lock performs a commit or rollback. The object can be locked at the time of pin by choosing the appropriate locking options. An object which was not locked at the time of pin also can be locked by calling explicit lock function *OCIObjectLock()*. A new locking function, *OCIObjectLockNoWait()*, has been added in Oracle8*i*. As the name indicates, this function does not wait to acquire the lock if another user holds a lock on the object.

In the optimistic locking scheme, objects are fetched and modified in the cache without acquiring a lock. A lock is acquired only when the object is flushed to the server. Optimistic locking allows for a higher degree of concurrent access than pessimistic locking. To use optimistic locking effectively, the Oracle8*i* object cache has been enhanced to detect if an object is changed by any other user since it was fetched into the cache. By turning on the *object change detection mode*, object modifications are made persistent only if the object has not been changed by any other user since it was fetched into the cache. This mode is activated by setting `OCI_OBJECT_DETECTCHANGE` attribute of the environment handle using the *OCIAttrSet()* function.

Flushing an Object from the Object Cache

Changes made to the objects in the object cache are not sent to the database until the object cache is flushed. The *OCICacheFlush()* function flushes all changes in a single network round-trip between the client and the server. The changes may involve insertion of new objects into the appropriate object tables, updating objects in object tables, and deletion of objects from object tables. If the application commits a transaction by calling the *OCITransCommit()* function, the object cache automatically performs a cache flush prior to committing the transaction.

Demonstration of OCI and Oracle Objects

For a demonstration of how to use OCI with Oracle objects, see the `cdemocor1.c` file in `$ORACLE_HOME/rdbms/demo`.

Pro*C/C++

Pro*C / C++ support for objects mirrors the support provided by OCI. Extensions to the embedded SQL syntax provide both associative and navigational access to objects. The Object Type Translator is used to generate C language representations (structs) for database object types that are used as host variables in the embedded SQL statements. By extending the embedded SQL syntax, Pro*C / C++ users retain the benefits of precompile-time syntactic and semantic checking for their object-relational applications.

Associative Access in Pro*C/C++

Pro*C / C++ offers the following capabilities for associative access to objects:

- Support for transient copies of objects allocated in the object cache
- Support for transient copies of objects referenced as input host variables in embedded SQL `INSERT`, `UPDATE`, and `DELETE` statements, or in the `WHERE` clause of a `SELECT` statement
- Support for transient copies of objects referenced as output host variables in embedded SQL `SELECT` and `FETCH` statements
- Support for ANSI dynamic SQL statements that reference object types through the `DESCRIBE` statement, to get the object's type and schema information

Navigational Access in Pro*C/C++

Object navigation is a new programming paradigm introduced in release 8.0 of Oracle. Pro*C / C++ offers the following capabilities to support a more object-oriented interface to objects:

- Support for de-referencing, pinning, and optionally locking an object in the object cache using an embedded SQL `OBJECT DEREF` statement
- Allowing a Pro*C / C++ user to inform the object cache when an object has been updated or deleted, or when it is no longer needed, using embedded SQL `OBJECT UPDATE`, `OBJECT DELETE`, and `OBJECT RELEASE` statements
- Support for creating new referenceable objects in the object cache using an embedded SQL `OBJECT CREATE` statement
- Support for flushing changes made in the object cache to the server with an embedded SQL `OBJECT FLUSH` statement

Converting Between Oracle Types and C Types

The C representation for objects that is generated by the Oracle Type Translator (OTT) uses opaque OCI types such as `OCIString` and `OCINumber` for scalar attributes. Collection types and object references are similarly represented using `OCITable`, `OCIArray`, and `OCIRef` types. While using opaque types insulates the application developer from changes to the internal format of these types, using such types in a C or C++ application is cumbersome. Pro*C/C++ provides the following ease-of-use enhancements to simplify use of OCI types in C and C++ applications:

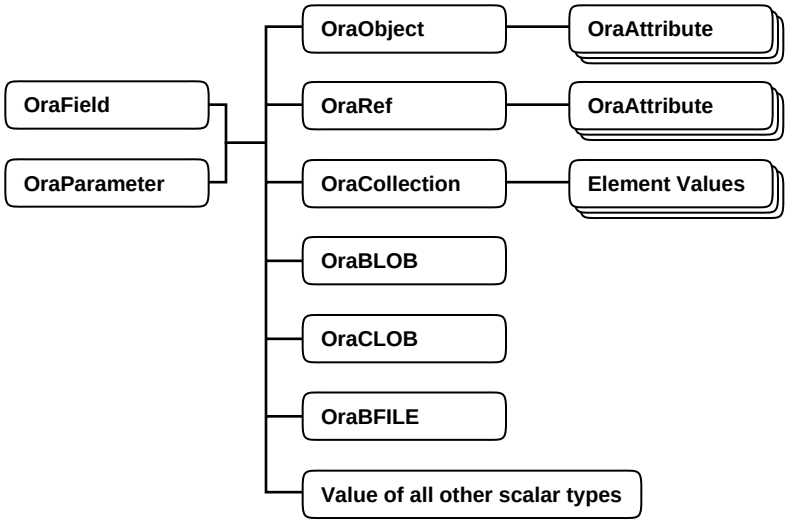
- Object attributes can be retrieved and implicitly converted to C types with the embedded SQL `OBJECT GET` statement.
- Object attributes can be set and converted from C types with the embedded SQL `OBJECT SET` statement.
- Collections can be mapped to a host array with the embedded SQL `COLLECTION GET` statement. Furthermore, if the collection is comprised of scalar types, then the OCI types can be implicitly converted to a compatible C type.
- Host arrays can be used to update the elements of a collection with the embedded SQL `COLLECTION SET` statement. As with the `COLLECTION GET` statement, if the collection is comprised of scalar types, C types are implicitly converted to OCI types.

Oracle Objects For OLE

Oracle Objects for OLE (OO4O) provides full support for accessing and manipulating instances of REFs, value instances, variable-length arrays (VARRAYs), and nested tables in an Oracle database server.

Figure 19–2 illustrates the containment hierarchy for value instances of all types in OO4O.

Figure 19–2 Supported Oracle Datatypes



Instances of these types can be fetched from the database or passed as input or output variables to SQL statements and PL/SQL blocks, including stored procedures and functions. All instances are mapped to COM Automation Interfaces that provide methods for dynamic attribute access and manipulation. These interfaces may be obtained from:

- The value property of an OraField object in a Dynaset
- The value property of an OraParameter object used as an input or an output parameter in SQL Statements or PL/SQL blocks
- An attribute of an object (REF)
- An element in a collection (varray or a nested table)

OraObject

The OraObject interface is a representation of an Oracle embedded object or a value instance. It contains a collection interface (OraAttributes) for accessing and manipulating (updating and inserting) individual attributes of a value instance. Individual attributes of an OraAttributes collection interface can be accessed by using a subscript or the name of the attribute.

The following Visual Basic example illustrates how to access attributes of the `Address` object in the `person_tab` table:

```
Set Person = OraDatabase.CreateDynaset("select * from person_tab", 0&)
set Address = Person.Fields("Addr").Value
msgbox Address.Zip
msgbox.Address.City
```

OraRef

The OraRef interface represents an Oracle object reference (REF) as well as referenceable objects in client applications. The object attributes are accessed in the same manner as attributes of an object represented by the OraObject interface. OraRef is derived from an OraObject interface via the containment mechanism in COM. REF objects are updated and deleted independent of the context they originated from, such as Dynasets. The OraRef interface also encapsulates the functionality for navigating through graphs of objects utilizing the Complex Object Retrieval Capability (COR) in OCI, described in "Using Complex Object Retrieval (COR)" on page 19-8.

OraCollection

The OraCollection interface provides methods for accessing and manipulating Oracle collection types, namely variable-length arrays (VARRAYs) and nested tables in OO4O. Elements contained in a collection are accessed by subscripts.

The following Visual Basic example illustrates how to access attributes of the `EnameList` object from the `department` table:

```
Set Person = OraDatabase.CreateDynaset("select * from department", 0&)
set EnameList = Department.Fields("Enames").Value
'access all elements of the EnameList VArray
for I=1 to I=EnameList.Size
   msgbox EnameList(I)
Next I
```

See Also: OO4O online help for detailed information about using OO4O with Oracle objects.

Java: JDBC and Oracle SQLJ

Java has emerged as a powerful, modern object-oriented language that provides developers with a simple, efficient, portable, and safe application development platform. Oracle provides two ways to integrate Oracle object features with Java: JDBC and Oracle SQLJ. The following sections provide more information about JDBC and Oracle SQLJ.

JDBC Access to Oracle Object Data

Oracle provides tight integration between its Oracle object features and its JDBC functionality. You can map SQL types to Java classes, and Oracle offers considerable flexibility in how this mapping is done.

Version 2.0 of the JDBC specification contains support for Object-Relational constructs, such as user-defined (Object) types. JDBC materializes Oracle objects as instances of particular Java classes. There are two main issues in using JDBC to access Oracle objects: creating the Java classes for the Oracle objects and populating these classes. You have the following options:

- Let JDBC materialize the object as a `STRUCT`. In this case, JDBC will create the classes for the attributes and populate them for you.
- Personally specify the mappings between Oracle objects and Java classes; that is, customize your Java classes for object data. The driver then needs to be able to populate the customized Java classes that you specify, which imposes a set of constraints on the Java classes. To satisfy these constraints, you can chose to define your classes according to either the `SQLData` interface or the `CustomDatum` interface.

> **See Also:** *Oracle8i JDBC Developer's Guide and Reference* for more information about JDBC access to Oracle object data.

Support for Objects in Oracle SQLJ

Oracle also provides Oracle SQLJ, a standard way to embed SQL statements in Java programs. Source files are then processed by Oracle SQLJ. When writing a SQLJ application, a user writes a Java program and embeds SQL statements in it, while following certain standard syntactic rules that govern how SQL statements can be embedded in Java programs. The user then runs the Oracle SQLJ translator, which converts this SQLJ program to a standard Java program, and replaces the embedded SQL statements with calls to the Oracle SQLJ runtime. The generated Java program

is compiled, using any Java compiler, and run against a database. The Oracle SQLJ runtime environment consists of a thin SQLJ runtime library, which is implemented in pure Java, and which implements your SQL operations, typically using a JDBC driver.

SQLJ, therefore, is similar to the ANSI/ISO Embedded SQL standards, which prescribe how static SQL is embedded in C/C++, COBOL, FORTRAN, and other languages. For example, Oracle's pre-compiler product, Pro*C/C++, is an implementation of the Embedded SQL standard in the C/C++ host language. The following are the general steps required for writing and running an Oracle SQLJ program:

1. Write Oracle SQLJ source files, embedding SQL statements within Java code. The embedded SQL statements are marked by a special `#sql` token.
2. Translate Oracle SQLJ source files with the Oracle SQLJ translator, which generates:
   - New Java source files with calls to the Oracle SQLJ runtime
   - Additional Oracle SQLJ profile files containing all the information about the static SQL statements that were found in the Oracle SQLJ source
3. Compile the Java sources with a Java compiler.
4. Customize the generated SQL profiles to use vendor-specific features.
5. Run the application.

Usually, the Oracle SQLJ translator performs steps 2, 3, and 4 automatically, invoking a Java compiler and profile customizer in the process. At translation time, the static SQL statements in the program can be checked against a given database schema. The Oracle SQLJ runtime uses a JDBC driver, typically the Oracle JDBC driver, in accessing the database.

Oracle SQLJ supports either strongly typed or weakly typed Java representations of object types, reference types (REFs), and collection types (VARRAYs and nested tables) to be used in iterators or host expressions. Strongly typed representations use a *custom Java class* that corresponds to a particular object type, reference type, or collection type and must implement the interface `oracle.sql.CustomDatum`. This paradigm is supported by the Oracle JPublisher utility, which can be used to automatically generate such custom Java classes. Weakly typed representations use the class `oracle.sql.STRUCT` (for objects), `oracle.sql.REF` (for references), or `oracle.sql.ARRAY` (for collections).

To use Oracle-specific object, reference, and collection types, you must customize your profile appropriately. The default Oracle customizer, `oracle.sqlj.runtime.util.OraCustomizer`, typically is recommended. This customization is performed automatically when you run the `sqlj` script unless you specify otherwise.

For Oracle-specific semantics checking, you must use an appropriate checker. The default checker, `oracle.sqlj.checker.OracleChecker`, is recommended. This acts as a front-end and chooses an appropriate checker for you, depending on whether you enable online checking and on which JDBC driver and Oracle database release you use.

Note: Custom Java classes used for objects, references, and collections are referred to as *custom object classes*, *custom reference classes*, and *custom collection classes*, respectively. Also, user-defined object types and user-defined collection types are sometimes simply referred to as *user-defined types*.

See Also: This section only provides an overview of support for objects in Oracle SQLJ. For detailed information about using objects in Oracle SQLJ, see the *Oracle8i SQLJ Developer's Guide and Reference*

About Custom Java Classes and the CustomDatum Interface

Custom Java classes are used by the JDBC driver to convert data between the database and your Java application, and they make the data accessible. You should provide custom Java classes for all user-defined types that you use in an Oracle SQLJ application. Even if you do not directly use custom Java class instances in your code, the JDBC driver can use such instances in order to convert data. Using custom Java classes is more convenient and less prone to error than using the weakly typed classes `oracle.sql.STRUCT`, `REF`, and `ARRAY`. Custom Java classes are first-class types that you can use to read from and write to user-defined SQL types transparently.

Note: Oracle JDBC drivers are required to use custom Java classes.

CustomDatum and CustomDatumFactory Specifications Oracle provides the interface `oracle.sql.CustomDatum` and the related interface `oracle.sql.CustomDatumFactory` as vehicles to use in mapping Oracle object types, reference types, and collection types to custom Java classes and in converting data between the database and your application. Custom Java classes must implement `CustomDatum` in order to be used in Oracle SQLJ iterators and host expressions.

Data passed to or from the database is in the form of an `oracle.sql.Datum` object, with the underlying data being in the format of the appropriate `oracle.sql.Datum` subclass, such as `oracle.sql.STRUCT`. This data is still in its codified database format; the `oracle.sql.Datum` object is just a wrapper.

The `CustomDatum` interface specifies a `toDatum()` method for data conversion from Java format to database format. This method takes as input your `OracleConnection` object (which is required by the Oracle JDBC drivers) and converts data to the appropriate `oracle.sql.*` representation. The `OracleConnection` object is necessary so that the JDBC driver can perform appropriate type checking and type conversions at runtime. The following is the `CustomDatum` and `toDatum()` specification:

```
interface oracle.sql.CustomDatum
{
   oracle.sql.Datum toDatum(OracleConnection c);
}
```

The `CustomDatumFactory` interface specifies a `create()` method that constructs instances of your custom Java class, converting from database format to Java format. This method takes as input a `Datum` object containing data from the database and an integer indicating the SQL type of the underlying data, such as `OracleTypes.RAW`. It returns an object of your custom Java class, which implements the `CustomDatum` interface. This object receives its data from the `Datum` object that was input. The following is the `CustomDatumFactory` and `create()` specification:

```
interface oracle.sql.CustomDatumFactory
{
   oracle.sql.CustomDatum create(oracle.sql.Datum d, int sqlType);
}
```

To complete the relationship between the `CustomDatum` and `CustomDatumFactory` interfaces, there is a requirement for a static `getFactory()` method that you must implement in any custom Java class that implements the `CustomDatum` interface. This method returns an object that

implements the `CustomDatumFactory` interface, and that therefore can be used to create instances of your custom Java class. This returned object may itself be an instance of your custom Java class, and its `create()` method is used by the Oracle JDBC driver to produce further instances of your custom Java class as necessary.

Custom Java classes produced by JPublisher automatically implement the `CustomDatum` and `CustomDatumFactory` interfaces and the `getFactory()` method.

See Also: *Oracle8i SQLJ Developer's Guide and Reference* for more information about the `CustomDatum` and `CustomDatumFactory` interfaces.

Custom Java Class Support for Object Methods

You can implement methods of Oracle objects as wrappers in custom Java classes. Whether the underlying stored procedure is written in PL/SQL or is written in Java and published to SQL is invisible to the user.

A Java wrapper method that is used to invoke a server method requires a connection in order to communicate with the server. The connection object can be provided as an explicit parameter, or can be associated in some other way (as an attribute of your custom Java class, for example).

You can write each wrapper method as an instance method of the custom Java class, regardless of whether the server method that the wrapper method invokes is an instance method or a static method. Custom Java classes generated by JPublisher use this technique.

There are also issues regarding output and input-output parameters in methods of Oracle objects. In the database, if a stored procedure (Oracle object method) modifies the internal state of one of its arguments, the actual argument that was passed to the stored procedure is modified. In Java this is not possible. When a JDBC output parameter is returned from a stored procedure call, it is stored in a newly created object. The original object identity is lost.

One way to return an output or input-output parameter to the caller is to pass the parameter as an element of an array. If the parameter is input-output, the wrapper method takes the array element as input; after processing, the wrapper assigns the output to the array element. Custom Java classes generated by JPublisher use this technique—each output or input-output parameter is passed in a one-element array.

See Also: The *Oracle8i JPublisher User's Guide* for more information.

Compiling Custom Java Classes

You can include the `.java` files for your custom Java classes on the Oracle SQLJ command line together with your `.sqlj` file. For example, if `ObjectDemo.sqlj` uses the Oracle object types `Address` and `Person`, and you have run JPublisher or otherwise produced custom Java classes for these objects, you can run Oracle SQLJ in the following way:

```
sqlj options ObjectDemo.sqlj Address.java AddressRef.java Person.java PersonRef.java
```

Otherwise you can compile them separately, using your Java compiler directly. If you do this, it must be done prior to translating the `.sqlj` file.

JPublisher and Creating Custom Java Classes

Oracle offers flexibility in how you can customize the mapping of Oracle object types, reference types, and collection types to Java classes in a strongly typed paradigm. You have the following choices in creating these custom Java classes:

- Use Oracle JPublisher to automatically generate custom Java classes and use those classes directly without modification.
- Use Oracle JPublisher to automatically generate custom Java classes and subclass them to create custom Java classes with added functionality.
- Manually code custom Java classes without using JPublisher, provided that the classes meet the requirements stated in the *Oracle8i SQLJ Developer's Guide and Reference* .

Although you have the option of manually coding your custom Java classes, it is recommended that you use JPublisher. If you need special functionality, you can subclass the classes that JPublisher creates and modify the subclasses as necessary.

What JPublisher Produces When you run JPublisher for a user-defined object type, it automatically creates the following:

- A custom object class to act as a type definition to correspond to your Oracle object type

  This class includes getter and setter methods for each attribute. The method names are of the form `getFoo()` and `setFoo()` for attribute `foo`.

  Also, you can optionally instruct JPublisher to generate wrapper methods in your class that invoke the associated Oracle object methods executing in the server.

- A related custom reference class for object references to your Oracle object type

  This class includes a `getValue()` method that returns an instance of your custom object class, and a `setValue()` method that updates an object value in the database, taking as input an instance of the custom object class.

When you run JPublisher for a user-defined collection type, it automatically creates the following:

- A custom collection class to act as a type definition to correspond to your Oracle collection type

  This class includes overloaded `getArray()` and `setArray()` methods to retrieve or update a collection as a whole, a `getElement()` method and `setElement()` method to retrieve or update individual elements of a collection, and additional utility methods.

JPublisher-produced custom Java classes in any of these categories implement the `CustomDatum` interface, the `CustomDatumFactory` interface, and the `getFactory()` method.

> **See Also:** The *Oracle8i JPublisher User's Guide* for more information about using JPublisher.

Strongly Typed Objects and References in Oracle SQLJ Executable Statements

Oracle SQLJ is flexible in how it allows you to use host variables and iterators in reading or writing object data through strongly typed objects or references.

For iterators, you can use custom object classes as iterator column types. Alternatively, you can have iterator columns that correspond to individual object attributes (similar to extent tables), using column types that appropriately map to the attribute datatypes in the database.

For host expressions, you can use host variables of your custom object class type or custom reference class type, or you can use host variables that correspond to object attributes, using variable types that appropriately map to the attribute datatypes in the database.

> **See Also:** *Oracle8i SQLJ Developer's Guide and Reference* for more information about how to manipulate Oracle objects using custom object classes, custom object class attributes, and custom reference classes for host variables and iterator columns in Oracle SQLJ executable statements.

Weakly Typed Objects, References, and Collections

Weakly typed objects, references, and collections are supported by Oracle SQLJ. Their general use is not recommended and there are some restrictions on their use, but in some circumstances they may be useful. For example, you may have generic code that can use "any STRUCT" or "any REF" (although if this code uses dynamic SQL it would require coding in JDBC instead of Oracle SQLJ).

In using Oracle objects, references, or collections in an Oracle SQLJ application, you have the option of using generic and weakly typed `oracle.sql` classes instead of the strongly typed custom Java classes that implement the `CustomDatum` interface.

The following `oracle.sql` classes can be used for iterator columns or host expressions in Oracle SQLJ:

- `oracle.sql.STRUCT` for objects
- `oracle.sql.REF` for object references
- `oracle.sql.ARRAY` for collections

In host expressions they are supported as follows:

- As input host expressions
- As output host expressions in an INTO-list

Using these classes is not generally recommended, however, as you would lose all the advantages of the strongly typed paradigm that Oracle SQLJ offers.

Each attribute in a STRUCT object or each element in an ARRAY object is stored in an `oracle.sql.Datum` object, with the underlying data in the form of the appropriate `oracle.sql.*` type (such as `oracle.sql.NUMBER` or `oracle.sql.CHAR`). Attributes in a STRUCT object are nameless.

Because of the generic nature of the STRUCT and ARRAY classes, Oracle SQLJ can do no type checking where objects or collections are written to or read from instances of these classes.

Oracle Corporation recommends that you use custom Java classes for objects, references, and collections, preferably classes produced by JPublisher.

Note: Oracle's implementations of STRUCT, REF, and ARRAY are designed to be compliant with JDBC 2.0, implementing interfaces based on Sun Microsystems standards.

Oracle SQLJ Restrictions on Weakly Typed Objects, References, and Collections A weakly typed object (STRUCT instance), reference (REF instance), or collection (ARRAY instance) *cannot* be used in host expressions in the following circumstances:

- OUT or INOUT parameter in stored procedure or function call
- OUT parameter in stored function result-expression

There are no Oracle SQLJ restrictions on their use in IN host expressions; however, there may be JDBC requirements to initialize weakly typed STRUCT, REF, and ARRAY objects with a SQL typecode from oracle.jdbc.driver.OracleTypes.

Part V

CUBE and ROLLUP Extensions to SQL

Part V contains the following chapter:

20

Analyzing Data with ROLLUP, CUBE, AND TOP-N QUERIES

This chapter covers the following topics:

Overview of CUBE, ROLLUP, and Top-N Queries

The last decade has seen a tremendous increase in the use of query, reporting, and on-line analytical processing (OLAP) tools, often in conjunction with data warehouses and data marts. Enterprises exploring new markets and facing greater competition expect these tools to provide the maximum possible decision-making value from their data resources.

Oracle expands its long-standing support for analytical applications in Oracle8*i* release 8.1.5 with the CUBE and ROLLUP extensions to SQL. Oracle also provides optimized performance and simplified syntax for Top-N queries. These enhancements make important calculations significantly easier and more efficient, enhancing database performance, scalability and simplicity.

ROLLUP and CUBE are simple extensions to the SELECT statement's GROUP BY clause. ROLLUP creates subtotals at any level of aggregation needed, from the most detailed up to a grand total. CUBE is an extension similar to ROLLUP, enabling a single statement to calculate all possible combinations of subtotals. CUBE can generate the information needed in cross-tab reports with a single query. To enhance performance, both CUBE and ROLLUP are parallelized: multiple processes can simultaneously execute both types of statements.

> **See Also:** For information on parallel execution, see *Oracle8i Concepts*.

Enhanced Top-N queries enable more efficient retrieval of the largest and smallest values of a data set. This chapter presents concepts, syntax, and examples of CUBE, ROLLUP and Top-N analysis.

Analyzing across Multiple Dimensions

One of the key concepts in decision support systems is "multi-dimensional analysis": examining the enterprise from all necessary combinations of dimensions. We use the term "dimension" to mean any category used in specifying questions. Among the most commonly specified dimensions are time, geography, product, department, and distribution channel, but the potential dimensions are as endless as the varieties of enterprise activity. The events or entities associated with a particular set of dimension values are usually referred to as "facts." The facts may be sales in units or local currency, profits, customer counts, production volumes, or anything else worth tracking.

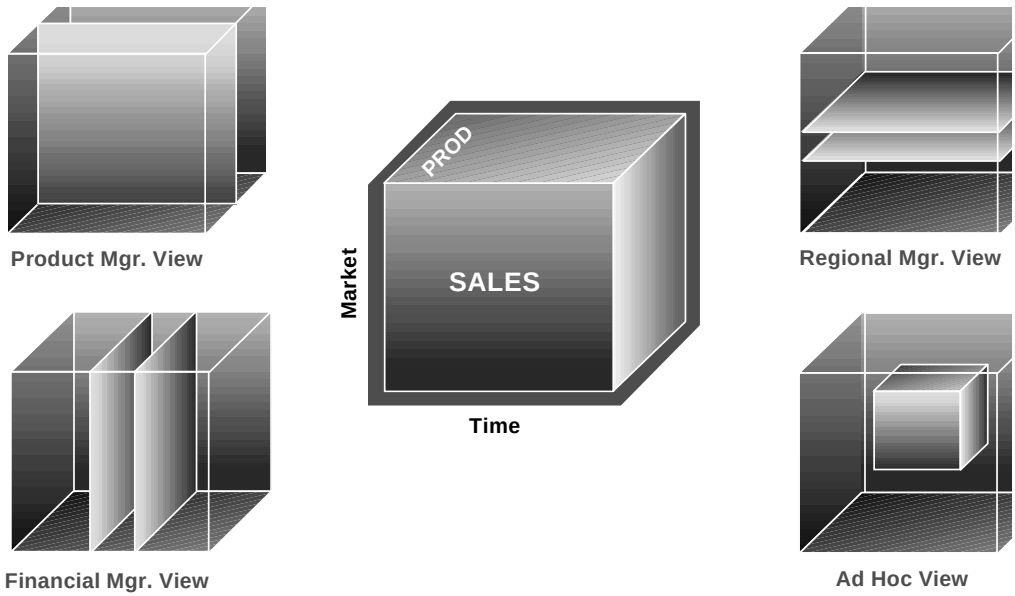
Here are some examples of multi-dimensional requests:

- Show total sales across all products at increasing aggregation levels: from state to country to region for 1996 and 1997.
- Create a cross-tabular analysis of our operations showing expenses by territory in South America for 1996 and 1997. Include all possible subtotals.
- List the top 10 sales representatives in Asia according to 1997 sales revenue in for automotive products and rank their commissions.

All the requests above constrain multiple dimensions. Many multi-dimensional questions require aggregated data and comparisons of data sets, often across time, geography or budgets.

To visualize data that has many dimensions, analysts commonly use the analogy of a data "cube," that is, a space where facts are stored at the intersection of n dimensions. Figure 20–1 shows a data cube and how it could be used differently by various groups. The cube stores sales data organized by the dimensions of Product, Market, and Time.

Figure 20–1 Cube and Views by Different Users



We can retrieve "slices" of data from the cube. These correspond to cross-tabular reports such as the one shown in Table 20–1 on page 20-5. Regional managers might study the data by comparing slices of the cube applicable to different markets. In contrast, product managers might compare slices that apply to different products. An ad hoc user might work with a wide variety of constraints, working in a subset cube.

Answering multi-dimensional questions often involves huge quantities of data, sometimes millions of rows. Because the flood of detailed data generated by large organizations cannot be interpreted at the lowest level, aggregated views of the information are essential. Subtotals across many dimensions are vital to multi-dimensional analyses. Therefore, analytical tasks require convenient and efficient data aggregation.

Optimized Performance

Not only multi-dimensional issues, but all types of processing can benefit from enhanced aggregation facilities. Transaction processing, financial and manufacturing systems—all of these generate large numbers of production reports needing substantial system resources. Improved efficiency when creating these reports will reduce system load. In fact, any computer process that aggregates data from details to higher levels needs optimized performance.

To leverage the power of the database server, powerful aggregation commands should be available inside the SQL engine. New extensions in Oracle provide these features and bring many benefits, including:

- Simplified programming requiring less SQL code for many tasks
- Quicker and more efficient query processing
- Reduced client processing loads and network traffic because aggregation work is shifted to servers
- Opportunities for caching aggregations because similar queries can leverage existing work

Oracle8*i* provides all these benefits with the new `CUBE` and `ROLLUP` extensions to the `GROUP BY` clause. These extensions adhere to the ANSI and ISO proposals for SQL3, a draft standard for enhancements to SQL.

A Scenario

To illustrate CUBE, ROLLUP, and Top-N queries, this chapter uses a hypothetical videotape sales and rental company. All the examples given refer to data from this scenario. The hypothetical company has stores in several regions and tracks sales and profit information. The data is categorized by three dimensions: Time, Department, and Region. The time dimensions are 1996 and 1997, the departments are Video Sales and Video Rentals, and the regions are East, West, and Central.

Table 20–1 is a sample cross-tabular report showing the total profit by region and department in 1997:

Table 20–1 Simple Cross-Tabular Report, with Subtotals Shaded

	1997		
Region	**Department**		
	Video Rental Profit	**Video Sales Profit**	**Total Profit**
Central	82,000	85,000	167,000
East	101,000	137,000	238,000
West	96,000	97,000	193,000
Total	279,000	319,000	598,000

Consider that even a simple report like Table 20–1, with just twelve values in its grid, needs five subtotals and a grand total. The subtotals are the shaded numbers, such as Video Rental Profits across regions, namely, 279,000, and Eastern region profits across department, namely, 238,000. Half of the values needed for this report would not be calculated with a query that used a standard SUM() and GROUP BY. Database commands that offer improved calculation of subtotals bring major benefits to querying, reporting and analytical operations.

ROLLUP

ROLLUP enables a SELECT statement to calculate multiple levels of subtotals across a specified group of dimensions. It also calculates a grand total. ROLLUP is a simple extension to the GROUP BY clause, so its syntax is extremely easy to use. The ROLLUP extension is highly efficient, adding minimal overhead to a query.

Syntax

ROLLUP appears in the GROUP BY clause in a SELECT statement. Its form is:

```
SELECT … GROUP BY
   ROLLUP(grouping_column_reference_list)
```

Details

ROLLUP's action is straightforward: it creates subtotals which "roll up" from the most detailed level to a grand total, following a grouping list specified in the ROLLUP clause. ROLLUP takes as its argument an ordered list of grouping columns. First, it calculates the standard aggregate values specified in the GROUP BY clause. Then, it creates progressively higher-level subtotals, moving from right to left through the list of grouping columns. Finally, it creates a grand total.

ROLLUP will create subtotals at n+1 levels, where n is the number of grouping columns. For instance, if a query specifies ROLLUP on grouping columns of Time, Region, and Department (n=3), the result set will include rows at four aggregation levels.

Example

This example of ROLLUP uses the data in the video store database.

```
SELECT Time, Region, Department,
 sum(Profit) AS Profit FROM sales
 GROUP BY ROLLUP(Time, Region, Dept)
```

As you can see in Table 20–2, this query returns the following sets of rows:

- Regular aggregation rows that would be produced by GROUP BY without using ROLLUP
- First-level subtotals aggregating across Department for each combination of Time and Region
- Second-level subtotals aggregating across Region and Department for each Time value
- A grand total row

Table 20–2 ROLLUP Aggregation across Three Dimensions

Time	Region	Department	Profit
1996	Central	VideoRental	75,000
1996	Central	VideoSales	74,000
1996	Central	[NULL]	149,000
1996	East	VideoRental	89,000
1996	East	VideoSales	115,000
1996	East	[NULL]	204,000
1996	West	VideoRental	87,000
1996	West	VideoSales	86,000
1996	West	[NULL]	173,000
1996	[NULL]	[NULL]	526,000
1997	Central	VideoRental	82,000
1997	Central	VideoSales	85,000
1997	Central	[NULL]	167,000
1997	East	VideoRental	101,000
1997	East	VideoSales	137,000
1997	East	[NULL]	238,000
1997	West	VideoRental	96,000
1997	West	VideoSales	97,000
1997	West	[NULL]	193,000
1997	[NULL]	[NULL]	598,000
[NULL]	[NULL]	[NULL]	1,124,000

Interpreting “[NULL]” Values in Results

The NULL values returned by ROLLUP and CUBE are not always the traditional NULL value meaning “value unknown.” Instead, a NULL may indicate that its row is a subtotal. For instance, the first NULL value shown in Table 20–2 is in the Department column. This NULL means that the row is a subtotal for "All Departments" for the Central region in 1996. To avoid introducing another non-value in the database system, these subtotal values are not given a special tag.

See the section "GROUPING Function" on page 20-13 for details on how the NULLs representing subtotals are distinguished from NULLs stored in the data.

> **Note:** The NULLs shown in the figures of this paper are displayed only for clarity: in standard Oracle output these cells would be blank.

Calculating Subtotals without ROLLUP

The result set in Table 20–1 could be generated by the UNION of four SELECT statements, as shown below. This is a subtotal across three dimensions. Notice that a complete set of ROLLUP-style subtotals in n dimensions would require n+1 SELECT statements linked with UNION ALL.

```
SELECT Time, Region, Department, SUM(Profit)
 FROM Sales
 GROUP BY Time, Region, Department
UNION  ALL
 SELECT Time, Region, '' , SUM(Profit)
 FROM Sales
 GROUP BY Time, Region
UNION ALL
 SELECT Time, '', '', SUM(Profits)
 FROM Sales
 GROUP BY Time
UNION ALL
 SELECT '', '', '', SUM(Profits)
 FROM Sales;
```

The approach shown in the SQL above has two shortcomings compared to using the ROLLUP operator. First, the syntax is complex, requiring more effort to generate and understand. Second, and more importantly, query execution is inefficient because the optimizer receives no guidance about the user's overall goal. Each of the four SELECT statements above causes table access even though all the needed subtotals could be gathered with a single pass. **The ROLLUP extension makes the desired result explicit and gathers its results with just one table access.**

The more columns used in a ROLLUP clause, the greater the savings versus the UNION approach. For instance, if a four-column ROLLUP replaces a UNION of 5 SELECT statements, the reduction in table access is four-fifths or 80%.

Some data access tools calculate subtotals on the client side and thereby avoid the multiple SELECT statements described above. While this approach can work, it

places significant loads on the computing environment. For large reports, the client must have substantial memory and processing power to handle the subtotaling tasks. Even if the client has the necessary resources, a heavy processing burden for subtotal calculations may slow down the client in its performance of other activities.

When to Use ROLLUP

Use the ROLLUP extension in tasks involving subtotals.

- It is very helpful for subtotaling along a hierarchical dimension such as time or geography. For instance, a query could specify a ROLLUP of year / month / day or country / state / city.
- It simplifies and speeds the population and maintenance of summary tables. Data warehouse administrators may want to make extensive use of it. Note that population of summary tables is even faster if the ROLLUP query executes in parallel.

  See Also: For information on parallel execution, see *Oracle8i Concepts.*

CUBE

Note that the subtotals created by ROLLUP are only a fraction of possible subtotal combinations. For instance, in the cross-tab shown in Table 20–1, the departmental totals across regions (279,000 and 319,000) would not be calculated by a ROLLUP(Time, Region, Department) clause. To generate those numbers would require a ROLLUP clause with the grouping columns specified in a different order: ROLLUP(Time, Department, Region). The easiest way to generate the full set of subtotals needed for cross-tabular reports such as those needed for Figure 20–1 is to use the CUBE extension.

CUBE enables a SELECT statement to calculate subtotals for all possible combinations of a group of dimensions. It also calculates a grand total. This is the set of information typically needed for all cross-tabular reports, so CUBE can calculate a cross-tabular report with a single SELECT statement. Like ROLLUP, CUBE is a simple extension to the GROUP BY clause, and its syntax is also easy to learn.

Syntax

CUBE appears in the GROUP BY clause in a SELECT statement. Its form is:

```
SELECT …  GROUP BY
  CUBE (grouping_column_reference_list)
```

Details

CUBE takes a specified set of grouping columns and creates subtotals for all possible combinations of them. In terms of multi-dimensional analysis, CUBE generates all the subtotals that could be calculated for a data cube with the specified dimensions. If you have specified CUBE(Time, Region, Department), the result set will include all the values that would be included in an equivalent ROLLUP statement plus additional combinations. For instance, in Table 20–1, the departmental totals across regions (279,000 and 319,000) would not be calculated by a ROLLUP(Time, Region, Department) clause, but they would be calculated by a CUBE(Time, Region, Department) clause. If there are n columns specified for a CUBE, there will be 2^n combinations of subtotals returned. Table 20–3 gives an example of a three-dimension CUBE.

Example

This example of CUBE uses the data in the video store database.

```
SELECT Time, Region, Department,
   sum(Profit) AS Profit FROM sales
   GROUP BY CUBE  (Time, Region, Dept)
```

Table 20–3 shows the results of this query.

Table 20–3 Cube Aggregation across Three Dimensions

Time	Region	Department	Profit
1996	Central	VideoRental	75,000
1996	Central	VideoSales	74,000
1996	Central	[NULL]	149,000
1996	East	VideoRental	89,000
1996	East	VideoSales	115,000
1996	East	[NULL]	204,000
1996	West	VideoRental	87,000

Table 20–3 Cube Aggregation across Three Dimensions

Time	Region	Department	Profit
1996	West	VideoSales	86,000
1996	West	[NULL]	173,000
1996	[NULL]	VideoRental	251,000
1996	[NULL]	VideoSales	275,000
1996	[NULL]	[NULL]	526,000
1997	Central	VideoRental	82,000
1997	Central	VideoSales	85,000
1997	Central	[NULL]	167,000
1997	East	VideoRental	101,000
1997	East	VideoSales	137,000
1997	East	[NULL]	238,000
1997	West	VideoRental	96,000
1997	West	VideoSales	97,000
1997	West	[NULL]	193,000
1997	[NULL]	VideoRental	279,000
1997	[NULL]	VideoSales	319,000
1997	[NULL]	[NULL]	598,000
[NULL]	Central	VideoRental	157,000
[NULL]	Central	VideoSales	159,000
[NULL]	Central	[NULL]	316,000
[NULL]	East	VideoRental	190,000
[NULL]	East	VideoSales	252,000
[NULL]	East	[NULL]	442,000
[NULL]	West	VideoRental	183,000
[NULL]	West	VideoSales	183,000
[NULL]	West	[NULL]	366,000
[NULL]	[NULL]	VideoRental	530,000

Table 20–3 Cube Aggregation across Three Dimensions

Time	Region	Department	Profit
[NULL]	[NULL]	VideoSales	594,000
[NULL]	[NULL]	[NULL]	1,124,000

Calculating subtotals without CUBE

Just as for ROLLUP, multiple SELECT statements combined with UNION statements could provide the same information gathered through CUBE. However, this may require many SELECT statements: for an n-dimensional cube, 2^n SELECT statements are needed. In our 3-dimension example, this would mean issuing 8 SELECTS linked with UNION ALL.

Consider the impact of adding just one more dimension when calculating all possible combinations: the number of SELECT statements would double to 16. The more columns used in a CUBE clause, the greater the savings versus the UNION approach. For instance, if a four-column CUBE replaces a UNION of 16 SELECT statements, the reduction in table access is fifteen-sixteenths or 93.75%.

When to Use CUBE

- Use CUBE in any situation requiring cross-tabular reports. The data needed for cross-tabular reports can be generated with a single SELECT using CUBE. Like ROLLUP, CUBE can be helpful in generating summary tables. Note that population of summary tables is even faster if the CUBE query executes in parallel.

  See Also: For information on parallel execution, see *Oracle8i Concepts.*

- CUBE is especially valuable in queries that use columns from multiple dimensions rather than columns representing different levels of a single dimension. For instance, a commonly requested cross-tabulation might need subtotals for all the combinations of month / state / product. These are three independent dimensions, and analysis of all possible subtotal combinations will be commonplace. In contrast, a cross-tabulation showing all possible combinations of year / month / day would have several values of limited interest, since there is a natural hierarchy in the time dimension. Subtotals such as profit by day of month summed across year would be unnecessary in most analyses.

Using Other Aggregate Functions with ROLLUP and CUBE

The examples in this chapter show ROLLUP and CUBE used with the SUM() operator. While this is the most common type of aggregation, the extensions can also be used with all the other functions available to Group by clauses, for example, COUNT, AVG, MIN, MAX, STDDEV, and VARIANCE. COUNT, which is often needed in cross-tabular analyses, is likely be the second most helpful function.

Note: The DISTINCT qualifier has ambiguous semantics when combined with ROLLUP and CUBE. To minimize confusion and opportunities for error, DISTINCT is not permitted together with the extensions.

GROUPING Function

Two challenges arise with the use of ROLLUP and CUBE. First, how can we programmatically determine which result set rows are subtotals, and how do we find the exact level of aggregation of a given subtotal? We will often need to use subtotals in calculations such as percent-of-totals, so we need an easy way to determine which rows are the subtotals we seek. Second, what happens if query results contain both stored NULL values and "NULL" values created by a ROLLUP or CUBE? How does an application or developer differentiate between the two?

To handle these issues, Oracle 8*i* introduces a new function called GROUPING. Using a single column as its argument, Grouping returns 1 when it encounters a NULL value created by a ROLLUP or CUBE operation. That is, if the NULL indicates the row is a subtotal, GROUPING returns a 1. Any other type of value, including a stored NULL, will return a 0.

Syntax

GROUPING appears in the selection list portion of a SELECT statement. Its form is:

```
SELECT …  [GROUPING(dimension_column)…]  …
  GROUP BY …    {CUBE | ROLLUP}
```

Examples

This example uses GROUPING to create a set of mask columns for the result set shown in Table 20–3. The mask columns are easy to analyze programmatically.

```
SELECT Time, Region, Department, SUM(Profit) AS Profit,
  GROUPING (Time) as T,
  GROUPING (Region) as R,
  GROUPING (Department) as D
  FROM Sales
GROUP BY ROLLUP (Time, Region, Department)
```

Table 20–4 shows the results of this query.

Table 20–4 Use of Grouping Function

Time	Region	Department	Profit	T	R	D
1996	Central	Video Rental	75,000	0	0	0
1996	Central	Video Sales	74,000	0	0	0
1996	Central	[NULL]	149,000	0	0	1
1996	East	Video Rental	89,000	0	0	0
1996	East	Video Sales	115,000	0	0	0
1996	East	[NULL]	204,000	0	0	1
1996	West	Video Rental	87,000	0	0	0
1996	West	Video Sales	86,000	0	0	0
1996	West	[NULL]	173,000	0	0	1
1996	[NULL]	[NULL]	526,000	0	1	1
1997	Central	Video Rental	82,000	0	0	0
1997	Central	Video Sales	85,000	0	0	0
1997	Central	[NULL]	167,000	0	0	1
1997	East	Video Rental	101,000	0	0	0
1997	East	Video Sales	137,000	0	0	0
1997	East	[NULL]	238,000	0	0	1
1997	West	VideoRental	96,000	0	0	0
1997	West	VideoSales	97,000	0	0	0
1997	West	[NULL]	193,000	0	0	1
1997	[NULL]	[NULL]	598,000	0	1	1
[NULL]	[NULL]	[NULL]	1,124,000	1	1	1

A program can easily identify the detail rows above by a mask of “0 0 0” on the T, R, and D columns. The first level subtotal rows have a mask of “0 0 1”, the second level subtotal rows have a mask of “0 1 1”, and the overall total row have a mask of “1 1 1”.

Table 20–5 shows an ambiguous result set created using the CUBE extension.

Table 20–5 Distinguishing Aggregate NULL from Stored NULL Value

Time	Region	Profit
1996	East	200,000
1996	[NULL]	200,000
[NULL]	East	200,000
[NULL]	[NULL]	190,000
[NULL]	[NULL]	190,000
[NULL]	[NULL]	190,000
[NULL]	[NULL]	390,000

In this case, four different rows show NULL for both Time and Region. Some of those NULLS must represent aggregates due to the CUBE extension, and others must be NULLS stored in the database. How can we tell which is which? GROUPING functions, combined with the NVL and DECODE functions, resolve the ambiguity so that human readers can easily interpret the values.

> **Note:** The numbers in this example differ from the set used in the other figures.

We can resolve the ambiguity by using the GROUPING and other functions in the code below.

```
SELECT
  DECODE(GROUPING(Time), 1, 'All Times', Time) as Time,
  DECODE(GROUPING(region), 1, 'All Regions', 0, null)) as
  Region, SUM(Profit) AS Profit from Sales
  GROUP BY CUBE(Time, Region)
```

This code generates the result set in Table 20–6. These results include text values clarifying which rows have aggregations.

Table 20–6 Grouping Function used to Differentiate Aggregate-based "NULL" from Stored Null Values

Time	Region	Profit
1996	East	200,000
1996	All Regions	200,000
All Times	East	200,000
[NULL]	[NULL]	190,000
[NULL]	All Regions	190,000
All Times	[NULL]	190,000
All Times	All Regions	390,000

To explain the SQL statement above, we will examine its first column specification, which handles the Time column. Look at the first line of the in the SQL code above, namely,

```
DECODE(GROUPING(Time), 1, 'All Times', Time) as Time,
```

The Time value is determined with a `DECODE` function that contains a `GROUPING` function. The `GROUPING` function returns a 1 if a row value is an aggregate created by `ROLLUP` or `CUBE`, otherwise it returns a 0. The `DECODE` function then operates on the `GROUPING` function's results. It returns the text "All Times" if it receives a 1 and the time value from the database if it receives a 0. Values from the database will be either a real value such as 1996 or a stored `NULL`. The second column specification, displaying Region, works the same way.

When to Use GROUPING

The `GROUPING` function is not only useful for identifying `NULLS`, it also enables sorting subtotal rows and filtering results. In the example below (Table 20–7), we retrieve a subset of the subtotals created by a `CUBE` and none of the base-level aggregations. The `HAVING` clause constrains columns which use `GROUPING` functions.

```
SELECT Time, Region, Department, SUM(Profit) AS Profit,
  GROUPING (Time) AS T,
  GROUPING (Region) AS R,
  GROUPING (Department) AS D
  FROM Sales
  GROUP BY CUBE (Time, Region, Department)
  HAVING (D=1 AND R=1 AND T=1)
  OR (R=1 AND D=1)
  OR (T=1 AND D=1)
```

Table 20–7 shows the results of this query.

Table 20–7 Example of GROUPING Function Used to Filter Results to Subtotals and Grand Total

Time	Region	Department	Profit
1996	[NULL]	[NULL]	526,000
1997	[NULL]	[NULL]	598,000
[NULL]	Central	[NULL]	316,000
[NULL]	East	[NULL]	442,000
[NULL]	West	[NULL]	366,000
[NULL]	[NULL]	[NULL]	1,124,000

Compare the result set of Table 20–7 with that in Table 20–3 to see how Table 20–7 is a precisely specified group: it contains only the yearly totals, regional totals aggregated over time and department, and the grand total.

Other Considerations when Using ROLLUP and CUBE

This section discusses the following topics.

- Hierarchy Handling in ROLLUP and CUBE
- Column Capacity in ROLLUP and CUBE
- HAVING Clause Used with ROLLUP and CUBE

Hierarchy Handling in ROLLUP and CUBE

The ROLLUP and CUBE extensions work independently of any hierarchy metadata in your system. Their calculations are based entirely on the columns specified in the

SELECT statement in which they appear. This approach enables CUBE and ROLLUP to be used whether or not hierarchy metadata is available. The simplest way to handle levels in hierarchical dimensions is by using the ROLLUP extension and indicating levels explicitly through separate columns. The code below shows a simple example of this with months rolled up to quarters and quarters rolled up to years.

```
SELECT Year, Quarter, Month,
    SUM(Profit) AS Profit FROM sales
    GROUP BY ROLLUP(Year, Quarter, Month)
```

This query returns the rows in Table 20–8.

Table 20–8 Example of ROLLUP across Time Levels

Year	Quarter	Month	Profit
1997	Winter	Jan	55,000
1997	Winter	Feb	64,000
1997	Winter	March	71,000
1997	Winter	[NULL]	190,000
1997	Spring	April	75,000
1997	Spring	May	86,000
1997	Spring	June	88,000
1997	Spring	[NULL]	249,000
1997	Summer	July	91,000
1997	Summer	August	87,000
1997	Summer	September	101,000
1997	Summer	[NULL]	279,000
1997	Fall	October	109,000
1997	Fall	November	114,000
1997	Fall	December	133,000
1997	Fall	[NULL]	356,000
1997	[NULL]	[NULL]	1,074,000

Note: The numbers in this example differ from the set used in the other figures.

Column Capacity in ROLLUP and CUBE

CUBE and ROLLUP do not restrict the GROUP BY clause column capacity. The GROUP BY clause, with or without the extensions, can work with up to 255 columns. However, the combinatorial explosion of CUBE makes it unwise to specify a large number of columns with the CUBE extension. Consider that a 20-column list for CUBE would create 2^{20} combinations in the result set. A very large CUBE list could strain system resources, so any such query needs to be tested carefully for performance and the load it places on the system.

HAVING Clause Used with ROLLUP and CUBE

The HAVING clause of SELECT statements is unaffected by the use of ROLLUP and CUBE. Note that the conditions specified in the HAVING clause apply to both the subtotal and non-subtotal rows of the result set. In some cases a query may need to exclude the subtotal rows or the non-subtotal rows from the HAVING clause. This can be achieved by using the GROUPING function together with the HAVING clause. See Table 20–7 and its associated SQL for an example.

Optimized "Top-N" Analysis

Top-N queries ask for the n largest or smallest values of a column. An example is "What are the top ten best selling products in the U.S.?" Of course, we may also want to ask "What are the 10 worst selling products?" Both largest-values and smallest-values sets are considered Top-N queries.

Details

Top-N queries use a consistent nested query structure with the elements described below.

- Subquery to generate the sorted list of data. The subquery includes the ORDER BY clause to ensure that the ranking is in the desired order. For results retrieving the largest values, a DESC parameter is needed.
- Outer Query to limit the number of rows in the final result set. The outer query includes:

- ROWNUM pseudo-column which assigns a sequential value starting with 1 to each of the rows returned from the subquery.
- WHERE clause used to specify the n returned rows. The outer WHERE clause must use a "<" or "<=" operator.

The high-level structure of these queries is:

```
SELECT column_list ROWNUM  FROM
  (SELECT column_list FROM table
   ORDER BY Top-N_column)
WHERE  ROWNUM <=  N
```

Examples

To illustrate the concepts here, we extend the scenario used in our earlier examples. We will now access the name of the sales representative associated with each sale, stored in the "name" column. and the sales commission earned on every sale. The SQL below returns the top 10 sales representatives ordered by dollar sales, with sample data shown in Table 20–9:

```
SELECT ROWNUM AS Rank, Name, Region, Sales FROM
  (SELECT Name, Region,  sum(Sales) AS Sales
      FROM Sales GROUP BY Name, Region
      ORDER BY sum(Sales) DESC)
WHERE ROWNUM <= 10
```

Table 20–9 Example of Top-10 Query

Rank	Name	Region	Sales
1	Jim Smith	West	2,321,000
2	Jane Riley	South	2,002,000
3	Paul Hernandez	South	1,951,000
4	Tammy Dewerr	East	1,874,000
5	Lisa Ishiru	*Central*	1,508,000
6	Phil Fabrese	East	1,467,000
7	Mary Adams	West	1,309,000
8	Linda Garton	South	1,211,000
9	Tom Cook	North	1,189,000
10	David Wu	West	1,043,000

This example can be augmented to show the sales representatives' ranks both for sales and commissions in a single query. We now extend our query to include the sales commission earned on every sale, stored in the "commission" column. The extra information requires another layer of nested subquery. Although interpreting several layers of queries can be challenging, the SQL below has been formatted to clarify the meaning.

Below is the SQL needed for our scenario, with the sample results shown in Table 20–10. To understand the query, please step through the code following the number sequence shown at the left edge:

```
4)  SELECT ROWNUM as SalesRank, Name, Region, SalesDollars,
      CommRank from
2)      (SELECT Name, Region, SalesDollars,
          ROWNUM AS CommRank from
1)        ( SELECT Name, Region, sum(Sales) AS SalesDollars,
            sum(commission)
            FROM Sales GROUP BY Name, Region
            ORDER BY sum(Commission) DESC )
3)        ORDER BY Sales DESC )
5)  WHERE ROWNUM <=10
```

Table 20–10 Example of Top-N query with Ranks on Two Columns

SalesRank	Name	Region	SalesDollars	CommRank
1	Jim Smith	West	2,321,000	1
2	Jane Riley	South	2,002,000	3
3	Paul Hernandez	South	1,951,000	2
4	Tammy Dewer	East	1,874,000	5
5	Lisa Ishiru	*Central*	1,508,000	4
6	Phil Fabrese	East	1,467,000	8
7	Mary Adams	West	1,309,000	6
8	Linda Garton	South	1,211,000	7
9	Tom Cook	North	1,189,000	12
10	David Wu	West	1,043,000	11

Note that the results in Table 20–10 show how commission ranks are not identical to sales ranks in this data set: some representatives had higher or lower commission rates tied to specific sales.

Reference

Joint Technical Committee ISO/IEC JTC 1, Information Technology. ISO Working Draft Database Language SQL —Part 2: Foundation (SQL/Foundation), *Document ID: ISO/IEC FCD 9075-2:199x, September 1997.*

A

Oracle XA

This chapter describes how to use the Oracle XA library. The chapter includes the following topics:

XA Library-Related Information

General Information about the Oracle XA

For preliminary reading and additional reference information regarding the Oracle XA library, see the following documents:

- *Oracle Call Interface Programmer's Guide*

  See Also: For information on library linking filenames, see the Oracle operating system-specific documentation.

README.doc

A `README.doc` file is located in a directory specified in the Oracle operating system-specific documentation and describes changes, bugs, or restrictions in the Oracle XA library for your platform since the last version.

Changes from Release 8.0 to Release 8.1

There are no changes for Release 8.1.

Changes from Release 7.3 to Release 8.0

The following changes have been made:

Session Caching Is No Longer Needed

Session caching is unnecessary with the new OCI. Therefore, the old `xa_open` string parameter, `SesCacheSz`, has been eliminated. Consequently, you can also reduce the *sessions* `init.ora` parameter. Instead, set the *transactions* `init.ora` parameter to the expected number of concurrent global transactions. Because sessions are not migrated when global transactions are resumed, applications must not refer to any session state beyond the scope of a service.

For information on how to organize your application into services, refer to the documentation provided with the transaction processing monitor. In particular, savepoints and cursor fetch state are cancelled when a transaction is suspended. This means that a savepoint taken by the application in a service is invalid in another service, even though the two services may belong to the same global transaction.

Dynamic Registration Is Supported

Dynamic registration can be used if both the XA application and the Oracle Server are Version 8.

See Also: "Extensions to the XA Interface" on page A-14

Loosely Coupled Transaction Branches Are Supported

The Oracle8 Server supports both loosely and tightly coupled transaction branches in a single Oracle instance. The Oracle7 Server supported only tightly coupled transaction branches in a single instance, and loosely coupled transaction branches in different instances.

SQLLIB Is Not Needed for OCI Applications

OCI applications used to require the use of `SQLLIB`. This means that OCI programmers had to buy `SQLLIB`, even if they had no desire to develop Pro* applications. This is no longer the case.

No Installation Script Is Needed to Run XA

The SQL script `XAVIEW.SQL` is not needed to run XA applications in Oracle Version 8. It is, however, still necessary for Version 7.3 applications.

See Also: "Responsibilities of the DBA or System Administrator" on page A-17

The XA Library Can Be Used with the Oracle Parallel Server Option on All Platforms

It was not possible with Version 7 to use the Oracle XA library together with the Oracle Parallel Server option on certain platforms. (Only if the platform's implementation of the distributed lock manager supported transaction-based rather than process-based locking would the two work together.) This limitation is no longer the case; if you can run the Oracle Parallel Server option, then you can run the Oracle XA library.

Transaction Recovery for Oracle Parallel Server Has Been Improved

All transactions can be recovered from any instance of Oracle Parallel Server. Use the `xa_recover` call to provide a snapshot of the pending transactions.

Both Global and Local Transactions Are Possible

It is now possible to have both global and local transactions within the same XA connection. Local transactions are transactions that are completely coordinated by the Oracle Server. For example, the update below belongs to a local transaction.

```
CONNECT scott/tiger;
UPDATE Emp_tab SET Sal = Sal + 1; /* begin local transaction*/
COMMIT;                           /* commit local transaction*/
```

Global transactions, on the other hand, are coordinated by an external transaction manager such as a transaction processing monitor. In these transactions, the Oracle Server acts as a subordinate and processes the XA commands issued by the transaction manager. The update shown below belongs to a global transaction.

```
xa_open(oracle_xa+acc=p/SCOTT/TIGER+sestm=10", 1, TMNOFLAGS);
                              /* Transaction manager opens */
                              /* connection to the Oracle server*/
tpbegin();                    /* begin global transaction, the transaction*/
                              /* manager issues XA commands to the oracle*/
                              /* server to start a global transaction */
UPDATE Emp_tab SET Sal = Sal + 1;
                              /* Update is performed in the */
                              /* global transaction*/
tpcommit();                   /* commit global transaction, */
                              /* the transaction manager issues XA commands*/
                              /* to the Oracle server to commit */
                              /* the global transaction */
```

The Oracle7 Server forbids a local transaction from being started in an XA connection. The update shown below would return an ORA-2041 error code.

```
xa_open("oracle_xa+acc=p/SCOTT/TIGER+sestm=10" , 1, TMNOFLAGS);
                              /* Transaction manager opens */
                              /*connection to the Oracle server */
UPDATE Emp_tab SET Sal = Sal + 1; /* Oracle 7 returns an error */
```

The Oracle8 Server, on the other hand, allows local transactions to be started in an XA connection. The only restriction is that the local transaction must be ended (committed or rolled back) before starting a global transaction in the connection.

The xa_open String Has Been Modified

Two new parameters have been added. They are:

- `Loose_Coupling`

  This parameter has a Boolean value and should not be set to true when connected to an Oracle7 Server. If set to true, then global transaction branches are loosely coupled; in other words, locks are not shared between branches.

- `SesWt`

  This parameter's value indicates the time-out limit when waiting for a transaction branch that is being used by another session. If Oracle cannot switch to the transaction branch within `SesWt` seconds, then `XA_RETRY` is returned.

Two parameters have been made obsolete and should only be used when connected to an Oracle Server Release 7.3.

- `GPWD`

  The group password is not used by Oracle8. A session that is logged in with the same user name as the session that created a transaction branch is allowed to switch to the transaction branch.

- `SesCacheSz`

  This parameter is not used by Oracle8 because session caching has been eliminated.

General Issues and Restrictions

Database Links

Oracle XA applications can access other Oracle Server databases through database links, with the following restrictions:

- Use the Multi-Threaded Server configuration.

  This means that the transaction processing monitors (TPMs) use shared servers to open the connection to Oracle. The O/S network connection required for the database link is opened by the dispatcher, instead of the Oracle server process. Thus, when a particular service or RPC completes, the transaction can be detached from the server so that it can be used by other services or RPCs.

- Access to the other database must use SQL*Net Version 2 or Net8.
- The other database being accessed should be another Oracle Server database.

Assuming that these restrictions are satisfied, Oracle Server allows such links and propagates the transaction protocol (prepare, rollback, and commit) to the other Oracle Server databases.

> **Caution: If these restrictions are not satisfied, then when you use database links within an XA transaction, it creates an O/S network connection in the Oracle Server that is connected to the TPM server process. Because this O/S network connection cannot be moved from one process to another, you cannot detach from this server. When you access a database through a database link, you receive an ORA#24777 error.**

If using the Multi-Threaded Server configuration is not possible, then access the remote database through the Pro*C/C++ application using EXEC SQL AT syntax.

The parameter `open_links_per_instance` specifies the number of migratable open database link connections. These `dblink` connections are used by XA transactions so that the connections are cached after a transaction is committed. Another transaction is free to use the dblink connection provided the user that created the connection is the same as the user who created the transaction. This parameter is different from the `open_links` parameter, which is the number of dblink connections from a session. The `open_links` parameter is not applicable to XA applications.

Oracle Parallel Server Option

You can recover failed transactions from any instance of Oracle Parallel Server. You can also heuristically commit in-doubt transactions from any instance. An XA recover call gives a list of all prepared transactions for all instances.

SQL-based Restrictions

Rollbacks and Commits

Because the transaction manager is responsible for coordinating and monitoring the progress of the global transaction, the application should not contain any Oracle Server-specific statement that independently rolls back or commits a global transaction. However, you can use rollbacks and commits in a local transaction.

Do not use `EXEC SQL ROLLBACK WORK` for precompiler applications when you are in the middle of a global transaction. Similarly, an OCI application should not execute `OCITransRollback`(), or the Version 7 equivalent `orol`(). You can roll back a global transaction by calling `tx_rollback`().

Similarly, a precompiler application should not have the `EXEC SQL COMMIT WORK` statement in the middle of a global transaction. An OCI application should not execute `OCITransCommit`() or the Version 7 equivalent `ocom`(). Instead, use `tx_commit`() or `tx_rollback`() to end a global transaction.

DDL Statements

Because a DDL SQL statement, such as `CREATE TABLE`, implies an implicit commit, the Oracle XA application cannot execute any DDL SQL statements.

Session State

Oracle does not guarantee that session state will be valid between services. For example, if a service updates a session variable (such as a global package variable), then another service that executes as part of the same global transaction may not see the change. Use savepoints only within a service. The application must not refer to a savepoint that was created in another service. Similarly, an application must not attempt to fetch from a cursor that was executed in another service.

SET TRANSACTION

Do not use the `SET TRANSACTION READ ONLY | READ WRITE | USE ROLLBACK SEGMENT SQL` statement.

Connecting or Disconnecting with EXEC SQL

Do not use the EXEC SQL command to connect or disconnect. That is, do not use EXEC SQL COMMIT WORK RELEASE or EXEC SQL ROLLBACK WORK RELEASE.

Miscellaneous XA Issues

Note the following additional information about Oracle XA:

Transaction Branches

Oracle Server transaction branches within the same global transaction can share locks in either a tightly or loosely coupled manner. However, if the branches are on different instances when running Oracle Parallel Server, then they will be loosely coupled.

In tightly coupled transaction branches, the locks are shared between the transaction branches. This means that updates performed in one transaction branch can be seen in other branches that belong to the same global transaction before the update is committed. The Oracle Server obtains the DX lock before executing any statement in a tightly coupled branch. Hence, the advantage of using loosely coupled transaction branches is that there is more concurrency (because a lock is not obtained before the statement is executed). The disadvantage is that all the transaction branches must go through the two phases of commit, that is, XA one phase optimization cannot be used. These trade-offs between tightly coupled branches and loosely coupled branches are illustrated in Table A–1.

Table A–1 Tightly and Loosely Coupled Transaction Branches

Attribute	Tightly Coupled Branches	Loosely Coupled Branches
Two Phase Commit	Read-only Optimization [prepare for all branches, commit for last branch]	Two phases [prepare and commit for all branches]
Serialization	Database Call	None

Association Migration

The Oracle Server does not support association migration (a means whereby a transaction manager may resume a suspended branch association in another branch).

Asynchronous Calls

The optional XA feature asynchronous XA calls is not supported.

Initialization Parameters

Set the `transactions` `init.ora` parameter to the expected number of concurrent global transactions.

The parameter `open_links_per_instance` specifies the number of migratable open database link connections. These dblink connections are used by XA transactions so that the connections are cached after a transaction is committed.

See Also: "Database Links" on page A-7

Maximum Connections per Thread

The maximum number of `xa_opens` per thread is now 32. Previously, it was 8.

Installation

No scripts need be executed to use XA. It is necessary, however, to run the xaview.sql script to run Release 7.3 applications with the Oracle8 Server. Grant the `SELECT` privilege on `SYS.DBA_PENDING_TRANSACTIONS` to all users that connect to Oracle through the XA interface.

Compatibility

The XA library supplied with Release 7.3 can be used with a Release 8.0 Oracle Server. You must use the Release 7.2 XA library with a Release 7.2 Oracle Server. You can use the 8.0 library with a Release 7.3 Oracle Server. There is only one case of backward compatibility: an XA application that uses Release 8.0 OCI works with a Release 7.3 Oracle Server, but only if you use `sqlld2` and obtain an `lda_def` before executing SQL statements. Client applications must remember to convert the Version 7 LDA to a service handle using `OCILdaToSvcCtx`() after completing the OCI calls.

Basic Architecture

The Oracle XA library is an external interface that allows global transactions to be coordinated by a transaction manager other than the Oracle8 Server. This allows inclusion of non-Oracle8 Server entities called resource managers (RM) in distributed transactions.

The Oracle XA library conforms to the X/Open Distributed Transaction Processing (DTP) software architecture's XA interface specification.

> **See Also:** For a general overview of XA, including basic architecture, see *X/Open CAE Specification - Distributed Transaction Processing: The XA Specification*. You can obtain a copy of this document by requesting X/Open Document No. XO/CAE/91/300 or ISBN 1 872630 24 3 from:
>
> - X/Open Company, Ltd., 1010 El Camino Real, Suite 380, Menlo Park, CA 94025, U.S.A.

X/Open Distributed Transaction Processing (DTP)

The X/Open DTP architecture defines a standard architecture or interface that allows multiple application programs to share resources, provided by multiple, and possibly different, resource managers. It coordinates the work between application programs and resource managers into global transactions.

Figure A–1 illustrates a possible X/Open DTP model.

A resource manager (RM) controls a shared, recoverable resource that can be returned to a consistent state after a failure. For example, Oracle8 Server is an RM and uses its redo log and undo segments to return to a consistent state after a failure. An RM provides access to shared resources such as a database, file systems, printer servers, and so forth.

A transaction manager (TM) provides an application program interface (API) for specifying the boundaries of the transaction and manages the commit and recovery procedures.

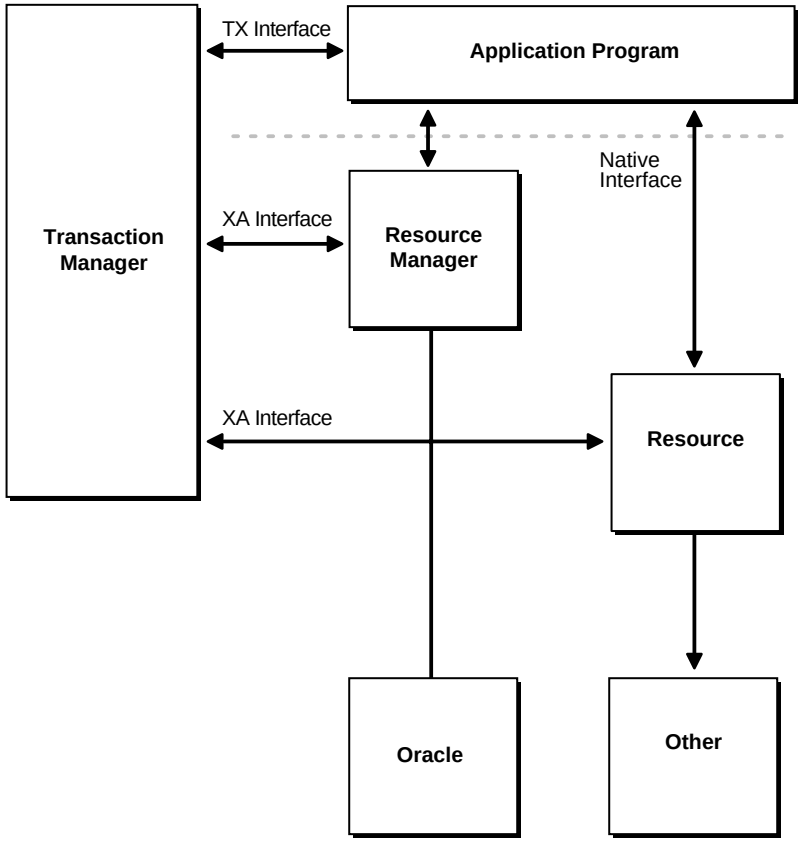
Normally, Oracle8 Server acts as its own TM and manages its own commit and recovery. However, using a standards-based TM allows Oracle8 Server to cooperate with other heterogeneous RMs in a single transaction.

A TM is usually a component provided by a transaction processing monitor (TPM) vendor. The TM assigns identifiers to transactions, and monitors and coordinates their progress. It uses Oracle XA library subroutines to tell Oracle8 Server how to process the transaction, based on its knowledge of all RMs in the transaction. You can find a list of the XA subroutines and their descriptions later in this section.

An application program (AP) defines transaction boundaries and specifies actions that constitute a transaction. For example, an AP can be a precompiler or OCI program. The AP operates on the RM's resource through the RM's native interface, for example SQL. However, it starts and completes all transaction operations via the

transaction manager through an interface called TX. The AP itself does not directly use the XA interface

Figure A–1 One Possible DTP Model



Note: The naming conventions for the TX interface and associated subroutines are vendor-specific, and may differ from those used here. For example, you may find that the `tx_open` call is referred to as `tp_open` on your system. To check terminology, see the documentation supplied with the transaction processing monitor.

Transaction Recovery Management

The Oracle XA library interface follows the two-phase commit protocol, consisting of a prepare phase and a commit phase, to commit transactions.

In phase one, the prepare phase, the TM asks each RM to guarantee the ability to commit any part of the transaction. If this is possible, then the RM records its prepared state and replies affirmatively to the TM. If it is not possible, then the RM may roll back any work, reply negatively to the TM, and forget any knowledge about the transaction. The protocol allows the application, or any RM, to roll back the transaction unilaterally until the prepare phase is complete.

In phase two, the commit phase, the TM records the commit decision. Then the TM issues a commit or rollback to all RMs which are participating in the transaction.

Note: TM can issue a commit for an RM only if all RMs have replied affirmatively to phase one.

Oracle XA Library Interface Subroutines

The Oracle XA library subroutines allow a TM to instruct an Oracle8 Server what to do about transactions. Generally, the TM must "open" the resource (using `xa_open`). Typically, this results from the AP's call to `tx_open`**.** Some TMs may call `xa_open` implicitly, when the application begins. Similarly, there is a close (using `xa_close`) that occurs when the application is finished with the resource. This may be when the AP calls `tx_close` or when the application terminates.

There are several other tasks the TM instructs the RMs to do. These include among others:

- Starting a new transaction and associating it with an ID
- Rolling back a transaction
- Preparing and committing a transaction

XA Library Subroutines

The following XA Library subroutines are available:

`xa_open`	Connects to the resource manager.
`xa_close`	Disconnects from the resource manager.
`xa_start`	Starts a new transaction and associate it with the given transaction ID (XID), or associates the process with an existing transaction.
`xa_end`	Disassociates the process from the given XID.
`xa_rollback`	Rolls back the transaction associated with the given XID.
`xa_prepare`	Prepares the transaction associated with the given XID. This is the first phase of the two-phase commit protocol.
`xa_commit`	Commits the transaction associated with the given XID. This is the second phase of the two-phase commit protocol.
`xa_recover`	Retrieves a list of prepared, heuristically committed or heuristically rolled back transaction.
`xa_forget`	Forgets the heuristic transaction associated with the given XID.

In general, the AP does not need to worry about these subroutines except to understand the role played by the `xa_open` string.

Extensions to the XA Interface

Two functions have been added to the XA interface, one for returning the OCI service handle associated with an XA connection, and one for returning an XA error code.

1. `OCISvcCtx *xaoSvcCtx(text *dbname)`:

   This function returns the OCI service handle for a given XA connection. The dbname parameter must be the same as the dbname parameter passed in the `xa_open` string. OCI applications can use this routing instead of the `sqlld2` calls to obtain the connection handle. Hence, OCI applications need not link with the SQLLIB library. The service handle can be converted to the Version 7 OCI logon data area (LDA) using `OCISvcCtxToLda`() [Version 8 OCI]. Client applications must remember to convert the Version 7 LDA to a service handle using `OCILdaToSvcCtx`() after completing the OCI calls.

2. `OCIEnv *xaoEnv(text *dbname)`:

   This function returns the OCI environment handle for a given XA connection. The dbname parameter must be the same as the dbname parameter passed in the `xa_open` string.

3. `int xaosterr(OCISvcCtx *SvcCtx, sb4 error)`:

   This function, only applicable to dynamic registration, converts an Oracle error code to an XA error code. The first parameter is the service handle used to execute the work in the database. The second parameter is the error code that was returned from Oracle. Use this function to determine if the error returned from an OCI command was caused because the `xa_start` failed. The function returns `XA_OK` if the error was not generated by the XA module and a valid XA error if the error was generated by the XA module.

Transaction Processing Monitors (TPMs)

A transaction processing monitor (TPM) coordinates the flow of transaction requests between the client processes that issue requests and the back-end servers that process them. Basically, it coordinates transactions that require the services of several different types of back-end processes, such as application servers and resource managers that are distributed over a network.

The TPM synchronizes any commits and rollbacks required to complete a distributed transaction. The transaction manager (TM) portion of the TPM is responsible for controlling when distributed commits and rollbacks take place. Thus, if a distributed application program is written to take advantage of a TPM, then the TM portion of the TPM is responsible for controlling the two-phase commit protocol. The RMs enable the TMs to do this.

Because the TM controls distributed commits or rollbacks, it must communicate directly with Oracle (or any other resource manager) through the Oracle XA library interface.

Required Public Information

As a resource manager, Oracle is required to publish the following information.

`xa_switch_t` structures	The Oracle Server `xa_switch_t` structure name for static registration is `xaosw`. The Oracle Server `xa_switch_t` structure name for dynamic registration is `xaoswd`. These structures contain entry points and other information for the resource manager.
`xa_switch_t` resource mgr	The Oracle Server resource manager name within the `xa_switch_t` structure is `Oracle_XA`.
`close string`	The close string used by `xa_close` () is ignored and is allowed to be null.
open string	The format of the open string used by `xa_open` () is described in detail in "Developing and Installing Applications That Use the XA Libraries" on page A-17.
libraries	Libraries needed to link applications using Oracle XA have operating system-specific names. It is similar to linking an ordinary precompiler or OCI program except you may have to link any TPM-specific libraries. If you are not using `sqllib`, then be sure to link with `$ORACLE_HOME/lib/xaonsl.o`.
requirements	A purchased and installed distributed database option.

Registration

Dynamic and static registration are supported by the Oracle8 Server. The basic possibilities are shown in Table A–2.

Table A–2 XA Registration

Client	Server	XA Registration
8.0 XA application	8.0	Dynamic
8.0 XA application	7.3	Static
7.3 XA application	8.0	Static

Developing and Installing Applications That Use the XA Libraries

This section discusses developing and installing Oracle8 Server applications. It describes the responsibilities of both the DBA, or system administrator, and the application developer. It also defines how to construct the open string.

Responsibilities of the DBA or System Administrator

The responsibilities of the DBA or system administrator are

1. Define the open string with the application developer's help.

   This is described in "Defining the xa_open String" on page A-19.

2. Make sure the DBA_PENDING_TRANSACTIONS view exists on the database.

   For Oracle Server Release 7.3:

   Make sure V$XATRANS$ exists.

   This view should have been created during the XA library installation. You can manually create the view, if needed, by running the SQL script XAVIEW.SQL. This SQL script should be executed as the Oracle user SYS. Grant the SELECT privilege to the V$XATRANS$ view for all Oracle Server accounts which will be used by Oracle XA library applications.

   See Also: Your Oracle operating system-specific documentation contains the location of the XAVIEW.SQL script.

   For Oracle Server Release 8.0:

   Grant the select privilege to the DBA_PENDING_TRANSACTIONS view for all Oracle Server *user*(s) specified in the xa_open string.

3. Install the resource manager, using the open string information, into the TPM configuration, following the TPM vendor instructions.

   The DBA or system administrator should be aware that a TPM system starts the process that connects to an Oracle8 Server. See your TPM documentation to determine what environment exists for the process and what user ID it will have.

   Be sure that correct values are set for ORACLE_HOME and ORACLE_SID.

> **See Also:** "Defining the xa_open String" on page A-19 has information on how to specify a *sid* or a trace directory that is different from the defaults.

Also be sure to grant the user the `SELECT` privilege on `DBA_PENDING_TRANSACTIONS`.

4. Start up the relevant databases to bring Oracle XA applications on-line.

   This should be done before starting any TPM servers.

Responsibilities of the Application Developer

The application developer's responsibilities are

1. Define the open string with the DBA or system administrator's help.

   Defining the open string is described later in this section.

2. Develop the applications.

   Observe special restrictions on transaction-oriented SQL statements for precompilers.

   > **See Also:** "Interfacing to Precompilers and OCIs" on page A-25

3. Link the application according to TPM vendor instructions.

Defining the xa_open String

The open string is used by the transaction monitor to open the database. The maximum number of characters in an open string is 256.

This section covers:

Syntax of the xa_open String

`Oracle_XA{+`*`required_fields...`*`} [+`*`optional_fields...`*`]`
where *required_fields* are:

`Acc=P//`

Or

`Acc=P/`*user/password*

`SesTm=`*session_time_limit*

and where *optional_fields* are:

`DB=`*db_name*

`LogDir=`*log_dir*

`MaxCur=`*maximum_#_of_open_cursors*

`SqlNet=`*connect_string*

`Loose_Coupling=`*true/false*

`SesWt=`*session_wait_limit*

`Threads=`*true/false*

Note:

- You can enter the required fields and optional fields *in any order* when constructing the open string.
- All field names are case insensitive. Their values may or may not be case-sensitive depending on the platform.
- There is no way to use the "+" character as part of the actual information string.

Required Fields

Required fields for the open string are described in this section.

`Acc=P//`

or

Acc=P/*user/password*

`Acc`	Specifies user access information
`P`	Indicates that explicit user and password information is provided.
`P//`	Indicates that no explicit user or password information is provided, and that the operating system authentication form will be used. For more information see *Oracle8i Administrator's Guide.*
user	A valid Oracle Server account.
password	The corresponding current password.

For example, `Acc=P/scott/tiger` indicates that user and password information is provided. In this case, the user is `scott` and the password is `tiger`.

As previously mentioned, make sure that `scott` has the `SELECT` privilege on the `DBA_PENDING_TRANSACTIONS` table.

`Acc=P//` indicates that no user or password information is provided, thus defaulting to operating system authentication.

`SesTm=`*session_time_limit*

`SesTm`	Specifies the maximum length of time a transaction can be inactive before it is automatically aborted by the system.
session_time_limit	This value should be the maximum time allowed in a transaction between one service and the next, or a service and the commit or rollback of the transaction. For example, if the TPM uses remote procedure calls between the client and the servers, then `SesTM` applies to the time between the completion of one RPC and the initiation of the next RPC, or the `tx_commit`, or the `tx_rollback`. The unit for this time limit is in seconds. The value of 0 indicates no limit, but entering a value of 0 is strongly discouraged. For example, `SesTM=15` indicates that the session idle time limit is 15 seconds.

Optional Fields

Optional fields are described below.

`DB=`*db_name*

`DB`	Specifies the database name.

db_name — Indicates the name used by Oracle precompilers to identify the database.

Application programs that use only the default database for the Oracle precompiler (that is, they do not use the AT clause in their SQL statements) should omit the `DB=`*db_name* clause in the open string.

Applications that use explicitly named databases should indicate that database name in their `DB=`*db_name* field.

Version 7 OCI programs need to call the `sqlld2()` function to obtain the correct `lda_def`, which is the equivalent of a service context. Version 8 OCI programs need to call the `xaoSvcCtx` function to get the `OCISvcCtx` service context.

The *db_name* is not the *sid* and is not used to locate the database to be opened. Rather, it correlates the database opened by this open string with the name used in the application program to execute SQL statements. The *sid* is set from either the environment variable `ORACLE_SID` of the TPM application server or the *sid* given in the Net8 (formerly, SQL*Net) clause in the open string. The Net8 clause is described later in this section.

Some TPM vendors provide a way to name a group of servers that use the same open string. The DBA may find it convenient to choose the same name both for that purpose and for *db_name*.

For example, `DB=payroll` indicates that the database name is "payroll", and that the application server program will use that name in AT clauses.

`LogDir=`*log_dir*

LogDir — Specifies the directory on a local machine where the Oracle XA library error and tracing information may be logged.

log_dir — Indicates the pathname of the directory where the tracing information should be stored. The default is `$ORACLE_HOME/rdbms/log` if `ORACLE_HOME` is set; otherwise, it is the current directory.

For example, `LogDir=/xa_trace` indicates that the error and tracing information is located under the `/xa_trace` directory.

Note: Ensure that the directory you specify for logging exists and the application server can write to it.

`MaxCur=`*maximum_#_of_open_cursors*

MaxCur	Specifies the number of cursors to be allocated when the database is opened. It serves the same purpose as the precompiler option `maxopencursors`.
*maximum_#_of_*	Indicates the number of open cursors to be cached.
open_cursors	

For example, `MaxCur=5` indicates that the precompiler should try to keep five open cursors cached.

Note: This parameter overrides the precompiler option `maxopencursors` that you might have specified in your source code or at compile time.

See Also: *Pro*C/C++ Precompiler Programmer's Guide*

SqlNet=*db_link*

SqlNet	Specifies the Net8 (formerly, SQL*Net) database link.
db_link	Indicates the string to use to log on to the system. The syntax for this string is the same as that used to set the `TWO-TASK` environment variable.

For example, `SqlNet=hqfin@NEWDB` indicates the database with *sid*=`NEWDB` accessed at host `hqfin` by TCP/IP.

The `SqlNet` parameter can be used to specify the `ORACLE_SID` in cases where you cannot control the server environment variable. It must also be used when the server needs to access more than one Oracle Server database. To use the Net8 string without actually accessing a remote database, use the Pipe driver.

For example:

```
SqlNet=localsid1
```

Where:

`localsid1`	An alias defined in the Net8 `tnsnames.ora` file.

Make sure that all databases to be accessed with a Net8 database link have an entry in `/etc/oratab`.

`Loose_Coupling`=*true/false*

`SesWt`=*session_wait_limit*

`SesWt`	Specifies the time-out limit when waiting for a transaction branch that is being used by another session. The default value is 60 seconds.
session_wait_limit	The number of seconds Oracle waits before XA_RETRY is returned.

`Threads`=*true/false*

Threads	Specifies whether the application is multi-threaded. The default value is False.
true/false	If the application is multi-threaded, then the setting is *true*.

Interfacing to Precompilers and OCIs

This section describes how to use the Oracle XA library with precompilers and Oracle Call Interfaces (OCIs).

Using Precompilers with the Oracle XA Library

When used in an Oracle XA application, cursors are valid only for the duration of the transaction. Explicit cursors should be opened after the transaction begins, and closed before the commit or rollback.

There are two options to choose from when interfacing with precompilers:

- Using precompilers with the default database
- Using precompilers with a named database

The following examples use the precompiler Pro*C/C++.

Using Precompilers with the Default Database

To interface to a precompiler with the default database, make certain that the DB=*db_name* field, used in the open string, is not present. The absence of this field indicates the default connection, and only one default connection is allowed per process.

The following is an example of an open string identifying a default Pro*C/C++ connection.

```
ORACLE_XA+SqlNet=host@MAIL+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/logs
```

Note that the DB=d*b_name* is absent, indicating an empty database ID string.

The syntax of a SQL statement would be:

```
EXEC SQL UPDATE Emp_tab SET Sal = Sal*1.5;
```

Using Precompilers with a Named Database

To interface to a precompiler with a named database, include the DB=*db_name field* in the open string. Any database you refer to must reference the same *db_name* you specified in the corresponding open string.

An application may include the default database, as well as one or more named databases, as shown in the following examples.

For example, suppose you want to update an employee's salary in one database, his department number (DEPTNO) in another, and his manager in a third database. You would configure the following open strings in the transaction manager:

```
ORACLE_XA+DB=MANAGERS+SqlNet=hqfin@SID1+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/xalog
ORACLE_XA+DB=PAYROLL+SqlNet=SID2+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/xalog
ORACLE_XA+SqlNet=hqemp@SID3+ACC=P/scott/tiger
  +SesTM=10+LogDir=/usr/local/xalog
```

Note that there is no DB=*db_name* field in the last open string.

In the application server program, you would enter declarations, such as:

```
EXEC SQL DECLARE PAYROLL DATABASE;
EXEC SQL DECLARE MANAGERS DATABASE;
```

Again, the default connection (corresponding to the third open string that does not contain the db_name field) needs no declaration.

When doing the update, you would enter statements similar to the following:

```
EXEC SQL AT PAYROLL UPDATE Emp_Tab SET Sal=4500 WHERE Empno=7788;
EXEC SQL AT MANAGERS UPDATE Emp_Tab SET Mgr=7566 WHERE Empno=7788;
EXEC SQL UPDATE Emp_Tab SET Deptno=30 WHERE Empno=7788;
```

There is no AT clause in the last statement because it is referring to the default database.

In Oracle precompilers release 1.5.3 or later, you can use a character host variable in the AT clause, as the following example shows:

```
EXEC SQL BEGIN DECLARE SECTION;
  DB_NAME1 CHARACTER(10);
  DB_NAME2 CHARACTER(10);
EXEC SQL END DECLARE SECTION;
    .
    .
SET DB_NAME1 = 'PAYROLL'
SET DB_NAME2 = 'MANAGERS'
    .
    .
EXEC SQL AT :DB_NAME1 UPDATE...
EXEC SQL AT :DB_NAME2 UPDATE...
```

Caution: Oracle recommends against using XA applications to create connections. Any work performed would be outside the global transaction and would have to be committed separately.

Using OCI with the Oracle XA Library

OCI applications that use the Oracle XA library should not call `OCISessionBegin`() (`olon`() or `orlon`() in Version 7) to log on to the resource manager. Rather, the logon should be done through the TPM. The applications can execute the function `xaoSvcCtx`() (`sqlld2`() in Version 7) to obtain the service context (`lda` in Version 7) structure they need to access the resource manager.

Because an application server can have multiple concurrent open Oracle Server resource managers, it should call the function `xaoSvcCtx`() with the correct arguments to obtain the correct service context.

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If `DB=`*db_name* is not present in the open string, then execute:

```
sqlld2(lda, NULL, 0);
```

This obtains the `lda` for this resource manager.

Alternatively, if `DB=`*db_name* is present in the open string, then execute:

```
sqlld2(lda, db_name, strlen(db_name));
```

This obtains the `lda` for this resource manager.

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If `DB=`*db_name* is not present in the open string, then execute:

```
xaoSvcCtx(NULL);
```

to obtain the `xaoSvcCtx` for this resource manager.

Alternatively, if `DB=`*db_name* is present in the open string, then execute:

```
xaoSvcCtx(db_name);
```

This obtains the `OCISvcCtx` for this resource manager.

See Also: *Oracle Call Interface Programmer's Guide.* has more information about using the `OCISvcCtx`.

Transaction Control

This section explains how to use transaction control within the Oracle XA library environment.

When the XA library is used, transactions are not controlled by the SQL statements which commit or roll back transactions. Rather, they are controlled by an API accepted by the TM which starts and stops transactions. Most of the TMs use the TX interface for this. It includes the following functions:

`tx_open`	Logs into the resource manager(s)
`tx_close`	Logs out of the resource manager(s)
`tx_begin`	Starts a new transaction
`tx_commit`	Commits a transaction
`tx_rollback`	Rolls back the transaction

Most TPM applications are written using a client-server architecture where an application client requests services and an application server provides services. The examples that follow use such a client-server model. A service is a logical unit of work, which in the case of the Oracle Server as the resource manager, comprises a set of SQL statements that perform a related unit of work.

For example, when a service named "credit" receives an account number and the amount to be credited, it executes SQL statements to update information in certain tables in the database. In addition, a service might request other services. For example, a "transfer fund" service might request services from a "credit" and "debit" service.

Usually application clients request services from the application servers to perform tasks within a transaction. However, for some TPM systems, the application client itself can offer its own local services.

You can encode transaction control statements within either the client or the server; as shown in the examples.

To have more than one process participating in the same transaction, the TPM provides a communication API that allows transaction information to flow between the participating processes. Examples of communications APIs include RPC, pseudo-RPC functions, and send / receive functions.

Because the leading vendors support different communication functions, the examples that follow use the communication pseudo-function `tpm_service` to generalize the communications API.

X/Open has included several alternative methods for providing communication functions in their preliminary specification. At least one of these alternatives is supported by each of the leading TPM vendors.

Examples of Precompiler Applications

The following examples illustrate precompiler applications. Assume that the application servers have already logged onto the TPM system, in a TPM-specific manner.

The first example shows a transaction started by an application server, and the second example shows a transaction started by an application client.

Example 1: Transaction started by an application server

Client:

```
tpm_service("ServiceName");              /*Request Service*/
```

Server:

```
ServiceName()
{
<get service specific data>
tx_begin();                              /* Begin transaction boundary*/
EXEC SQL UPDATE ....;

/*This application server temporarily becomes*/
/*a client and requests another service.*/

tpm_service("AnotherService");
tx_commit();                              /*Commit the transaction*/
<return service status back to the client>
}
```

Example 2: Transaction started by an application client.

Client:

```
tx_begin();                              /* Begin transaction boundary */
tpm_service("Service1");
tpm_service("Service2");
```

```
tx_commit();                          /* Commit the transaction */
```

Server:

```
Service1()
{
<get service specific data>
EXEC SQL UPDATE ....;
<return service status back to the client>
}
Service2()
{
<get service specific data>
EXEC SQL UPDATE ....;
...
<return service status back to client>
}
```

Migrating Precompiler or OCI Applications to TPM Applications

To migrate existing precompiler or OCI applications to a TPM application using the Oracle XA library, you must do the following:

1. Reorganize the application into a framework of "services".

   This means that application clients request services from application servers.

   Some TPMs require the application to use the `tx_open` and `tx_close` functions, whereas other TPMs do the logon and logoff implicitly.

   If you do not specify the `sqlnet` parameter in your open string, then the application uses the default Net8 driver. Thus, you must be sure that the application server is brought up with the `ORACLE_HOME` and `ORACLE_SID` environment variables properly defined. This is accomplished in a TPM-specific fashion. See your TPM vendor documentation for instructions on how to accomplish this.

2. Ensure that the application replaces the regular connect and disconnect statements.

   For example, replace the connect statements `EXEC SQL CONNECT` (for precompilers) or `OCISessionBegin`() (for OCIs) by `tx_open`(). Replace the disconnect statements `EXEC SQL COMMIT / ROLLBACK RELEASE WORK` (for precompilers), or `OCISessionEnd`() (for OCIs) by `tx_close( )`. The V7 equivalent for `OCISessionBegin`() was `olon( )` and for `OCISessionEnd`(), `ologof`().

3. Ensure that the application replaces the regular commit / rollback statements and begins the transaction explicitly.

   For example, replace the commit / rollback statements `EXEC SQL COMMIT / ROLLBACK WORK` (for precompilers), or `ocom`()`/orol`() (for OCIs) by `tx_commit`()/`tx_rollback`() and start the transaction by calling `tx_begin`().

4. Ensure that the application resets the fetch state prior to ending a transaction. In general, `release_cursor=no` should be used. Use `release_cursor=yes` only when you are certain that a statement will be executed only once.

Table A–3 lists the TPM functions that replace regular Oracle commands when migrating precompiler or OCI applications to TPM applications.

Table A–3 TPM Replacement Commands

Regular Oracle Commands	TPM Functions
`CONNECT` *user/password*	`tx_open` (possibly implicit)
implicit start of transaction	`tx_begin`
`SQL`	Service that executes the SQL
`COMMIT`	`tx_commit`
`ROLLBACK`	`tx_rollback`
disconnect	`tx_close` (possibly implicit)
`SET TRANSACTION READ ONLY`	Illegal

XA Library Thread Safety

If you use a transaction monitor that supports threads, then the Oracle XA library allows you to write applications that are thread safe. Certain issues must be kept in mind, however.

A *thread of control* (or thread) refers to the set of connections to resource managers. In an unthreaded system, each process could be considered a thread of control, because each process has its own set of connections to resource managers and each process maintains its own independent resource manager table.

In a threaded system, each thread has an autonomous set of connections to resource managers and each thread maintains a *private* resource manager table. This private resource manager table must be allocated for each new thread and de-allocated when the thread terminates, even if the termination is abnormal.

Note: In an Oracle system, once a thread has been started and establishes a connection, only that thread can use that connection. No other thread can make a call on that connection.

The Open String Specification

The `xa_open` string parameter, `xa_info`, provides the clause, Threads=, which must be specified as true to enable the use of threads by the transaction monitor. The default is false. Note that, in most cases, threads are created by the transaction monitor, and the application does not know when a new thread is created. Therefore, it is advisable to allocate a service context (`lda` in Version 7) on the stack within each service that is written for a transaction monitor application. Before doing any Oracle-related calls in that service, the `xaoSvcCtx` (`sqlld2` for Version 7 OCI) function must be called and the service context initialized. This LDA can then be used for all OCI calls within that service.

Restrictions

The following restrictions apply when using threads:

- Any Pro* or OCI code that executes as part of the application server process on the transaction monitor cannot be threaded unless the transaction monitor is explicitly told when each new application thread is started. This is typically accomplished by using a special C compiler provided by the transaction monitor vendor.

- The Pro* statements, EXEC SQL ALLOCATE and EXEC SQL USE are not supported. Therefore, when threading is enabled, embedded SQL statements cannot be used across non-XA connections.

Troubleshooting

This section discusses how to find information in case of problems or system failure. It also discusses trace files and recovery of pending transactions.

Trace Files

The Oracle XA library logs any error and tracing information to its trace file. This information is useful in supplementing the XA error codes. For example, it can indicate whether an `xa_open` failure is caused by an incorrect open string, failure to find the Oracle Server instance, or a logon authorization failure.

The name of the trace file is:

`xa_`*db_namedate*`.trc`

where *db_name* is the database name you specified in the open string field `DB=`*db_name*, and *date* is the date when the information is logged to the trace file.

If you do not specify `DB=`*db_name* in the open string, then it automatically defaults to the name `NULL`.

The xa_open string DbgFl

Normally, the XA trace file is opened only if an error is detected. The `xa_open` string DbgFl provides a tracing facility to record additional detail about the XA library. By default, its value is zero. It can be set to any combination of the following values. Note that they are independent, so to get printout from two or more flags, each must be set.

- `0x1` Trace the entry and exit to each procedure in the XA interface. This can be useful in seeing exactly what XA calls the TP Monitor is making and what transaction identifier it is generating.
- `0x2` Trace the entry to and exit from other non-public XA library routines. This is generally of use only to Oracle developers.
- `0x4` Trace various other "interesting" calls made by the XA library, such as specific calls to the Oracle Call Interface. This is generally of use only to Oracle developers.

Trace File Locations

The trace file can be placed in one of the following locations:

- The trace file can be created in the LogDir directory as specified in the open string.
- If you do not specify LogDir in the open string, then the Oracle XA application attempts to create the trace file in the $ORACLE_HOME/rdbms/log directory, if it can determine where $ORACLE_HOME is located.
- If the Oracle XA application cannot determine where $ORACLE_HOME is located, then the trace file is created in the current working directory.

Trace File Examples

Examples of two types of trace files are discussed below:

The example, xa_NULL040292.trc, shows a trace file that was created on April 2, 1992. Its DB field was not specified in the open string when the resource manager was opened.

The example, xa_Finance121591.trc, shows a trace file was created on December 15, 1991. Its DB field was specified as "Finance" in the open string when the resource manager was opened.

Note: multiple Oracle XA library resource managers with the same DB field and LogDir field in their open strings log all trace information that occurs on the same day to the same trace file.

Each entry in the trace file contains information that looks like this:

```
1032.12345.2:  ORA-01017:  invalid username/password;  logon denied
1032.12345.2:  xaolgn:  XAER_INVAL;  logon denied
```

Where "1032" is the time when the information is logged, "12345" is the process ID (PID), "2" is the resource manager ID, xaolgn is the module name, XAER_INVAL was the error returned as specified in the XA standard, and ORA-1017 is the Oracle Server information that was returned.

In-doubt or Pending Transactions

In-doubt or pending transactions are transactions that have been prepared, but not yet committed to the database.

Generally, the transaction manager provided by the TPM system should resolve any failure and recovery of in-doubt or pending transactions. However, the DBA may

have to override an in-doubt transaction in certain circumstances, such as when the in-doubt transaction is:

- Locking data that is required by other transactions
- Not resolved in a reasonable amount of time

For more information about overriding in-doubt transactions in the circumstances described above, or about how to decide whether the in-doubt transaction should be committed or rolled back, see the TPM documentation.

Oracle Server SYS Account Tables

There are four tables under the Oracle Server SYS account that contain transactions generated by regular Oracle Server applications and Oracle XA applications. They are DBA_PENDING_TRANSACTIONS, V$GLOBAL_TRANSACTIONS, DBA_2PC_PENDING and DBA_2PC_NEIGHBORS

For transactions generated by Oracle XA applications, the following column information applies specifically to the DBA_2PC_NEIGHBORS table.

- The DBID column is always xa_orcl
- The DBUSER_OWNER column is always *db_name*xa.oracle.com

Remember that the *db_name* is always specified as DB=*db_name* in the open string. If you do not specify this field in the open string, then the value of this column is NULLxa.oracle.com for transactions generated by Oracle XA applications.

For example, you could use the SQL statement below to obtain more information about in-doubt transactions generated by Oracle XA applications.

```
SELECT * FROM Dba_2pc_pending p, Dba_2pc_neighbors n
   WHERE p.Local_tran_id = n.Local_tran_id
      AND
      n.Dbid = 'xa_orcl';
```

Alternatively, if you know the format ID used by the transaction processing monitor, then you can use DBA_PENDING_TRANSACTIONS or V$GLOBAL_TRANSACTIONS. While DBA_PENDING_TRANSACTIONS gives a list of both active and failed prepared transactions, V$GLOBAL_TRANSACTIONS gives a list of all active global transactions.

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