ROUTING PROTOCOLS IN UNDERWATER SENSOR NETWORKS

A proposal for an integrated new routing protocol using existing technologies used for underwater communications

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For CMSC 601: Research Skills in Computer Science

Date: April 20th, 2011

Overview

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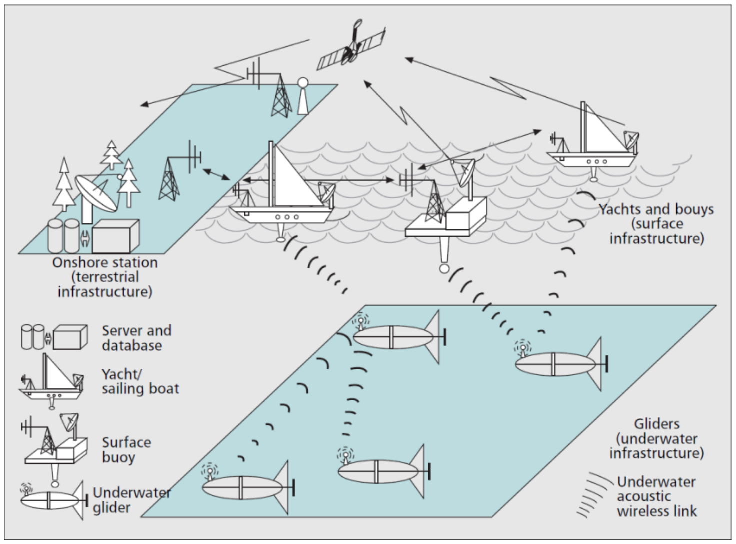
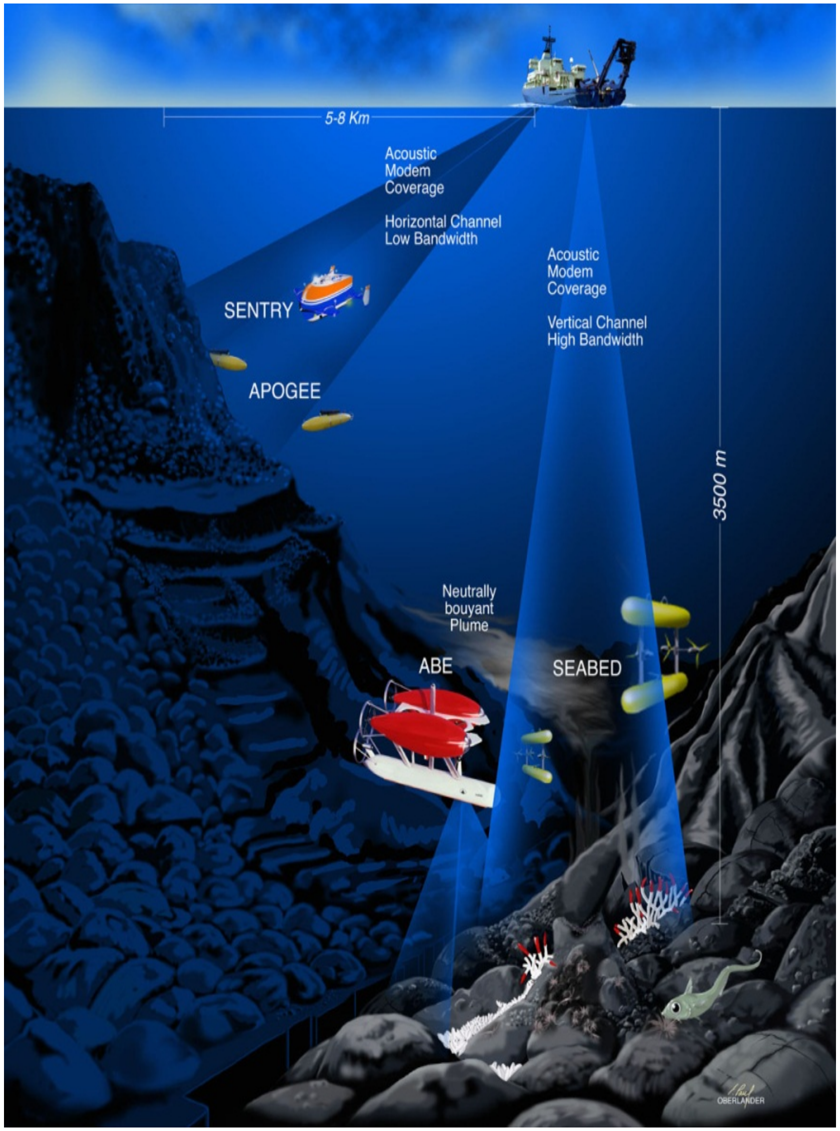
Underwater Wireless Sensor Network

- Undersea Explorations
  - Detect underwater oilfields
  - Determine routes for laying undersea cables
- Environmental Monitoring
  - Monitoring of ocean currents and winds, for improved weather forecast
  - Biological monitoring such as tracking of fishes or micro-organisms
- Disaster Prevention
  - Measure seismic activity from remote locations provide tsunami warnings to coastal areas
- Distributed Tactical Surveillance
  - AUVs and fixed underwater sensors collaboratively monitor areas for surveillance, reconnaissance, targeting, and intrusion detection



Scenario of a UW-ASN composed of underwater and surface vehicles.



An Example

- Distance of epicenter of recent earthquake in Japan from Sendai = 128.74752 km
- @ 970 km/h (speed of a wave) the Tsunami takes 7 minutes 59 seconds to reach the Sendai coast.
- Information about the Tsunami can be transmitted to coastal warning centers at the speed of sound – takes 1 min 26 seconds
- 6 minutes 33 seconds for saving lives;
- How important do you think that is?

- Using optical communication instead, same communication can be done in 1/2500th fraction of a second ignoring re-transmission delays for nodes
- Wired networks are unreliable; can easily get disconnected due to various factors but use of wireless sensor networks allows us to implement recovery mechanisms.

Purpose of underwater communication

- Need for monitoring ocean environment for Scientific, Commercial and Military purposes.
- Communication between various underwater sensors and vehicles is required.
- Sensors are deployed in remote locations and collect data over a long period of time.
- Amount of data is large and is expected to grow as sensor technology becomes more complex.

Need for Acoustic Communication

- Traditional wireless protocols: Use Electromagnetic Waves; suffer from scattering and attenuation problems underwater.
- Radio waves propagate at long distances through conductive salty water only at extra low frequencies (30 − 300Hz) requiring large antennae and high transmission power.
- Berkeley MICA2 Motes, a popular experimental platform in the sensor networking community, have been reported to reach an underwater transmission range of 120 cm at 433MHz in experiments performed at the University of Southern California.
- Optical waves do not suffer from such high attenuation but are affected by scattering. Furthermore, transmitting optical signals requires high precision in pointing the narrow laser beams. Thus, links in underwater networks are typically based on acoustic wireless communications [1]

Why is a study of routing protocols needed?

- Traditional routing protocols are either
  - Reactive protocols like DSR(Dynamic Source Routing) cannot be used in Routing in UWSN due to high bandwidth requirement (calculates cost of whole path)
  - or, Proactive protocols like OLSR(Optimized Link State Routing) cannot be used in UWSN due to overhead of route establishment every time there is a change in the network topology

Challenges of Acoustic Networks

- Severely limited bandwidth
- Underwater channels are severely impaired, especially due to multipath and fading;
- Propagation delay is five orders of magnitude higher than in Radio Frequency (RF) terrestrial channels
- High bit error rates and temporary losses of connectivity (shadow zones) can be experienced;
- Battery power is limited and usually batteries can not be recharged, also because solar energy cannot be exploited
- Power absorption and attenuation
- Underwater sensors are prone to failures because of fouling and corrosion. [1]

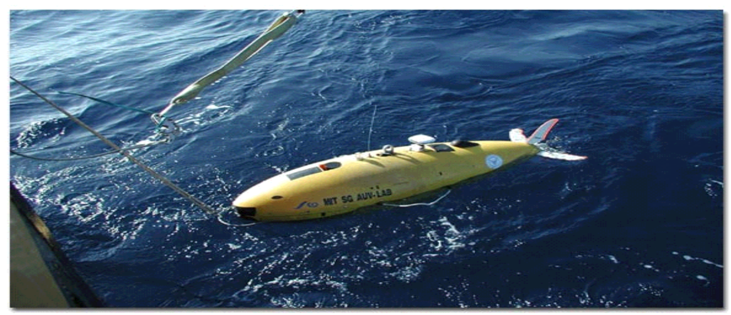
Example: Real-time underwater video?

Underwater image transmission: sequence of images (JPEG) at < 1 frame/sec

MPEG-4 : 64 kbps (video conferencing)

Can we achieve 100 kbps over an acoustic channel?

Compression to reduce bit rate needed for video representation → ? ← High-level modulation to increase the bit rate supported by acoustic channel



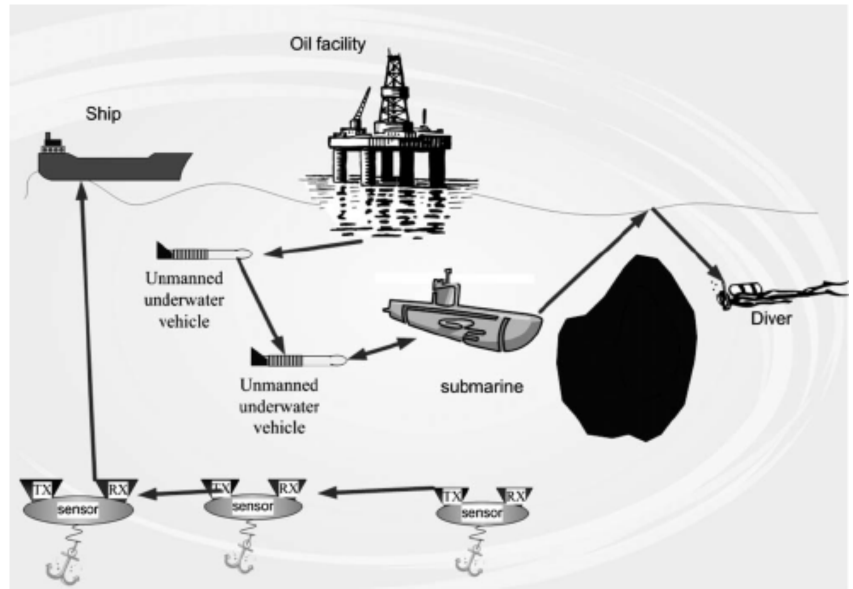
Acoustic Communication Bandwidth

	Range [km]	Bandwidth
Very Long	3000	10 bps
Long	10-100	1 kbps
Medium	1-10	10 kbps
Vertical	3	15 kbps
Vertical	0.01	150 kbps

Acoustic technology is capable of transmitting data at a very low bandwidth only

What is the solution?

- Use of optical communication - Over short distances ~ 10 m
- [Hanson, 2008] [2] states that in their experiments in three different water conditions it was seen that a data rate > 1 Gbit/s was achievable for several tens of meters.
- "Some early experiments demonstrated data rates up to 50 Mbits/s in seawater over a 9 m path (5.1 attenuation lengths) using an argon-ion laser operating at 514 nm and a bulk electro-optic (EO) modulator [2]."



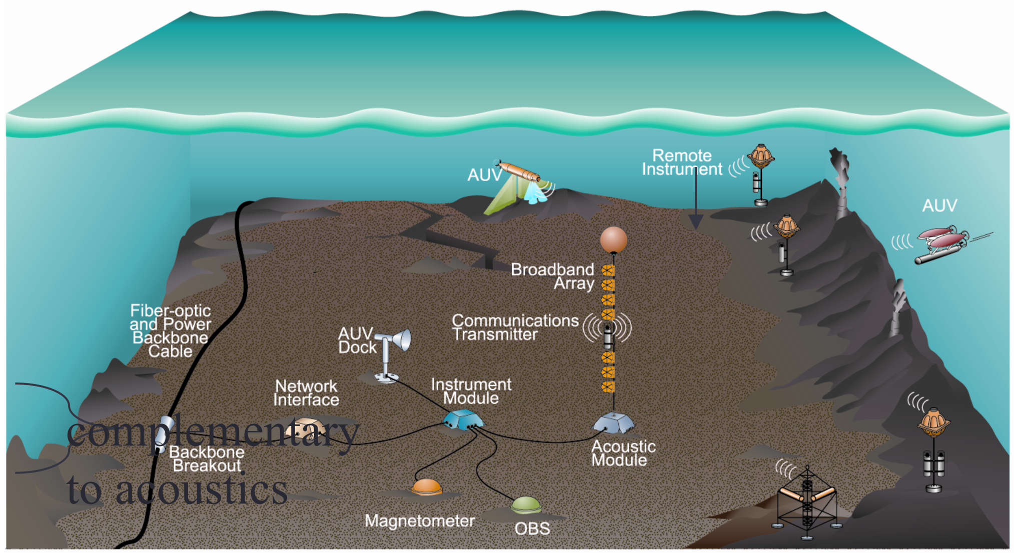
The line-of-sight communication scenario.

Open problems and future research

Research areas:
Data compression
Communication networks:
- network layout / resource allocation and reuse
- network architecture / cross layer optimization
- network protocols: all layers

System integration:
- Cabled observatories
- Integration of wireless communications: cabled backbone + mobile nodes = extended reach
- Wireless extension: acoustical and optical

Underwater optical communications:
blue-green region (450-550 nm) + much higher bandwidth (~Mbps) +negligible delay - short distance (<100 m)



complementary to acoustics

Deep-Sea Observatory with Acoustic Communications for AUVs and Instruments

From the slides and the paper for Wiley Encyclopedia of Telecommunication on underwater communication by Dr. Milica Stojanovic

Research Proposal

- The proposed research is to pursue the creation of a networking protocol which will use optical communication techniques for short distances taking advantage of the high bandwidth.
- For longer distances acoustic communication with multiple hops will be used to ensure connectivity.
- Use of multi hop technology is proposed because it has been observed to have better information rate and reliability with increasing number of hops[3].

Parameters for evaluation

- Bit Error Rate
- Collision Rate
- Speed of communication
- Reliability of network
- Failure detection and recovery
- Energy consmuption

Methods of Evaluation

- Simulation using AUVNetSim [4]
  - The main goals of AUVNetSim are:
    - i) To accurately model the underwater acoustic channel in terms of path-loss and noise.
    - ii) To provide a great variety of existing solutions for MAC, routing and transport layer protocols for underwater acoustic networks.
    - iii) To ease the development of new MAC, routing and transport layer protocols as well as cross-layer solutions for underwater acoustic networks.

  - In terms of outputs, AUVNetSim provides the following information:
    - i) Energy consumption for every single node while
    - actively transmitting
    - actively receiving
    - sleeping or being idle
    - energy consumption for every single packet
    - total energy consumption of the network.
    - ii) End-to-end delay for every single packet, route followed by every single packet.
    - iii) Number of collisions for every single packet, number of retransmissions per packet.
    - iv) Route followed by every node in the network (when moving).

Conclusion

- High bandwidth of optical communication
- Longer distance of Acoustic Communication
- Reliability of multi hop technique

- Protocol needs to be simulated and verified to have better transmission speed
- Lower error rate
- Ability to handle future advancements; supporting underwater video communication

Acknowledgements

- I would like to acknowledge the help and guidance of Dr. Mohamed Younis in my research on Underwater Sensor Networks. This presentation, however, does not conform to his standards, as I still have limited knowledge of the field and thus should not be taken as an impression on him.
- I have requested permission from Dr. Milica Stojanovic of the Massachusetts Institute of Technology Seagrant College Program for the use of figures and material from her presentation on Underwater Communication and would like to acknowledge the help I had in understanding the current research on the topic from her presentation.

References

- [1] Akyildiz, I. F., Pompili, D., and Melodia, T. State-of-the-art in protocol research for underwater acoustic sensor networks. In Proceedings of the 1st ACM international workshop on Underwater networks (New York, NY, USA, 2006), WUWNet '06, ACM, pp. 7–16.
- [2] Hanson, F., and Radic, S. High bandwidth underwater optical communication. Appl. Opt. 47, 2 (Jan 2008), 277–283.
- [3] Akyildiz, I. F., Pompili, D., and Melodia, T. Underwater acoustic sensor networks: research challenges. Ad Hoc Networks 3, 3 (2005), 257 – 279.
- [4] J.M. Jornet, "AUVNetSim: A Simulator for Underwater Acoustic Networks", MIT Sea Grant Technical Report, 2008. Available: http://seagrant.mit.edu/media/publications/MITSG08-4.pdf