NETWORK LAYER ANALYSIS & NOVEL RECOMMENDATIONS REGARDING FEASIBILITY TOWARDS UWSN

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Abstract

Oceans becoming communication channels today. For the last few years raised more interest in monitoring oceanic environments, security, and military etc. Shipbuilding industries are showing more interested in technologies like sensor networks used in applications such as monitoring, mooring etc. So Underwater sensor networks are providing more technologies for the applications like mooring and structural health monitoring etc. This paper presents more fundamental key aspects of UWSNs for the underwater sensor networks and underwater communications though devices for more applications.

Keywords: *Underwater Sensor Networks (UWSNs), Acoustic Communication, Cross layer protoc*

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1. INTRODUCTION

The shipbuilding and offshore engineering industries are also increasingly interested in technologies like wireless sensor networks as an economically viable alternative to currently adopted and costly methods used in seismic monitoring, structural health monitoring, installation and mooring, etc. More Technologies are introduced for more new networking schemes. Sensor networks have revolutionized all the areas of technology i.e. science, industry and government. The revolution is due to the miniaturization and the advancement in technology i.e. availability of low powered processing, storage units and Micro Electrical and Mechanical Systems (MEMS) for constructing onboard sensing units. The ability to have small devices physically distributed near the objects being sensed brings new opportunities to observe and act on the world, for example with micro-habitat monitoring, structural monitoring [2].

1.1 Structural applications – a wireless seismic data acquisition system:

Our goal is to build a wireless system that can collect tens of channels of vibration measurements in near real-time. Traditional data acquisition systems require several hundreds of feet of wiring from the sensors to a centralized data acquisition node. A wireless data acquisition system is much easier to deploy, not just because the placement of sensor is unconstrained by the availability of power and network connectivity, but also because a multi-hop wireless network (in which nodes can relay data towards one or more base stations) offers significant placement flexibility in not requiring nodes to be within radio range of a base station.

The design of the software subsystem for wireless data acquisition is quite challenging. In the rest of this section, we describe how we design a self-configuring wireless data acquisition system which allows rapid, reliable and time synchronized delivery of many channels of structural response to a base station. Our software subsystem is built on top of TinyOS, the operating system for the motes.

Self-configuration:

A key requirement for a wireless seismic array is self-configuration – the ability to form, without manual intervention, a (possibly multi-hop) communication structure across all nodes for transporting data to the base station.

Reliability:

Selection of a reliable parent is not a guarantee for lossless communication. Thus, on top of this communication structure, we have built a simple mechanism for ensuring reliable transmissions. Such mechanisms have been extensively studied in the computer network literature, and involve signaling between nodes to detect and repair message loss.

Compression:

Loss in packet transmission is just one of the challenges encountered while operating in a wireless environment. Another is limited data transfer bandwidth. In particular, the data transfer rate of the entire network is constrained by the radio receive bandwidth offered by a single radio (that at the base station).

We use two simple techniques to deal with this challenge. First for an N channel seismic array, we constrain each node to transmit at 1/N of the nominal radio bandwidth. More importantly, however, we use data compression to reduce the transfer rate requirements.

While lossy compression schemes can provide significant reduction in data rates, they are clearly not applicable given that we are designing a data acquisition system. Lossless compression schemes generally rely on detecting repeating patterns in the data. Our system uses a simple but effective silence suppression scheme for compressing vibration data. Essentially, it encodes a silence period (defined as a sequence of samples whose values lie within a small range) as a "run-length" (a sample value and a number of samples). This approach can reduce the volume of data transferred in situations where the duty-cycle of vibrations is expected to be small. The approach is also desirable since it reduces network communication (and therefore energy expenditure).

1.2. Underwater sensor networks applications are:

Ocean Sampling Networks: Networks of sensors and AUVs, such as the Odyssey-class AUVs, can perform synoptic, cooperative adaptive sampling of the 3D coastal ocean environment.

Pollution Monitoring and other environmental monitoring (chemical, biological, etc.).

Distributed Tactical Surveillance. AUVs and fixed underwater sensors can collaboratively monitor areas for surveillance, reconnaissance, targeting and intrusion detection systems.

Under water sensor network consists of a variable number of sensors and vehicles that are deployed to perform collaborative monitoring tasks over a given area. To achieve this objective, sensors and vehicles self-organize in an autonomous network which can adapt to the characteristics of the ocean environment. Underwater networks can be characterized by their spatial coverage and by the density of nodes.

Major Challenges are:

- Battery power is limited and usually batteries cannot be recharged, also because solar energy cannot be exploited[5].
- The available bandwidth is severely limited.
- Channel characteristics, including long and variable propagation delays, multi-path and fading problems.
- High bit error rates.
- Underwater sensors are prone to failures because of fouling, corrosion, etc.

Differences between underwater sensor networks and terrestrial networks[4] are Cost-Underwater sensors are more expensive, Deployment-deemed to be more sparse in USNs, Power-Higher power is needed in USNs due to higher distances and more complex signal processing at receivers. Memory-Underwater sensors need to have large memory compared to terrestrial sensors as the underwater channel is intermittent.

1.3. Factors that influence the acoustic communications in UWSNs:

Path Loss:

Attenuation is mainly provoked by absorption due to conversion of acoustic energy into heat, which increases with distance and frequency. It is also caused by scattering and reverberation (on rough ocean surface and bottom), refraction, and dispersion (due to the displacement of the reflection point caused by wind on the surface). Water depth plays a key role in determining the attenuation. Geometric Spreading refers to the spreading of sound energy as a result of the expansion of the wave fronts. It increases with the propagation distance and is independent of frequency. There are two common kinds of geometric spreading: spherical (Omni-directional point source), and cylindrical (horizontal radiation only).

Noise:

Man-made noises mainly caused by machinery noise (pumps, reduction gears, power plants, etc.), and shipping activity (hull fouling, animal life on hull, cavitations).

Ambient Noise. Is related to hydrodynamics (Movement of water including tides, currents, storms, wind, rain, etc.), seismic and biological phenomena.

Multi path:

Multi-path propagation may be responsible for severe degradation of the acoustic communication signal, since it generates Inter-Symbol Interference (ISI). It depends on the link configuration. Vertical channels are characterized by little time dispersion, whereas horizontal channels may have extremely long multi-path spreads, whose value depend on the water depth.

High delay and delay variance:

The propagation speed in the UW-A channel is five orders of magnitude lower than in the radio channel. This large propagation delay (0.67 s/km)can reduce the throughput of the system considerably. The very high delay variance is even more harmful for efficient protocol design, as it prevents from accurately estimating the round trip time (RTT), key measure for many common communication protocols.

1.4 Applications of Underwater sensor networks:

Sonar:

Sonar is the name given to the acoustic equivalent of radar. Pulses of sound are used to probe the sea, and the echoes are then processed to extract information about the sea, its boundaries and submerged objects. An alternative use, known as passive sonar, attempts to do the same by listening to the sounds radiated by underwater objects.

Underwater communication:

The need for underwater acoustic telemetry exists in applications such as data harvesting for environmental monitoring, communication with and between manned and unmanned underwater vehicles, transmission of diver speech, etc. A related application is underwater remote control, in which acoustic telemetry is used to remotely actuate a switch or trigger an event. A prominent example of underwater remote control are acoustic releases, devices that are used to return sea floor deployed instrument packages or other payloads to the surface per remote command at the end of a deployment. Acoustic communications form an active field of research with significant challenges to overcome, especially in horizontal, shallow-water channels.

Underwater Navigation and Tracking:

Underwater navigation and tracking is a common requirement for exploration and work by divers, ROV, autonomous underwater vehicles (AUV), manned submersibles and submarines alike. Unlike most radio signals which are quickly absorbed, sound propagates far underwater and at a rate that can be precisely measured or estimated. It can thus be used to measure distances between a tracked target and one or multiple reference of baseline stations precisely, and triangulate the position of the target, sometimes with centimeter accuracy. Starting in the 1960s, this has given rise to underwater acoustic positioning systems which are now widely used.

Weather and climate observation:
Acoustic sensors can be used to monitor the sound made by wind and precipitation. Lightning strikes can also be detected. Acoustic thermometry of ocean climate (ATOC) uses low frequency sound to measure the global ocean temperature.

2. UNDER WATER ACOUSTIC SENSOR NETWORKS

Ocean bottom sensor nodes are deemed to enable applications for oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation and tactical surveillance applications. Multiple Unmanned or Autonomous Underwater Vehicles (UUVs, AUVs), equipped with underwater sensors, will also find application in exploration of natural undersea resources and gathering of scientific data in collaborative monitoring missions. To make these applications viable, there is a need to enable underwater communications among underwater devices. Underwater sensor nodes and vehicles must possess self-configuration capabilities, i.e., they must be able to coordinate their operation by exchanging configuration, location and movement information, and to relay monitored data to an onshore station.

Wireless underwater acoustic networking is the enabling technology for these applications. Under Water Acoustic Sensor Networks (UW-ASN) consist of a variable number of sensors and vehicles that are deployed to perform collaborative monitoring tasks over a given area. To achieve this objective, sensors and vehicles self-organize in an autonomous network which can adapt to the characteristics of the ocean environment.

Underwater networking is a rather unexplored area although underwater communications have been experimented since World War II, when, in 1945, an underwater telephone was developed in the United States to communicate with submarines. Acoustic communications are the typical physical layer technology in underwater networks. In fact, radio waves propagate at long distances through conductive sea water only at extra low frequencies (30-300 Hz), which require large antennae and high transmission power. Optical waves do not suffer from such high attenuation but are affected by scattering. Moreover, transmission of optical signals requires high precision in pointing the narrow laser beams. Thus, links in underwater networks are based on acoustic wireless communications.

2.1 Underwater network architecture

The underwater sensor network topology is still an open research issue for the research community. Some of the architectures supporting underwater sensor networks are static two-dimensional under water acoustic sensor networks (UW-ASNs), static three dimensional under water acoustic sensor networks and three dimensional networks of autonomous underwater vehicles.

There are several different architectures for Underwater Acoustic Sensor Networks, depending on the application:

Two-dimensional UW-ASNs for ocean bottom monitoring. These are constituted by sensor nodes that are anchored to the bottom of the ocean. Typical applications may be environmental monitoring, or monitoring of underwater plates in tectonics.

Three-dimensional UW-ASNs for ocean column monitoring. These include networks of sensors whose depth can be controlled, and may be used for surveillance applications or monitoring of ocean phenomena (ocean bio-geo-chemical processes, water streams, pollution, etc).

Three-dimensional networks of Autonomous Underwater Vehicles(AUVs). These networks include fixed portions composed of anchored sensors and mobile portions constituted by autonomous vehicles.

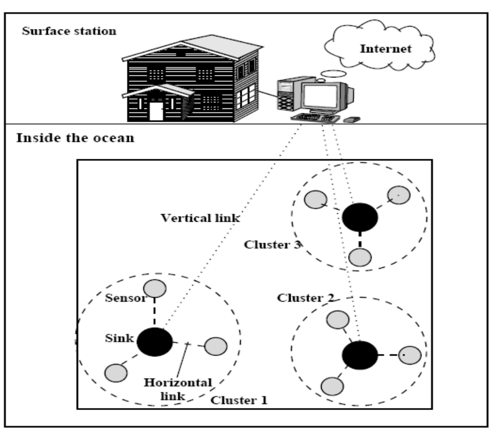

Fig. 1. Underwater Network Environment

3. RESEARCH CHALLENGES IN UNDERWATER SENSOR NETWORK

A protocol stack for uw-sensors should combine power awareness and management, and promote cooperation among the sensor nodes. It should consist of physical layer, data link layer, network layer, transport layer, and application layer functionalities.

3.1 Physical layer:

The communication media that can be chosen for underwater sensor networks are radio frequency waves or optical wave or acoustic wave. The main objective of underwater acoustic communication is to overcome performance limitations observed in dispersive channel and also improve bandwidth efficiency. To achieve high bandwidth efficiency the suitable modulation schemes are as follows.

Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. The simplest FSK isbinary FSK (BFSK). BFSK uses a pair of discrete frequencies to transmit binary (0s and 1s) information. With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency.

3.2 Data link layer:

Frequency division multiple access (FDMA) is not suitable for UW-ASNs due to the narrow bandwidth in UW-A channels. Time division multiple access (TDMA) shows a limited bandwidth efficiency because of the long time guards required in the UW-A channel. Although the high delay spread which characterizes the horizontal link in underwater channels makes it difficult to maintain synchronization among the stations, CDMA is a promising multiple access technique for underwater acoustic networks.

3.3 Network layer:

The network layer is in charge of determining the path between a source (the sensor that samples a physical phenomenon) and a destination node(usually the surface station).There has been intensive study to find the route from source to the destination in different gateways of underwater sensor networks. Existing routing protocols are divided into three categories, namely proactive, reactive and geographical routing protocols[8].

In virtual circuit routing, the networks use virtual circuits to decide on the path at the beginning of the network operation. In packet-switch routing, every node that is part of the transmission makes its own routing decision, i.e., decides its next hop to relay the packet. Packet-switch routing can be further classified into proactive routing and reactive routing protocols. Most routing protocols for ground-based wireless networks are packet-switch based.

Proactive routing protocols attempt to minimize the message latency by maintaining up-to-date routing information at all times from each node to any other node. It broadcasts control packets that contain routing table information. Typical protocols include Destination Sequence Distance Vector (DSDV) and Temporally Ordered Routing Algorithm (TORA). However, proactive routing protocols provoke a large signaling overhead to establish routes for the first time and each time the network topology changes. It may not be a good fit in underwater environment due to the high probability of link failure and extremely limited bandwidth there.

Virtual-circuit-switch routing protocols can be a better choice for underwater acoustic networks. The reasons are:
a) Underwater acoustic networks are typical asymmetric instead of symmetric. However, packet switched routing protocols are proposed for symmetric network architecture;
b) Virtual-circuit-switch routing protocols work robust against link failure, which is critical in underwater environment; and
c) Virtual-circuit-switch routing protocols have less
signal overhead and low latency, which are needed for underwater acoustic channel environment. However, virtual-circuit-switch routing protocols usually lack of flexibility. How to adapt some degree of flexibility into virtual-circuit-switch routing protocols is a question that needs to be answered by UAN network layer research.

3.4Transport layer:

In this section existing reliable data transport solutions for Wireless sensor Networks, along with their shortcomings in the underwater environment, and fundamental challenges for the development of an efficient reliable transport layer protocol for underwater sensor networks are discussed. In sensor networks reliable event detection at the sink[6] should be based on collective information provided by source nodes and not just on individual reports from each single source. Therefore, new ways should be defined to provide reliable could feasible lead to wastage of scarce resources.

The features must have for the underwater environment to fulfill the design principles are: Although correct handling of shadow zones requires assistance from the routing layer, a transport protocol should also handle the shadow zones.

-A transport protocol should be explicitly designed to minimize the energy consumption.

-Packets should be continuously forwarded to accelerate the packet delivery process.
-A transport protocol should adapt to local conditions immediately, to decrease the response time in case of congestion. Thus, rather than sinks, intermediate nodes should be capable of determining and reacting to local congestion

3.5 Application layer:

The research of application layer protocols for UANs is a brand new topic. The purpose of application layer is to provide a network management protocol that makes hardware and software detail of the lower layers transparent to management applications. The functionalities include:
1) Identifying communication partners;
2) Determining resource availability; and,
3) Synchronizing communications.

Some examples of application layer protocols for ground-based wireless networks are Telnet, File Transport Protocol (FTP), and Simple Mail Transfer Protocol (SMTP). Not much effort has been made to address the specific needs of the underwater acoustic environment. Instead of designing a complete new set of protocols, we can modify existing protocols of ground-based wireless networks to meet the UAN needs. Thus, it is a necessity to understand the application areas and the communication issues for UANs, and to apply its uniqueness into the existing application protocols.

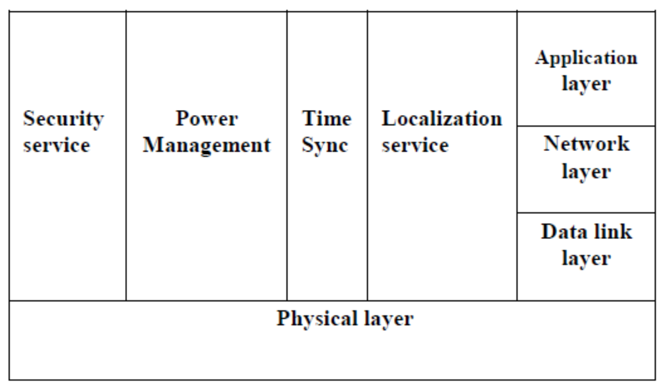

Fig.2 Cross layer protocol stack in underwater sensor networks

CONCLUSION

This paper reviews the recent research development of Underwater Acoustic Networks (UANs). It analyzes the uniqueness of underwater acoustic channel first. Several practical issues of UANs are then raised, ranging from network topology, power efficiency, physical layer, network layer to application layer. To use the scare resource more efficiently, it is shown that cross layer design can be a proper approach for UANs, due to its optimization prospect.

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