Study of Applications of Underwater Wireless Sensor Networks

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Abstract: ***While sensor networks are the source point to be grown in today's applications on the ground, under water operations and research are not attaining the highest goals by comparison. This paper explores the various applications of underwater wireless sensor networks and the major challenges in the design of underwater wireless sensor networks.***

Keywords: Underwater Wireless Sensor Networks, Applications and Challenges

1. Introduction

In our earth one fourth is covered by living and three fourth is covered with water. Underwater networks are utilized in the modern era in the multiple areas of underwater research which includes industrial, structural, micro habitat etc. Underwater wireless sensor networks plays a major experience in physical applications like oil and gas exploration, sensing of chemical and biological phenomena, seismic studies etc. Compared to its terrestrial counterpart this UWSNs is in the beginning stage due to the involvement of high cost and physical challenges involved in.

To know about underwater applications, there are some design challenges and tools from ground based wireless sensor networks. Even underwater networks resembles like terrestrial networks, there are some fundamentally different from terrestrial networks which are not suitable for the underwater environment. Radio signals in terrestrial networks are not applicable for underwater networks due to the propagation of long distances at very low frequencies, requires high transmission power and large antennas. Due to the shadow zones, temporary connectivity loss is experienced [1].

When compared with radio waves, acoustic waves have high propagation delay, low or insufficient bandwidth, path loss and more consumption of energy. Additionally, some other challenges such as continuous movement of sensor nodes, which is unsuitable for the (GPS) Global Positioning System for the underwater environment [2].

2. Potential Applications

Some of the possible wireless sensor network applications are: industrial monitoring, Environmental, warfare, healthcare, education, agriculture etc. With the joint hands and efforts of the college of Atlantic and the university of California, some environmental monitoring parameters is carried out in the Great Duck Island on the coast of maine by means of network of Berkeley equipped with more number of wireless sensors. The nodes send their information to the base station which makes them available on the internet.

In India, 18 to 106 meteorological and oceanographic parameters which include subsurface data are measured by moored buoys. This information are transmitted in the real – time to the centre called NIOT (National Institute of Ocean Technology) Data Centre, Chennai via satellite telemetry at hourly/interval and are being disseminated in Global Telecommunication System (GTS) for benefit through World Meteorological Organization.

2.1 Seismic Monitoring

Seismic monitoring can be of underground seismic monitoring and underwater seismic monitoring. The below diagram in Figure1 shows about the classification of seismic monitoring.

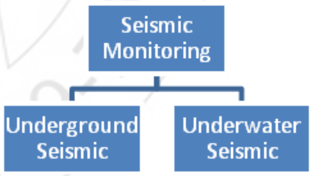

Figure 1: Classification of Seismic monitoring

2.1.1 Underground Seismic

In today's world, earth quakes are happening frequently in many countries of the world, with any appearance of a sudden and unexpected event. The majority of earth quakes are due to sudden slip of a rock formation by faults, which results in a seismic waves that shakes the ground, damage structures, land slides and deadly events. The damage on underground strongly depends on three mechanisms: Seismic source: Refers to the failure of the rock mass which pre-exists frequently on a weakness such as fault, where the seismic energy release, Rock burst: This mechanism refers only when the hanging and sidewall Collapses. The major Rock burst damage will be caused by the fall of slabs due to the thickness which is < 1.6m.

2.1.2 Underwater Seismic

Seismic monitoring is a promising application for underwater sensor networks for oil extraction from underwater fields. 3-D seismic monitoring is an important technology used in the oil industry for oil exploration and reservoir management. Frequent seismic monitoring is of importance in oil extraction and studies of variation in the reservoir over time are called “4-D seismic” with time series which improves resource recovery and oil productivity and also useful for judging field performance and motivating intervention. In the last two decades, there has an effective increase in monitoring the undersea seismic process due to the technique has been successfully applied to large hydrocarbon fields, especially in North Sea. One seismic survey can generate 7TB of data or more [7]. Successful 4D studies aim to increase production and cost savings through better planning of production and injection wells and increased understanding of reservoir characteristics.

Today, most seismic imaging tasks for offshore oil fields are carried out by a ship that tows a large array of hydrophones on the surface. A compressed-air gun generates a shock wave in the water. The wave travels down the sea floor and is reflected by different layers of the rock. The seismic signal is eventually received by each hydrophone on surface, and the data are processed coherently to form an image. Due to the high cost of such seismic imaging, it is only performed rarely, for example, once a year. An alternative way used for underwater seismic is to deploy sensors in undersea, which are connected by cables. The approach has the advantage of frequent data collection. However, it is very expensive to lay cables in underwater for a vast area. The below diagram in Figure 2 shows an example of underwater seismic monitoring.

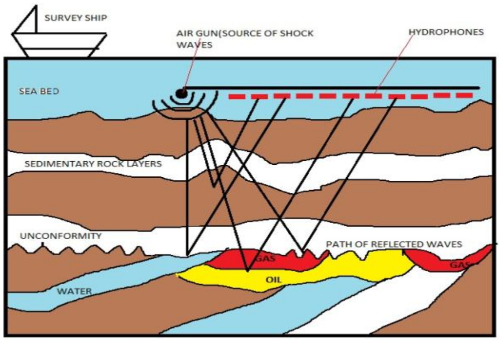

Figure 2: Underwater Seismic Monitoring

Terrestrial oil fields can be frequently monitored, typically being surveyed annually or quarterly. In some fields, and even daily or continuously in some gas storage facilities and permanently instrumented fields [8]. But monitoring of underwater oil fields is much more challenging, because seismic sensors are not currently permanently deployed in underwater fields. Instead, seismic monitoring of underwater fields typically involves a ship with a towed sonar array as the sensor and an air cannon as the actuator. Such a study involves both large capital and operational costs. Current underwater fields are evaluated rarely, typically every 2-3 years.

2.2 Environmental Monitoring

Ocean environment has an enormous amount of environmental variables which includes multi-path occurrences, movement of nodes by the water current, salt water corrosion and radio wave attenuation. Environmental monitoring includes: shipping noise, pipeline leak detection, hydro dams, earth quakes, tsunamis and sea ice monitoring. Hydrophones are the one which detect these issues in the environment. For example, in shipping noise, hydrophones are used to know about the marine environment and understand of how sound in underwater effects cetacean activity. Hydrophones are the tool for understanding the sensitivity of the ocean environment. Hydrophones are also used in acoustic leak detectors which notify the sound induced by water leaking from pipelines under pressure.

UW-ASNs can perform pollution monitoring (chemical monitoring, biological and nuclear monitoring). For example, it may be possible to detail the chemical slurry of antibiotics, estrogen-type hormones and insecticides to monitor streams, rivers, lakes and ocean bays (water quality in-situ analysis). Monitoring of oceanographic currents and winds, improved weather forecast, notifying climate change, under-standing and predicting the effect of human activities on marine ecosystems such as tracking of fishes or micro-organisms, are other possible applications. More specifically underwater sensor networks can be used to detect extreme temperature gradients (thermo clines) which are considered to be a breeding ground for certain marine micro-organisms [4].

2.3 Ocean Sampling Networks

Because the ocean is a three dimensional environment, that is constantly changing over time. Oceanographers must often install many instruments over large areas or use mobile vehicles such as robotic submarines to carry their instruments around. The figure 3 shows about the ocean sampling networks. By linking instruments at many locations together in networks that send data back to shore automatically called Ocean Observations. The Ocean sampling networks were designed to test a variety of cutting edge methods for monitoring large areas of the coastal ocean [12].

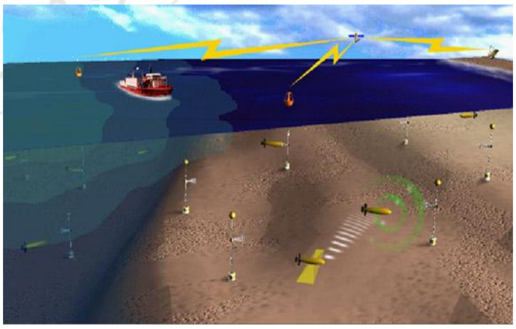

Figure 3: Ocean Sampling Networks

Networks of sensors and autonomous underwater underwater vehicles (AUVs) such as the Odyssey class AUV [3] can perform synoptic, co-operative adaptive sampling of the 3-D coastal ocean environment. Recent underwater experiments demonstrate the advantages of bringing together sophisticated new robotic vehicles with advanced ocean model to improve the ability to observe and predict the characteristics of the ocean environment[6], [4].

2.4 Undersea explorations or Deep sea explorations:

These are the chemical and physical properties of the seawater as well as the geophysical and geological features of the earth's crust [9]. In the existed years, new tools and technologies has allowed to visit many unexplored areas of the deep sea or ocean, for the discovery of new species and new ecosystems. The diagram in Figure 4 shows about the deep sea exploration [13].

The NOAA – National Oceanic and Atmospheric Administration created the authority of ocean exploration to know more about explored areas. Some of the expeditions are [10]:
- Anticipated for new anti – cancer drugs
- Methane Hydrate deposits has been investigated.
- Discovered The Civil war ironclad – the historic turret and engine.
- Discovered steam ship Portland – Lost in 1898 in the coast of Massachusetts.

Figure 4: Deep Sea Exploration

These underwater sensor networks can also help to detect underwater oilfields or reservoirs, determine routes for laying undersea cables, and assist in the exploration for valuable minerals in the undersea.

2.5 Disaster prevention

Some natural disasters cause danger to the living things such as Volcanoes, earthquakes and tsunamis which can occur anytime and anywhere on the earth surface. In March 2011, the most powerful earthquake that hit Japan with the magnitude of 9.0 which generates major tsunami waves as high as 130 feet that spread across the miles of the shore [11]. From remote locations, Sensor networks measure the seismic activity to inform tsunami warnings to coastal areas or study the effects of submarine earthquakes (seaquakes) [3].

2.6 Assisted navigation

Sensors can be used to identify hazards on the seabed, to locate dangerous rocks or shoals in shallow waters, mooring positions, and submerged wrecks, and to perform bathymetry profiling.

2.7 Distributed tactical surveillance in underwater

Underwater Vehicles - AUVs and fixed underwater nodes are being monitored under the areas for surveillance, targeting information and intrusion detection systems. As an example, a 3-D underwater sensor network can realize a tactical surveillance system that is able to detect and classify submarines, small delivery vehicles (SDVs), and divers based on the sensed data from mechanical, radiation, magnetic, and acoustic micro sensors. With respect to traditional radar/sonar systems, underwater sensor networks can reach a higher accuracy, higher coverage, and robustness as well as enable detection and classification of low-signature targets by also combining measures from different types of sensors.

2.8 Mine reconnaissance

The simultaneous operation of multiple AUVs with acoustic and optical sensors can be used to perform rapid environmental assessment and detect mine-like objects [4]. The below diagram shows the underwater vehicles to detect the mine like objects [14]. The autonomous underwater vehicle is a self-controlled unmanned vehicles or submersibles to perform a variety of tasks from pipelines to find the mines. These submersibles carry sensors that ranges from acoustic mapping tools to biological samplers and chemical samplers.

Figure 5: AUV to detect mine like objects

3. Challenges

There are some major challenges in the design of underwater sensor networks are as follows:
- The available bandwidth is severely limited.
- Propagation delay under water is five orders of magnitude higher than that in RF terrestrial channels and extremely variable.
- The underwater channel is severely impaired, especially because of multi-path and fading problems.
- Error rates are very high and temporary loss of connectivity (shadow zones) can be experienced due to the characteristics of the underwater channel.
- Battery power is limited and usually batteries cannot be recharged; also, solar energy cannot be exploited
- Underwater sensor networks are prone to failure because of fouling and corrosion.

4. Conclusion

The potential capabilities of underwater sensor networks and the wide variety of new applications that will be enabled by them motivate the development of communication techniques for the underwater environment. While the vast amount of solutions for terrestrial WSNs provides a valuable insight into networking in this environment, there exist many challenges unique to underwater communication. Especially, the significantly different characteristics of communication in water require many networking paradigms to be revisited.

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