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UNDERWATER SENSOR NETWORKS: OVERVIEW OF APPLICATIONS AND RESEARCH CHALLENGES

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Abstract

A review on the challenges in underwater wireless network systems is discussed in this paper. In underwater network systems different methodologies have to be adopted in comparison to the overland network systems. Acoustic signals are used instead of electromagnetic signals. One of the issue is the propagation of electromagnetic signals through water. The marine environment also poses serious challenges in deploying the underwater wireless systems. The architecture and the applications of underwater network systems is also discussed.

Keywords: Underwater wireless sensor networks, Acoustic sensor networks, oceanographic data collection.

I. Introduction

Water bodies are unique to have physical, chemical and biological properties compared to terrestrial systems. These properties include water currents of various velocity, force and torque, light variations of intensity and wavelength, temperature, density, turbidity, salinity, acidity, alkalinity, chemicals and dissolved gas, microorganisms, algae and aquatic life. Number of natural and man-made factors affects the properties of ocean. These include air currents, sun light, lightning, rain, algal bloom, etc. In addition to these there are, man-made interferences like solid, liquid and chemical pollutants, passenger boats and oil rigs.

Propagation of electromagnetic waves have very high attenuation in water. Whereas sound waves travel long distances in water and have very low attenuation. Hence acoustic signals are preferred for communication systems in water. In underwater acoustic communication, acoustic signals are transmitted and received under water. This communication technique uses the acoustic signals for variety of underwater applications like data collection of physical parameters of the ocean, pollution monitoring, disaster prevention, monitoring vibrations in the crust of the earth, offshore exploration, military, strategic surveillance applications etc.

Underwater Wireless Sensor Networks (UWSNs) also face various challenges. The fabrication of these sensors need to account for the marine environment. The deployment and maintenance as well as the recovery is challenging and expensive. The sensors used in underwater equipment are prone to physical damage due to algae collection, salt accumulation and thus decreasing their effectiveness. The energy requirement and cost of these sensors are high. Battery restoring techniques are also expensive. The sensing and transmission vary for different sea environments. The reliability of underwater sensor networks is affected by the marine environment.

In this paper wesurveythe applications of underwater sensors, the challenges faced by UWSNs followed by literature review of selected research projects employing UWSNs for various applications. In the end final conclusion is discussed.

II. Related Works

Transmission of electromagnetic waves in water is very difficult due to very high attenuation and also have a very short range. Acoustic waves are the preferred means to communicate in water. The usual routing protocols, MAC protocols used for electromagnetic signals are not applicable for acoustic waves, new methods have to be developed.

The characteristics of acoustic signals in water and the challenges occurring are discussed by Sharif-Yazd et al. [XII],along with the different protocols for the UASNs. To observe the applications, the underwater sensors need to be monitored regularly. To collect data from these sensors precisely, the sensors are networked. Installation of underwater wired networks or access point wireless networks is very expensive and time consuming and hence ad-hoc wireless networks are preferred and used. Such underwater ad-hoc wireless networks have complex networking challenges. Therefore, specific and efficient protocols need to be developed. Each node of the network acts as a sensor and it exchanges data with other nodes. This can be used for enhancing the network signaling. The challenges faced were traffic and security, link reliability, energy consumption and battery lifetimes. Bandwidth limitation is also a major challenge for acoustic sensors.

The architecture, potential applications and challenges for underwater sensor networks is discussed by Devee Prasan et al. [XV]. Network of sensor nodes, anchor nodes and autonomous vehicles is deployed underwater to monitor the various physical parameters. The acoustic communication with sensor nodes, underwater network self-configuration, time synchronization and MAC protocols have been investigated. The drawbacks include the necessity to periodically clean the deployed sensors and other equipment against corrosion and fouling.The sensors also should be stable against environmental changes as sensor drift is of concern.

Monitoring of offshore oil fields and seismic monitoring is an important application where UWSNs are used. Heidemann et al. [VI] has summarized their research in seismic monitoring for oil extraction and underwater fields. The variation in the reservoir capacity over time is monitored for field performance and this is done by the seismic monitoring.

Architecture of UWSNs :

The effective functioning and deployment of networks is based on specific rules and protocols. The architecture of networks defines the rules and protocols. Wireless sensor networks have different architectures, but those architectures are not easily deployable for UWSNs. A typical under water network sensor architecture is shown in Figure 1. As UWSNs use acoustic signals instead of electromagnetic waves, the medium of propagation of these signals have different properties. On account of these reasons different architectures have to be developed for UWSNs. Various architectures for UWSNs [III] have been classified as 1D UWSNs [IV], 2D UWSNs [V], 3D UWSNs [XI], and 4D UWSNs [XIV].

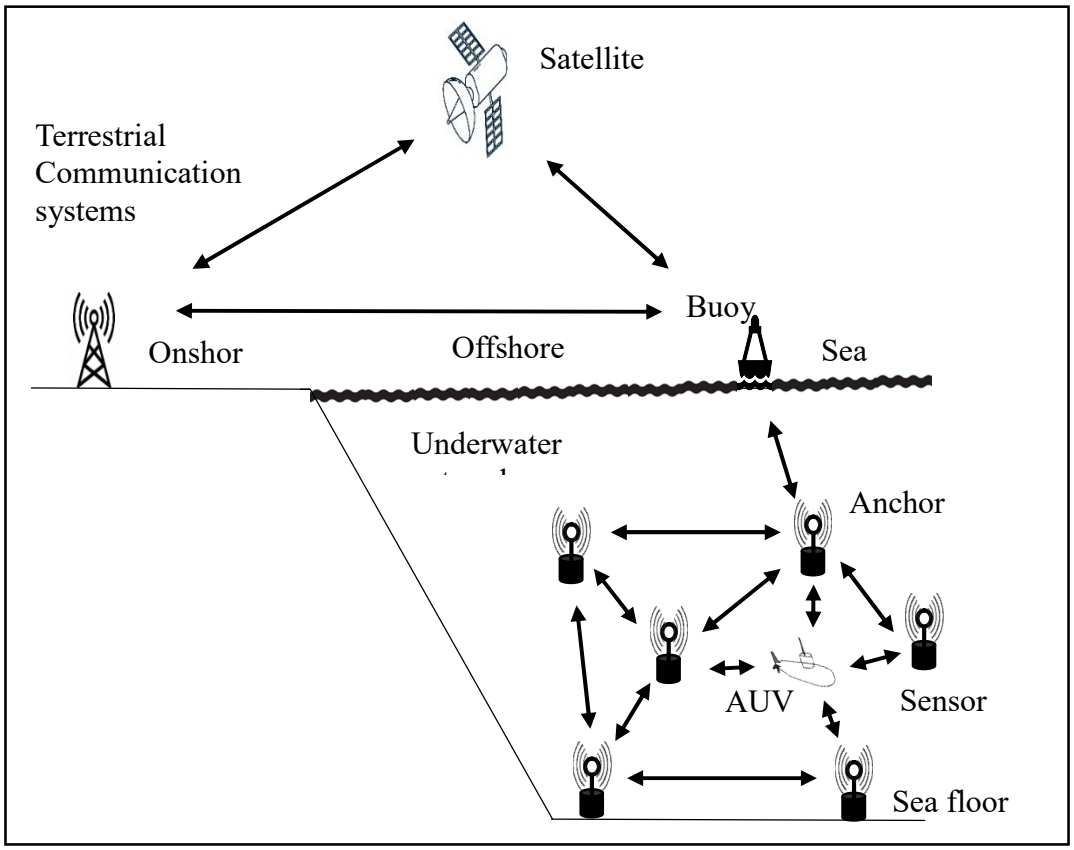

Fig. 1: Underwater sensor network architecture. AUV (Autonomous underwater vehicle)

Autonomously deployed sensor nodes are referred as 1D UWSNs. In this type of network each sensor node has a sensor and the related components to perform the function of sensing the physical parameter, processing the obtained data, and transmitting it to the remote station [IV]. In this architecture the sensor node is a floating buoy or an Autonomous Underwater Vehicle (AUV), which can dive below the surface of water, collect the data from the sensors and float to the surface to relay it to the remote station.

In 2D UWSNs the sensor nodes form a cluster underwater, which can communicate amongst themselves. The sensor nodes are in turn communicate with an anchor node, which collects the data from the sensor nodes and transmits it to the remote station.

3D UWSNs has a sensor node, anchor node and a floating buoy. The data collected from the sensor nodes and the anchor node is transmitted to the floating buoys which in turn transmit the data to the remote station. In 4D UWSNs along with the sensor node, anchor node and the floating buoy an AUV is also part of the network. The autonomous underwater vehicle collects the data from the sensor nodes and anchor nodes and transmit the data to the floating buoys and which transmit it to the remote stations.

Application of UWSNs :

UWSNs can be used for collecting the physical parameter information of the ocean like temperature, pressure, salinity, ocean currents, wind flow etc. [X], [VII].It can also be used monitoring the contamination of ocean water by pollutants, microorganisms, man-made wastages etc. It is also used for applications like offshore oilfield and mineral explorations andseismic or plate tectonic movements and as well as for surveillance and monitoring systems. The Ocean is a vast body of water. It has shallow as well as deep regions. The marine environment in the different regions vary considerably. The physical properties of water like temperature, pressure, pH, turbidity, density, salinity, oxygen level etc can vary significantly in the different regions. This variation can happen due to the water currents and the temperature and pressure variations, pollutants in the ocean. These variations also significantly affect the global weather conditions, marine life, fisheries, etc. Monitoring of these conditions help in making predictions in the weather of any location on the Earth. Sensors are deployed at appropriate locations in the Ocean. These sensors collect the data and send the data to the remote station. The analysis of these data is used to make the predictions on weather.

The biggest challenge of oceanographic data collection is in the deployment of the sensors and the collection of data from the sensors. UWSNs are used to collect the data. To collect this data the sensor network has to perform effectively. Researchers have developed specific network algorithms, protocols and routing mechanisms as per the marine environments and the requirements. A communication protocol with lower delay and better energy efficiency was developed for disaster mitigation and rescue operation [XI]. WSN frameworks and routing protocols were developed for environmental monitoring [VIII] and oil spillage monitoring [I].

Challenges and opportunities :

The deployment of sensor networks in marine environment have various challenges. Some of the issues are the protection of the sensors in a highly corrosive environment, remote location, energy harvesting etc. The marine environment poses serious challenges due to biofouling. Various methods are proposed to protect the sensors, but these methods are very costly to implement and may also consume a lot of energy.

Energy supply to the wireless sensor networks is another big challenge. As these sensors are located remotely, where the power from the grid will not be available, and hence all these sensors run on batteries. Due to remote location frequent replacement of the batteries is not possible. Energy harvesting methods should be developed for running these sensors on long term.

III. Discussion

Communication is mainly carried out using electromagnetic or acoustic waves. In terrestrial systems electromagnetic waves are preferred as it is high speed and most of the radio wave spectrum have very low attenuation through the atmosphere. Optical waves can be used to transmit information via optical cables. In underwater communication systems acoustic waves are preferred compared to electromagnetic waves. Electromagnetic transmission needs a large amount of energy and has high signal attenuation in water. Optical transmission requires high transmission rate. Therefore, acoustic are sound waves are considered to be functional to perform underwater communication. Underwater Acoustic Sensor Networks are made up of number of sensor nodes, anchor nodes,and autonomous vehicles which are deployed to perform appropriate tasks over the required area. An autonomous network of sensors and the vehicles is formedto perform certain specific tasks underwater. Few of the important applications of underwater sensor networks are discussed below

1. Oceanographic data collection: Underwater sensors are deployed in the ocean for collecting data regarding sea surface temperature, wind speed and direction, sea state wave height, air temperature above the surface, and atmospheric pressure at sea level. They can also be used to collect the real time data.
2. Pollution monitoring: Sensor networks are used to detect pollution and also to locate the source of pollution. Undersea vehicle access data from the sensors regularly and send them to the base station. The pollution in the water is identified using the sensor based monitoring system. The monitoring system has the chemical and biological sensors, along with the temperature, humidity sensors, for the identification of pollution [XIII].
3. Offshore explorations: Offshore oil platforms have to monitor the system for seismic activities, structural health of the installations, and also for exploration activities. UWSNs are highly cost effective and efficient in monitoring the offshore installations compared to the traditional methods. The operation is carried out by a monitoring system consisting of a network of sensors distributed over an offshore installation. Data is transmitted by underwater sensors, to the platforms and vessels. The vessels collect the data and also provide information for positioning the sensor.
4. Seismic monitoring: Seismic vibrations can cause significant damage to offshore installations and hence monitoring these vibrations and taking timely action to prevent any major damage or loss is important. Underwater position sensors are placed along the seafloor at different locations. The motion or vibration of the seafloor is monitored and any measurable signal is collected and transmitted to the base station to alert the concerned authorities.

5. Surveillance systems: Underwater surveillance systems are used for defense applications. Sensors are placed on the surface in the buoys, on the seafloor as well as at various depths in the sea. This gives a three dimensional coverage of the sea. Sensor nodes communicate with one another using acoustic waves in the aqueous mediumand the antennas in the surface buoys send the signal to the base station or via satellite communication to the overland stations. [II]

Some of the disadvantages of underwater sensors are as follows :

1. Underwater sensors have limited space for data storage. The storage devices in the underwater sensor systems are small and hence the capacity of the storage devices is limited.
2. The power of the batteries is limited and the power consumption is higher than regular electrochemical sensors
3. The sensors are expensive than the sensors used overland, as the sensors should have protection against extreme marine environment. They are easily affected by environment and surroundings. Underwater sensors are prone to failure due to the harsh marine environment which causes corrosion and foulingetc.
4. The deployment of underwater sensor networks is very challenging. The energy consumption, the bandwidth and the type of network is determined by the underwater environment.

IV. Conclusion

A brief review of the main challenges for deploying efficient underwater acoustic sensor networks have been discussed. As water being a medium not conducive to propagation of electromagnetic waves, acoustic waves are the preferred means of signal or data transmission. The usual wired networks or access point networks are very costly and time consuming, hence ad-hoc wireless networks are the preferred method for underwater sensing, data collection and communication. The sensor network require specific configuration and protocols. The marine environment also need to be considered while choosing the sensor networks. The architecture and applications of the sensor networks is also discussed. Which also considered based on the conditions underwater.Underwater sensors can be used to explore the unexplored side of the oceans.The sensor networks are used for oceanographic data collection like, temperature, pH, salinity, density etc. It is also used for offshore monitoring, seismic monitoring, pollution and water quality monitoring, surveillance systems etc.

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