Abstract
Wireless sensor network is a group of spatially distributed and dedicated tiny nodes that monitor and sense the environmental phenomena like temperature, pressure, humidity, or object location etc. Wireless sensor network can be of many types like terrestrial WSN and underwater WSN. Underwater WSN has emerged as a promising technique for various applications of underwater like pollution monitoring, prevention of disaster, detection of submarine and so on. UWSN is a network which consists of a range of sensor nodes which are spatially scattered to detect the water related properties like excellence, temperature, pollution tracking. The detected information can be implemented to a wide variety of area. The focus of this survey paper is to provide an overview on different applications of underwater wireless sensor network. Various design challenges for deployment of UWSN are also discussed.

Keywords: Underwater Sensor Networks, Applications, Challenges, Architecture.

I. Introduction

A WSN is made out of various small, low cost sensor devices which are having the abilities to detect their environment, perform restricted computation and communicating with other nodes in that network and monitoring the tasks over a given area. Wireless sensor nodes are used for both terrestrial and underwater applications. In our earth about 75% area is enclosed by water in the form of lakes, rivers, canals, oceans and seas. Most of the valuable resources lie under the water which is to be discovered. Underwater sensor network is an emerging technique that is used for the exploration of underwater. UWSN is an arrangement of independent sensor nodes which are spatially scattered under the water to detect the water associated properties for example, excellence and temperature [1][8][9]. The detected information can be used in various applications. The sensor nodes whether stationary or mobile are connected wirelessly by means of communication modules to exchange different types of information. Due to complex environment of water various routing protocols are used for communication between the sensor nodes in UWSN. UWSNs are used in various applications such as monitoring marine environment, pollution monitoring, prevention of disaster, detection of submarine etc. UWSN provides a promising solution for these applications. However, UWSN applications are energizing however complex at the same time.

This review paper focuses on different applications of UWSN used in different research areas over the years. In the” related work” section of this paper work done by various researchers in the field of UWSN is discussed. Work is summarized in the “conclusion and future work” section of the paper.

II. Applications of Underwater Wireless Sensor Network

This section describes various applications of UWSN.[10][11][12]

i) Monitoring application: Underwater monitoring refers to a system of sensors which is sent underwater to monitor the underwater environment, its attributes and properties. Underwater monitoring is of many types:
Water quality monitoring: With the fast improvement of the society and economy, an increasing number of human behavior have slowly but surely devastated the marine condition. So marine supervising is a fundamental issue. Various parameters of water are monitored like ammonium nitrogen, pH, electrical conductivity, dissolved oxygen with the help of underwater sensors [2].

Habitat monitoring: Underwater habitat monitoring manages the investigation of condition of any living creature living above or under water. It is one of the most challenging and exciting fields of natural sciences. Habitat monitoring, when measured underwater, turns out to be significantly difficult due to susceptible underwater conditions. ACMENet is an underwater acoustic sensor network which is used for monitoring various activities of marine organism inside water [3].

Underwater explorations monitoring: underwater is explored for the various types of minerals such as oil and gas with the help of UWSN. UWSN is used to explore various precious natural resources such as minerals and it also explores underwater pipelines and marine cables.

Disaster Prevention: disaster underwater is more dangerous than other natural disaster and this produce more destruction to the earth. UWSN offers an extensive wide range of applications for the administration and recuperation of such calamities. Along with insufficient resources for far reaching examining of the huge region of water like seas, the task turns out to be considerably more difficult with ruthless climate. In this manner, well-organized monitoring of nautical and aquatic environment is very difficult research confront. UWSN monitoring methodologies for the management of disaster and its avoidance is categorized into a variety of applications, for example, floods, volcanic explosion. Earthquakes under the water and their subsequent torrents, and oil spills which prompt above the water and underwater environmental variability [4].

Mine reconnaissance: The concurrent activity of various Autonomous Underwater vehicles with acoustic and optical sensors can be utilized to survey quickly natural variations and detect mine-like objects. The mines are generally comprised of ferrous materials and they can be separated from underwater clutter in view of the reality that the clutter is non metallic. Therefore utilizing metal detecting sensors can help to discover clutter underwater.[13]

Sampling ocean networks: Since the ocean is a three dimensional environment, that is continually changing. Oceanographers must frequently introduce numerous instruments over large areas or utilize portable vehicles, for example, robotics submarines to convey their instruments around. The sampling ocean systems were intended to test a variety of cutting edge strategies for monitoring vast areas of the seaside area. Systems of sensors and independent underwater vehicles can do brief, cooperative adaptive testing of the three dimensional coastal ocean atmosphere. Recently underwater experiments show the benefits of uniting complex new robotics vehicles with propelled ocean model to enhance the capacity to observe and foresee the qualities of the ocean condition [5].
v) **Assisted navigation:** Sensors can be exploiting to distinguish vulnerability on the seabed, to find risky rocks or shores in shallow waters, mooring positions, and underwater rocks.

### III. Challenges in Underwater Sensor Network

1. **Cost:** Sensors in marine cases are very costly and the prerequisite of sensors intended for the sensor system may be vast relying on the application. The cost of every sensor must be kept low generally otherwise cost of sensor network is not justified. Underwater sensor network devices are not easily accessible in the market.[24][25]

2. **Propagation delay:** The propagation delay in underwater sensor network is a major problem. The propagation delay of acoustic channels in underwater is of higher magnitude than radio frequency in the terrestrial sensor network.

3. **Attenuation:** Attenuation stands for loss of energy. There can be different reasons for the loss of energy in water. There are additionally absorptive losses that are caused by the transmission media. The loss of energy is because of the process of refraction, reflection and diffusing. There are also losses that are caused by multipath reflections from the surface, deterrents and variations of temperature in water.

4. **Limited battery power:** Underwater sensor network lifetime is a zone of broad research. In underwater sensor battery has restricted power. Hardware and electronics components have a tendency to corrupt under very low temperatures. As a result, underwater sensor network lifetime is significantly shorter than the lifetime of terrestrial sensor network. A shorter lifetime of battery increases the replacement cost since the underwater sensor battery is not chargeable. To save the battery of underwater sensors, sensor goes into sleep mode when not being used.

5. **High power requirement for communication:** In underwater sensor communication more power is required because the transfer of information is done in water medium. So, in water more power is required for information exchange. Communication among underwater sensor networks is likely the greatest challenge. Attenuation, noise, propagation delays, low bandwidth, and Doppler Effect can degrade the underwater communication channel. Another issue is that acoustic transducers cannot transmit and receive at the same time. Communication in underwater network is half duplex.

6. **Corrosion of hardware components:** Underwater Sensor nodes are sent in very ruthless conditions of underwater which leads to erosion of hardware components. If failure occurs then it becomes difficult to detect these failures before the recovery of instruments and this may lead to total failure of monitoring.

7. **Localization:** Localization implies discovering the area of sensor in underwater sensor network. So, localization is another significant issue to be solved. Localization is the challenging factor that requires labeling of data while basic applications require data without any time delay.

8. **Reliability:** This is one of the major problems in design issues of underwater sensor network. The delivery of data that is sensed underwater, to the surface sink or on surface of water is very difficult as compared to delivery of data to the control center on earth.

### IV. Architecture of Underwater Wireless Sensor Network

UWSN architecture is divided into many types[22][23].

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1) **2 D Architecture of UWSN**: This is the simple architecture of UWSN. In this architecture the individual nodes are placed down at the base surface of the ocean. The size of these nodes is smaller, operated by battery and they transmit information by means of acoustic modems. The cluster heads are too tied down to the floor of ocean. Cluster heads are having two acoustic transceivers called vertical and horizontal transceivers in addition with acoustic modems. The horizontal transceiver is used by the cluster head or underwater sink for communication with the sensor nodes. The communication between the cluster head and all other nodes in the cluster is done by the horizontal acoustic modems. The vertical transceivers are utilized by the underwater sinks to transmit the information to a surface station. The range of vertical transceivers must be long. The surface station is having an acoustic transceiver that can handle parallel communication with the underwater sinks. At last base station will send the detected information to the surface base station by means of radio frequency signal [6].

![Figure 1: 2D architecture of UWSN](image1)

2) **3 D Architecture of UWSN**: 3 D underwater sensor networks identify and monitor those phenomena that are not possible to detect by the ocean bottom sensor node. In three dimensional architecture of UWSN, the sensor nodes drift in the ocean at different -different depth in order to detect the given phenomena. In this architecture each and every sensor node is attached to the base surface of the ocean and prepared with a drifting buoy that is puffed up with the help of a pump. The buoy then move forwards the sensors in the direction of the surface of the ocean. Sensor depth is managed by alternating the length of wire that interface the sensor to the anchor, with the help of an automatically controlled engine [7].

![Figure 2: 3D architecture of UWSN](image2)

V. Related Work

1. Jun-Hong Cui et al. [14] in their paper proposed top down approach for exploring various research challenges in designing of underwater sensor network. The authors used layered protocol stack in describing challenges in design issue. They also described various unique characteristics of underwater sensor network and also explained two layer architecture of underwater sensor network.

2. Dario Pompili et al.[15] discussed about the problem to gather data in a 3D UWSN. Authors investigated this problem at network layer by considering the associations between the routing functions and the submarine acoustic physical channel. Authors also discussed about two stage resilient routing solution for monitoring purpose. The two stage routing solution is very effective because it provides energy efficient data paths and it is robust in nature.
3. John Heidemann et al.[16] discussed about various potential applications of underwater sensor network. Authors also described different architectures of UWSN. Authors in their research also discussed about acoustic communication in underwater network. They reviewed about various hardware components used for communication in underwater network. Various routing protocols like Latency-Tolerant MAC Protocols, in high latency network are also discussed.

4. S. Beeno Ancy et al.[6] described about the MPT (Multipath Power control Transmission) for efficient and reliable communication under water. MPT method consumes less energy than other transmission techniques. Retransmission also not required in MPT technique. MPT technique is divided into three parts for its working. In first step multipath routing method is explained. In second stage source initiated power-control transmission method is described. In the last stage combination of destination packet is done. Authors simulated the proposed method with the help of Aqua Sim simulator . They performed the simulation on 200 sensor nodes and these nodes are placed in a square area of 250 m x 250 m. The performance is analyzed with the help of various parameters like throughput, ratio of packet delivery, packet drop rate and energy consumption.

5. Shashank Yadav et al.[17] described about a technique named network management system for improvement of performance of underwater sensor network. Network management system sense the congestion in the network and then take corrective actions against this. NMS system performs various management tasks like power management, controlling the bandwidth use, controlling sampling frequency and also fault recovery. Authors also discussed about layered form conceptual architecture for underwater sensor network. This architecture is free from various limitations such as power limitation, bandwidth limitation, propagation delay, signal fading etc. They also used underwater autonomous vehicle used for various monitoring tasks. Authors discussed about working of each layer of underwater architecture and also discussed various challenges in designing underwater architecture. Authors explained basic properties of underwater wireless sensor network and build a reliable architecture that is free from congestion.

6. Jim Partan et al.[18] emphasized on practical issues in underwater network. The authors also discussed about various differences between terrestrial network and underwater networks. They also classified underwater network on various basic factors like node density, geographic coverage of node, range of link layer etc. authors also discussed about various technological limitations that are faced in underwater network. They also reviewed about MAC protocols and CDMA access method used in underwater network.

7. John Heidemann et al.[19] emphasizes the important applications like “off-shore oilfields for seismic supervising, “tools examining”, and “under robotics”. The authors in their work discuss about the MAC, Time-Synchronization, Short variety acoustic communication implementations and localization protocol for high latency acoustic networks. They focus on three important areas of underwater sensor networks: First, discuss the “hardware” required for acoustic communication in sensor networking. Second, “protocols” (like MAC, time synchronization, protocol and protocol for localization) needed for self-configuring of underwater network and third is, “Procedures” for forwarding and energy alert data caching purpose.

8. Salvador Climent et al.[20] by using the researches over the past years show the status of physical layer, MAC layer, routing layer and also show advances that can be made to these layers. They discussed the security threads of underwater network and many applications like monitoring of pollution underwater, oil extraction monitoring and aquiculture monitoring. The authors focus on using acoustic waves for communication purpose in water network. Authors in their work also discussed about lower layer i.e. physical layer of the
communication stack. They also discussed about MAC layer and various routing protocols used in that layer. Authors in their work also characterized underwater acoustic channel based on various key factors.

9. Davide Anguita et al.[21] discussed about various research challenges in building wireless underwater sensor network. They focus on using optical waves in communication underwater because these waves propagate faster in water and are of high bandwidth. Authors also discussed about various applications of optical underwater wireless sensor network like underwater environment monitoring, exploring biological life activities underwater etc. Authors also build a prototype of UWSN in their work that is based on optical communication. Optical physical layer is also developed that is having characteristics of IEEE 802.11 IR physical layer. Authors also verified the functionality of optical physical layer using a preliminary test.

VI. Conclusion and Future Work

In this paper the various applications over the past years and architectures mostly used in the field of underwater sensor network are discussed. UWSN sensor networks have various applications in various fields like monitoring, because they are equipped with intelligent sensors. The architecture design of underwater wireless sensor networks depends upon various key factors like environment, application's outline targets, and cost and so on. In this paper, overview of various papers on applications of UWSN is discussed. Various challenges and architecture design of underwater wireless sensor networks is also discussed. Underwater wireless sensing is an exciting and proliferating field of wireless sensor. It is quite hard to figure out an up-to-date and fine informed summary and discussions of the newest advancement in this area. There are no complete solutions for underwater networks since there is lot of challenges in building these networks and communications is not so easy. So the effective routings techniques for acoustic networks will remain an open research challenge in the coming years.

References


[9] Ian F. Akyildiz, Dario Pompili and Tommaso Melodia,”Challenges for Efficient


