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# Underwater Sensor Network Applications: A Review

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***Abstract:*** **There is no escaping fact that a huge amount of unexploited resources lies underwater which covers almost 70% of the Earth. Yet, the aquatic world has mainly been unaffected by the recent advances in the area of wireless sensor networks (WSNs) and their pervasive penetration in modern day research and industrial development. The current pace of research in the area of underwater sensor networks (UWSNs) is slow due to the difficulties arising in transferring the state-of-the-art WSNs to their underwater equivalent. Maximum underwater deployments rely on acoustics for enabling communication combined with special sensors having the capacity to take on harsh environment of the oceans. However, sensing and subsequent transmission tend to vary as per different subsea environments; for example, deep sea exploration requires altogether a different approach for communication as compared to shallow water communication. This paper particularly focuses on comprehensively gathering most recent developments in UWSN applications and their deployments. We have classified the underwater applications into five main classes, namely, monitoring, disaster, military, navigation, and sports, to cover the large spectrum of UWSN.**

***Keywords:*** **UWSN, WSN, Energy optimization.**

## I. INTRODUCTION

The 75% of earth's surface is covered with water in the form of rivers, canals, seas, and oceans. Plenty of precious resources lie underwater which are required to be explored. The key to successful explorations has always been technology dependent. Recent advances in technologies have led the possibilities to do the underwater explorations using sensors at all levels which were not possible previously. Accordingly, underwater sensor network (UWSN) is emerging as an enabling technology for underwater explorations. UWSN is a fusion of wireless technology with extremely small microme- chanical sensor technology having smart sensing, intelligent computing, and communication capabilities. UWSN is a network of autonomous sensor nodes [1] which are spatially distributed underwater to sense the water-related properties such as quality, temperature, and pressure. The sensed data can be utilized by variety of applications that can be used for the benefit of humans. The sensor nodes, stationary or mobile, are connected wirelessly via communication modules to transfer various events of interest [2]. Underwater com- munication is mainly done with a set of nodes transmitting their data to buoyant gateway nodes that relay the data to nearest coastal monitoring and control station also called remote station [3]. Generally, in UWSN acoustic transceivers are used for communication. The acoustic waves are low frequency waves which offer small bandwidth but have long wavelengths. Thus, acoustic waves can travel long distances and are used for relaying information over kilometers [4]. UWSNs are utilized for a wide range of applications such as monitoring the marine environment for scientific explo- ration to commercial exploitation and coastline protection to underwater pollution monitoring, from water-based disaster preventions to water-based sports facilitation. UWSN offers a promising solution to ever demanding applications. However, UWSN applications are exciting but challenging at the same time. The reason lies in unpredictable conditions of water environment which creates serious constraints in the design and deployment of such networks. The focus of this paper is to survey the available UWSN application. The paper further focuses on classifying these applications and presenting a summary for each class.

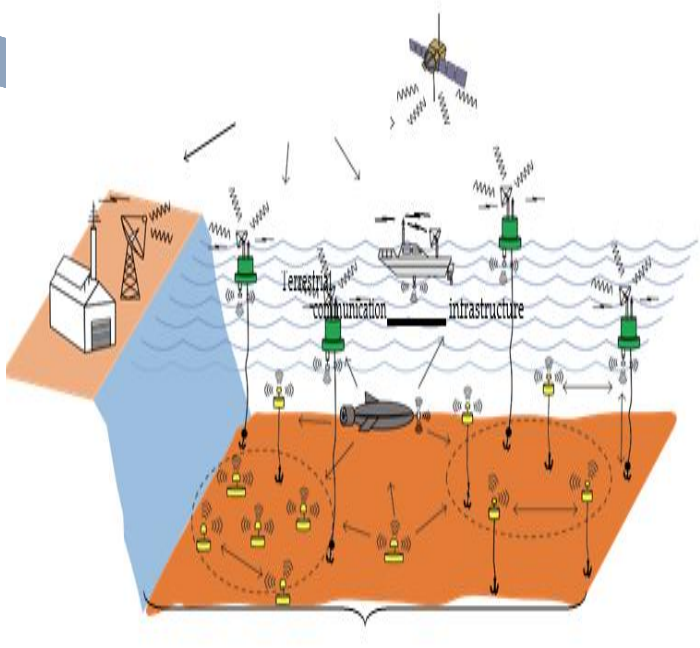


Figure 1 UWSN

The rest of the paper is organized as follows: Section 2 dis- cusses the general architecture of UWSNs. Section 3 discusses the recent research contributions in the field of UWSN and provides a detailed application classification. The challenges and opportunities for UWSN are detailed in Section 4. In the end, Section 5 concludes the paper.

## II. UNDERWATER WIRELESS SENSOR NETWORK ARCHITECTURE

In this section, we discuss the common UWSN architectures (Figure 1) which are basis for designing the UWSN applications.1D-UWSN Architecture. One-dimensional- (1D-) UWSN architecture refers to a network where the sensor nodes are deployed autonomously. Each sensor node is a stand-alone network itself, responsible for sensing, processing, and transmitting the information to the remote station [5]. A node in this type of architecture can be a floating buoy which can sense underwater properties or it can be deployed underwater for a particular period of time to sense information and then float towards the surface to transmit the sensed information to the remote station. It can be an autonomous underwater vehicle (AUV) which dives inside the water, sense or collect the underwater properties, and relay the information to the remote station. In 1D-UWSN the nodes can communicate using acoustic, Radio Frequency (RF), or optical commu- nication. Moreover, the topological nature of 1D-UWSN is star where the transmission across the sensor node and the remote station is carried over a single hop.

2D-UWSN Architecture. Two-dimensional- (2D-) UWSN architecture refers to a network where a group of sensor nodes (cluster) are deployed underwater. Each cluster has a cluster head (also called anchor node). The clusters are fixed as they are anchored at the underwater surface. Each member of the cluster gathers the underwater data and communicates it to the anchor node. The anchor node gathers the information/data from all its member nodes and relays it to the surface buoyant nodes. In 2D-UWSN, the communication is carried in two dimensions; that is, (i) each member of the cluster communicates with its anchor node with horizontal communication link while (ii) the anchor node communicates with the surface buoyant node with vertical communication link. In 2D-UWSN, acoustic, optical, and RF communication can be used depending on the type of application and nature of underwater environment. In 2D-UWSN, acoustics communication is preferred for underwater anchor node and the surface buoyant node due to typically high distance between them. For the cluster of nodes, the network arrangement can be star, mesh, or ring depending on the application requirement. The 2D-UWSN can be used for both time-critical and delay tolerant applications [6].

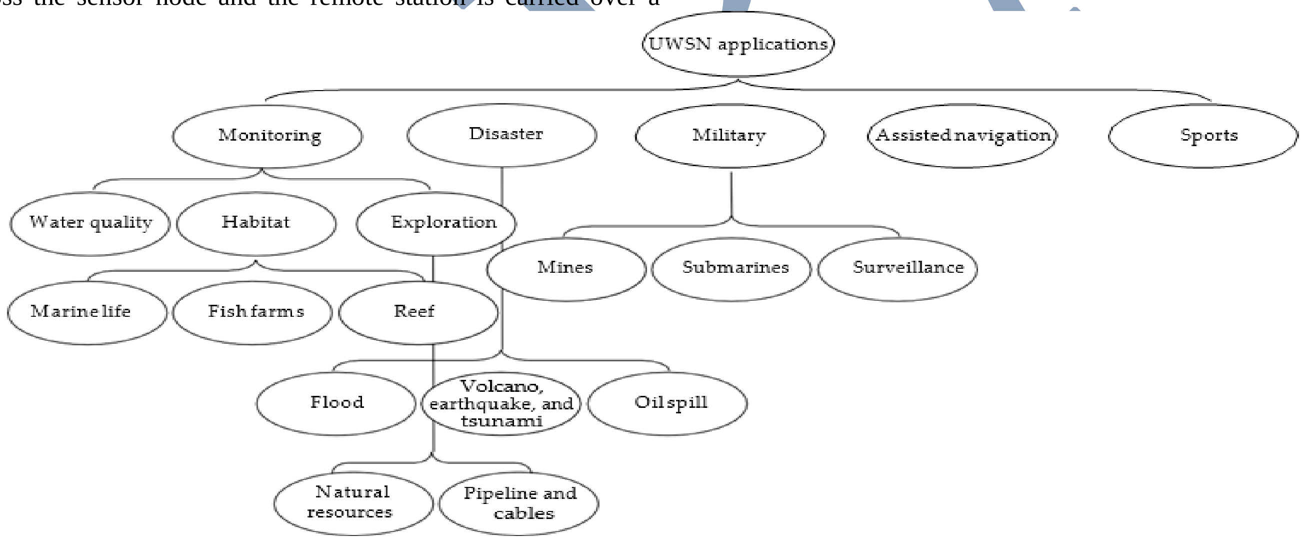


Figure 2: Classification of underwater wireless sensor network applications.

3D-UWSN Architecture. In this type of network, the sensors are deployed underwater in the form of clusters and are anchored at different depths. Due to the deploy- ment of the sensors at variable heights, the communication between the sensors goes beyond the two dimensions. There are three communication scenarios in this architecture: (i) intercluster communication of nodes at different depths, (ii) intracluster (sensor-anchor node) communication, and (iii) anchor-buoyant node communication. In all three types of communication scenarios, acoustic, optical, and RF links can be used.

4D-UWSN Architecture. Four-dimensional- (4D-) UWSN is designed by the combination of fixed UWSN, that is, 3D-UWSN and mobile UWSNs. The mobile UWSN consists of remotely operative underwater vehicles (ROVs) to collect data from the anchor nodes and relay the data to the remote station. ROVs can be autonomous submersible robots, vehicles, ships, and even submarines. Each underwater sensor node can be autonomous in relaying the data directly to ROVs depending on how close that particular sensor node is to the ROV. The communication scenario between ROV and underwater sensor node depends on the distance and data between them and either acoustic or radio can be used. As the transmission is to be directly relayed to ROV, the sensors which have large data and are close to ROVs can use radio links while the sensors which have small data to transmit or are far from ROV can use acoustics links [7, 8].

## III. UNDERWATER WIRELESS SENSOR NETWORK APPLICATION CLASSIFICATION

UWSN applications are rapidly gaining popularity for enabling advances in the area of ocean monitoring and observatory systems, deep sea surveillance, tracking of var- ious entities of the aquatic environment, and unearthing resources. UWSNs find their application in fields like off- shore oil and gas extraction, oil spills, military surveillance and reconnaissance, mine detection, pollution monitoring, natural calamities like tsunami and hurricane forecast, coral reef and habitat monitoring of marine life, and fish farming. A comprehensive classification of potential UWSN applications is shown in Figure 2. This section presentsa survey of recent developments in the domain of UWSN applications. At the top level we classify the UWSN applications as monitoring, disaster forecasting and management, military, navigation, and sports which are going to have a significant impact on the underwater world and provide benefits to the humans. We then further classified monitoring, disaster, and military applications into relevant subclasses.

Monitoring Applications. Underwater monitoring refers to a network of sensors which is deployed underwater to monitor the underwater environment, its characteristics, properties, or any object of interest. These applications areparticularly related to monitoring the physical environment. Underwater monitoring applications can further be classified into (i) water quality monitoring, (ii) habitat monitoring, and

(iii) monitoring underwater explorations.

Disaster. Generally, the natural disasters are inevitable. Among others, water based natural disasters are more dan- gerous and produced huge destruction to the earth. Accord- ingly, disaster monitoring and preventive mechanisms are very necessary. UWSN offers a wide range of applications for management and recovery of such disasters. More par- ticularly, it relates to the monitoring of events that aggravate a disasters aftermath. Along with inadequate resources for comprehensive monitoring of the vast area of water (e.g., ocean), the task becomes even more challenging with occa- sionally ruthless weather. Therefore, efficient monitoring of marine and aquatic dynamics is a significant research chal- lenge. UWSN monitoring strategies for disaster management and prevention can be formulated into a wide variety of applications such as floods, underwater volcanic eruptions, underwater earthquakes and their resulting tsunamis, and oil spills which lead to above-the-water and underwater ecological instabilities.

Military. UWSNs are employed to assist military appli- cations as well. These systems take the aid of different sensors deployed for detection of different aspects of military appli- cations. Different sensors such as cameras, imaging sonars, and metal detectors integrated with AUVs are used to assist in finding underwater mines, securing ports, and submarines and are also used for monitoring and surveillance. These applications can lead to economic solution to protect naval forces.

## IV. Challenges and Opportunities

While UWSN is a promising new field and may help in exploring the unfathomed world that lies underwater, there are many challenges and opportunities as well.

Unpredictable Underwater Environment. Underwater condi- tions are extremely unpredictable. The anonymous high water pressure, unpredictable underwater activities, and uneven depths of the underwater surface make it difficult to design and deploy UWSNs. Intricate Network Design and Deployment. Due to the unpre- dictable underwater environment, it is extremely difficult to deploy the network underwater which works reliably and wirelessly. The current tethered technology allows con- strained communication but it incurs significant cost of deployment, maintenance, and device recovery to cope with volatile undersea conditions.

Unscalability.

Traditional underwater exploration relies on either a single high-cost underwater device or a small- scale underwater network. Neither existing technology is suitable for applications covering a large area. Enabling a scalable underwater sensor network technology is essential for exploring a huge underwater space.Unreliable Information. Underwater nodes are in continuous motion due to the water currents; thus locating nodes underwater becomes much more crucial. Traditional posi- tioning and localization systems do not work underwater. Therefore, underwater conditions dismantle the location of the nodes and the network topology which ultimately makes the information transmission unreliable. Requirement of Novel Protocols for UWSNs. In underwater communication, the medium of communication is water, unlike air as in terrestrial sensor networks. Therefore, terrestrial sensor network communication protocols get void underwater. Mostly, acoustic signals are used for underwater communication over large distances, while radios are con- sidered for short-distance, water surface communication. But radio signals transmit for long distances at extra low frequen- cies, which requires large antennas and high transmission power [1], which can decrease the overall network lifetime of UWSNs. Moreover, the propagation delay of acoustic com- munication is very high compared to RF communication; hence many algorithms and protocols for terrestrial WSN cannot be adapted directly to UWSN.Low Data Rates. Radio frequency (RF) communications are not effective in underwater communication due to medium effect on communication. Water absorbs much of the RF energy and hence only very short range communication is allowable using RF [4]. Instead, acoustic communication is being used to transmit pulse signals and low fidelity informa- tion underwater due to its low bandwidth. Potential UWSN applications such as measuring the amount of pollution from a fishing farm at the seabed [21] require transmitting lots of data. However, with such low frequencies, it requires a lot of time to send such dynamic data. Physical Damage to Equipment. The sensors used in underwater devices are susceptible to routine underwater challenges, for example, algae collection on camera lens and salt accumulation, decreasing the effectiveness of sensors and so forth. Cost. Finally, the energy requirements and cost of UASNs are high compared to higher power and regular battery replenishing techniques are quite costly. The amount of challenges in designing of UWSNs makes it an interesting area for researchers to work on. With the advancement in sensor and wireless technologies, UWSNs have attracted a lot of researchers and have contributed significantly to this field. However, the window is still wide open for upcoming research and opportunities.

## V. CONCLUSION

In this paper, we have presented a comprehensive literature review of UWSN applications and their classification. It was observed that a good number of applications are assisted by UWSNs for the harsh underwater environment. UWSN has become one of the prime focuses for researchers. If these applications are properly exploited and catered, a lot of lives, time, and money can be saved. Although UWSNs have seen a tremendous amount of growth in the past few years, there is still a room for ample contributions particularly in the physical deployments of the systems on large scale.

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