

# UW-Hybrid Architecture of Underwater Acoustic Sensor Networks

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**Abstract:** Ocean is one of the concerning research these days. Many marine applications seems comparatively slow in exploiting the information communication technology. In this paper, new UW-Hybrid architecture for 2D and 3D communication is proposed for underwater acoustic sensor networks. The objective of this paper is to highlight the drawbacks in the existing architecture of underwater networks. This paper also focuses on the research issues of different layers in the protocol stack of underwater networks. Cross layer protocol stack is one of the solution of above given problem is explained briefly here to compensate for possible limitation in the layer interface.

**Keywords:** UW-hybrid subnet, Gateway collector, cross layer protocol, underwater acoustic sensor networks.

## 1. Introduction

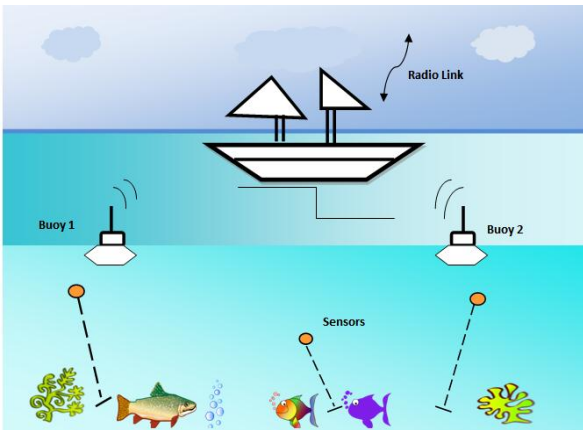
The research of underwater networks pays an important attention due to their various applications like military, commercial, scientific and industry application purposes. After the end of Second World War, a submarine communication system was developed in USA as a first underwater acoustic system. Technology has since developed from digital modulation of radio frequency signals into the forefront of modern acoustic communications [1]. Today, different acoustic modems are available commercially for the purpose of underwater communications. Further, research has moved to the acoustic networks.

Underwater networks is made up of some components like sensors equipped with transducer, buoys, surface sink or station used for exploration purpose as shown in Figure1. An Underwater acoustic networks (UANs) can be of different types like underwater acoustic sensor networks (UASNs) or autonomous underwater vehicle networks (AUVNs) or unmanned underwater vehicle networks (UUVNs) or the combination of all of them [2]. UASNs are composed of many sensors which are used for communication using acoustic signals.

AUVNs or UUVNs are computer controlled robot systems operating in underwater environment. They are self guiding, position tracking and self power vehicles. Most of the AUVs Vehicles are less expensive and lighter in weights which are used for the research purposes [3]. Till date, different underwater vehicles are launched. It is used to collect the data from ocean and computerize the process of data gathering with accurate Geographic locations.

The broad applications of underwater networks include but not limited to [5][6]-

- Underwater Exploration – underwater exploration are very difficult for human beings due to low temperature, high pressure, dangerous mammals, unpredictable water activity and vast size of unknown area. Researchers used UANs to explore such a wide area of ocean and make familiar of ocean environment to us. It includes ocean test beds, minerals, oil fields, cable or pipeline tracking, navigational routes, etc.
- Environmental Monitoring – Global warming is one of the important issues in the ocean environment. UANs can be used to monitor change in ocean current, variation in temperature and levels of water in the ocean scenario. Pollution is also one of the main aspects in the underwater environment. UANs are used to observe different kinds of pollution like chemical, biological, nuclear and oil leakage pollution in the ocean.
- Disaster Prevention – Tsunami, sea-quack and under marine activities warned to the coastal areas in real time by acoustic sensor networks which are deployed in underwater surroundings.
- Seismic Communications – In underwater networks, exchanging the information among different sensors with the help of gateways and underwater vehicles. The primary goal of underwater networking is to exchange information from underwater networks to onshore sinks to get the real time information of oceans.



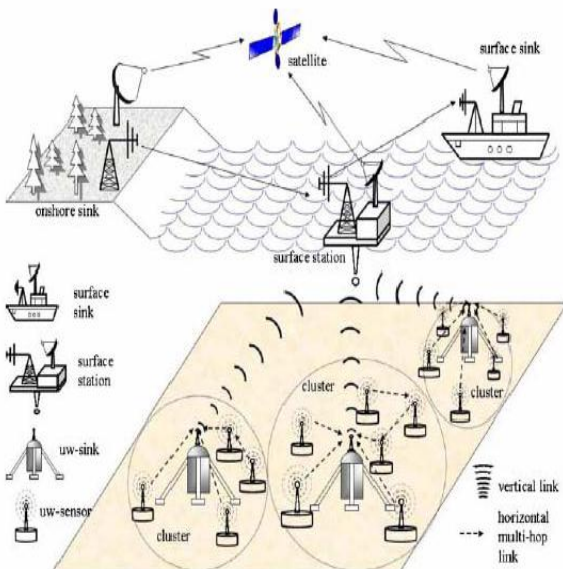
**Figure 1:** Underwater Acoustic Sensor Networks (UASNs).

## 2. Architecture of Underwater

There are two architecture of underwater acoustic sensor networks are as under-

### 2.1 Two-Dimensional Architecture

In this deployment strategy, all the sensor nodes and uw-gateways are anchored to the bottom of the ocean in such a manner that they form cluster based architecture. Each sensor nodes are equipped with uw-gateways through horizontal acoustic link. Information collected by the sensors nodes are conveyed to uw-gateways through acoustic signal. UW-gateways are electronic devices used to convey the collected data to surface sink by the mean of vertical acoustic links. Surface sink is equipped with acoustic trans-receiver for the purpose of parallel communication with uw-gateways [7]. The architecture of 2D-UASNS is shown in Figure2. Here, the main objective of 2D architecture is to monitor the ocean bottom but failed to define 3D environment.



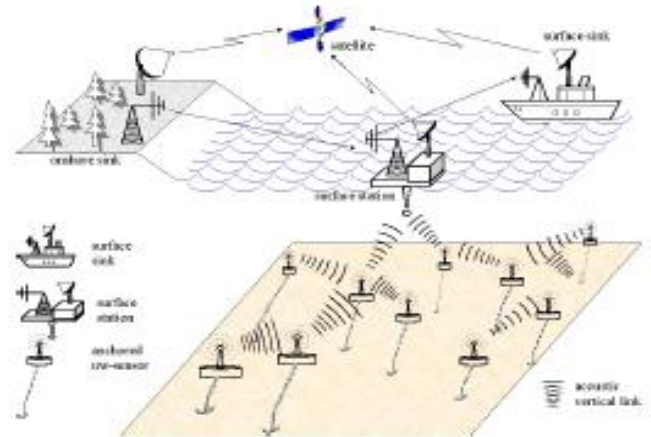
**Figure 2:** Two Dimensional Architecture.

### 2.2 Three-Dimensional Architecture

3D UASNs is used for column monitoring in underwater environment. In this, sensors are equipped with surface buoys by the mean of wires whose length can be regulated to monitor different depths in 3D surroundings. But this solution of 3D UASNs fails due to navigational obstruct on the ocean surface. Surface buoys can be easily detected and disengaged by the

enemies. Furthermore, surface buoys are vulnerable to weather and meddling and purloining [8].

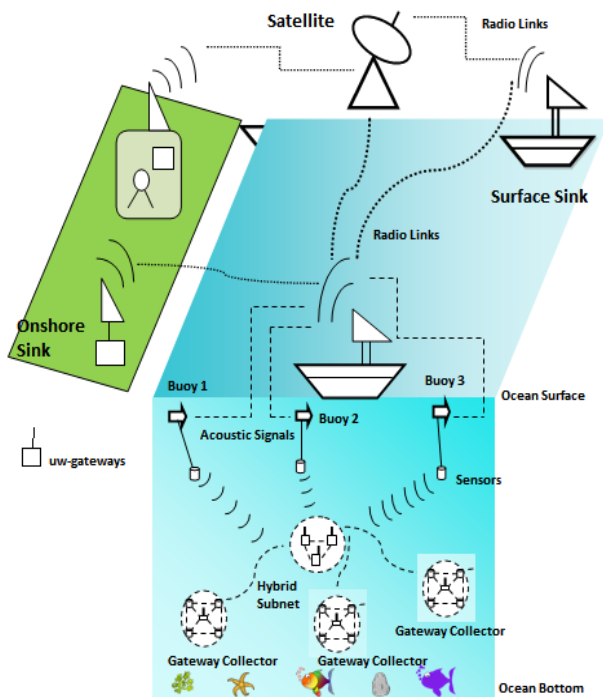
A different approach is used to solve the above problem in underwater approach. A winch-based sensor device is deployed in such a manner that each sensor are anchored to the ocean bottom and is equipped with floating buoys that can be raised by the pump as shown in Figure 3. The floating buoys tow the sensors towards the ocean surface. [9] The depth can be arranged by the mean of wire that connects the anchored sensor in underwater networks. But this architecture also leads to some problem in improper 3D coverage, failure of sensor nodes, improper communication between the sensors, alarm of danger signals is still not mentioned.



**Figure 3:** Three Dimensional Architecture

## 3. Proposed Architecture of Underwater

A new architecture is deployed named as UW-Hybrid Architecture of UASNs for heterogeneous network communications. This architecture is the combination of both 2D and 3D environment. In this, transducer sensors, uw-gateways, hybrid subnet of gateway are anchored to the ocean bottom. Each sensor is connected with uw-gateways electronic device by the mean of horizontal acoustic links. UW-Gateway devices are used to collect data from each sensor via acoustic link. Furthermore, all the anchored sensors are also connected with acoustic signals to each other. The information received by uw-gateway devices are conveyed to uw-hybrid subnet that is equipped with highly powered gateways through coaxial cable. UW-hybrid subnet is a hub of all the information or data received by all gateway collectors. A gateway collector is a combination of sensor and uw-gateways by the mean of acoustic signal coverage. The diagram of uw-hybrid architecture is shown below as Figure 4. Floating buoys are equipped with sensor by the mean of wire that can be regulated to monitor the different depth in 3D column of ocean. Floating buoys are inflated with pumps and pulls the sensors towards the ocean surface. Floating buoys are placed in underwater in such a manner that avoids navigational obstruct. UW-Hybrid subnet network relay the data to the sensors of floating buoys which in turn communicate with surface sink. Surface sink is equipped with acoustic transponder for multi path communication to floating buoys. Further this reference is relayed to onshore sink on satellite through radio signals.



**Figure 4:** UW-Hybrid Architecture

The advantages of using uw-hybrid architecture are given below:

- UW-Hybrid subnet focuses on the failure or unused network or sensors.
- Multipath communication is used in this architecture due to low bandwidth to avoid propagation delay.
- One of the sensors in uw-gateway collector is danger active sensor which immediately informs to the other sensors or surface sink.
- Fading is comparatively low in this architecture because the environment of underwater is sparse network environment.
- UW-Hybrid subnet also signals for low power to the surface sink. AUVs are used to supply energy to the uw-hybrid subnet or sensors time to time or when needed.
- The data rate of uw-hybrid subnet is comparatively high due to the collection of gateways and multipath environment.

## 4. Research Challenges in Underwater Sensor Network

In this section communication of underwater acoustic sensors network is more challenging issue than terrestrial network. Different layers of underwater sensor network for communication are focused with respect to physical layer, data link layer, network layer, transport layer and application layer.

### 4.1. Physical Layer

The communication media for underwater network is acoustic signals. But there are so many limitations of acoustic communication in performance criteria, lower bandwidth and propagation delay. Many modulation techniques are used to improve the efficiency like Frequency Shift Keying (FSK), Frequency Hopped (FH), Code Division Multiple Access (CDMA), Spread Spectrum, Multicarrier Modulation and Multi-input Multi-output Techniques. But every modulation technique has some drawback related to physical challenges in underwater like low data rate, high propagation delay, low bandwidth, etc. Other issues in physical layers are to design

inexpensive transportation modem in underwater communication. Also necessary to enable real time underwater communication with low cost. Also focus on the low complexity coverage area rapid communication.

### 4.2. Data Link Layer

Data Link Layer can be divided into Logical Link Control (LLC) and Medium Access Control (MAC) Layer. The function of LLC are error recovery, user addressing and perform flow control operation. MAC layer is used to perform control of access to the media of underwater network. MAC controls the sensor nodes in underwater network to access the channel and also used to detect the error during the communication of underwater acoustic sensor network. There are so many MAC protocols for underwater network but still some of the open research issues are mentioned below [11][12][13][14]:

- Transmitting and receiving nodes are not synchronized.
- Low complexity encoders and decoders are needed for Forward Error Corrections (FEC) functionalities to limit the processing power.
- Optional Data packet length is record to maximize the network efficiency.
- Distributed protocol should be designed to overcome the activity of the nodes

### 4.3. Network Layer

The duty of network layer is to find the route from source to destination using different gateways of underwater sensor networks. Different routing protocols for underwater sensor network are discussed in [15][16]. Due to different nature of underwater environment there are so many difficulties in network layer that need to be focused as [17][18]

- Redeveloped algorithms and protocols for time critical applications that deals with disconnection caused by failure mobility of nodes on battery depletion.
- Robust algorithm should be designed as the quality of link is not predictable.
- Simulation tools needed to be developed.
- Mechanism should be designed to overcome the loss of connectivity without algorithm retransmission for delay tolerant applications.
- Necessary to design global positioning system for underwater.
- Reconfiguration of underwater network is also challenging issue.

### 4.4. Transport Layer

The function of transport layer is to provide end-to-end connectivity of underwater sensor network. Transport layer provide reliable connectivity between the underwater networks. Till date transport layer is unexplored research area for underwater. Many protocols of transport layer is developed and discussed in [21][22][23]. Some open issues for transport layer in underwater sensor networks are as shown below:

- New transport reliability algorithm should be propped for underwater acoustic channel.
- New mechanism should be developed to overcome the packet loss during transmission in underwater communication.
- Efficient algorithm should be designed to deal with reliability and network performance.
- Optional update policies are needed to present congestion an maximize the network efficiency.



#### 4.5. Application Layer

The function of application layer is to provide network management protocol that make lower layer transparent to the management application layer . Different application layer protocol for terrestrial sensor networks are Telnet, FTP, SMTP, etc. Not much effort has been made address different protocols for different purposes. Complete set of new protocol should be required for underwater acoustic environment [19]. This layer is also unexplored till date. Hence need lot of effort to understand the application area and communication issues for UANs.

### 5. Cross Layer Protocol Stack

A cross layer approach is highly recommended to optimize the above problem of different layers during communications in underwater environment. The protocol stack of Physical layer is used for connection services like activate, maintain, and deactivate connections and transmission services. Transmission service includes data rate, energy of sensor nodes and the bandwidth of underwater communication. Also focus on half duplex or full duplex mode of underwater communications. A protocol stack for uw sensor should combine power management, synchronize service, error and flow control service, routing services, end-to-end services, security services and network services as shown in Figure 5. Data link layer, network layer, application layer should be designed and studied jointly to improve the existing issues of underwater networks [20]. The synchronization service is responsible for synchronizing between different communications nodes to avoid delay tolerant application. Error and flow control management services is responsible for error in correction and communication, etc. Routing management services are responsible for deciding proper and shortest route from source to destination to avoid congestion network failure, etc. Reliability services should be focus on the reliable and accurate transmission of data between the nodes. Power management services are responsible for network functionalities to avoid energy extra consumption. Security plane is responsible for providing secure data during communication. Localization plane is responsible for providing global positioning services for accurate information in underwater acoustic sensor networks. These above techniques can be used to improve the network efficiency. The objective of the cross layer protocol stack is to overcome the shortcomings of the traditional layer in the underwater network.

### 6. Conclusion

In this paper we have discussed the issues posed by different architecture of underwater acoustic sensor networks. We have developed a new architecture in this paper to compensate the existing issues in existing underwater architecture. Also focus on the research issues and challenges of traditional layers in the network protocol stack of communication. This paper also highlights cross layer protocol stack as a optimal solution for a new network design. By this, we may conclude that he research on the underwater sensor network is still in the progress stage.

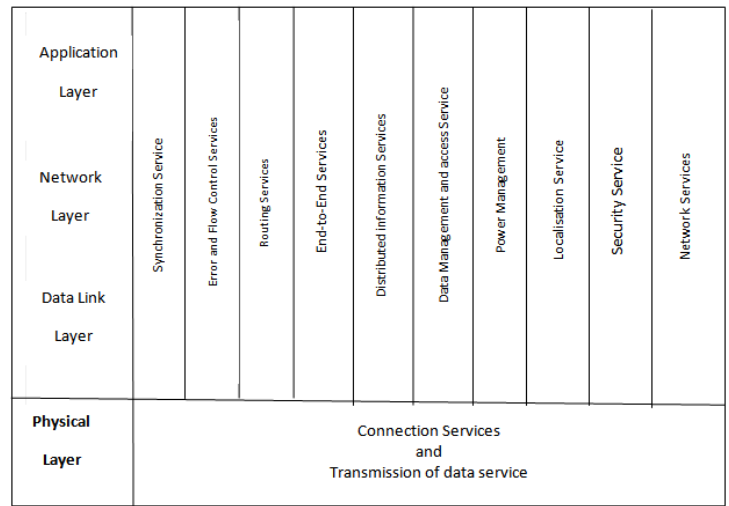


Figure 5: A Cross Layer Protocol Stack in underwater networks.

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**Tanu Singh** Regular M.Tech Scholar with various computer as well as technical Skills with first class in Feb 2014 from Punjab Technical University, Jalandhar. Completed B.Tech from Punjab Technical University, Jalandhar with first class in 2011. During my training era of 6 Months, I worked in an organization to develop the eLearning Platform for students i.e. Skylearning.in – learning for anywhere at any time. Indulge in the portion of feasibility study of the product, Modeling, creating documents, testing portion. Also indulge to provide Telephonic as well as Client Site Support to the learners and Users.



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