Directional Vector Forward Focused Beam Routing Protocol for Underwater Sensor Network

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This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Electronics and Telecommunication Engineering.
(B. Sc. in ETE)

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APPROVAL

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We hereby declare that this thesis Report has been done by us under the supervision of Engr. **Md. Zahirul Islam**, Assistant Professor, Department of ICE, Daffodil International University. We also declare that neither this report nor any part of it has been submitted elsewhere for award of any degree or diploma.

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DEDICATION

THIS THESIS IS DEDICATED

To the Martyred Intellectuals of 1971

ABSTRACT

Providing scalable and efficient routing services in underwater sensor networks (UWSNs) is very challenging due to the unique characteristics of UWSNs. Firstly, UWSNs often employ acoustic channels for communications because radio signals do not work well in water. Compared with radio-frequency channels, acoustic channels feature much lower bandwidths and several orders of magnitudes longer propagation delays. Secondly, UWSNs usually have very dynamic topology as sensors move passively with water currents. Some routing protocols have been proposed to address the challenging problem in UWSNs. However, most of them assume that the full-dimensional location information of all sensor nodes in a network is known in prior through a localization process, which is yet another challenging issue to be solved in UWSNs. In this report, Directional Vector Forward Focused beam routing (DVFBR) is proposed for UWSN. Former protocols have been compared & constructed with new one. Routing in UWSN will be made more dynamic with this new protocol. Later on performance of newly derived protocol are revised efficiently.

Chapter One

Introduction

1.1 General Introduction

The ocean is colossal as it covers approximately two-three of the entire earth surface. In fact, the oceans accommodate approximately 96.5% of entirely earth aquatic (Zenia et al,2015) [1]. And the majority of the population of the world resides closer to the 100 Km of the coastal areas. Surprisingly we don't have substantial understanding about the world's aquatic forms. Regardless of its vivid character in as long as crucial aspects of our lives e.g. Nutriment, methods of moving, environmental possessions better guard embellishment, although an extensive ration of the territories immobile unfamiliar (Felemban et al,2015) [2]. The submerged wireless device network is an expeditiously expanding area of research. A new phenomenon that submerged sensor nodes arranged to enable logical and viable, uses, environment and pollution monitoring, seismic monitoring equipment monitor, calamity avoidance planned scrutiny and supported navigation (Akyildiz et al, 2005) [3].Tomake To make application possible,it is expected to empower correspondence among submerged gadgets. (Headrick and Freitag, 2009) [4].

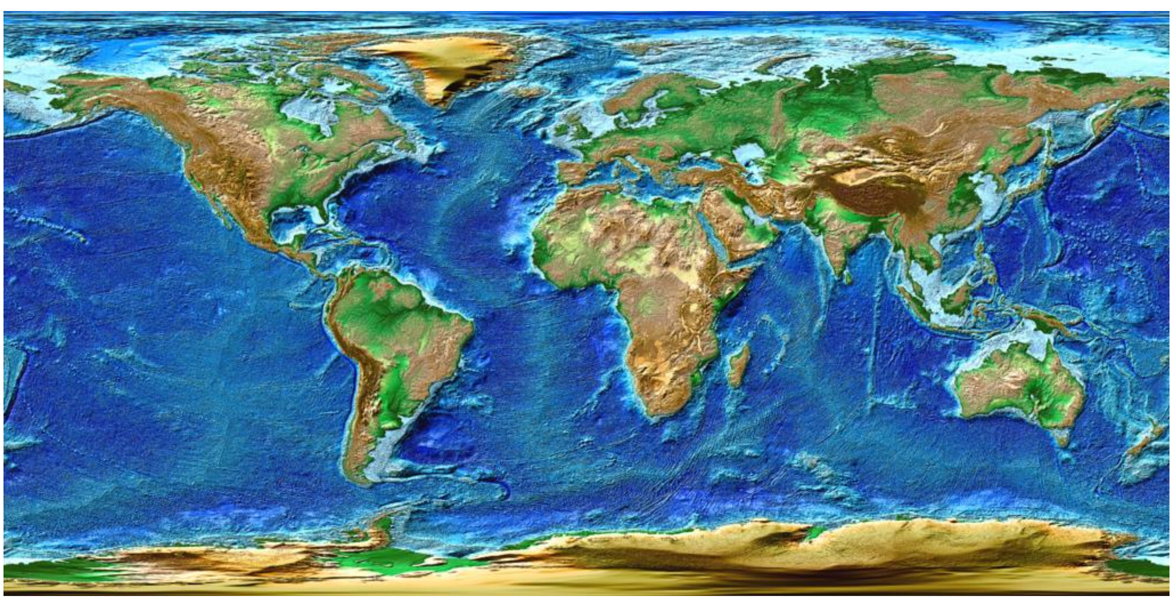


Figure 1.1: Earth water and surface portion.

The classic underwater applications stand in need multi-hop, Cooperative network sensor hubs must be capable of substituting configuration position and effort data and of conveying data to an aground location via satellite-terrestrial radio frequency (RF) network (Heidemann et al, 2012)[5]. Yet, RF be able to be broadcasted over conductive seawater at small frequencies of between 30 and 300 Hz, which requires a enormous antenna and high transmission power(Talley and Calcutt 2001) [6]. There is another way of communication that scientist have been thought about Optical signal communication, but there is some problem on it, that is it also has attenuation and dispersion (Ali 2013) [7]. Underwater wireless sensor networks are widely used to collect oceanographic data, such as abnormalities that cause natural calamities, to track other submarines (navigation and surveillance) and also water pollution. The main limitations of wireless sensor networks underwater are battery power, limited bandwidth, multi-path, fading problems, high bit error rates, propagation delays and they are also more prone to corrosion, foul formation, etc. These limitations show that they have fewer lifetimes compared to TWSNs. Ultralight weight components are required due to the limitations and requirements of these UWSNs. The main physical attacks of wireless underwater sensors jam and drop. Due to the removal of data, confidentiality losses can lead to other malicious attacks which lose both the availability and the integrity of the data. The main problem with underwater wireless sensor networks is that they provide highly efficient safety but use less space, fewer computations and low bit rates. Therefore, the security techniques used for terrestrial wireless sensor networks based on all the above reasons are not at all suitable for UWSN. So above this method are not properly apply for the good communication of underwater environment. The wireless acoustic sensor networks (WASN) use as the substitute that like to be a realistic technology for underwater communication. In underwater here we create a new set of routing protocols optimized the various factors that differ from the traditional routing technique. Acoustic communication is usually physical layer technologies that use sound wave propagation to link communication. The acoustic network improves the distance whereas the typical technologies lie in between frequency 10 Hz to 1 MHz . For the minimizing various factors from the raw difference in the wireless sensor network and terrestrial network scientist create a new set of a routing protocol. The protocol proposes low performance of terrestrial wireless sensors (WSN) in underwater environments (Rahman et al, 2013) [8]. For this reason, most researchers have focused on the development of a new network infrastructure and protocol suitable for UWSNs. A state-of - the-art outline of UWSN is provided in (Akyidiz et al, 2007) [9] where the feature of the underwater channel in ocean environmental monitoring applications is discussed (Akyidiz et al. 2005)[3]. Authors discussed several fundamental UWSN effects.

1.2 Motivation

More than two third of the planet secured with water whose huge measures of potential have been stayed untouched. As of late as an endeavor to investigate this potential, numerous basic applications like oceanographic information accumulation, sea testing, etc. The underwater sensor network can be called a network having the core portion built underwater environment elementarily. It has found sustainability has been found in "Acoustic wave" rather than "Radio wave". Underwater sensor network research is, no doubt, a revolutionary step to explore the Ocean and break the solemn silence of the mystery of an unknown world. Conventional sensor network work in the terrestrial communication scheme. Underwater sensor network design, indeed, a complex task due to its adverse environment entirely asymmetric to the terrestrial network Nevertheless, such a challenging topic has been taken as our research object. To say frankly, the data transmission has been considered as the most decisive approach in this research owing to the substantially nondeterministic nature of the aquatic environment. In addition, various transmission overhead like salinity, Doppler shift, Channel fading, multipath effect etc. is a bar to efficient network design. Specific protocols are inevitable for acoustic communication severely. In this paper, various protocols are discussed with their properties and also well illustrated. Keeping the conveniences and inconveniences of the protocols, a new protocol has been proposed. This topic has been chosen for the diversity and innovation of the acoustic communication technology as it has emerged as a newer stream of sensor network research.

1.2.1 Types of Communication Links

There are a number of ways of communicating underwater because of external environmental challenges. They are discussed as follows:

RF Communication: For the sea water nature the nature, the propagation of radio wave in under water is not so good. As we know, attenuation for high frequencies is higher; therefore, most commercial radio equipment cannot be used underwater in the MHz and GHz ranges. To prevent this, if we use a very low-frequency radio wave, we would need a large antenna because it consumes a lot of power. The electromagnetic wave attenuation in water for the 2,4 GHz band is 1695db/m in the sea and 189db/min fresh water.

Acoustic Communication: This technology is most mature in underwater communication. The sound speed in the water is 1.5 x 103 m / sec, while it is only 340 m / sec in air. It is mainly used due to its distance communication capability, but also has limits such as high signal attenuation and low bandwidth. In addition, the report of the Council for the Defense of Natural Resources states that rising ocean noise has a serious impact on the lives of mammals such as dolphins and whales, causing hearing loss or sometimes becoming fatal.

Optical Communication: Light travels in water at a speed of 2.25 x 108 m / sec, which is very high compared to the sound wave speed. In addition, visible light communication in no way harms maritime life. Higher bandwidth, faster speed, efficient power, and less noise interference are the advantages of optical communication. However, the main challenge of optical communication is that it can only work more closely. Sullivan and Dimtley et al's study. In 1963, it was discovered that the attenuation of 450- 540 nm is much smaller than the other light wavelengths in the water. (Shown in Fig 1.2). This band of wavelength is thus best used for the communication of underwater light waves.

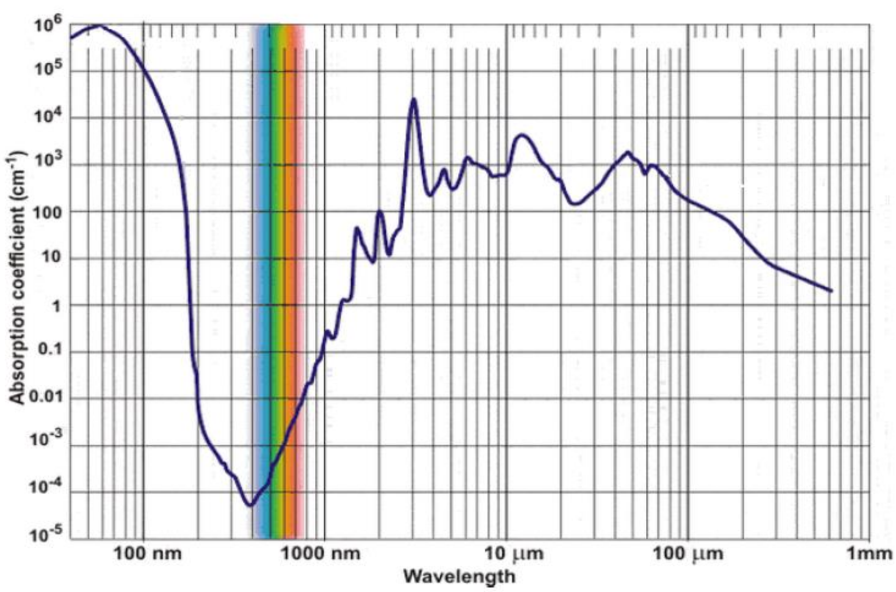


Fig 1.2: Light absorption vs wavelength curve.

Hybrid Optical Acoustic Communication: The constraints of both technologies can be overcome by combining the two. An optimal network can be developed to use the required technology appropriately at the right time. In (Wang et al, 2011) [10], Depending on the SNR value of the signal at the receiver ends, the technology used to transmit the data is determined. High, medium and low SNR allows optical communication, while the SNR needs acoustic communication below the threshold. In addition to that, multi-hop technology is used to transfer data from source to sink node. A number of layer protocols were also developed for this purpose. Besides, the speed of an acoustic wave with water profundity, saltiness and temperature changes fundamentally. This makes the acoustic waves travel on bended conduits, making zones of obscure sensor hubs. Such sensor hubs don't take part in the information transmission process which influences the execution of the system. The marine life, shadow zones and capriciousness of the submerged medium with high impedance and high clamor further compromise the dependable supply of information bundles from the base to the surface of the water. Moreover, the battery life of the sensor hubs is constrained and it is wasteful to supplant the sensor hub batteries, particularly in the sea bed (Partan et al., 2007) [11]. Plan of the UWSN directing conventions is critical. These conventions recognize ways from the base to the water surface to guarantee that the system performs as per the parameters required. Specifically, these conventions consider the difficulties related with the submerged medium and amid bundle transmission so as to accomplish ideal system execution as indicated by the ideal targets. For instance, these conventions handle low battery control, serious commotion and obstruction, shadow zones, development of sensor hubs, with water currents, reliable data packet delivery under unfavorable channel conditions and high propagation delays.

1.3 Related Work

Even though various authors have submitted quality routing protocol papers and study papers in various territories of UWSNs, motionless possibility of the routing protocol introduced in this article is recognized from the current works in numerous perspectives ((Li et al,2016),(Anwar et al,2015),(Han et al,2015),(Coutinho et al,2018)) [12-15]. In addition, some authors talked about analyzing the energy effectiveness.(Ovaliadis and N.S.a.V.K,2010; Domingo and Prior,2008)[16-17] formation (Pompili et al., 2009) [18] prospective uses (Heidemann et al., 2006; Jiejun et al., 2005) [19-20], the plans of network coding (Lucani et al., 2007)[21], besides numerous entrance strategies (Casari et al., 2007)[22].Issues such as data transmission, deployment and location in various conditions under UWSNs have been discussed in Architecture is a must for designing a robust routing protocol. Models of two dimensional and three dimensional submerged sensor system have been talked about. A survey on the present answers for medium access control, system and transport layer conventions are given and open research issues are talked about in (Akyildiz et al.,2006) [23]. Various elementary parts of submerged acoustic correspondence have been researched. Divers researched for the both two dimensional and three dimensional submerged sensor systems are talked about and submerged channel is portrayed. The fundamental difficulties for the improvement of effective underwater explanations of networking are detailed at all stack protocol levels level. Open research issues are also discussed and conceivable outcomes are delineated in (T.Kaur, 2018) [24]. A geographical routing technique called Focused Beam Routing (Stojanovic et al,2010) [25], which requires each node to know only its own location and ultimate location of destination, is coupled with the distance- conscious collision prevention protocol that regulates access to the channel. MAC protocol of UWSN has been discussed in (Molins et al, 2006) [26]. Some protocols are distance aware and collision avoiding of them (Peleato et al, 2007) [27] is considerable. Various protocols deal with reliability and energy efficiency such as (Chen et al, 2008), (Zenia t al, 2016), (Ahmed et al, 2015), (Xie et al, 2007), (Wahid et al, 2011) [28-32]. Some protocols suggested that including depth sensors would enhance the possibility of efficient routing in comparatively deeper water. One of them is Depth based routing explained in (Yan et al., 2008) [33] (Guangzhong et al., 2010) [34]. In various protocols, the clustering scheme of the sensor nodes has been discussed. The focusing on them is (Dominigo et al., 2007), (Yang et al., 2010), (Wang et al., 2007) [35-37]. Focused beam routing is also a widely discussed protocol for the efficiency of acoustic communication. It is analyzed in several papers like in (Jornet et al. 2008), (Montana et al, 2008) [38-39]. The matter such as data transmission, positioning and the area which it's locate in UWSNs in UWSNs upon various circumstances have been discussed and the group also divided into many groups depend on their behavior and features. There are several paper published on the topic of UWSNs but there paper don't focused welly. In the case of protocol review of UWSNs many author just do the shortcomings and the possibilities of the protocol. And they are conventional ideas. But after that the ideas of the conventional their merits demerits and their parameters so on help the researcher, engineers, scientists who want to work in this field. This parameters and their outline help one who want to work take the appropriate decision that which area he/she work for his right application in UWSNs. Additionally, all of the past works help the researcher for introducing a new protocol and help to comparison with the old one and the new one parameters and their performances .Thus this promotes the motivation on going directing convention which extremely powerful, astute, practical and sensible in examination with self-tended to protocols. The studies for the routing protocols addressing a new protocol which is comparatively better than the existing protocol up-to-date is provided in this paper. When we contrasted with the current overview and protocol also this survey considers solely recent and progressive protocols (planed for last one or two years with expectation of some spearheading protocols). Researchers and scientists giving a lot of protocol and initially we are divided these protocols into two categories. Among two of them one is based on location and left one is not location base it is location free protocols. Previous kind needs axis of two or three dimensional that the nodes of data sensing elements, while the last kind just requires, the gravity of water on detecting components hub (depth) to distinguish the directing direction. Moreover, we classified the two classes into a few sub categories that depends on the UMSNs parameters. And this sub categories depends on the understanding of energy, hubs excellence, vigor, energy ingestion and void zone. And this classes and sub- classes are very much important and effective for the researcher in this area to design a protocol and obviously the unique one. Introducing a new protocol is obviously our major tasks and make the protocol most effective one among the existing. Besides our paper and literature review obviously this paper helps it gives a overview of protocol, it merits, demerits and performance also. And introducing protocol is not like the conventional protocol. Its quality of all the parameters is high. The researcher are the main beneficiary of the outline of the routing ways so that they introduce new ideas of protocols)

1.4 Goal of this research work:

The research work is done for a novel purpose. The major key of any protocol that should be considered fast that is the routing and it's responsible for the revelation and maintenance of paths. The researcher of underwater sensor networks most of the case they concentrated on the case of physical issues, the routing strategies are comparatively a new area of network layer and the important task it done that is it introducing an effective routing algorithm. Decades after decades the researcher, engineers and scientists work in this field but there are not utmost protocol that fulfill are the necessities and quarry also. The underwater networks protocol now also in infancy position. In our paper we give a short review of existing major routing protocols and also the proposed popular routing protocols for the UWSNs. And also introducing the new unique robust routing technique for the protocol of UWSN. Which will be an era-changing protocol for the UWSN. People of the world main beneficiary of it. In this paper, we also give a short review of the existing protocol.

1.5 Outline Methodology

We have named our protocol UWSN Directional vector based forward focused beam routing (DVFBR) We will make our protocol work consecutively one by one which will include the association of several afore worked protocols findings. Some specific protocols like "Clustered Communication", "Depth Based Routing" etc. We have analyzed their performances through successive parameters. Several parameters have been considered to compare protocols and design.

1.6 Organization of this thesis

Chapter One: Introduction. It briefs the general Introduction, Motivation, Related work of UWSN.

Chapter two: Underwater sensor networks

Chapter three: A comparative study to UWSN routing protocol

Chapter four: Simulations and results

Chapter Five: Conclusion

Chapter Two

Underwater Sensor Networks

2.1 Introduction

Underwater sensor network gives us the opportunity of the unexplored applications and strengthen the aptitude of forecasting the infinite ocean. Autonomous water vehicle which are acoustic sensor enabled are expected to be using software technology in order to get information of the undersea assets and gather scientific information via successive tracking missions. It will be easier in case of boosting the capability of underwater gadgets. A collaborative monitoring will be done through the encompassing of the sensors and vehicles which are in connectivity through acoustic link. (M. Ayaz et al., 2011) [40]

2.2 History of underwater sensor networks

With a view to realizing the downturn in recent sensor network technology, the background of them has to be analyzed and evaluated sincerely. It seen that sensor network technology is used in military and heavy industrial applications alike many latest technologies. The first wireless network is the Sound Surveillance System (SOSUS) which comply with modern WSN. It got upgraded to detect and track Soviet submarines by the US defense force during world war. Submerged acoustic sensors–hydrophones have been used which was spread across the Atlantic and Pacific. This sensing technology is used still now, although it serves more nonviolent roles to monitor natural world and seismic activity in the underwater. Distributed Sensor Silicon Laboratories Inc. was established by the US Defense Advanced Research Projects Agency (DARPA), in response to investments made in the 1960s and 1970s to improve hardware for the Internet today. Rev 1.0 2 Network (DSN) program in 1980 to solve the tests of distributing wireless sensor networks officially sensor network technology soon took a position among academicians and general scientific research after the birth of DSN and its improvement into academia through the universities who were partners such as Carnegie Mellon University and the Lincoln Labs Massachusetts Institute of Technology. Governments and universities ultimately started using WSNs in applications such as air quality monitoring, forest fire detection, prevention of natural disasters, weather stations and structural surveillance. Then engineering students started moving to the world of present corporate giants, such as IBM and Bell Labs, the promotion of WSNs in heavy industrial appliances such as power distribution, wastewater treatment and factory automation services was initiated. Although sensor network had a high market value, a challenge was existent owing to the limited functions in proportion to commercial necessity. The military functionary was largely dependent on comparatively more expensive sensors, efficient routing protocols. A premium functionality and performance was put by these WSNs, while other reasons, such as hardware and deployment costs, networking standards, power consumption and scalability lost their efficiency severely. There was a combination of high costs and low volume which prevented WSNs from being widely used and deployed in versatile application.

WSN Technology Transitions

In last century, there was no such technology for immense industrial and consumer application initially. Later academia and industry recognized sensor network technology and made substantial effort for solving problem. Here are some examples of these academic/industrial initiatives include:

- UCLA Wireless Integrated Network Sensors (1993)
- University of California at Berkeley Pico Radio program (1999)
- μ Adaptive Multi-domain Power Aware Sensors program at MIT (2000)
- NASA Sensor Webs (2001)
- Zig Bee Alliance (2002)
- Center for Embedded Network Sensing (2002)

The aim of these measures and standardizing organizations is nothing but the wider deployment of the sensors. Cost and availability of the sensors has to be considered wisely in order to simplify the industrial applications. A comparative graphical illustration of relation among some parameter is given in Figure (2.1) below .We will be given a conspicuous scenario of the commercial functionalities of sensor network.

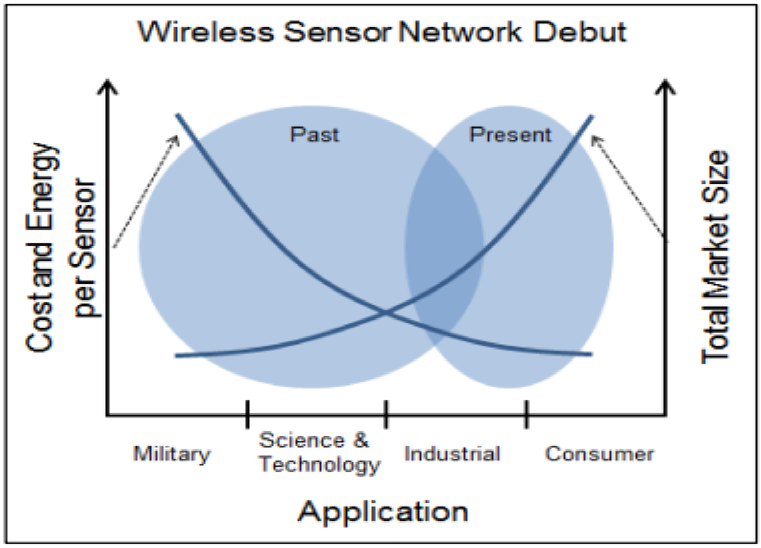


Fig 2.1: Relationship between reducing sensor cost and market traction

Underwater networking is a comparatively unexplored area. Though it was taken in 1945 when an underwater telephone was designed to perform the communications among the American submarines. At the eve of the war, it had been an enthusiastic move to the powerful states to occupy the ocean and fight more than they do. Subsequently, research has been no longer confined to battle but to the development of non - military activities. The research trend continues and is gradually increasing.

2.3 Architectural Model

In this section, architectures of UWSN is classified. The following architectures have been discussed to design a perfect acoustic network considering the adverse environment:

• **Static 2D model for ocean bottom monitoring**

Sensor nodes are anchored to the bottom of the sea as discussed in 2.3.1 and used for undersea tectonic plates.

• **Static 3D model for ocean-column monitoring**.

In this model, the sensor nodes are deployed in wider area where the nodes can be controlled discussed in details in section 2.3.2 and may be use to monitor ocean phenomena.

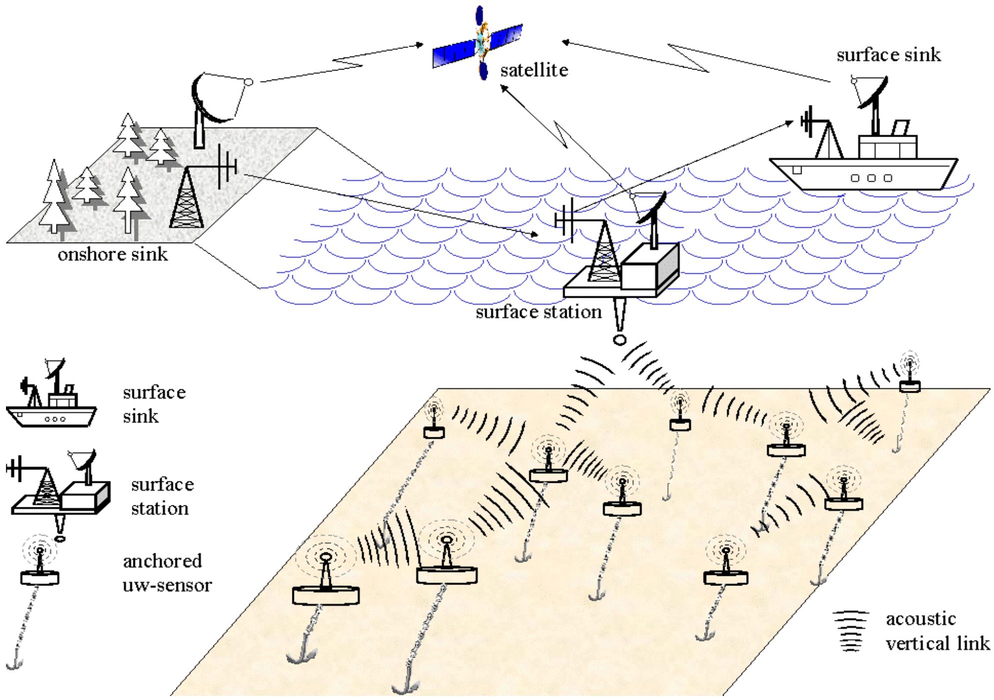


Fig 2.2: 2D architecture

2.3.1. Two dimensional Underwater Sensor Networks

A standard construction has been shown in Fig 2.2 for underwater sensor network. There is a widely positioned sensor nodes which are connected through acoustic links via underwater gateways. These gateways transmit data from the bottom nodes to the surface nodes. To achieve this goal, two acoustic transceivers are provided of them one is vertical and the another is horizontal transceivers. The horizontal transceivers are used to communicate with sensor nodes to: (i) send commands and configuration data to sensors (underwater-gateway to sensors);

(ii) Collect monitored data (underwater-gateway sensors).

The vertical connection is used by the UWSNs to relay data to a surface station. Deep water applications need vertical transceivers, which must be of long - range. The surface station has a powerful acoustic transceiver which can perform communication in parallel scheme. There is also a satellite system installed on the surface station which will communicate in further functionary. In general sensor network the nodes connect with each other via a underwater gateway. But in acoustic communication it is quite complex due to the adverse nature of the environment. In conventional radio communication bandwidth is allocated for a communication through a estimation. Since underwater environment is so indecisive due to its several impairments.

Bandwidth is a very focal term in communication here undoubtedly. Energy is another concern in such adverse communication. So, allocation of adequate bandwidth is considered which saves energy and increases the network efficiency. Direct connection among sensors is most effective but not always it is energy saving. It also increases the complexity of the routing function often. Since energy and capacity are considered as valuable resources in the underwater environment, the UW-ASNs intends to deliver event features by taking advantage of multi-hop paths and minimizing the overhead signaling required to build underwater pathways.

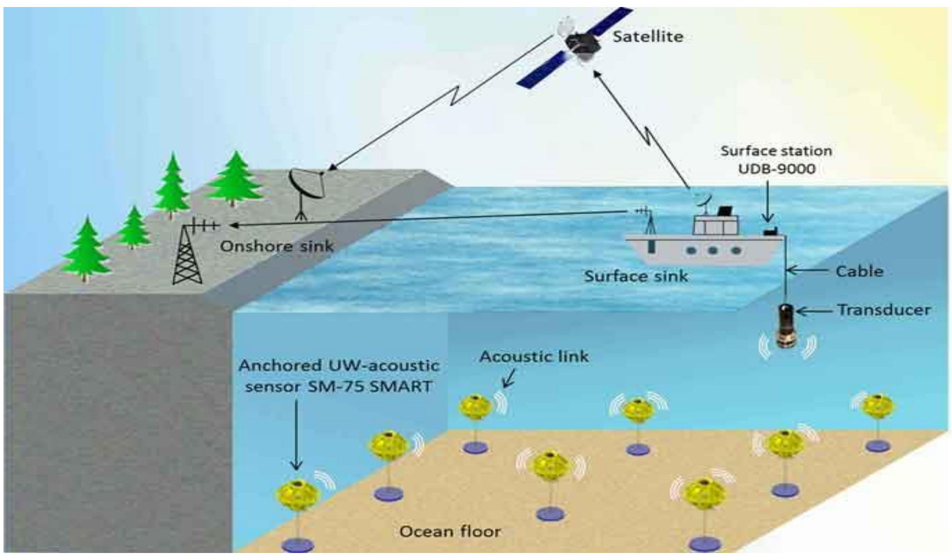


Figure 2.3: Underwater Sensor Networks 3D model

2.3.2. Three dimensional Underwater Sensor Networks

Three dimensional network is designed to monitor the oceanic activities which can not be detected by the two dimensional model. Sensors are anchored at the bottom of the sea which is not a convenient way to monitor the three dimensional environment of the sea. In three dimensional model, sensor nodes are positioned at altered depth level of the sea to observe acoustic phenomena. It's easily understood that the three dimensional model is more sustainable than the two dimensional model in configuration and functionality. There are specific solutions of the problems. Acoustic sensors can be attached to a buoy with wire in the sea surface so that the depth complexity can be simplified fruitfully. But frequent presence of buoy hampers the navigation of the ships. It's also comfortable to locate the position of the buoy for the enemies. Besides, ecological balance may be at stake due to excessive presence of buoy. However, in figure 2.3 the sensors are anchored in the bottom of the sea and is fitted by a extensible floating buoy. The sensor depth can be controlled adjusting the wire that connects the sensor to the anchor by an electronically controlled motor installed in the sensor node. Sensing and communication is strictly investigated in three dimensional architecture. Parameters like diameter, minimum and maximum degree of the accessibility graph is derived from the communication range and they shape the network. While diverse coverage degrees for the 3D environment are categorized by the sensing range (Ian F. Akyildiz at el, 2006) [41].

2.4 Methodology of UWSN

Prior to the study of UWSN, it's a must to know the conventional sensor network. It's very important for the researchers to be knowledgeable with conventional concept. Sensor network is a vastly dispersed arrangement of the sensor nodes which makes a centralized communication system. The nodes deployed connects each other with a successive manner. The concept is largely dependent on the ad hoc networking scheme which is established through a spontaneous wireless communication. Ad hoc networking is commonly seen in battle field or in any emergency areas where the communication is quite complex to be established. The data is transmitted wirelessly with the collaborations of the widely deployed sensor nodes. In any sensor network from hundreds to thousands exist and make a efficient communication. Formerly, sensor network was a very costlier concept. The trend is now being changed. While considering the market evaluation, it may be seen that sensors are of different prices. Senor networks were used only for the observation of natural responses. It has now taken a place in industrial appliances like monitoring the health of machine, mechanical responses. A sensor node has some inner construction which includes power supply, circuitry, electronic sensor, microcontroller and etc. Sensor nodes communicates both in hop by hop and multi hop scheme. As it's a ad hoc basis network they make their own communication route and makes own routing scheme. Efficient communication needs proper routing protocol. Data transmission is largely dependent on the routing technique. Sensor nodes are used for the sensing of various environmental monitoring The WSN topology can differ from a simple star network to a advanced wireless multi-hop network. The propagation method between the hops of the network may be routing or flooding. Organization of the network is one of the criteria of communication. Like conventional terrestrial communication it needs proper topology which helps the sensor node work in right way following their chosen protocol. That is how the whole communication takes place in sensor network.

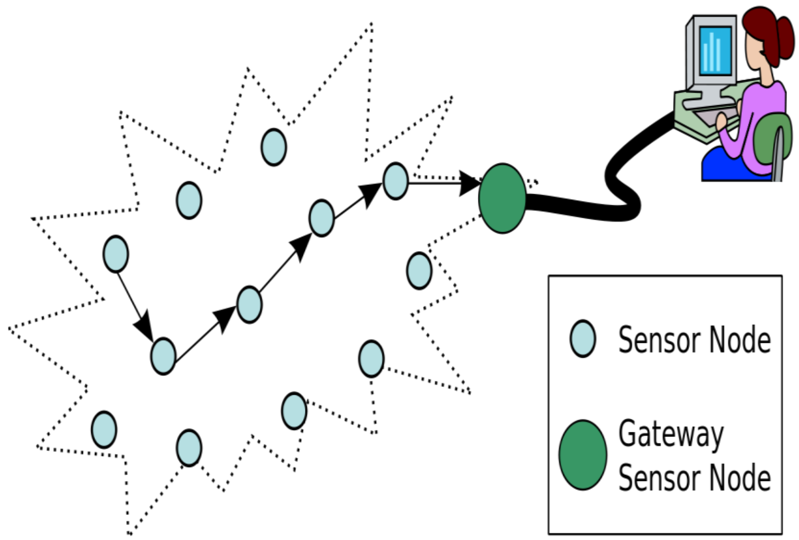


Fig 2.4: Typical multi-hop wireless sensor network architecture.

UWSN 's consistency with the conventional sensor network is significant. However, UWSN must deal with serious natural impairments that have given the network comparative sustainability. The basic analysis of the wireless sensor network will clarify the UWSN principle. The UWSN principle will then be discussed substantially. Traditional sensor network has immense application in present days which has high efficiency, transmission rate bandwidth etc. as seen in cellular communication. Underwater sensor network is completely different from terrestrial sensor network. It has high latency, low maintenance cost, severe transmission impairments. In radio transmission network, the data is in the form of electromagnetic wave which has the velocity of light. Radio communication is not convenient in acoustic communication due to the environment. Radio wave propagation is hampered in acoustic environment. Fading of signal is so common in UWSN. Acoustic wave is convenient for designing a network in undersea environment. Acoustic wave has a velocity of 1500 meter per second. Despite having numerous challenges underwater sensor network is working efficiently for the sea monitoring, tactical surveillance, mine recognition, sea depth determination, oil tanker safety, ecological balance etc. It is a sophisticated sector of sensor water research. The increasing trend of this research is opening new window of possibility every year. The drawbacks are being reconsidered and the present findings are being upgraded. Besides, the 2D and 3D architecture UWSN has some other concerns in designing a networks. They are as follows:

- Three-dimensional networks of autonomous underwater vehicles (AUVs): In this networks, autonomous underwater vehicle that are sensor enables perform their observation in different depth levels of the sea. 3D underwater network is used for the capturing, sensing, gathering of the environmental information through the sensor nodes installed at the bottom of the sea. But 3D architecture often can not give the detailed information. The lacking can be covered by the participation of underwater vehicles. One interesting thing is that one sensor can not observe a certain event at different depth level.

- Whose length can be adjusted to control the depth of each sensor node: while positioning the buoys in the sea surface, the situations have to be well revised. The ecological balance, ship navigation and availability of military applications have to be considered wisely. The connectivity between buoy and sensors has to be recalled. Sea currents is a most deterministic parameter of the continuity and sustainability of the sensor network. Three dimensional localization can immensely help the system solve the problems.

- Sensing coverage: Sensors which are deployed need to cover the whole column of the depth so that perfect sensing happens. The sensing range is an important term to be recalled in each calculation. Thus the network can determine phenomenon at different depths. Sensing coverage boosts the system. There is a linear relationship between the sensing coverage and the efficiency of the network. Despite having immense challenges, this linear relationship always plays a deterministic role for underwater sensor network.

- Communication coverage: In 3D underwater networks, the sink may not be instantaneously accessible; so, sensors choose multiple hop to transmit data to the surface sink situated on shore. Network devices hence need a coordination so that the sensor network becomes connected. The synchronization of the network is very important. So that there is at least one path between each sensor and the sink. If so happens then data transmission becomes comparatively more effective than before. Autonomous underwater vehicles don’t need any kind of cable, remote control etc which impede them from moving one depth to another depth. That’s AUV has special significance in environmental monitoring, oceanography etc.

2.5 Mechanism

2.5.1 Organization of the network

Underwater wireless sensor networks (UWSN) which comprise of a limited set of sensor devices which are (usually predefined) geographically distributed in a given indoor or outdoor environment. A UWSN has a goal with a view to gathering ecological data, and the location of node devices can be a priority familiar or unfamiliar. All devices have logical communication with network nodes; this communication signifies application topology. For example, there may be a UWSN with the same topology for both types (mesh, star, etc.).However, this is not repeated in all case. The logical role of the nodes direct logical topology. It can be on ad hoc basis or based on strategies like self-organization, clustering, pheromone tracking, etc.. The strategy is defined on the basis of the available network elements. Centralized training techniques will be perfect for networks where single device is the decisive factor of processing capacity. This device is accountable for the processing, coordination and management of the sensed information activities in such aspects. This data is also forwarded to the sink node (Figure 2.4).The main conveniences of this tactic are:

(i) Efficient energy management is allowed by centralized schemes

(ii)The network allows roaming inside its coverage.

(iii)Simple network coverage synthesis.

(iv)Availability of context information help design a better application. (Node localization, application awareness, etc.).

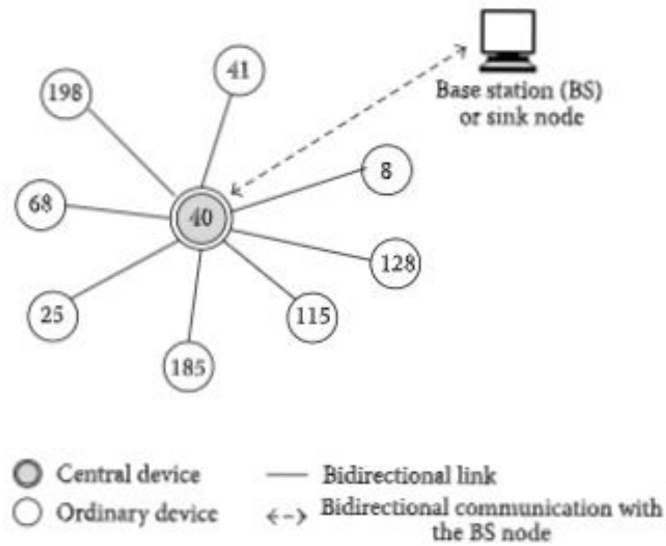


Fig 2.5: Centralized strategy.

Generally, in a distributed network the information is managed by each node and its confined to the neighboring node (single hop). The main characteristics is as follows:

(i)The devices are mostly autonomous..

(ii)Information is shared to its neighboring node.

(iii)There is sustainability for distributed applications (Multi agent systems, self-organized systems, etc.)

(iv)The information flow is basically advanced to a single node.

(v) Interconnection devices like bridge, router are not required.

(vi) Harsh environment is allowed. Flexibility stands there.

The complexity of the process of transmission of information requires strong algorithms. The former must ensure that specific tasks with a comparable performance with centralized solutions are carried out. Self-organization was one of the most important distributed techniques of recent years. A sensor network using this strategy can achieve an emergent behavior in which nodes interact separately and autonomously coordinate (Figure 2.6). The objective is to achieve tasks which exceed one node's individual capabilities. We can find examples of existing techniques in environment mostly (insect colonies, biological cells, bird flocks, animal feeding).

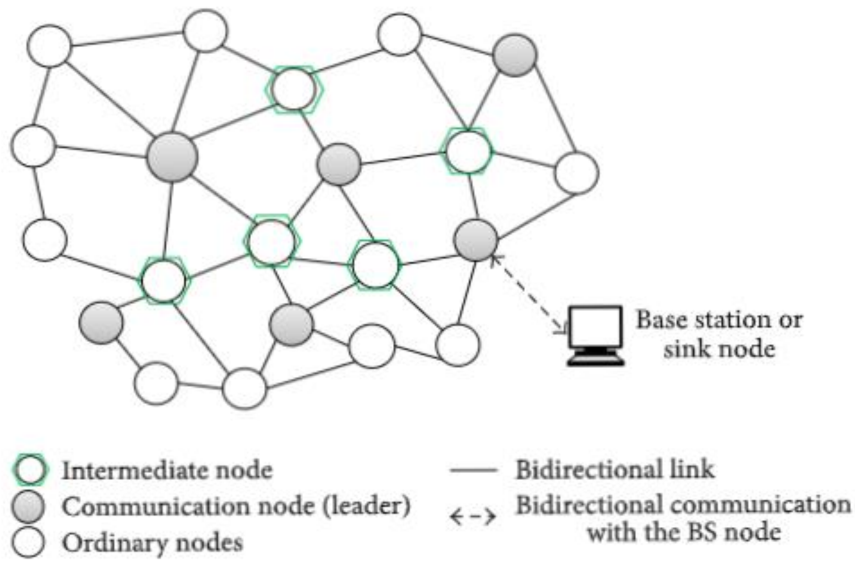


Fig 2.6: Self-organization strategy.

The protocols for distributed wireless sensor networks must be able to provide efficient energy consumption, including mobility of nodes, noise from the environment, limited batteries and loss of messages. This is a debate in the following section. Figure 2.7 shows the taxonomy of the classification we have proposed. All underwater network organization technique is classified into two groups: centralized and distributed. The following sections providean additional classification for each group and its main works.

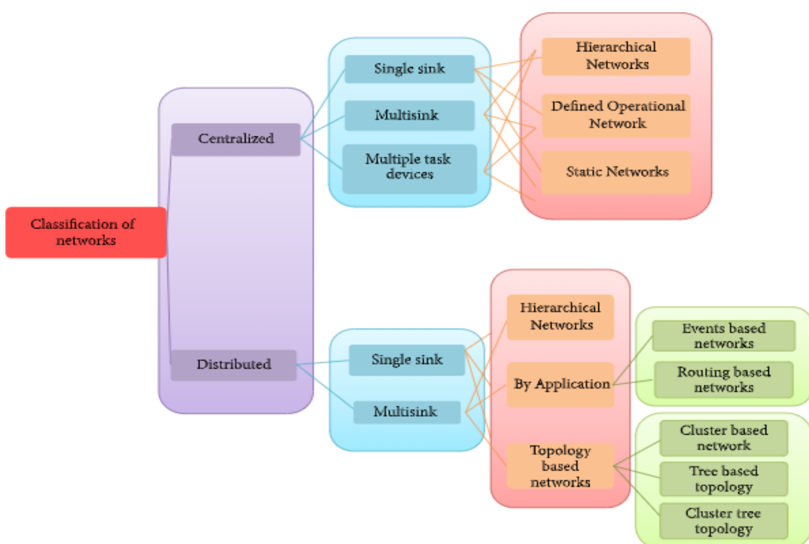


Fig 2.7: Propos Aid classification.

A unique devices direction is taken by centralized network. Node location, event detection and traffic routing are provided by the central node. A logical topology is essential here. The centralized networks are classified as per the processing of the operation . These groups contain the following:

(i)Individual Sink. The objective of the training strategy is to reduce the transmission time and to transmit information to a unique sink. The main disadvantage of single sink systems is that there is no redundancy.

(ii)Multi-functioning. Multiple sinks are used to distribute the previous tasks to multiple nodes. This is done for a number of reasons, including network density, coverage area, redundancy, traffic flow distribution, network life and potential energy consumption.

(iii)Multiple task apparatus. Recent research suggests the use of auxiliary network devices, which can be responsible for carrying out a specific activity within the network, such as knowing the entire environment to define a route, to control node movements and to define a target node, with a view to upgrading the overall performance of UWSN(Carlos-Mancilla at el,2016)[42].

2.5.2 Underwater Sensing Applications

Underwater sensor network research is upgraded when the sensing of the network is needed. Some parameters which decide how the network will form. It is a fact whether the network will be fixed or mobile, short lived or long lived etc. In this section, different kinds of applications, specific examples have been given:

(a) Deployments

Different types of underwater network have two common variable which are mobility and density. The main focus is on acoustic sensor network. Immense research has been done still now from the 1950s to the recent ocean observatory research (Fairley, 2005) [43].Figure 2.8 illustrates numerous ways to deploy a network. Underwater nodes are mostly static, anchored in the sea bottom (such as cabled or wireless sensors in Figure 2.8). Often semi mobile networks are installed from ship and kept for hours temporarily (Shusta, 2010) [44]. The mounted sensors shown in fig 2.7 can be long term initiative through proper topology organization. However, the connectivity of the network is still changeable owing to minor movement (The way a buoy proceeds) or water dynamics (as currents, surface waves or other effects change).It is very significant for the whole network. In case of activating power the static topology may face energy threat. UWSN network can also be mobile. Mobility depends on specific parameters. Autonomous water vehicle can make the topology dynamic. A vibrant topology increases the efficiency of the network. Network coverage is another factor which is inevitable for designing a specific network. In a network, the sensor node coverage must be considerable. Otherwise the data accumulation won't be fruitful as estimated. While deploy sensors, these parameters have to be considered. For example, a model of sensor network that

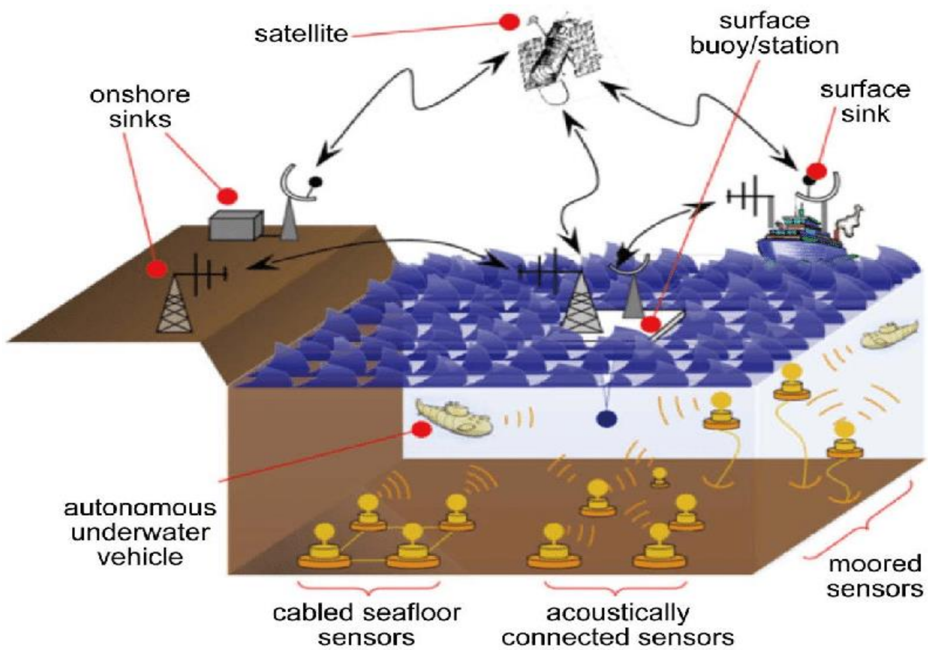


Fig 2.8: Deployment is full of diversity.

Derived from Akyildiz et al. (2005, Figure 1). Encompassed a 16 km^2 area having 5 neighboring node is illustrated in (Proakis et al., 2001) [45]. Connecting to internet is quite complex. Though in fig 2.8 there is a probability of connection through wires and satellites.

(b) Application Domains

Underwater communication is same like the terrestrial communication. The basic difference is in the mechanism and medium of communication. It is used for environmental observation and military purposes. It has now become comparatively feasible than before due to the reduction of prices of the network related apparatus. Cost effective networking is a buzzing topic in sensor networking. As it is very effective for sophisticated research work. Scientists have given emphasis over designing such sustainable network for the increment of observation. (Heidemann et al., 2006)[46] provides a inspirational framework that has given oxygen to immense research efforts which are currently discovering low - cost underwater options. But emphasis has been given over deep water sensing. Finally, underwater sensing is for short time duration and the deployment can be complex at time than the conventional sensor networking. UWSN has almost same functionality like the terrestrial network. There may be a integrated system including the autonomous vehicles with power glider and sensor node enabled anchor. Such model will substantially shape the system. It will obviously give a sustainable model of application.

(c) Examples

Numerous examples of sensing experiment are existent of them a few are described here. (Proakis et al., 2001)[47] describes a substantially designed network which was primarily for a military concern. That was used for the interconnection among the submarines. The model was efficient and trustworthy. The Massachusetts Institute of Technology and the Commonwealth Scientific and Industrial Research Organization of Australia have done a supervision over both static network and a dynamic network with autonomous underwater vehicle. The deployments took place in neighboring Australia and the South Pacific which is explained in (Vasilescu et al., 2005) [48]. It was done in relatively in short time duration. The ocean observation initiative generally consider large scale deployment (Fairley, 2005) [49]. Substantial investment is a determinant factor for large scale observation.

Underwater Communications and Networking Technology

In this section, various technological complexities are discussed concerning the deployment analysis, implementation and testing of underwater sensor network. The physical level functionalities are discussed here relating the hardware setup, testing and simulation instruments.

(a) Physical Layer

In terrestrial network, the communication takes place in a layered task. The same happens in acoustic communication also. The physical layer is the initial stage of any kind of data communication whether it be a terrestrial or a acoustic network. In terrestrial electromagnetic wave is the propagation medium which has a range of kilometers. In contrast, the acoustic communication takes place with the help of acoustic waves which has a range of merely ten meters.

Figure 2.9 gives an illustration to the integrated effect of attenuation and acoustic wave by showing a diagram of the quantity [A (d, f) N (f)] −1 determined utilizing the core (ideal) propagation loss A (d, f) and the distinctive power spectral density N (f) of the background noise elucidated in (Urick, 1983; Stojanovic, 2007) [50]. The feature signifies that the signal to noise ratio is compared in a narrow band frequency. The figure clearly shows that the frequency becomes faint with distance increases. There is a inverse relation between the frequency and distance. It is also experimented that the bandwidth also decreases as the distance increases (Stojanovic, 2007) [51]. The initialization of a large system deals with frequency and certain bandwidth allocation. The data propagated in multipath can have conspicuous delays in transmission. The delay depend on the location of the system. The delay can be of a few milliseconds to hundred milliseconds. The consequence of that a frequency selective channel is designed. The channel response often creates small or large vibrations in its power related concern due to the sea currents non deterministic nature. Besides, extra time change is caused by Doppler shift which initiates directional motion. Autonomous underwater vehicles can keep peace with the sea currents. It has a few m/s speed. The speed of sound in acoustic nature is so slow that the relative ratio of the transmitter or receiver becomes very small. The situation finds differences severely with radio communication system. The corresponding speed will bear a smaller magnitude and only the central frequency shift keying is considered sincerely. Former systems had given emphasis on frequency modulation (FSK) and non-coherent (energy) determination to avoid phase distortion concerned with time. Although, these methods are not efficient enough for bandwidth but it suggests the transmission at lower bit rate (almost 100 bps over a few kilometer). It has also been used in commercial application such as the tele sonar series produced by Teledyne-Benthos explained in (Green, 2010)[52] and in research work such as the Woods Hole Oceanographic and some other ones .In a conventional acoustic system, the center frequency and bandwidth are mutually dependent. (e.g., 5kHz is centered around 10 kHz). Frequency is a influential term in these communications. Underwater communication platform is a very challenging owing to its environmental resistances. While designing a standard network cumulative calculations over the network has to be performed. The layered architecture has to be under consideration as architecture plays an influential role to overcome the adversities largely. When other consideration concerning the adversity are combined with the architecture, the complexity of designing a network immensely gets reduced. Proper evaluation of the whole scenario must give us a vivid networking infrastructure.

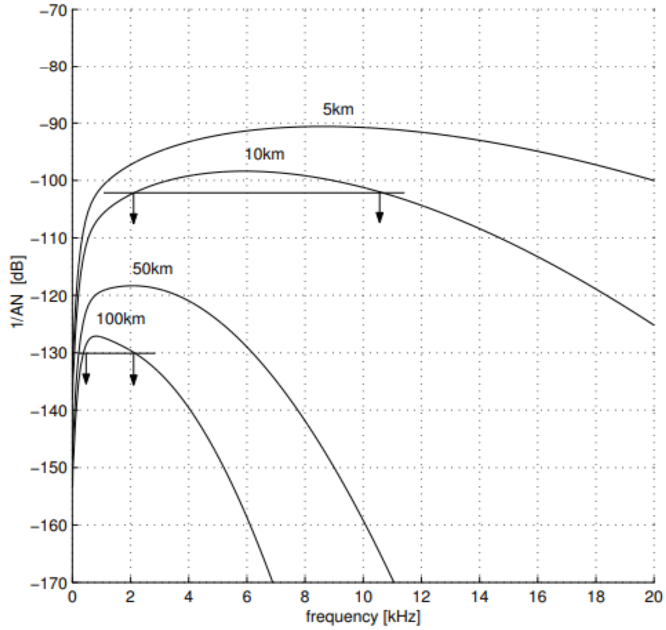
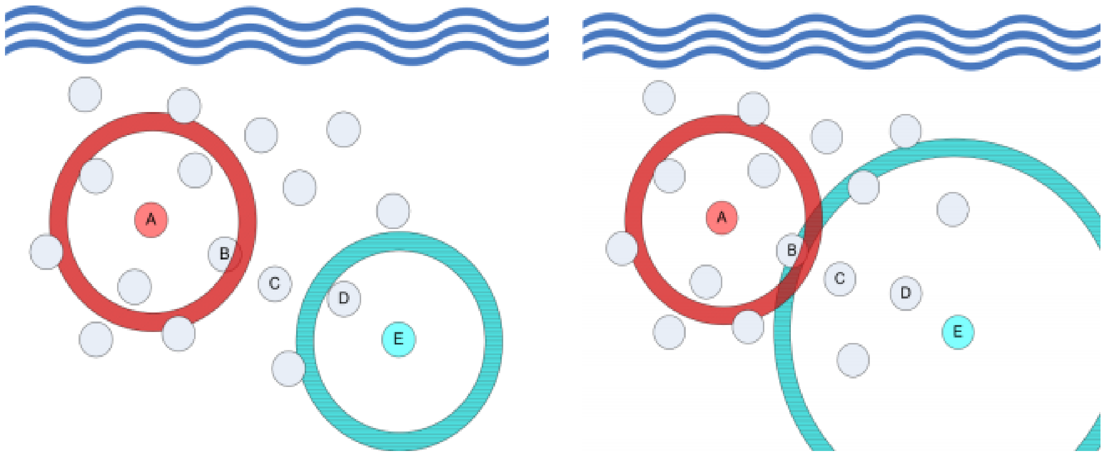


Fig2.9:A narrow band SNR and the inverse relationship between distance and frequency

At 1990s amplitude and phase modulation was considered for bandwidth efficiency and demonstrated over acoustic networks.(Stojanovic et al., 1993)[53]. Horizontal and vertical link configuration and autonomous vehicles initiated high speed single career wide band modulation scheme with appropriate equalization and synchronization. Physical layer works with extreme activeness (Singer et al., 2009)[54]. Single career modulation has been done through powerful coding and turbo charging (e.g. (Roy et al.,2009)[55], On the other hand multi-carrier modulation / detection has been thought as an alternative (e.g. (Carrascosa&Stojanovic, 2010)[56], (Berger et al., 2010)[57]. Both systems got expansion to multi-input multi-output configurations (MIMO) which supports spatial multiplexing (the quality of parallel transmission from multiple transmitter) and had experimental demonstrations of bit rates of several tens of kbps. In case of an acoustic setting the segregation of a long connection into short hops in small numbers saves power and bandwidth expectedly (Stojanovic, 2007) [58]. A higher bandwidth results in higher bit rate with adequate energy and vice versa for lower bandwidth. Both features bear positive effects on network characteristics (and lifetime) considering the interference management. These Physical layer helps in designing medium access control and high level routing. Different frequency allocation can make the same network protocol work differently. Besides, propagation delay and the duration of the packet are significant, later interfering packets may exist in a free channel; The efficiency of the retransmission (throughput) and he probability of collisions are affected by their length. Finally, interference can be reduced through combining intelligent routing protocol and power control (Montana et al., 2010) [59].

(b) Medium Access Control and Resource Sharing

Need an effective way to share communication resources between the nodes in multi-user system. In wireless networks it is shared frequency range inherently because interference needs to managed properly. To deliver rules that allow diverse stations to share the resource effectively and separate the signals that exist in a common medium various technique have been developed. The account should be taken for the unique characteristics of the acoustic channel, while designing resource sharing system for underwater networks. There are some important context, such as long delays, frequency dependent attenuation and the relatively long reach of acoustic signals. The limitation of bandwidth of acoustic hardware (and the transducer in particular) must be taken into account. In TDMA (Multiple Access Time Division) and FDMA (Multiple Access Frequency Division) signals may be divided deterministically. User switch to the medium in the initial fact for the reason signals do not overlap over time and thus interference is evaded. In the first case, users switch to the medium so that the signals do not overlap over time and interference is therefore avoided. The separation of signal is instead accomplish in the FDMA, although frequency domain although it can overlap in time signals inhabit separate portion of the spectrum. Most communication system is widely using these technique and have been taken into consideration in underwater networks (Sozer et al,2000 [60]. For example, The early deployment of Sea Web FDMA has been chosen for the acoustic modem restrictions (Proakis et al,2001) [61],while the use of channel separation guards band results in some efficiency, this type of frequency channel distribution has very little flexibility (e.g. to accommodate different transmission charges. Using TDMA is more flexible, but all users need to sync to ensure access to separate time slits. There are many schemes and protocols are based on such a construction of time-division, which nevertheless needs some management and some time-conserving to recompense for variations in dealing with interruptions. The Multiple Access Code Division (CDMA) is another quasi-deterministic signal separation technique, in which time and frequency co-existing signal can be divided consuming precisely considered codes in combination with signal dispensation procedure. For that reason, expanse of the bandwidth is increase, mostly severe with the acoustic station slight bandwidth (20 kHZ or less for typical hardware). In acoustic networks CDMA depended power-measured medium- access protocol (Pompili et a,2009) [62] have been proposed and got recompenses of not needing slit synchronization and being sturdy to fade multi-way. While the deterministic procedure can be used straight in multi-user scheme, information carrying nodes characteristically used conflict-based protocol that specify with rules nodes choose when to communicate on common channel. The nodes only generate when they required (random access) and terminals recuperate from errors for overlying signals (called collisions) with retransmission. Many upgraded outlines implement multiple access carriers (CSMA), with or without collisions prevention mechanism (CA) to avoid transmission on an engaged channel. Although CSMA/CA has been actual effective in radio networks, the underwater latency (up to several second) makes the underwater very effective (even worse than ALOHA). Even, when ALOHA is hardly considered in radio system because of its poor performance ALOHA is possible applicant for underwater sensor networks with simple CSM proficiencies (Ahn et al,2011) [63] the two example of protocols DACAP (Peleato&Stojanovic ,2007) [64] and (T-Lohi (Syed et al,2008) [65] specifically designed for underwater networks according to the CSMA/CA approach. DACAP is depended on an primary channel standby signaling interchange, reducing the likelihood of collisions. T-Lohi uses collision evasion tones, in which nodes want to send narrowband signals, and procced with data transmission if tones sent by other nodes are no heard and other signal at the expense of hidden terminal sensitivity are provided (Syed et al,2008) [66. High acoustic latency is used by T-Lohi to calculate contestant with radios in ways that are impossible to converge very quickly (Syed & Heidemann,2010) [67]. Inefficiency still caused by long propagation, to use space-time volume and intentionally overlap packets allows synchronization and in that time when remaining separate in space (Ahn et al,2011) [68]. Fig 2.9 provides an illustration of this principle where unlike nearby immediate radio communication long acoustic latencies mean that concomitant packets can be received successfully Fig 2.9(a) and packets sent in different times may strike Fig 2.9(b).



(a) Same transmission time; no collision at B (b) Different transmission time but collision at B

Fig 2.10: Space time volume illustration from (Ahn et al,2011, Fig 1) long acoustic latencies mean that packets from A to E received effectively in B and D in Fig 2.10(a) even if they are sent simultaneously, while in Fig 2.10(b).

Several protocols are proposed to a general located structure that the different nodes in the system have access. This effect was demoralized by early work with centralized scheduling rather than random access to avoid collision completely for static topology and supplementary signals however (Badia et al,2006) [69]. Slotted FAMA (Molins &Stojanovic, 2006) [70] is a CDMA based decentralized protocol that uses synchronization to reduce the likelihood of collisions but is also subject to longer delays due to time spent on guard. The another protocol UWSN-MAC (Park & Rodoplu,2007) [71] is designed UWAN-MAC (Park &Rodoplu, 2007)[71] to reduce sleep and local synchronization energy consumption. Some hybrid systems have also been studied in which two or more of the above technique are combined (Kredo et al,2007) [72].

(c) The Network Layer, Routing, and Transport

In sparse networks, it’s improbable that any part of nodes can connect directly and that multi-hop process, that is usually sends message to the final destination using intermediate nodes, is used. In additions multi-hop process is helpful in sight of dependency on the bandwidth of distance as described in section 2.10. In this process routing procedures are used to identify a inconstant path. that a packet follows. Where there are many papers on ad hoc routing of wireless radio networks, the routing structure for underwater networks continues to be enthusiastically studied. Initial works on underwater routing contains (Pompili et al,2006) [73] there are many protocols distributed for delay sensitive applications, they are planned and nodes can choice the following hop to reduce energy consumption, considering both the exact appearances of acoustic propagation and application necessities. A topographical tactic has been planned in (Zorzi et al,2008) [74] there is a theoretic analysis shows that it is likely to determine the optimum development that node should try to achieve nearby to reduce the whole energy consumption.A comparable arrangement was introduced in (Montana et al,2010) [75], that is also include power control in a cross-layer approach. Other approaches contain pressure routing where depth verdict can simply be decided nearby using a pressure page (Lee et al,2010) [76]. A data broadcasting approach was anticipated in (Nicopolitidi et al,2010) [77], there is an adaptive pressure system for data distribution in underwater networks is anticipated and demonstrated to do well, while works with this environment, despite the high latencies. The development of transport protocols in underwater networks is another important issue. Protocols such as TCP planned for low to reasonable expectancies, no large segment of second normally found in underwater networks, and limited bandwidth and high losses designate that retransmission end-to-end is unfortunate (Xie& Cui 2007) [78] for instance, it proposes a new transport protocol that consistently conducts segmented data blog laterally multi-hop path using inconstant block size erasure codes. Network coding and onward error correction can also be used to deal with extensive delay losses, programming assistances from heightening encoding and response (Lucani et al,2009) [79]. Various approaches such as delay tolerate networking (Fall & Farrell,2008) [80] maybe more compatible with so many acoustic networks by ignoring end-to-end retransmission and subsidiary very large and frequently detached system. The work on higher-level data The sparse dissemination underwater protocol works on higher-level data transmission, usually consuming a convention explanation for each placement. One system shows (Vasilescu et al,2005) [81] advising harmonization of environmental monitoring and protocols for data gathering storage and retrieval. Lastly, the problem of topology control, in which node snooze in order to condense energy while sustaining network connectivity. Although harmonization and planning mechanism can be used for this determination there have been fascinating observations (Harris III et al,2009) [82], where it was recognized that acoustic devices, dissimilar radios can actually be wakened up by an arriving acoustic signal without additional hardware. This feature enables nodes to be woken up on demand and achieve a virtually perfect mechanism for topology control. The SUNSE modem apparatuses a low power wakeup system (Syed et al,2008) [83] and the Benthos modem also has a wake-up mode.

(d) Network Services

There are some possible network facilities, location and period synchronization have studiedimportant research because they are applicable for various circumstances. Localization and time organization are, in a sense, double, where time-of-flight communication is often estimated, pretending precise timers, time organization estimates timers slope, demonstrating deliberately varying communication delays. In underwater the challenge of managing with lengthy communication expectancy and noisy, channels which change time both are happen. Time synchronization in underwired networks times go back to the 1990s Network Time Protocol, a decade later, wireless sensor networks led to a renaissance of research with a focus on data and power discussion through one-to-many or many-to-many synchronization (Elson et al, 2002) [84] and integration with jitter reduction hardware (Generiwal et al, 2003) [85]. The synchronization of underwater time was revised in order to meet the challenges of slow acoustic diffusion. High expectancynetwork time synchronization (TSHL (Syed &Heidemann, 2006) [86] exposed that timers drift controls at acoustic channel error that exceed 500 m during message propagation. D-Sync has recently included Doppler Shift estimates for node mobility errors of current water (Lu et al, 2010) [87]. Localization also has a history in underwired and radio-based wireless networks, where node to node ranges (depend on time flight communication) and ideal immediacy (attenuation accessibility) are the two basic techniques of locating devices. but bandwidth limitations make reducing message numbers even more important than radio networks. Like time synchronization location protocols are frequently in pairs or beacon can be passedon to the number of potential beneficiaries. Measured acoustic propagation expands the location, as each microsecond timing error only resembles to a 15 mm location error but bandwidth restrictions make it even more important to reduce message number than radio networks. The appropriate reserve chart estimates (SDME (Mirza & Schurgers,2008) [2008] and the structure planned by Webster et al are two experimental validation underwater definite localization method 2009 (2009). SDME uses post-facto location (analog to RBS post-facto time synchronization) (Elson et al,2002) [89] to decrease the number of messages sing an all-pair, transmission, inter-station range, otherwise standard scheme. They observe the location accuracy of approximately 1 m in 139 m ranges. The (Webster et al,2009) [90] system use a single reference beacon constructed on GPS to locate the moving AUV. Their location outline is constructed on the acoustic range amongst vehicles and synchronized, high precision clocks and an inertial AUV location estimate and an prolonged post-fact Kalman filter. Their outline estimates the location with a usual deviation of approximately 10-14 m in sea tests with an AUV at depths of 4000 m.

2.6 Characteristics

Distributed techniques are used when the application preserves certain properties, such as energy saving, the number of connections, memory and efficiency, or when the processing of information is centrally inefficient. Some special characteristics of the distributed techniques are:

- Independence. It is present when a user chooses only where the data is stored and when the data can be changed or deleted. The information saved does not have any dependence on information about other devices. The key decisions are based on the data for the device. This feature offers most of the time information support from a supporting company's own server or host.
- Integrity for other services. The presence of these distributed techniques does not mean that the integrity offered by the centralized models is disregarded.
- Scalability. Scalability allows the application to add more nodes to the network without changing the network performance, which means that this does not affect the rest of the network.
- Reduced Information Management. Networks are based on the knowledge of local information, namely neighbors.

These types of networks are characterized as centralized networks by the use of single or multi-sink environments. These networks are divided according to their application into different categories; they are hierarchical networks, by application and by topological nature. Some of the metrics addressed are network life, loss of messages, overhead, efficiency, latency and response time (how long it takes to reach the sink node). The topologies considered for this work are flat, cluster, tree and chain based.

Metrics are divided into important critical issues:

- Energy utilization is divided into efficient, energy distribution, average dissipated energy, resource spent per distributed data, that is demarcated as the relation between the number of broken pairs to the total delivered packets and the number of packets before the partition, measured by the number of data packets sent and delivered successfully before the network partition.
- The network lifetime is determined from the moment the first node fails; other parameters, namely the percentage of node failures and the number of packets delivered in a certain time, can also be determined.
- Scalability measures how a protocol performs at different node densities, overall network sizes or data sources and sinks.
- Overhead and efficiency are determined by the message cost of the routing protocol, lost message, overhead control, average route and so on.
- The criteria for temporary evaluation are as follows. Latency and time of reaction are some of the parameters of this problem.

Each topology can be well evaluated based on the application and the resources available in the network and the metrics used. The performance assessment of a topology with respect to other topologies is presented below: Chain-based topology saves more energy compared to other topologies according to energy consumption. Flat topology is the worst because it has a high latency with low message losses; this method doesn't carry in the account the energy constraints and may cause implosion and overlap, but it is better than others because it does not maintain a defined structure with regard to overhead.The best topology in terms of reliability is cluster-based due to easy reconfiguration, scalability, low latency and energy savings, but the energy dissipation rate differs greatly from eachnode to other and network connectivity is unguaranteed. In this study the most promisingnetwork is chain-based topology. The leader on chain-based topology performances as the sink; its save muchpower than group-based topologies & proposals of lengthier life, but spends a lot of time collecting data and overhead. Cluster-based topology is more efficient than Tree Topology, but when this topology is established it's very exclusive & time consuming, it is not resistant to node failures, power consumption is uneven across network nodes and tree maintenance is high. Comments are presented on the behavior of the different topologies, but there are no cases of study for the behavior performance of the cited topologies; they do not consider reconfiguration techniques, the topology assessment depends entirely on the type of application and the results are not absolute.

2.7 Standards

2.7.1: Wireless sensor network (WSN) created on the Institute of Electrical and Electronics Engineers (IEEE)'s 1451.0, 1451.5, and 802.11 standards. The employment of the IEEE-based WSN was established at the National Institute of Standards and Technology (NIST). The WSN contains of two wireless nodes - the network capable application processor (NCAP) node and wireless transducer interface module (WTIM) node. In procedure the NCAP node interconnects wirelessly by the WTIM node with the IEEE 1451.0 and IEEE 1451.5 interfaces over the IEEE 802.11 wireless communication units[91].

2.7.2: ISO/IEC 30140-4:2018 The ISO/IEC 30140 series provides general requirements, reference architecture and high-level interface guidelines supporting interoperability among underwater acoustic sensor networks (UWASNs). Portion 4 delivers data on interoperability necessities among objects inside a UWASN and among several UWASNs[92]

2.8 Areas of Application of UWSN

A substantial change has been brought with the emergence of underwater sensor network which is discussed in this paper.

Ocean biology: The health of the water bodies and of the marine life it supports, is a precise indicator of the environmental pollution level. In order to study this, we need a powerful,self-sustained network to detect and analyze the parameters required.

Management of Disaster: The seabed under surveillance would help in disaster management, because at an early stage we could feel different disastershaving their epic centre in the ocean or the sea . Pre-waring can be generated from the information collected, for the nearby terrestrial areas.

System for Surveillance: The world has seen many frontier problem between countries that share borders, weather or land or in waters. So the Wireless Sensor network can be used to monitor the disputed water areas for any enemy intrusion.

AUV/ROV operation: The unmanned robots are used underwater for different data collection aspiration. Contrary to the country, communication between different robots can not be done via RF. Autonomous underwater vehicles can therefore form a sophisticated network if communication occurs through appropriate links.

Aid in search and rescue operations: In the event of an accident in oceans and other water bodies, deployed networks can be helpful in searching for and rescuing operations. Critical data, which is very important in these scenarios, can be collected from these.

Seismic monitoring: seismic monitoring contributes to underwater oil extractions. Like terrestrial oil fields that are frequently monitored over a period of time, frequent seismic monitoring is also required for the extraction of oil in underwater. The problem is that earthly monitoring in underwater is often difficult because it is difficult to deploy a permanent sensor in underwater areas. The hydrophone and air cannon ships are used as actuators here. This increases the operating cost of both capital.

Apparatus nursing and control: Underwater equipment nursing is another case. Long - time nursing of the existing infrastructure is carried out. When the equipment is first deployed at sea, temporary monitoring is used to confirm the successful deployment. Low power and wireless communication are required for temporary monitoring. Once connected successfully, the equipment with acoustic sensor networks can be easily controlled and remotely operated.

Underwater robots: A robot or group of robots supports the coordination of pollution, monitoring of equipment, oil leaks and chemical leaks. Coordinated action is necessary to monitor operations above and to study biological phenomena. The underwater robots are generally autonomous and coordinate the deployment of low data rates in the coordination of robots, which reduces command delivery. The robots are chemically coordinated.

Military security: this is an important application requiring secure data confidentiality and integrity protocols and mechanisms. It includes port facility monitoring, ship-to-submarine communications. The existing mechanisms, based mainly on terrestrial wireless sensor networks, are not sufficient. Underwater is affected by multi-path interference, limited bandwidth, low data rate, signal decay and long transmission delays. (Shanthi et al,2014)[93].

Chapter Three

A Comparative Study to UWSN Routing Protocol

3.1 Introduction

In this paper, we will emphasize basically on routing protocols which, indeed one of the major concerns for fruitful connectivity among the sensor nodes in such adverse communication environment. Here in this chapter, a overview of some existing UWSN routing protocols will be given in a nutshell. Afterwards, we will describe a robust protocol designed by ourselves. Observing the dynamic condition of acoustic change isn't an agreeable errand. To protect marine assets and accomplish reasonable advancement, changes in the marine condition must be adequately monitored. The risk of environmental change and expanded water-borne exercises can influence sea life and biological communities incredibly. A quick change in the marine condition can majorly affect arrive life and nature.

3.2 Basics of acoustic communications

Acoustic signal is considered to be most influential medium for underwater communication. Though some other options in the pattern of radio communication and optical communication exist. But these mediums are not well appreciated due to the asymmetry of characteristics with acoustic communication. Since electromagnetic wave has high frequency, it makes the propagation range limited through immense attenuation, absorption rather within less than 1 km(Bin et al., 2004) [94].In case of being high transmission power and high antenna size, low frequency propagation is granted. Recently, several research works have been done for the appropriateness of electromagnetic modem in acoustic communication but they are not satisfactory (S1510, 2007) [95].

3.3 Deployment and network architecture

Underwater sensor network is a vastly distributed network of sensors which covers a estimated area . Alike terrestrial network, coverage is an important issue so that the sensor networks can communicate through multi hop path. Various important issues of acoustic network has been discussed in some papers such as (Tarng et al,2009)[96], (Neelofer and Mohamed 2010)[97] and (Jain and Qilian 2005)[98], but the deployment of UWSNs prefers three dimensional architecture more as it has comparative consistence with three dimensional characteristics . The work has been done in (Akyildiz et al.2005)[99] is supposed as a advanced effort for the management of sensor nodes. Some deployment procedures, including (Ibrahim et al. 2008)[100] and (Alsalih et al. 2008)[101]on which, appropriate emphasis has been given location to establish gateway. This step undoubtedly is undoubtedly efficient.

3.4 Localization

In some functions, data sensing needs location information and time consuming application needs information of time. In (Oktug and Erol 2008) [102], the mention two are combined in a localization framework which is named after “catch up or pass". Where they help each other mutually. It reduces the uncontrolled movement of sensor nodes. Thus these nodes uses the position and speed information whether to a relay node which may be slower or faster.

3.5 Reliability

Reliability is a determinant factor for successful data transmission. Flooding of the data from the local sensor nodes to the sink is challenging task owing to the severely adverse environment. Packet redundancy is frequently discussed in papers like (Peng etal, 2007) [103], (Seah and Tan, 2006) [104]. Data recovery through retransmission is a efficient technique but it creates excessive traffic. TCP protocol is considered as the most reliable one for data transmission. However, it’s not a pragmatic solution to follow these congestion control protocol for multi hop communication. (Holland and Vaidya, 1999) [105]; (Scheuermann etal.,2008) [106].Three time handshake takes place between the source and sink before data transmission starts. But frequent handshaking may be a burden for such complex network most of the time. Data losses happen due to heavy congestion of the network. That’s why it has to be reduced.However, error prone packet and node failure is also equal responsible for packet loss. consequently, transmission rate reduction is not a wise step with a view to maintain the efficiency of network.

3.6 Directional Flooding-based routing(DFR):

DFR is solely designed for minimum number of nodes. Most of the existing protocols emphasize on the reliability of transmission but don’t consider the link quality. Link quality assures whether the message will be transmitted or not. (Daeyoup and Dongkyun,2008)[107] has designed a new protocol considering the link quality in mind. Fig 3.1 illustrates the protocol that how it will work. There will be a intermediate node F shown in fig 3.1 which will receive packet from source S and pass it to the sink D. The area will be determined by a BASE_ANGLE between node S and node D. In this way the rest packets will be transferred to the final sink. The angle is changeable with acoustic condition to maintain high transmission rate through hop by hop. Void problem is another issue. At least one node will be working in case of void problem in the network. The sensors know about its own position, neighbors position and the destination. Thus the protocol works efficiently comparatively than other ones.

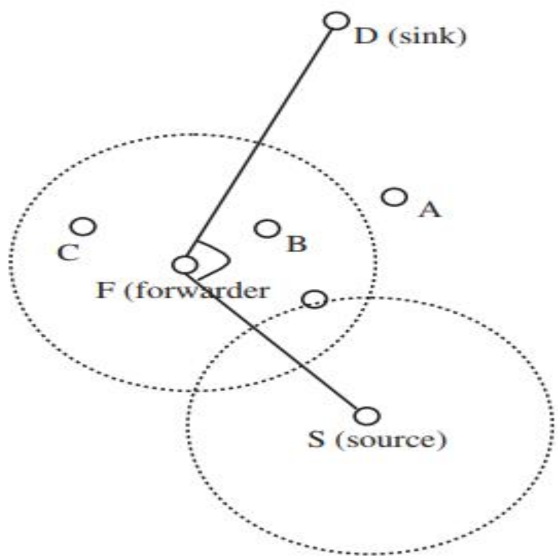


Fig 3.1: DFR packet transmission

3.7 Distributed underwater clustering scheme(DUCH):

(Domingo and Prior,2007)[108] provides us a new and robust energy saving protocol. The protocol is divided into cluster in two phase. The first phase deals with the organization of the cluster and the second phase deals with the operation of the network. The sensors are organized into a cluster centering on a cluster head. In this way, several local clusters are formed which are responsible for the collection of the local data. The cluster heads will communicate through multi hop communication to reach the sink node. Various performance issues are related with the operation of the network. Due to a disciplined framework of data transmission, the percentage of energy efficiency rises significantly. But this architecture may at risk due to environmental hazards like tsunami, seismic threat etc. However, its considered for the energy issues basically.

3.8 Depth Based Routing (DBR):

DBR (Yan et al., 2008)[109] is a unique protocol which deals with depth functionalities. The sensor nodes at different depth are installed with depth sensors. The sensors in higher depth will calculate the depth of respective positions with respect to sea surface and forward data packet to comparatively lower depth sensors. While sending packet, the depth information will be put in the packet header. The whole network will transmit data in this way. But this protocol is applicable for shallow water and it may not be applicable for higher depth water. Sometimes it’s seen that a node can’t find a target node having lesser depth than it. Then it broadcast the data packet frequently which can collapse whole network. Though void problem is taken into account always so that such problem can’t happen. There will be scopes for the development of this protocol and make it feasible in deep water.

3.9 Hop-by-Hop Dynamic Addressing Based Routing (H2-DAB):

The node movement problem is very troublesome for the UWSN. It causes much complexities in acoustic data communication. (Ayaz and Abdullah, 2009)[110] has given us a new idea to solve this problem. The nodes will be given dynamic addresses. Maximum nodes will be connected with buoy and the rest will be mounted on the sea bottom. Dynamic addresses will be given from the upper level to the lower level. Small address will be attributed to upper level and larger address for the ones located in lower ones. The data communication will take place through Hello packet initialization. The sink nodes are connected via radio links where communication is easier for the data received from the acoustic sensor nodes. The difference between the small and large dynamic address is relative to the surface. The node closer to the surface will be having small address and vice versa for the other nodes. The main condition for any protocol is introducing a network architecture first. Because the whole performance depends on the network architecture and the organization of the sensor nodes. If these conditions satisfy then a networking protocol can be called intelligent one. Besides, hardware infrastructure is also a crying need for sensor network. The main advantage of this protocol is that it does not need any hardware infrastructure and complex routing table synchronization. As this protocol follows multi hop communication scheme. So the complexities of that communication is existent in this protocol. Nevertheless, this protocol is more sustainable in case of dynamic characteristics of nodes. Fig 3.2 illustrates H2-DAB protocol.

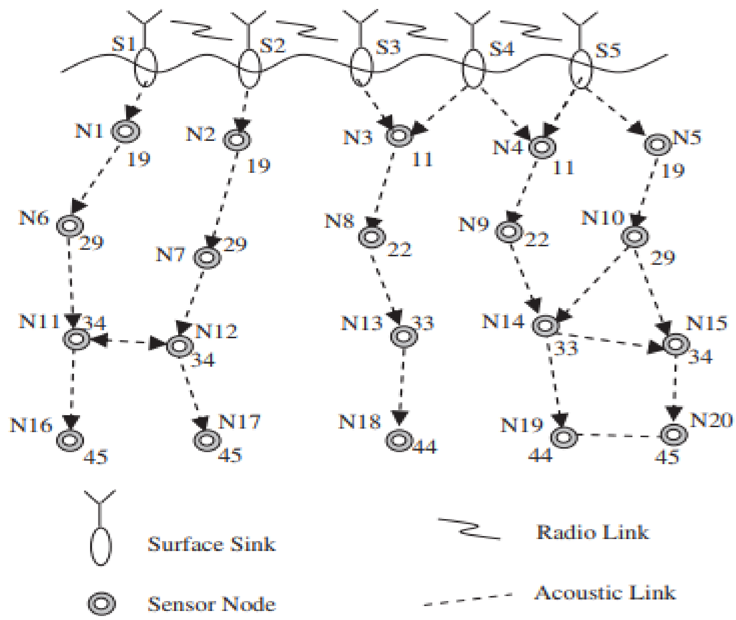


Fig 3.2: H2-DAB protocol and the assignment of addressing ID with Hello message

3.10 Sector-based Routing with Destination Location Prediction (SBR-DLP):

Several protocols proposed that if networking overhead is reduced the energy efficiency will increase. (Chirdchoo et al. (2009)[111]proposed a protocol for mobile environment of nodes.Itsa location based protocol where there is no intermediate node for data transmission.The protocol is named after SBR-DLP and carrying information to neighboring nodes is not required. Its assumed that each node knows its position and the neighboring one position. It is shown in shown in Fig.3.3, that node S wants to send a data packet to destination node D. It will broadcast Chk_Ngb packet including current position and ID to find the next hop. The node then calculates whether the distance of it is lesser than the distance of SD or not. If condition is satisfied, the node will send reply message to the S node otherwise it will discard the packet. This system is further elucidated in Table 1. (Xie et al, (2006a)[112] and (Jinming et al,2008)[113]also states about this location based protocol from different perspectives. In other explanations, multiple relay node exists which create a misery. But in this protocol the sender will determine the next hop for sending data packet. This protocol reduces the flexibility of a network. If the organization is installed once, its quite complex to change the topology. Besides, sea current is also a factor which can deviate the topology. Table 1 has explains the calculation of determining next hop.

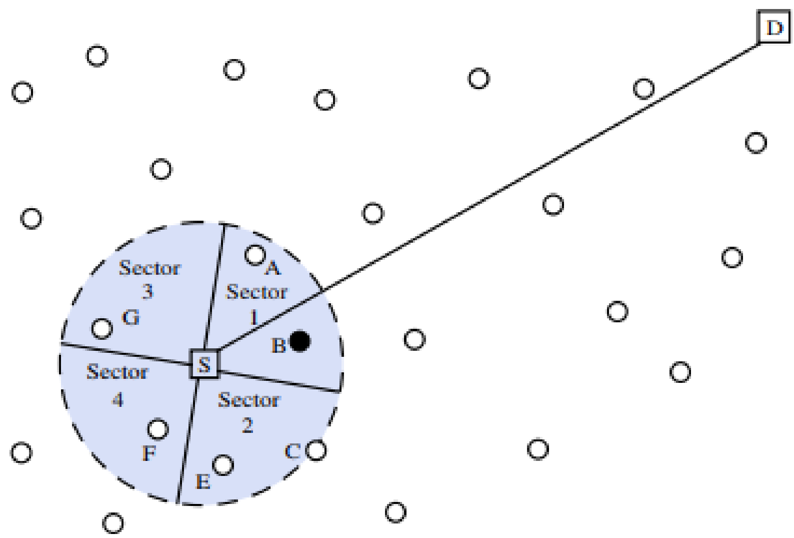


Figure 3.3: Next hop selection at the sender in SBR-DLP.

Table 3.1 How node S picks it's relay node

Sector	Candidates	Distance to D	After filtering
1	A, B	500, 480	A, B
2	C	550	
3	-	-	
4	-	Next relay node	B

3.11 Multipath virtual sink architecture:

Network reliability, capacity and energy consumption are three most important issue of this network topology. We can find sufficient redundancy and robustness so that the communication will take place in case of mismanagement in any portion of the network. (Seah and Tan (2006)[114]has proposed a Multipath Virtual Sink architecture with a view to making a robust network. The whole network is divided into many local clusters which consist of several aggregator, local sink. The local sinks are connected through high radio network. When the sensors broadcast data the local sinks receive it and instantly establish virtual sink. This protocol helps to reduce multiple retransmission. Fig 3.4 illustrates the protocol. The local sink send hop count message to reach the destination. The topology forms a mesh for the data transmission. The advantage of is that the multiple sink will combine the data given from different local clusters.

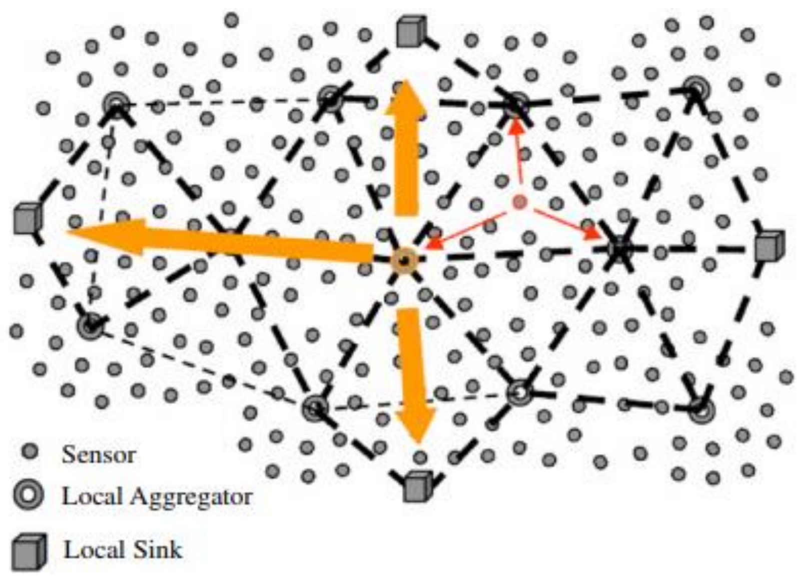


Fig. 3.4: Multipath Virtual Sink organization.

3.12 Mobile delay-tolerant approach (DDD):

Acoustic communication causes higher energy consumption than the radio network due to successive attenuation. Frequent usage of acoustic modem is a cause of more energy consumption. In order to reduce energy consumption (Magestretti et al., 2007) [115] suggested a mobile delay tolerant protocol. In this protocol collector nodes are supposed to gather data from the mobile topology. The collector nodes are called dolphin nodes who wander randomly from one place to another place. These nodes collect data from hops and finally transmit them to the surface sink.

The sensor nodes transmit data closer to it in the scattered organization. A dolphin node reaches to the sensor nodes through beaconing and the sensor nodes feel the presence of that. The number of dolphin nodes is an important parameter. If the number increases, the efficiency increases as it randomly travels in every nook and corner.

3.13 Multi-sink opportunistic routing protocol:

The multi sink resourceful routing protocol are introduce for the underwater in the case of mesh network (Tonghong, 2008) [116] (Tonghong,2008)[116]. In between of depth under water nodes and the central nodes there will be create a mesh construction that is like the main nodes of the architecture. For the short depth range of the water here we considered a two dimensional under water network which is quasi stationary. The construction of this is categories into five parts and these parts are, simple sensor nodes, node of mesh, underwater sink, buoy which in the surface position last one is the observing. In the sea bottom surface three are participated among this five and they are follows nodes of mesh, sensor node, underwater sink and in the opposite the buoys position is in the ocean surface. In addition the underwater sink and the buoy of the two different depth rage are connected through a wire or through the virtual pipe. And there introduce a central observing system and that is also connected with the internet. If we compare with the conventional simple node then we see that the node of mesh is morechic, and the data transmit range is also so high. For the betterment of underwater network the mesh node is a major factor, the underwater vehicle also considerable. Later monitoring the incidents of nodes every sensor forwarding the data from the nearest mesh. In this case the mesh nodes are firstly collective and received the data and then sent it underwater sink through multi hop. And at last the packets are collective and it forward to the surface buoy in the onshore observing system.

3.14 Resilient routing algorithm for long-term applications:

In underwater communications, there are various types of defect and various types of layers, such as the acoustic channel are having some injuries in the physical layer and while the features like restricted bandwidth, there are no continuous connectivity and the nodes which are not capable of success they are necessities to introduced with the higher layer, And keep in mind all this matter

(Dario pompili and Ian (2006)[117] for the case of long observing in the underwater application it introduced a robust routing technique which divided into two parts for the finishing the task. First and foremost which work wedo that is to remove the initial joint of the optimal node and discovered for the purpose of resume the energy. It is not as same as the terrestrial networks there are some major differs from the terrestrial network and there it needs a minimum number of nodes or hubs. But in the latter phase or the second phase the nodes are distributed virtually in the online platform it observes and their it has backup paths. The observing of underwater is very costly; so it is needed to be the network is being highly trusted for the avoid of the unsuccessful step of the single and the multiple devices. In this case, all the communication is construction based, and the communication it is starts from the ocean bottom. Every sensor node are not at the fixing position they are floating and these devices are adjusted through a impel. And so in some case the node is not vulnerable and tempering and this is partially affected.

3.15 Energy-Efficient Routing Protocol (EUROP):

The sensor network of underwater and it's all the function run by the power of a battery. There is no alternative energy source. The battery once it placed it can't be the change for the averse of weather and the environment. So the productivity of power is a major question in underwater. For the causes of excessive long delays, it may occur the collapse of acoustic communication with the terrestrial routing because of the routing delay. For the manage this kind of issues,(ChunHao and KuoFeng (2008)) [118] structured vital energy-effective protocol under this title which above we set in 3.15, to the skip of transmission hello message because of minimizing the big amount of energy consumption. The construction which they are proposed for the energy consumption they give a suggestion and that is the use of weight sensor as noteworthy for each sensor hub to get its underwater distance and the location also. The underwater distance we can call it the depth. And the depth base sensor will give permission and denied the hello message for the every sensor nodes, it means it controls the hello message and it is very efficient for the case of energy efficiency. And the depth sensor of the underwater network is deployed in a different position for notice the events that occur in the different location simultaneously. And in the next step bottom of the ocean every node is situated and they are floating and it magnified by a drive or pump. This bottom node is the first step of work they give their information by pushing the nodes towards the surface and came back the initial position after passing the information. The most important thing is the depth based sensor how they structured they are regulating by the length that connects with the sensor one another presented. Here layer is a major fact bust the layers depends on the depth length in the different length there are different layer will caret. In the severe water, sensor interconnect with the surface sink. The forces determining the which layer and which nodes communicates via the channel. There are a request and response packets which are denoted by the RREQ for the request and the RREP for the response for every single node for the communication of the next level or the next hop are use and so on for the latter. This energy efficient protocol is generally run by the rule of packets eliminated for the depth sensor node. Further, these depth sensors basically depend on the distance and every node from their position give a push to give information and the information transmission to the upper layer and sensor node after transmission it back it's the previous position. And set up this in the every depth based sensor it is not so easy task and to do this the cost is increasing and energy may also burden, and it may a cause of short life time of node.

3.16 Focused beam routing (FBR):

The network can be charged with a large number of broadcast queries without early node location information, which can reduce the expected overall output. In order to reduce these unnecessary floods (Jornet et al,2008) [38] the Focused Beam Routing protocol has been introduced. The routing procedure assumes that each source node knows about the final destination location. In addition to this information, intermediate node need not be located. In the time of data packet traverse of its destination, rote are dynamically established and the next hop decision is taken for each step of the route after the relevant nodes have been proposed.

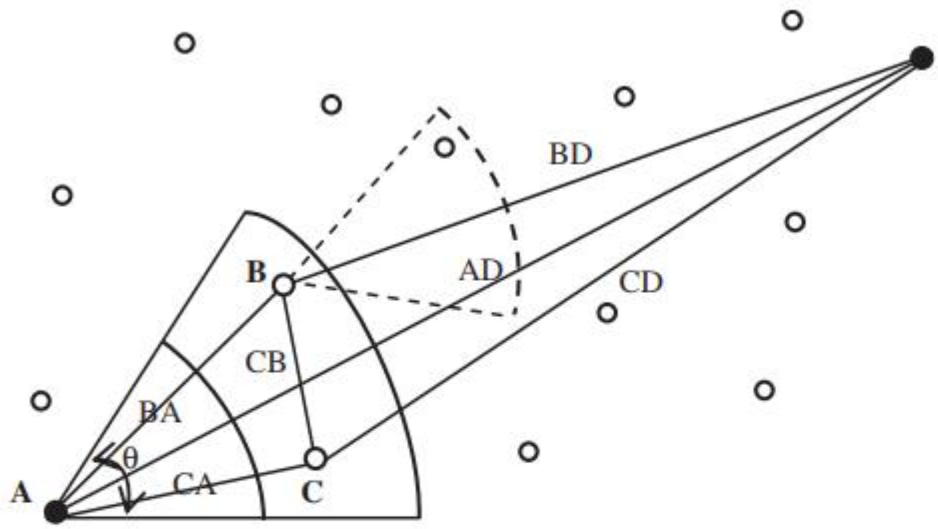


Fig. 3.5:FBR routing protocol illustration: the node in the transmitter cone y are candidate relays.

Fig 3.5 describes the system used to transfer data to FBR. Node A has a data packet that needs to be sent to the destination node D. Node A multicast a request to send the packet (RTS) to its nearby nodes for this purpose. The RTS packet contains the location source(A) and final destination(D). Initially, the multicast action is carried out at lowest power level, which can be improved if one node is found in next hop in this communication range. They define a limited number of P1through PN power level, which can be increased if required. All nodes that receive this RTS multicast now calculate their current location related to the AD line. When the angle is calculated, it respond to the RTS if a node determines that it is in the transmitting cone. However, the approach followed by FBR could present some problems. Firstly, if the nodes become spare due to water movement, no node may lie within the forwarding cone. Some nodes may also be available as candidates outside the forwarding area for the next hop. In this cases, if the next relay node can not be found in the transmitting cone, the RTS must be retransmitted at all time, which ultimately increases overhead communication and therefore affects data delivery in these sparse areas. Secondly, it assumes that the sink is fixed and that its location is known and that the network flexibility is reduced. To date, several protocols with their limits and conveniences have been discussed technically. In view of the constraints, a new protocol was developed to overcome them. It can be assumed that the newly derived protocol will bring about comparative improvement. The protocol is designed to keep the required communication parameters in mind so that the complexity of existing protocols can be reduced. Due to the adverse environment of underwater sensor communication, different communication parameters such as reliability, efficiency and data propagation are subject to serious malfunctions. Underwater communication is not as smooth as terrestrial communication. Whatever the detailed view of the Protocol, the next chapter will be discussed.

So far, several protocols have been discussed technically with their limitations and conveniences. Considering the limitations, a new protocol has been designed to overcome them. It’s may be thought that comparative improvement will be brought through the newly derived protocol. The protocol is designed keeping the necessary communication parameters in mind so that it can reduce the complexities of the existing protocols. Due to the adverse environment of underwater sensor communication, various communication parameters like reliability, efficiency, data propagation fall a victim to severe malfunction. It is aforesaid that underwater communication is not so smoother like terrestrial communication. Whatever, the detailed view of the Protocol will be discussed in next chapter.

Chapter Four

Simulation and Results

4.1 Experimental Setup

For the simulation of the proposed method, Network Simulator Version 3 (ns-3) is been used. ns-3 is a discrete-event network simulator, targeted primarily for research and educational use. ns-3 is free software, licensed under the GNU GPLv2 license, and is publicly available for research, development, and use.

The ns-3 project is committed to building a solid simulation core that is well documented, easy to use and debug, and that caters to the needs of the entire simulation workflow, from simulation configuration to trace collection and analysis. Furthermore, the ns-3 software infrastructure encourages the development of simulation models which are sufficiently realistic to allow ns-3 to be used as a real-time network emulator, interconnected with the real world and which allows many existing real-world protocol implementations to be reused within ns-3. The ns-3 simulation core supports research on both IP and non-IP based networks. However, the large majority of its users focuses on wireless/IP simulations which involve models for Wi-Fi, WiMAX, or LTE for layers 1 and 2 and a variety of static or dynamic routing protocols such as OLSR and AODV for IP-based applications. Ns-3 also supports a real-time scheduler that facilitates a number of "simulation-in-the-loop" use cases for interacting with real systems. For instance, users can emit and receive ns-3-generated packets on real network devices, and ns-3 can serve as an interconnection framework to add link effects between virtual machines.

Figure 5.1 shows the experimental setup which is designed in ns-3. In this figure the red color node is the surface sink node, blue color nodes are the surface buoy and green color nodes are the underwater sensor node. Two scenario is designed between them one is applied with the proposed routing protocol and another is configured with Depth based routing (DBR).

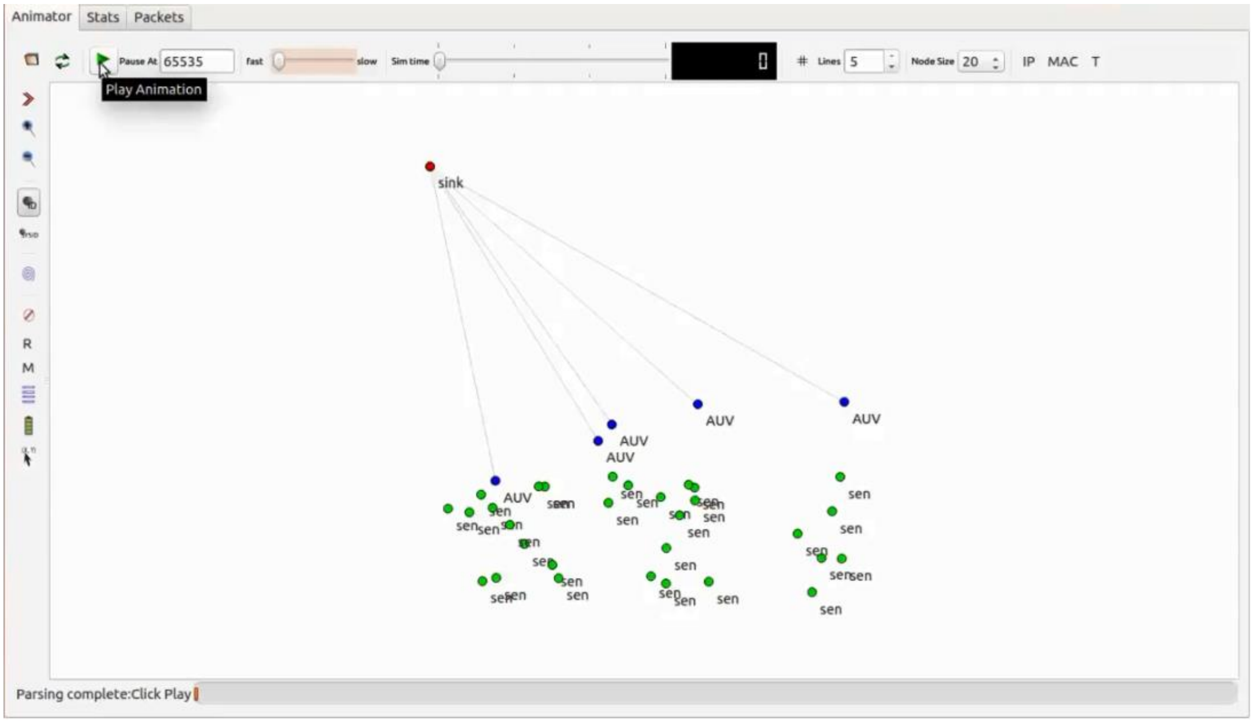
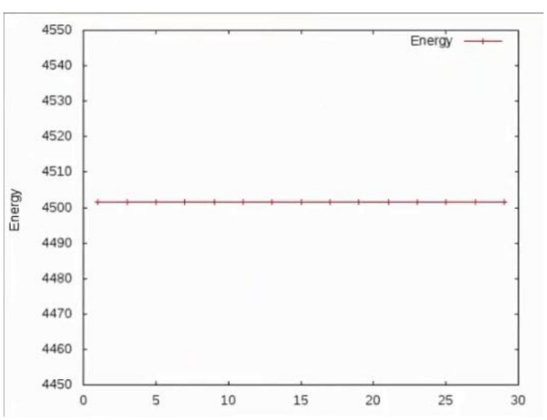
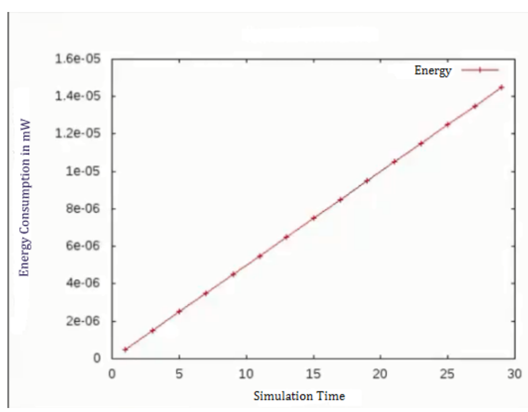


Figure 4.1: Experimental Setup

The energy consumption graph of proposed method and DBR method is illustrated in figure 4.2. The X-axis of the graph denotes the simulation time and Y-axis of the graph denotes energy consumption in mW. After observing the graph it is seen that in the proposed method there is no change of energy consumption compared the conventional DBR method.



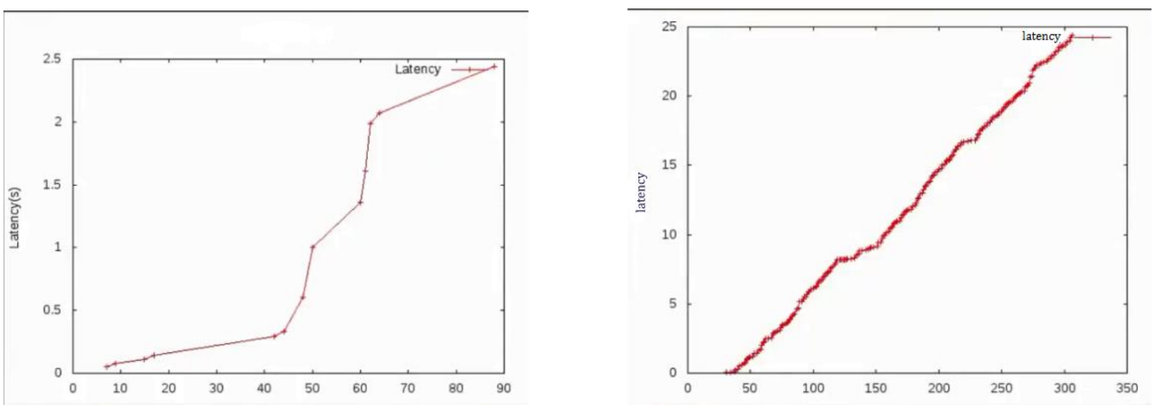
(a) Energy Consumption (Proposed)



(b) Energy Consumption (DBR)

Figure 4.2: Energy Consumption Comparison graph

Latency of the UWSN is illustrated in figure 4.3. Both proposed and DBR based method is applied to calculate the latency. The X-axis describes the simulation time and Y-axis of the graph describes latency in second. At the simulation time 90, the latency in proposed method is 2.5s whereas in DBF method the value is almost double 5s. The proposed method converge the network comparatively faster than DBF method.



(a) Latency in S (Proposed)   (b) Latency in S (DBR)

Figure 4.3: Latency Comparison graph

Here we give a comparison table which we compare our protocol with some existing new protocol. When we compare the protocols, we take some major parameters that are the delivery ratio, delivery efficiency , energy efficiency , bandwidth efficiency , reliability , cost efficiency , and finally the performance. And obviously we compare with that protocol which are related to our protocol. The protocol chosen for the comparison that are the vector based forwarding, focused beam routing, reliable and energy balanced routing algorithm, information carrying routing protocol, directional flood based routing protocol, distributed underwater clustering scheme depth base routing , and finally we give the result which we find after the simulation . And we said that it is a robust routing protocol.

Table 4.1 Parameters Comparison

Protocol/architecture	Delivery Ratio	Delay efficiency	Energy efficiency	Bandwidth efficiency	Reliability	Cost efficiency	Performance
Vector based forwarding	Low	Low	Fair	Fair	Low	Not applicable	Low
Directional flood-based routing	Fair	Fair	Low	Fair	High	N/A	Fair
Depth based routing	High	High	Low	Fair	High	Fair	High
Directional vector based forward focused beam routing	Very High	Very High	Fair	Fair	High	N/A	High

Chapter 5

Conclusion

5.1 Conclusion

Both in terrestrial and underwater network system routing is an important issue. A short overview given in this paper on underwater sensor networks. Routing system in underwater network is very important because every parameters and their performances somehow connected with the routing protocol. Here in this paper we give a vigorous drive on routing protocol of UWSNs. The routing protocol which are related to our protocol that are analyzed anxiously their merits, demerits. In addition we compare protocol energy efficiency, latency etc. In underwater wireless sensor networks still there are huge scope of work on it because many research challenges are yet not solved. Therefore, the scope of future work should be performed in order to superintend that the available solutions in greater detailed.

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