UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUTE OF SCIENCE AND TECHNOLOGY

PERFORMANCE ANALYSIS OF LOCALIZATION AND NETWORK CONNECTIVITY IN UNDERWATER SENSOR NETWORKS

MASTER THESIS

Mohanad Khairulddin ABDULJABBAR

DEPARTMENT OF INFORMATION TECHNOLOGY

PROGRAM OF INFORMATION TECHNOLOGY

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Supervisor: Asst. Prof. Dr. Yuriy ALYEKSYEYENKOV

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I hereby declare that all the information in this study I presented as my Master's Thesis, called: "Performance Analysis of Localization and Network Connectivity in Underwater Sensor Networks", has been presented in accordance with the academic rules and ethical conduct. I also declare and certify with my honor that I have fully cited and referenced all the sources I made use of in this present study.

24.11.2017
Mohanad Khairulddin ABDULJABBAR

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Thanks to the most compassionate, gracious and merciful. May Allah's blessings and peace be upon our prophet Mohammed who protects us from the depths of darkness and leads us forth into light, and his house hold.

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November 2017 Mohanad Khairulddin ABDULJABBAR

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LIST OF ABBREVIATION

ADSL : Asymmetric digital subscriber line
ASK : Amplitude shift keying
AUV : Autonomous Underwater Vehicle
BASK : Binary amplitude shift keying
BPSK : Binary Phase Shift Keying
BFSK : Binary frequency shift keying
BPSK : Binary Phase Shift Keying
DPSK : Differential Phase Shift Keying
FSK : Frequency Shift Keying
LEACH : Low Energy Adaptive Clustering Hierarchy
MANET : Mobile Ad-Hoc Network
PSK : Phase Shifting Keying
SOFAR : Sound Fixing and Ranging
WSN : Wireless Sensor Network
UT : Underwater telephone
SSB : Single Side Bond
RTT : Roundtrip time
PSK : Phase Shift Keying
QAM : Quadrature Amplitude Modulation
WLAN : Wireless Local Area Network
DVB-T : Digital Video Broadcasting — Terrestrial
OFDM : Orthogonal Frequency-Division Multiplexing
RBCRP : Region-based cooperative routing protocol
PACT : Pressure based Acoustically Coupled Tsunameter
OBU : Ocean Bottom Unit

ABSTRACT

PERFORMANCE ANALYSIS OF LOCALIZATION AND NETWORK CONNECTIVITY IN UNDERWATER SENSOR NETWORKS

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Underwater wireless communication opens up a wide field of application in the field of civilian and military surveillance and exploration of the oceans. Sensor networks, consisting of sensor nodes exposed under and above water, use ultra- and infrared for communication in order to transmit data in the water. This thesis gives an overview of the problems associated with the acoustic communication under water and presents appropriate solutions. It also examines the current modulation methods and provides an overview of current applications. In this thesis, fundamental problem of node deployment in underwater acoustic sensor network is investigated. The random, regular and cube deployment discussed in three dimensional underwater acoustic sensor network. Also these methods are compared with their performances in detail in terms of localization ratio, localization error, average number of neighboring anchor nodes, and network connectivity. For Localization ratio we got the 89.2473, for Localization error the 24.6079 is reached. Also for Average neighborhood and Network connectivity we got 5 and 141.29 respectively. In this thesis we used the MATLAB 2014a version.

Keywords: Wireless Sensor Network, Underwater Wireless Communication, Localization.

ÖZET

ALT SENSÖR AĞLARININ LOKALİZASYON VE AĞ BAĞLANTISINA BAĞLI PERFORMANS ANALİZİ

ABDULJABBAR, Mohanad Khairulddin
Yüksek Lisans, Bilgi Teknolojileri Bölümü
Tez Danışmanı: Yrd. Prof. Dr.Yuriy ALYEKSYEYENKOV
Kasım 2017, 49 sayfa

Sualtı kablosuz iletişim sistemleri, sivil ve askeri gözetim ve okyanusların araştırılması alanında geniş bir uygulama alanına sahiptir.Suyun altında ve üstünde bulunan sensör düğümlerinden oluşan sensör ağları, sudaki verileri iletmek için ultra sonik -ve kızılötesi haberleşmeyi kullanır. Bu tez, su altındaki akustik iletişimle ilgili problemlere genel bir bakış yapmakta ve problemlere uygun çözümler sunmaktadır. Ayrıca, mevcut modülasyon yöntemleri ve mevcut uygulamalar genel olarak incelenmiştir.

Bu tez çalışmasında, sualtı akustik algılayıcı ağında düğüm dağıtımının temel problemi araştırılmıştır. Üç boyutlu su altı akustik sensör ağında rasgele, düzenli ve küp dağıtım yöntemleri tartışılmıştır. Ayrıca bu yöntemlerin; lokalizasyon oranı, yerelleştirme hatası, komşu çapa düğümlerinin ortalama sayısı ve ağ bağlantısı bakımından performansları karşılaştırılmıştır. Çalışmada yerelleştirme oranı 89.2473 olarak elde edilmiş, bu yerelleştirme için yerelleştirme hatası 24.6079 değerine ulaşılmıştır. Ortalama komşu ve ağ bağlantısında sırasıyla 5 ve 141.29 değerleri elde edilmiştir. Bu tez çalışmasında MATLAB 2014a versiyonu kullanılmıştır.

Anahtar Kelimeler: Kablosuz Algılayıcı Ağı, Su Altı Kablosuz Iletişim, Yerelleştirme.

CHAPTER ONE

INTRODUCTION

1.1 Background

Sound waves are of great importance for communication in the ocean, since, in contrast to electromagnetic waves, water sound waves hardly absorb. Electromagnetic waves have a range of only a few hundred meters in water, but sound waves can reach distances of more than 1000 km depending on the application scenario. Because of the electrical conductivity of salt water, much energy is needed to communicate with electromagnetic waves under water. Only relatively low frequencies below 300 Hz can be communicated over further distances [1]. However, relatively large antennas are required for this purpose. High-frequency electromagnetic waves, on the other hand, are shielded as far as possible at low depths. As a rule, sound waves are used for communication, positioning and navigation [1].

Underwater wireless communication opens up a range of military and civilian applications: it is used to monitor climatic, biological and seismographic changes in the oceans, explore the seabed, and so on. For the detection of new oil deposits, but also for the detection of enemy submarines and mines. Not least due to the major tsunami catastrophes of 2004 and 2011 is a response-oriented tsunami early warning system of global interest, which is based on fast and efficient communication structures.

Acoustic underwater telephone is a method for underwater communication, in particular with submarines. It is also known under its original cover name Gertrude [2].

The range is very limited and depends on the water depth and temperature. Gertrude does not work through the thermocline. Simply put, Gertrude is a powerful loudspeaker that emits the sound waves directly into the surrounding water. The passive sonar sensors of another boat or vessel can intercept these waves.

Although Wasserschall meets the requirements of today's communication requirements, electromagnetic waves are practically unsuitable, depending on the turbidity of the water, over distances between 10 and 300 m, and the water sound is therefore not an alternative. The speech signal is shifted to a higher frequency range by a modulation method in order to achieve a better signal-to-noise ratio.

Already in the Second World War, the Underwater Telephone (UT) or Gertrude, was used. It was an analogue voice transmission in Single Side Bond (SSB) technology in the upper sideband with 9 kHz as carrier and the frequency range 300 Hz to 3 kHz usual from the then telephony. Especially in the shallow water the reception was extremely bad because of the multipath transmission. There was also only this one frequency channel available.

In the meantime, transmission methods from modern mobile radio technology are being used which, due to the poor propagation conditions and the low available bandwidth (predominantly frequencies between 5 kHz and 40 kHz), also allow only small amounts of information and range. The system used by NATO today achieves reach up to 10 km, the successor system Deep Siren promises some 100 km range [3].

Sensor networks are often used for this purpose, which are composed of distributed sensor nodes, equipped with the respective measuring devices and devices for communication, in order to perform collaborative monitoring tasks. In this thesis, the physical basis of the propagation of sound waves under water is first dealt with. Subsequently, the transfer of data under water is considered in more detail, and the modulation aspect is taken with the aid of a subsea water. In section 4 the components of subsea water sources are described. After considering the basics, two applications of sound waves underwater are presented and, in particular, a system for early detection of tsunami is presented. As a conclusion, the most important aspects of acoustic underwater communication are summarized again and a brief outlook on the future development in this area is given. The conceptual drawing of an underwater sensor network is shown in Figure 1.1.

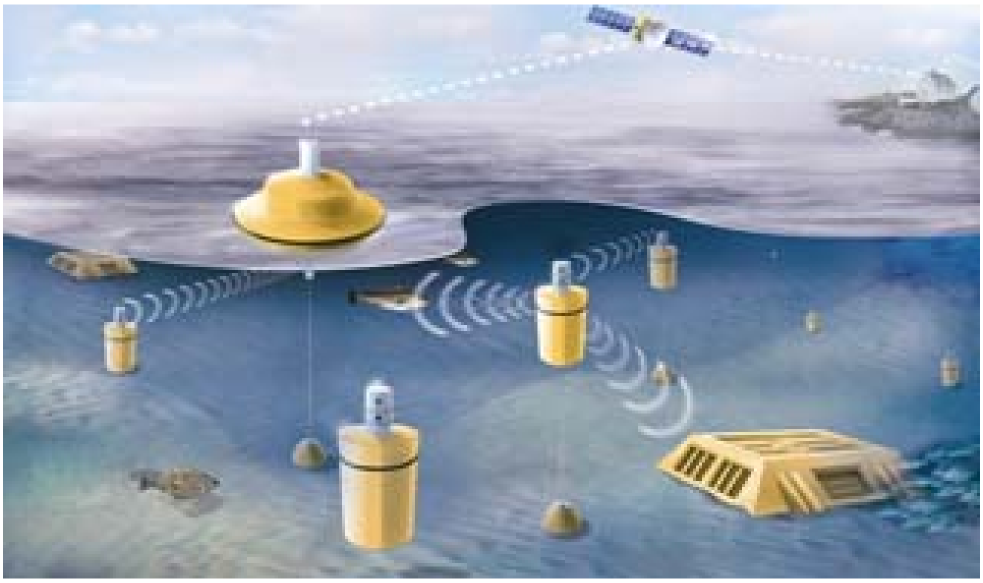

Figure 1.1: Conceptual drawing of an underwater sensor network [4]

1.2 Basics of Water Sound

In this section, the physical basics of sound propagation in the water are treated to provide an overview of the requirements for systems for acoustic communication in the ocean.

Sound propagates in the form of a wave, the vibrations in the propagation direction (longitudinal wave) occur under water.

The frequency range used for the communication is between 10 Hz and 1 MHz [5]. These frequencies lie within the frequency ranges of the infrared (<16 Hz), the hearing sound (16 Hz to 20 kHz) and the ultrasound (20 kHz to 1.6 GHz).

1.3 Sound Velocity in the Water

The speed of sound waves under water depends essentially on three factors: pressure, water temperature and salt content. At a temperature of 20 ○ C and under atmospheric pressure, the sound velocity in water is 1484 m / s, whereas the sound in air is only moved at a comparatively low speed of approximately 340 m / s. With increasing depth (or pressure), salt content or temperature, the sound velocity increases [6].

Depending on the latitude and therefore the water temperature in the upper water levels, the increase in velocity caused by the pressure increase is superimposed by the temperature decrease to a depth of about 1 km. From this depth, the water temperature is constant at about 4 ○ C [7]. The resulting velocity profile as a function of the depth is schematically shown in Figure 1.2.

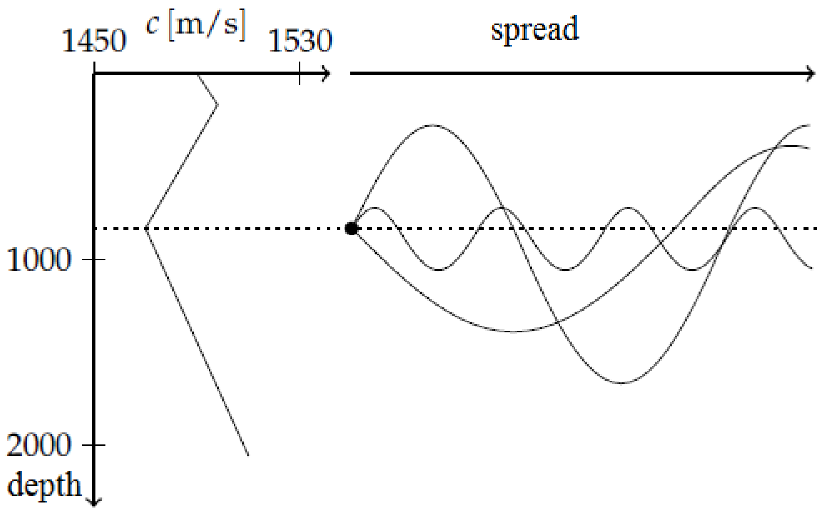

Figure 1.2: Left: schematic velocity profile, right: sound propagation in the short for sound fixing and ranging (SOFAR) (Channel, Dotted: SOFAR Channel) [7, 8].

According to the law of refraction, a sound wave is always refracted in the direction of the lower propagation velocity. Sound waves emitted in the region of the minimum sound velocity are therefore "fixed" within this water layer. As a result, the sound waves can spread over long distances within this channel (the so-called SOFAR channel) (see Figure 1.2).

Directly below the surface of the sea, the temperature is often the highest and then decreases relatively quickly to about 50 m depth. As a result, sound waves that move below or above this limit cannot reach the other layer due to refraction. This so-called acoustic shadow zone strongly influences the communication between these water layers [7].

1.4 Multipath

As a result of reflections on the seabed or on the water surface, the pathways of the signals (the so-called multipath propagation) vary in length. The resulting amplitude and phase fluctuations increase with increasing distance from the sound source, which affects the demands on the modulation method and the possible data rate. This is referred to as inter symbol interference [9].

1.5 Doppler Effect

A Because of the Doppler Effect, movements of the transmitter or receiver lead to frequency shifts and thus to an expansion of the frequency bandwidth. This effect occurs not only in immersion robots by controlled movements, but also in buoys and underwater measurement units, which are exposed to swell and currents. The magnitude of the Doppler Effect is proportional to the ratio of the motion to the propagation velocity [10]. Due to the relatively low speed of the sound waves compared to electromagnetic waves, the signal is significantly more distorted by the frequency shift than doe’s e.g. terrestrial radio.

1.6 Underwater Noise

Underwater noise is referred to as sound waves, which are not generated directly by the transmitter. These are, on the one hand, natural ambient noises generated by wind, currents, rain, seismic activities or marine inhabitants. However, the greater part of the underwater noise is artificial noise from ships, oil platforms or pumps.

Underwater noise is the strongest in the low frequency range and decreases with increasing frequency. Depending on the frequency band used, these noises can influence the signal-to-noise ratio differently [7]. When using higher frequency bands, the effect thus decreases, which in turn is associated with other disadvantages such as the higher damping.

1.7 Damping

The absorption damping (conversion of sound energy into heat) can be largely attributed to the relaxation damping in seawater. Relaxation damping occurs with a delayed adjustment of a chemical equilibrium with pressure change. Since many components are present in seawater in various chemical states and the ratio of one another is only delayed by pressure-dependent equilibrium reactions, energy is withdrawn from the sound wave.

In the kHz range, this effect is mainly caused by boric acid and magnesium sulfate [8]. In [11] was added the sound velocity in water is also dependent on the frequency, which leads to dispersion phenomena. Dispersion describes the dependence of the phase velocity on the frequency of a wave. Depending on the relative bandwidth of the signals, this effect can lead to considerable changes in the run-time or pulse shape [11].

This relationship is experimentally confirmed and an empirical formula for the energy attenuation coefficient is given. Absorption also occurs in the water during reflections on the sea floor, ice, air bubbles or other obstacles. The sound intensity also decreases with the square of the distance to the sound source (divergence). All these effects lead to a decrease in the energy of a sound wave and therefore to its range.

1.8 Latency

The transmission speed, which can be achieved with electromagnetic waves, corresponds to the speed of light and is therefore about 300,000 km / s. The associated latencies are negligibly small for many applications. In the case of acoustic underwater communication, on the other hand, the latencies are much higher due to the much lower speed of the sound waves.

An indication of the roundtrip time (RTT), transit time of a data packet from the source to the receiver and back) for a packet is hardly possible due to the high variability of the sound velocity caused by the multipath propagation [1]. Thus, many known transport layer protocols are unsuitable for use under water since they require accurate estimation of (RTT).

1.9 Range

The range of sound waves under water, as indicated in section 2.5, depends strongly on the respective frequencies. Depending on the application and the desired range, the frequency band must be chosen accordingly. In Reference [5], the frequency bands are divided into five categories according to reach.

The data rate depends to a great extent on the frequency used. High frequencies are therefore desirable for high data rates, but these can only be used over short distances.

CHAPTER TWO

MESSAGE TRANSMISSION

2.1 Background

For the acoustic transmission of data under water, the previously mentioned limitations and obstacles have to be considered and adequate solutions have to be found.

In order to transmit or receive messages under water, you need a water-sound transducer (also called a submersible). The piezoelectric and the magneto astrictive transformation is predominantly used as the conversion effect [5]. The object of a water-borne sound transducer is to modulate the data to be transmitted to a carrier frequency and to deposit the sound waves, as well as to receive signals and to restore data there from (demodulation).

The requirements for the design of a water-borne sound transducer are high: they must be resistant to external influences such as, for example, Tightness, corrosion resistance and compressive strength, have a good adaptability to the transfer medium water [5]. For a more detailed description of the functioning of a water-borne sound transducer, reference is made here to Troin and Cazaoulou [12].

The following section presents some common modulation methods and a classification of the signals.

In [13] they focuses on underwater routing protocols in the network layer, where underwater sensor nodes can collaborate to transmit data.

2.1.1 Amplitude Shift (ASK)

Amplitude Shift Keying (ASK) is an amplitude modulation method that modulates the signal states with the aid of different amplitudes. For binary amplitude shift keying (BASK), two different amplitudes are used which encode states 0 and 1 [14]. Figure 2.1 shows the modulation of the signal sequence "1010".

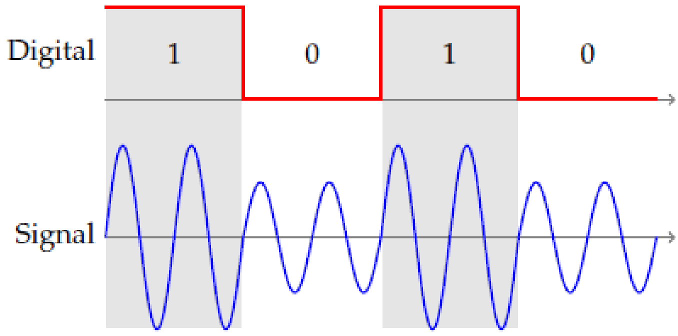

Figure 2.1: Binary Amplitude Shifting [14]

2.1.2 Frequency Shift Keying (FSK)

In Frequency Shifting (FSK), the carrier frequency of a periodic sinusoidal oscillation is varied between a set of different frequencies which represent the individual discrete states (such as 0 or 1) to be transmitted. The signals to be sent are synthesized by juxtaposing the respective frequencies [14]. Figure 2.2 shows the form of the binary frequency shift keying (BFSK) with two states for the signal sequence "1010".

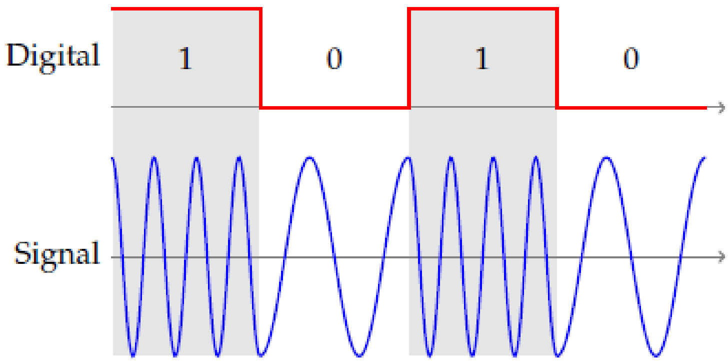

Figure 2.2: Binary frequency shift keying [14]

In underwater environments, the phenomenon of signal disorder that affects network protocols has come to the exhibition and the sensor nodes connected by the wires are randomly moved at a spherical crown surface [15]. This article [16] presents an Autonomous Underwater Vehicles (AUV) efficient data collector routing protocol for delivering trusted data.

2.1.3 Phase Shift Keying (PSK)

Phase Shift Keying (PSK) uses phase shifts or shifts of the carrier signal to modulate the message signal.

The simplest case of the Binary Phase Shift Keying (BPSK) can be described as a multiplication of the carrier with ± 1 (+1 for the logical 1, -1 for the logical 0 of the data signal) [14]. As a result, the phase of the carrier signal is shifted by 0 "and 180", respectively.

The problem with receiving a (PSK) signal is the phase synchronization.

To establish the assignment of phase to signal value, a special synchronization word is transmitted during the connection setup. Otherwise, the bit sequence at the receiver could be inverted in the case of incorrect assignment, ie, if the receiver locks into the wrong phase and the phase is shifted by P, [14].

In the phase difference modulation, Differential Phase Shift Keying (DPSK), the bits are encoded by changing the phase. When two symbols are used, a change in the phase encodes by 0 "a 0, the change of the phase by 180". The information is encoded in the difference between the phase positions of successive steps, while in the classical (PSK) the information is stored directly in the Phase is encoded. Two consecutive ones would not cause a phase shift in the simple binary (PSK), whereas in the binary (DPSK), the second 1 is encoded by an (additional) phase jump by 180 [14].

This variant of the coding has two main advantages: On the one hand, the measurement of a phase change on the receiver side is significantly easier to realize since no common reference time is required. On the other hand, by means of this type of coding, automatic synchronization is ensured even after connection interrupts since the information is correctly interpreted at the latest from the second bit read [14].

Figure 2.3 shows phase shifting using the example of signal sequence "0110".

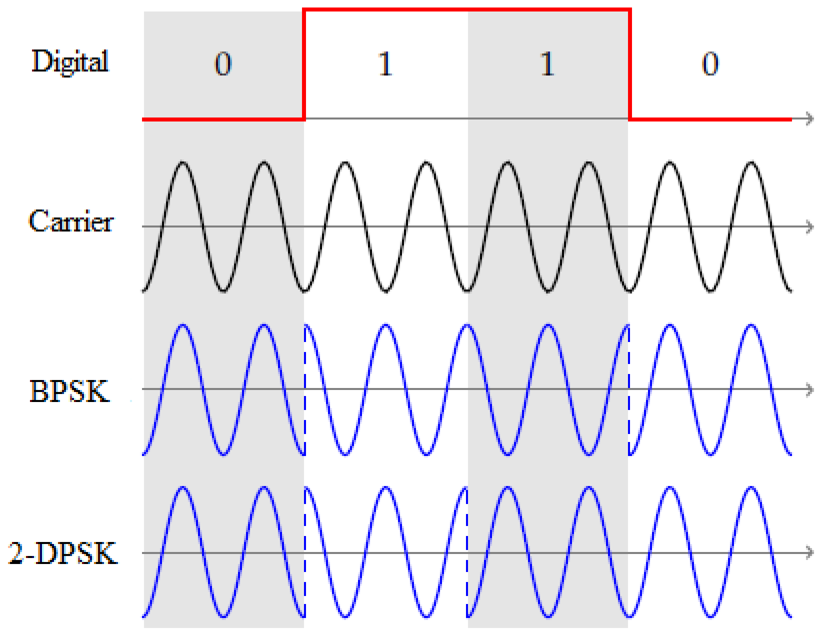

Figure 2.3: Phase shift keying [14]

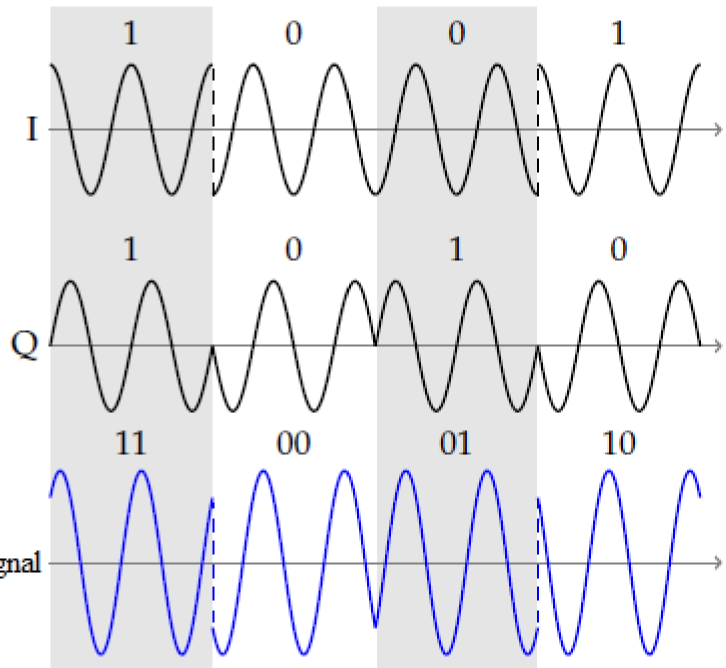

Figure 2.4: Quadrature amplitude modulation (4-QAM)

The paper [17] concerns the definition and performance evaluation of a new multi-hop routing protocol for underwater wireless sensor networks.

2.1.4 Quadrature Amplitude Modulation (QAM)

The Quadrature Amplitude Modulation (QAM) is a modulation method realized by a combination of phase shift keying and amplitude shift keying. The digital data signal is divided into two signals of the same frequency which are added to the carrier (also the same frequency). The two signals, Inphase I and the so-called quadrature Q, shifted to I by 90 "can both be used to transmit information.

For this purpose, both are modulated independently of one another by means of amplitude modulation. The two signals are orthogonal to each other and do not interfere with each other.

In [18], a load control model is considered for loading time in the external sensor network with time delay.

For illustrative purposes, the amplitude and phase of the added signal at the time of sampling in polar coordinates are expressed in a constellation diagram, the amplitude corresponding to the distance from the origin and the phase being the angle relative to the intersection of the I/Q axes. This type of representation is possible since I and Q are orthogonal to each other. The number of representable symbols representing points in the complex plane is expressed as a number. Figure 2.5 shows such a constellation diagram for the (QAM) with four symbols showing the arrangement of the data symbols. Figure 2.6 shows the components of the 4-QAM and the added signal, whereby it must be noted here that the modulation of the amplitude takes place by multiplication by 1 or -1. In principle, it is possible to arbitrarily increase the number of symbols which can be represented, but this increasingly makes demodulation more difficult. During the demodulation, the reconstructed point in the constellation diagram must be assigned to the previously defined symbols. If the number of symbols that can be displayed is increased, the tolerance ranges between the symbols are simultaneously reduced, making a clear assignment more difficult [14].

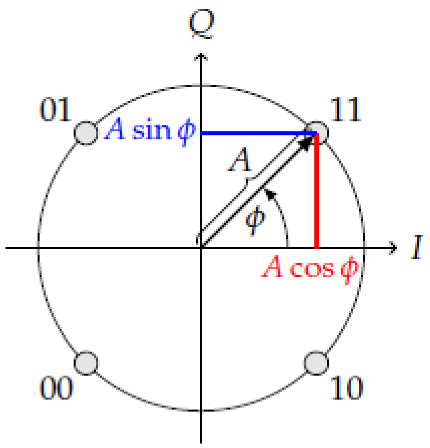

Figure 2.5: Constellation diagram for 4-QAM [14]

2.1.5 Orthogonal Frequency Division Multiplexing (OFDM)

The orthogonal frequency division multiplexing method (OFDM) is a so-called multicarrier modulation method which uses several orthogonal carrier signals for data transmission. This method is particularly suitable for wireless communication, since it is less susceptible to narrow-band interference, since, if they relate to only a portion of the carrier signals, they relate to only a part of the data. If disturbances occur in a part of the carrier signals, they can simply be excluded from the data transfer [9].

The data stream with a high data rate to be transmitted is divided into sub-data streams of low data rate at the (OFDM), which are modulated individually on subcarriers by one of the previously presented modulation methods. The functional spaces of the individual sub signals described by the carrier signals are to be selected orthogonally to one another, so that the carrier signals can be distinguished during the demodulation on the receiver side.

The (OFDM) signal is generated from the individual sub signals by a complex-calculating inverse discrete Fourier transform. On the receiver side, the signal can then be separated back into the individual sub signals by means of the fast Fourier transformation [9].

(OFDM) is used in radio technology for Wireless Local Area Network (WLAN), (DVB-T) and (LTE). It is also used with (ADSL). Figure 2.6 shows a schematic representation of the modulation process. The data to be transmitted have already been subdivided into sub signals and individually modulated to the carrier frequencies F1 to Fn.

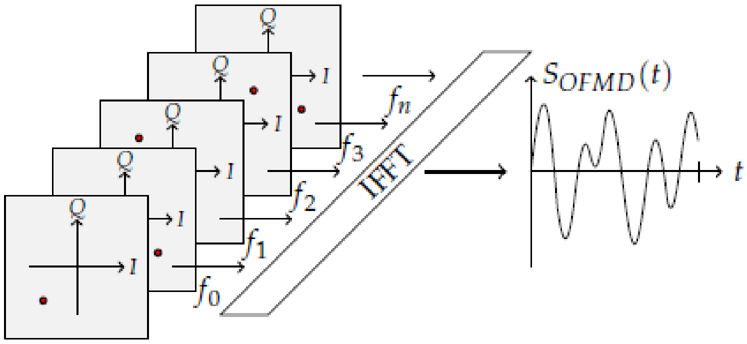

Figure 2.6: Schematic representation of a modulation with OFDM [19]

2.2 Signal Types

Data throughput and reliability of an underwater sensor node are severely limited by the physical limitations. Accordingly, it is useful to classify the requirements for such a system according to the application. In [20], such a division of the signals to be transmitted is made into control, measured value and video signals, which are considered in more detail below:

2.2.1 Control Signals

Signals for control, navigation and status transmission are referred to as control signals. They must be transmitted with high reliability, but require a low bandwidth of less than 1 kbit / s.

2.2.2 Measured Value Signals

For the transmission of measurement data and images with low resolution, however, bandwidths of up to about 10 kbit / s are required. In this case, small transmission errors in the range from 10-4 to 10-3 are justifiable.

2.2.3 Video Signals

The transmission of high-resolution image and video data requires the greatest bandwidth. With a resolution of one megapixel (8 MBits), the transmission of the image requires several seconds even at a bandwidth of 500 kbit / s. In this case, an error rate of up to 10-4 is acceptable.

Towards the end of the twentieth century, Terrestrial Wireless Sensor Networks (WSN) have become popular topics for researchers. These pile-driven, simple and small networked networks were first used in terrestrial applications and were preferred in a wide range of applications ranging from military applications to earthquake prediction, with the ability to create an ad hoc network with ease. In all these application areas, the main goal is to collect environmental data and ensure that these data are transmitted to a center in the most efficient manner. It is important to remember that the fact that sensor devices are pliers and have a simple processor. For this reason, the simplicity of energy consumption and node-to-node messaging should be considered first in the design of protocols to be developed for sensor networks.

Even though there are similarities with terrestrial (CAI), Underwater Wireless Sensor Networks need to be examined separately with their specific features. (WSN) is a well-studied topic by researchers and there are a number of protocols developed for use in these networks. However, using these protocols for (UWSN) may not be an effective approach. The main reason for this is that communication environments are completely different.

2.3 Underwater Wireless Sensor Networks Overview

The oceans and seas have attracted the attention of researchers at all times, but they lag behind terrestrial environments because they are physically difficult environments. In the recent past, the unobstructed curiosity of searching for unknowns on the planet we live on has begun to be used in the seas and oceans that make up 70% of the Earth's earth. This use can be used to observe underwater live populations, underground mine-historical works, to search for underwater oil pipelines, to conduct water pollution analysis, as well as for military and commercial scientific research.

Some application areas are briefly described below:

1. Environmental observation: With Underwater Sensor Networks, chemical, biological and nuclear pollution observations can be made. For example, underwater sensor networks can be used to perform chemical analysis of water from the seas,

rivers or lakes, or the bottom mud. In addition, applications such as ocean currents and wind observation, advanced weather forecasting, and submerging of underwater organisms or micro-organisms can be considered as examples in this group [21].

In [22], they propose a region-based cooperative routing protocol (RBCRP) for reinforcement and forward techniques on compressed-rail channels in the (UWSN).

a) Underwater discovery: Underwater Sensor Networks can be used in the discovery of oil basins or mineral deposits underwater, in determining the pathway for cables to be laid in water.

b) Disaster prevention: Underwater Sensing Networks are also involved in measuring upcoming tsunami [23] or investigating the effects of underwater earthquakes by measuring distant seismic activity from distant points.

c) Seaway assistance: Underwater Sensor Networks are used to identify hazards in the sea bed, hazardous rocks in the shallow water, suitable locations for mooring, and bathymetry profiles.

d) Military applications: Underwater Sensing Networks are also used in applications such as determination of infringement of territorial waters, mine screening, discovery of battlefield and target detection[24].

The traditional approach used to observe the water to place perceptions and leave them as they are until the observation is complete;[25], which is the method of collecting and storing the perceptors after the end of the application period. The disadvantages of this method are as follows:

2. Real-time observation is impossible: The pool of underwater observation devices is accessible only after the application has been completed, after the nodes have been removed, and this observation process may continue for months. Such an approach is not at all suitable for an application that requires rapid transfer of data to the water surface, for example, an application that measures seismic movements.

a) Online restructuring of the system is impossible: The interaction and communication of the sensors with the control systems on the shore is not possible in traditional systems. Therefore, traditional systems are inadequate when it comes to network restructuring.

b) Error detection is impossible: If any device fails or any error condition arises, this can be recognized only after the devices have been collected.

c) Devices have limited storage capability: During the observation, the sensors store the data they collect. However, memory sizes limit the size of this data.

d) Due to all the reasons listed above, underwater networks need to be designed to be self-organizing, remotely controllable, real-time monitoring. This can be achieved by wireless links based on acoustic communication between sensor nodes. At this point, our Underwater Wireless Sensor Networks are emerging.

(UWSN) is a network of sensor nodes that are placed underwater, two- or three-dimensional, and which transmit the data they collect to one or more data collectors on the surface of the water. A wireless underwater network is shown in Figure 2.7. The data collector on the surface of the water can use radio waves to communicate with the shore or a ship's center. Figure 2.7 shows a data collector. The (UWSN), in which the sensors are placed as two dimensions, consists of nodes in the steady state anchored to the sea bottom for use in more observational applications. The sensor nodes are connected to each other and to an underwater or a surveillance data collector with wireless acoustic links.

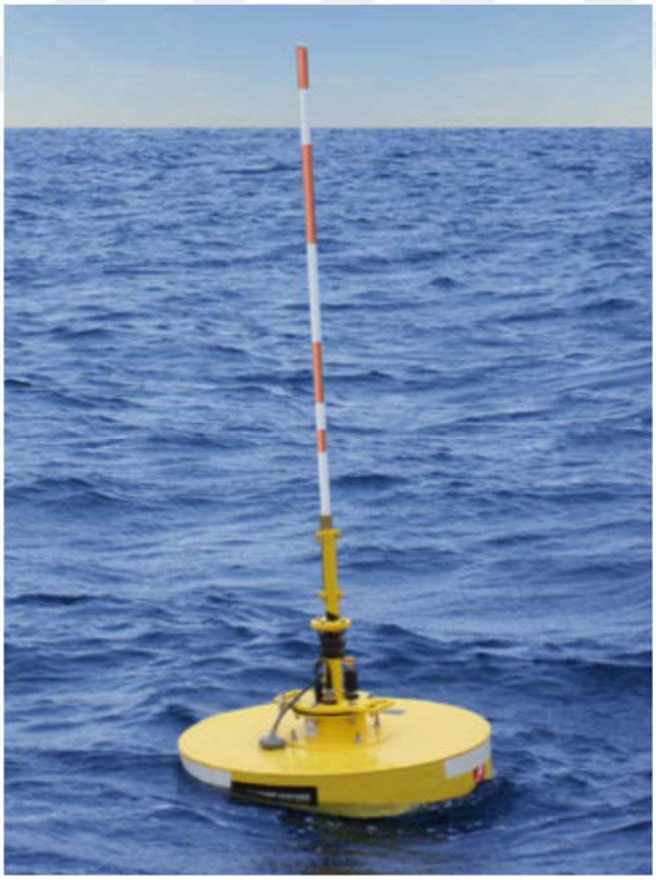

Figure 2.7: Surveillance station belonging to teledyne benthos

Underwater data collectors are usually units that are tasked with transmitting data to a station on the water. For this purpose, underwater data collectors are equipped with both vertical and horizontal transceivers. It communicates horizontally with underwater sensors and vertically with the underwater station. In deep water applications, the vertical transceiver must have a long range. The data-gathering station, which is now on standby, has both a receiver-transmitter for acoustic communication as well as a radio or satellite transmitter, which is required to communicate with other facilities on the ground or under water. The use of underwater data collectors may not be necessary if the underwater sensor nodes also have a vertical transceiver.

In [26] they presents a new solution to the (FDR) data recovery problem using a "communication material" paradigm.

The underwater sensors can reach the data collectors directly or in multi-plies. Although direct communication does not seem to be the easiest way, the choice of multi-step methods will be a more correct approach in terms of efficient use of energy. Moreover, the excess collision due to high transmission power is also an effect which directly reduces the transaction volume of communication.

In three-dimensional (UWSN), the sensing nodes hang underwater by making slight fluctuations at different depths. One way to build such nets is to tune the depth of the reel system by connecting each sensor to a Buoy[24]. Although such an approach may seem easy, it is not a preferred method because it can be easily affected by waves and storms, which can be an obstacle for ships and can be easily recognized in military practice. Instead, the sensors can be routed to the seafloor and can be elevated to the desired depth by means of a pumped float mechanism.

Moving autonomous underwater vehicles can also be used to reconstruct the system, with both three- or three-dimensional (UWSNs), for data collection purposes.

In [27] they propose an error control and adjustment method to correct all sensor localization accuracy. They use the distance information between the nodes to create a network error setting model that can improve the localization accuracy and the localization error of the network is compatible.

In [28], an analytical framework is designed to evaluate the performance of blank communication algorithms for wireless sensor networks (UWSNs). Geographical and opportunistic routing (GOR) has been shown to deliver multi-heap data in (UWSNs).

CHAPTER THREE

SENSOR SYSTEMS KNOT

3.1 Classification

Sensor core systems for monitoring ocean activities consist of a combination of different sensor and communication units, as shown in Figure 3.1.

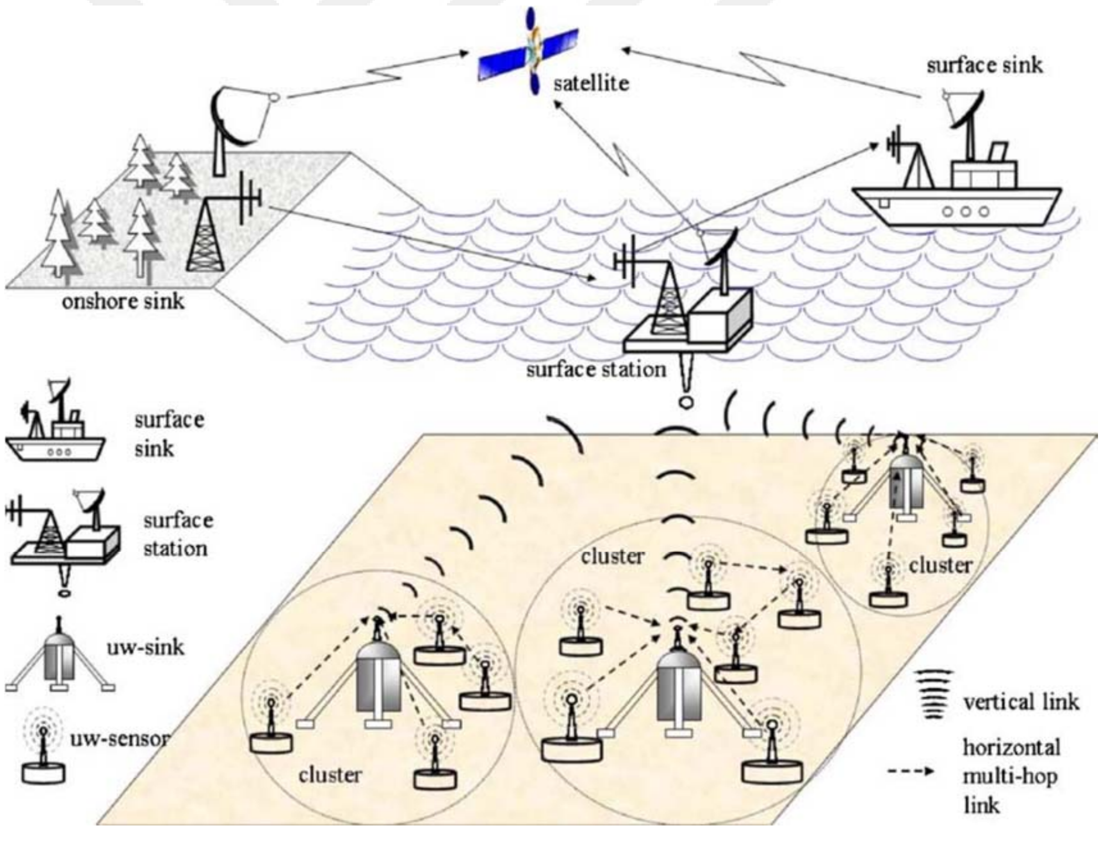

Figure 3.1: Architecture of an underwater sensor network [5]

3.2 Underwater Sensor

Underwater sensor nodes are often anchored at the seabed and communicate directly or via a special sensor node with a platform floating on the surface, which in turn transmits data by satellite or radio for evaluation on land or ship. There are a number of applications for which the use of sensor cords on the seabed is possible. A sensor node may e.g. are used to measure temperature, water quality, flow behavior or seismic activities.

The power supply of an underwater sensor node is ensured by batteries. A separate power supply with solar panels is not possible due to the darkness at the seabed. The sensor can also be boosted by means of a special rescue mechanism when the load is low or for maintenance work [5].

3.3 Recovery Mechanism

The rescue mechanism is used to separate the sensor from the anchor and to propel it. This process is usually activated remotely and also operates acoustically, usually by means of a frequency-modulated signal, since this type of modulation is most reliable at low data rates [29]. There are different approaches to how the sensor can be reliably separated from the anchor. In [30], a mechanism is described for melting the connecting wire between the armature and the sensor with a high voltage. The advantage of this variant is that it manages without a motor.

3.4 Autonomous Underwater Vehicles (AUVs)

As an addition to the more or less statically anchored sensor nodes, the development of (AUVs) has been stepped up in recent years. Their advantage lies in the relatively large operating range, which is limited only by the range of the acoustic signal [31, 32]. The use of autonomous underwater vehicles creates additional requirements for communication technology, since the Doppler effect is more important here [7]. Figure 3.2 shows an (AUV) from Saab Seaeye, which is used for environmental monitoring.

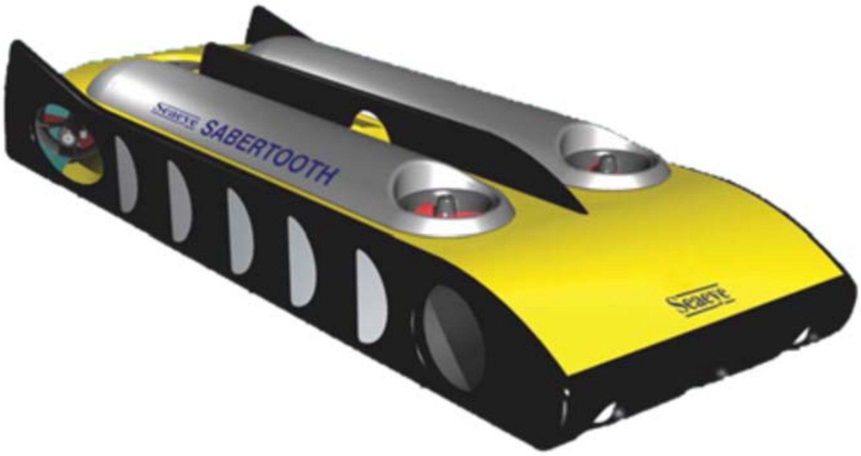

Figure 3.2: AUV seaeye - sabertooth [33]

3.5 Underwater Sensor Networks

The architecture of an underwater sensor grid has a major impact on energy consumption, capacity and reliability [5]. Reliability is the decisive criterion because of the often high costs of an underwater sensor grid. In [5], three different reference architectures are presented which, depending on the application, weight these factors differently.

Data traffic within a sensor network increases rapidly with the number of sensor nodes involved. Therefore, efficient routing and collision avoidance mechanisms are necessary to regulate the traffic in the common transmission medium water. Routing nodes are often used for this purpose, which communicate horizontally with the neighboring sensor nodes and pass the collected data vertically to the transmission platform above the water surface [33].

3.6 Applications

The application areas of communication under water are versatile. Since the beginning of the twentieth century and the invention of the first water sounder, the acoustic communication has been intensively discussed. However, the Second World War gave the impetus for the greatest developments. At this time the sonar was developed for locating submarines. In addition, the first system of underwater telephony ("Gertrude") was developed. Further devices for positioning and navigation followed. Besides the use for military communication and location, the practical application of sound waves under water is also of great interest in the civilian sphere. In the following, two systems, which make use of the sound propagation under water, are presented.

3.7 Sound Surveillance System (SOSUS)

The SOSUS (SOund SUrveillance System) is a US-American noise monitoring system, originally developed for monitoring submarine activities in the oceans. This is a network of permanently installed and wired underwater sensors, which, with submerged microphones, record noise and transmit them by cable for evaluation on land. The highly sensitive sensors allow to detect noise with an acoustic output of less than one Watt over several hundred kilometers. After the end of the Cold War parts of the system were shut down. Some of the underwater sensors are still used to monitor the activities of whales [4].

3.8 Tsunami Early Warning System (GITEWS)

The German-Indonesian system for the early detection of tsunami (GITEWS) is a complex system of different types of sensors, such as seismometers, ocean instruments and GPS Sensors, which has been used in the Indian Ocean since 2008.

3.8.1 System Components

A number of different systems have been combined in order to quickly and reliably identify a spreading tsunami wave. On land seismometers and GPS stations capture the smallest movements of the continental plates. In this way, the strength, the breaking direction and the epicenter of a shift in the earth can be determined within a very short time, which is essential for the assessment of the tsunami risk. On the high seas, measuring buoys and underwater pressure sensors detect earth shaking and changes in water pressure. The underwater sensors communicate acoustically with surface buoys, which transmit the collected data via satellite connection for evaluation on land. In addition, detectors in the vicinity of the coast register changes in the water level to make a prediction where the wave hits the coast [34].

3.8.2 Subsea Water Sensors

For the detection of a spreading tsunami tidal wave, an underwater sensor measures the pressure of the water column on it, thereby determining the wave front on the surface. Precise pressure sensors are required for this purpose, which can determine the wave speed precisely from a depth of several kilometers. Because a tsunami wave has the property that it is often only a few centimeters high in the deep water and has a wave length of 100 to 500 km [6]. For this purpose, two independent soil sensors (PACT and OBU) have been developed for the (GITEWS) project and are used in seismo logically critical areas such as on the continental shelf edges. A surface buoy was additionally installed near each floor unit. For communication, all three systems (PACT, OBU and Buoy) use the underwater water hum Ham.node from Develogic. Depending on the application, the modem uses either OFDM-mDPSK for high data rates or n-mFSK (non-coherent variant of the FSK) for lower data rates with higher reliability. The task of the PACT system is to measure the water pressure at the seabed. The energy reserves amount to about 3000 Wh. With an expected operating period of 29 months. The OBU system measures seismological activities in addition to the water pressure and stores these on an internal hard disk. The energy reserves of 12500 Wh allow a duration of approximately 12 months [34]. PACT and OBU both measure the pressure of the water column every 15 seconds and transmit the collected data in regular operation every 4 or 6 hours. If a tsunami is detected by the system, data are transferred automatically every two minutes. The seismological data collected by OBU can be transmitted externally triggered in real time. OBU uses OFDM-mDPSK (11.2- 19.2 kHz) for modulation, while PACT (n-mFSK (9-12.8 kHz) because of the lower data volume (100 bytes per message as opposed to 50 to 500 KB for OBU).

3.9 Routing Protocols in the Literature

3.9.1 Vector-Based Forwarding Protocol (VBF)

VBF [35] is a location-based routing protocol designed for underwater sensor networks. In VBF, a "virtual bus" is established between the source and the destination and data transmission is done via this bus. Each data packet contains the source, destination, and transmit node locations and range information to manage the mobility issue.

When a node receives a packet, it calculates the relative position of the transmitter using the arrival angle of the signal and distance information of the transmitting node.

It is assumed that each node has the equipment to calculate the angle of arrival of the signal. All nodes receiving the packet recursively calculate their location. If a node determines that it is close to the routing vector, taking into account the predetermined threshold value, the packet continues its routing process by adding its own location information, otherwise it ignores the package. In this way, a virtual datum is formed between the source and the target. Nodes outside this virtual bus do not participate in the routing process.

The performance of (VBF) has been evaluated with simulations. As the performance criteria, the transmission rate, energy consumption and average delay are used. (VBF) only provides good results for dense underwater sensor networks because only the nodes in the bus join the routing process and greatly reduce the traffic on the virtual bus network. However, (VBF) also has some disadvantages. For example, it is assumed that complete location information exists for the entire network. In addition, the node density affects the efficiency of the virtual bus creation process at a high rate. In a network where nodes are infrequently deployed, there may be few nodes or no nodes in the virtual bus to provide data transmission. At the same time, the selection of the threshold value can affect the routing performance remarkably. This kind of sensitivity to real-life applications is an undesirable situation.

3.9.2 Robustness Improved Location-Based Routing for Underwater Sensor Networks (HH-VBF)

HH-VBF [36] is also a routing protocol that uses the "virtual bus" mechanism and resembles VBF. However, rather than creating a single virtual datagram across the entire network between the source and destination, a routing vector is created for each transport node in the HH-VBF.

With this approach, authors suggest that low data transmission in sparse-deployed networks and solution to high-radius problems at the radius of the routing path. The mechanism that allows each node to take routing decisions in an adaptive way, taking into account its own position, is at the same time the largest virtual pathway, with transmission range. With multiple controls in the adaptation process, HH-VBF also provides a solution to the problem of non-detectable node in nodes where nodes are sparsely located. The routing process in HH-VBF is as follows: Similar to (VBF), when a node receives a packet, it keeps it for a certain amount of time. This waiting period is proportional to the so-called " request factor ", which indicates the suitability of a node as a transmitting node and is calculated by considering the angle, distance and transmission range between the two nodes. When the waiting period has come to an end, the node with the lowest "request factor" first directs the packet. The HH-VBF permits random hearing. A node receiving a message calculates its distance to the vectors of the transmitting nodes. The node determines whether to forward the packet by comparing the predefined " minimum distance " threshold value with these distance values.

The authors used the ns-2 network simulation environment to simulate three-dimensional underwater sensor networks and set the parameters of the acoustic communication similar to the acoustic qualities of Link Quest UWMI1000. Experiments aim to measure node density and mobility, energy consumption and the effect on the transmission rate. In the first test group, the network was assumed to be stationary and the number of nodes changed between 500-3000. Experimental results show that the increase in the number of nodes increases the transmission rate. The reason for this is the number of transmitting nodes in the transmission path, which increases with the increase in the number of nodes; which in turn increases the likelihood of successful delivery of packages. Taking into account the energy consumption and the transmission rate, it is seen in the experimental results that HH-VBF gives better results than (VBF).

3.9.3 Depth-Based Routing for Underwater Sensor Networks (DBR)

Each node is a greedy algorithm that individually decides not to forward the packet based on the depth information of the previous sender and himself[37]. When a node wants to send data, it does so by sending it. When neighboring nodes receive a packet, they compute their depth and compare it to the depth of the sender node.

Nodes with a smaller depth value will accept packets, while others will not process packets.

In the simulations, AquaSim, an add-on to ns-2 and underwater sensor networks, was used. Packet transmission rate, average end-to-end delay and total energy consumption metrics were used in the evaluation of the protocol performance. One of the disadvantages of the (DBR) is that each node must be equipped with a depth sensor, which can increase energy consumption and cost.

The second disadvantage is that as the number of transmitting nodes increases, the load on the forwarding based on the forwarding method can be mentioned. Another problem is the dramatically changing performance depending on the number of nodes.

In networks where nodes are infrequently deployed, if the depth difference between the two nodes is not large enough, the appropriate transport node discovery process may be repeated many times, which may result in a large drop in performance.

3.9.4 Hop-by-Hop Dynamic Addressing Based (H2-DAB)

It is a routing algorithm that acknowledges that there is a network structure consisting of multiple floats on the sea surface that gather data from nodes that are anchored to the sea bottom and deployed at different depths. A dynamic HopID has been assigned to each floating node in the network. The bottom anchored nodes have a fixed and single HopID value of 100, while the nodes on the surface and floating in the water have two types of adrese. Each floating node has a default HopID of 99. The nodes on the surface send a "Hello" message, allowing them to retrieve the HopIDs of the other nodes. The HopIDs of floating nodes do not change unless they receive a "Hello" message. The node receiving the message " Hello " sends this message and the new HopID to its neighbors after updating the HopID, and subtracts the maximum number of tabs. This process continues until a tab count of zero or a "Hello" message is anchored to the bottom. Nodes that are adjacent to the sender node and smaller than the sender of the HopID are advisory to be the forwarding node. The node closest to the sender is selected as the forwarding node.

The success of H2-DAB [38] was assessed using transmission rate and end-to-end delay and using ns-2 simulated environment. The authors state that the transmission rate is around 90% and does not affect node density. Despite this good transmission rate, H2-DAB has some disadvantages. When selecting the communicating node, the sending node may not be able to receive responses from its neighbors, especially in networks where the nodes are infrequently deployed. To solve this problem, the protocol waits for a certain amount of time and at the end of this time it directs the package to another neighbor at the same depth. This will cause high-to-end delays. However, since H2-DAB does not require any special hardware, there is no problem with hardware cost. It also does not require full size information or complex routing tables. The nodal movements caused by currents are easily addressed and the protocol benefits from the use of multiple data collectors.

3.9.5 Focused Beam Routing Protocol for Underwater Acoustic Networks (FBR)

FBR [39] is a scalable routing technique based on location information. FBR is introduced as a routing protocol that is suitable for both fixed and mobile underwater acoustic nets and does not require time synchronization. The main idea of the FBR is to reduce energy consumption by limiting transmission to transmission power. It is assumed in the network that there is a finite number of energy levels ranging from P1 to PN, and that each energy level is matched to a transmission radius. The nodes that are candidates to be relayed are determined depending on the angle of the cone-shaped area starting from the source and going towards the target.

The source nodes send RTS messages to the area they can reach with the energy level 1, and the nodes in this area also respond with the source node CTS packet. If the source node receives no response, it increases the energy level to the next and sends a new RTS message. This process continues until the source node receives any response. If the highest energy level is reached or no response is received, the source node continues to search for the transmitting node in the new subspace by shifting the con- tinue towards the left and right sides of the main con-figuration.

To evaluate the performance of the FBR, a discrete event underwater acoustic network simulator was used that takes into account different node densities and different network loads. During the experiments, the authors firstly evaluated the effect of node density on performance by comparing Dijkastra's shortest path algorithm. According to the authors, the technique they have developed can dynamically realize the discovery of the smallest energetic routes with minimal knowledge.

3.9.6 Path Unaware Layered Routing Protocol (PULRP)

PULRP [40] is a routing protocol developed for intensively deployed and well-connected 3-D underwater networks.

The PULRP algorithm consists of two phases. The first phase is the layering phase in which concentric spheres are formed in such a way that each sphere coincides with a layer around a data collector node. The radiuses of the concentric spheres are determined according to the probability of successful packet transmission and packet transmission delay. The choice of intermediate nodes and the transmission of data from the source to the destination take place in the second phase. It is assumed that the nodes are equal and that the packet length is equal for all nodes.

The area in which the nodes are located is divided into small virtual cubic areas, each node corresponding to a tree. To create a path from the source to the data collector, a node sends a control packet to the cluster. If there is no other neighbor sending the control packet at the same node, the collision-free communication is guaranteed. When a sender node receives a control message, which is deployed at a lower depth, it responds with a feedback message. The data packet is then forwarded by the source node to the intermediate node. After the intermediate node has successfully received the data packet, the aggregator node sends the correct packet. When the package reaches the destination, the process ends.

In addition to the high transmission rate, another advantage of the PULRP is that it does not require fixed routing tables, location algorithms and clock synchronization. However, the disadvantage of PULRP is that it significantly affects the transmission rate of the ring radius.

CHAPTER FOUR

SIMULATION RESULT AND DISCUSSION

4.1 Proposed Method

The routing protocols developed for Underwater Wireless Sensor Networks (UWSN) are protocols that differ from the protocols developed for terrestrial wireless sensor networks, which must be designed to take into account the unique characteristics of acoustic communication and submersion in order to transmit the underwater detected changes to a data collection center. In this thesis, for the Underwater Wireless Sensor Networks, one protocol is designed to extend the life of the network, consume the energy of the nodes in a balanced manner, and increase the number of successfully transmitted packets to a level higher than the existing protocols. These protocols are the Energy-Distance Class Underwater Routing Protocol. For simulation result we used the MATLAB 2014a.

The architecture of proposed method is shown in Figure 4.1.

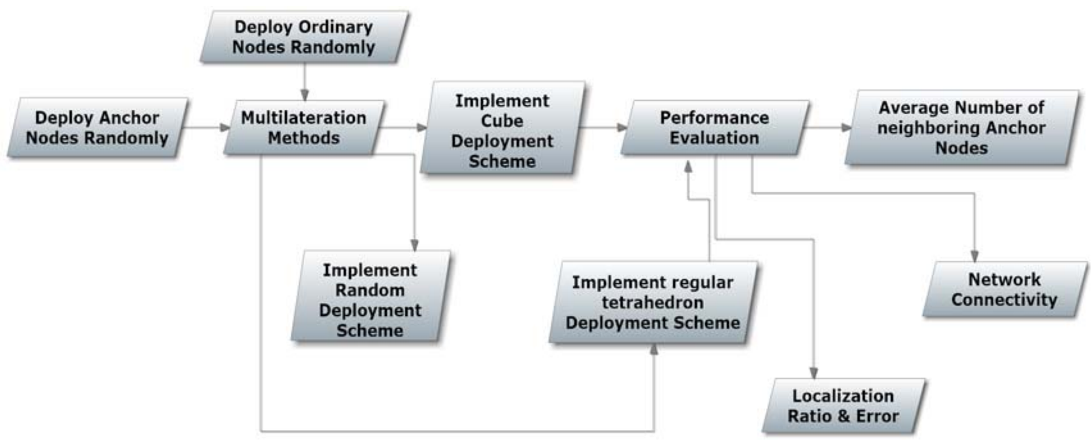

Figure 4.1: Architecture of proposed method

For simulation of the network we used the 7 node randomly for Bottom node. The Number of underwater node was 17. For the AUV we used the 5 number. The Number of Sink Node was 9. Finally for the cube deployment we used the 6 nodes.

4.1.1 Initialization The Place

In the first step the place of the sensors is designed. The Figure 4.2 shows the initial place of the sensors. For this shape we used the following code in MATLAB 2014a version.

```
Pas = 0;
pos=[1 2 7 5;3 5 7 5];
X1=[pos(1,1) (pos(1,1)+pos(1,3)) pos(1,1) (pos(1,1)+pos(1,3))];
X2=[pos(2,1) (pos(2,1)+pos(2,3)) pos(2,1) (pos(2,1)+pos(2,3))];
Y1=[pos(1,2) pos(1,2) (pos(1,2)+pos(1,4)) (pos(1,2)+pos(1,4))];
Y2=[pos(2,2) pos(2,2) (pos(2,2)+pos(2,4)) (pos(2,2)+pos(2,4))];
figure,
rectangle('Position',[1 2 7 5],'FaceColor','r')
holdon;
rectangle('Position',[3 5 7 5],'FaceColor','g')
holdon;
x=[X1(1) X1(2) X2(2) X2(1)];
y=[Y1(1) Y1(2) Y2(2) Y2(1)];
holdon;
fill(x,y,'b')
x1=[X1(1) X1(2) X2(2) X2(1)];
y1=[Y1(3) Y1(3) Y2(4) Y2(4)];
holdon;
fill(x1,y1,'m')
fori=1:length(X1)
L1(1,1)=X1(i);
L1(1,2)=Y1(i);
L1(2,1)=X2(i);
L1(2,2)=Y2(i);
holdon;
  plot(L1(:,1),L1(:,2),'k-','LineWidth',1);
pause(Pas)
end
```

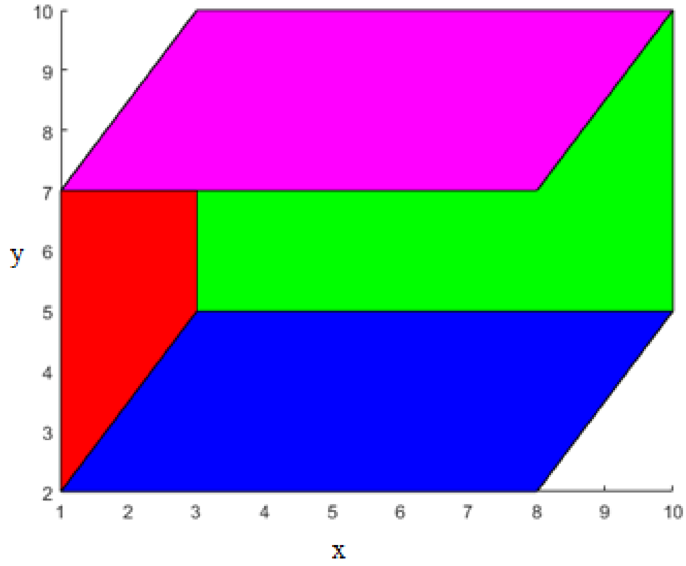

Figure 4. 2. Initial place of the sensors

4.1.2 Deploy Bottom Node

After initialization of the place, the nodes will deploy in this place. About 13 nodes deployed in this place. The number of these nodes are select randomly. Figure 4.3 shows the sensors which deployed in the proposed area.

The following MATLAB code is used for this Figure.

```
Bottom_node_x=rand(1,75)*10;
Bottom_node_y=rand(1,75)*5;
Bottom_node_x=abs(Bottom_node_x);
Bottom_node_y=abs(Bottom_node_y);
holdon;
[in,on] = inpolygon(Bottom_node_x,Bottom_node_y,[X1(1)
X2(1) X2(1) X2(2)],[Y1(1) Y2(1) Y2(1) Y2(2)]);
Bot=Bottom_node_x(in&~on);
Bot_len=length(Bot);
fprintf('Number of Bottom node is: %g\n',Bot_len);
plot(Bottom_node_x(in&~on),Bottom_node_y(in&~on),'ko','Ma
rkerFaceColor','y','MarkerSize',5);
pause(Pas)
ylim([0 12])
xlim([0 12])
```

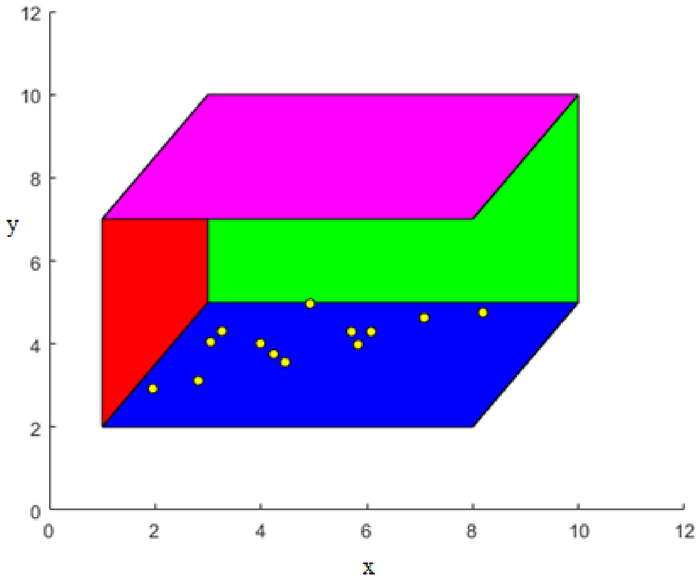

Figure 4.3: Number of bottom nodes which deployed in the proposed area

4.1.3 Deploy Underwater Node

After deploying the bottom nodes in the place, the underwater nodes will deploy in this place. About 10 nodes deployed in this place. The number of these nodes are select randomly. Figure 4.4 shows the underwater nodes which deployed in the proposed area. These nodes shows as red color.

The following code is implemented for this Figure.

```
Un_node_x=rand(1,50)*10;
Un_node_y=rand(1,50)*7;

[in,on] = inpolygon(Un_node_x,Un_node_y,[X1 X2],[Y1 Y2]);
holdon;
UnNo=Un_node_x(in&~on);
Un_len=length(UnNo);
fprintf('Number of underwater node is: %g\n',Un_len);
plot(Un_node_x(in&~on),Un_node_y(in&~on),'ko','MarkerFace
Color','r','MarkerSize',5);hold on;
pause(Pas)
unknown_node_x=Un_node_x(in&~on);
unknown_node_y=Un_node_y(in&~on);

forui=1:length(unknown_node_x)
aa=(unknown_node_x(ui)-0.1);
bb=(unknown_node_y(ui)-0.1);
  [in,on] = inpolygon(aa,bb,[X1(1) X1(2)],[Y1(1) Y1(1)]);
text(aa,bb,'\downarrow','fontsize',20)
pause(Pas)
end
```

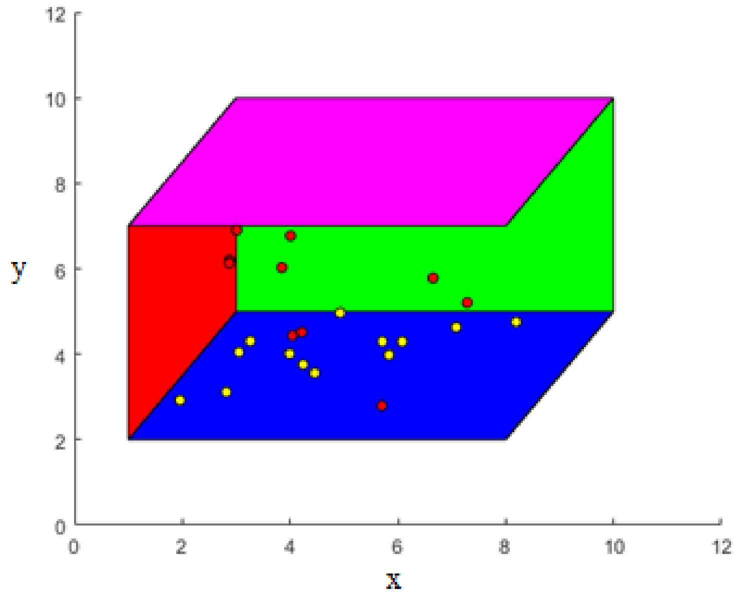

Figure 4.4: Underwater nodes which shows as red color.

The direction of the underwater nodes is shown in Figure 4.5.

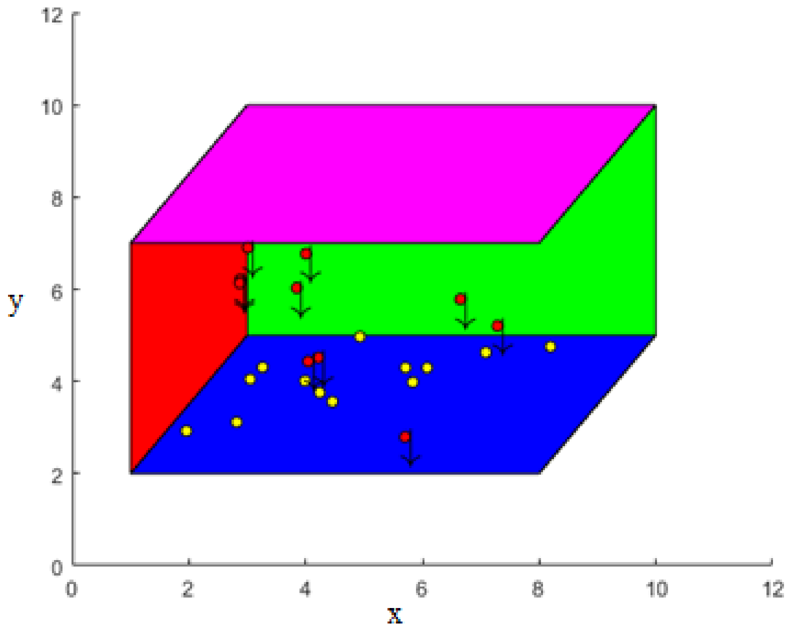

Figure 4. 5. Direction of the underwater nodes.

4.1.4 Deploy Autonomous Underwater Vehicle (AUV)

In this step the Autonomous Underwater Vehicle (AUV) is setup. About 5 AUV are setup in proposed place. This scenario is illustrated in figure 4.6.

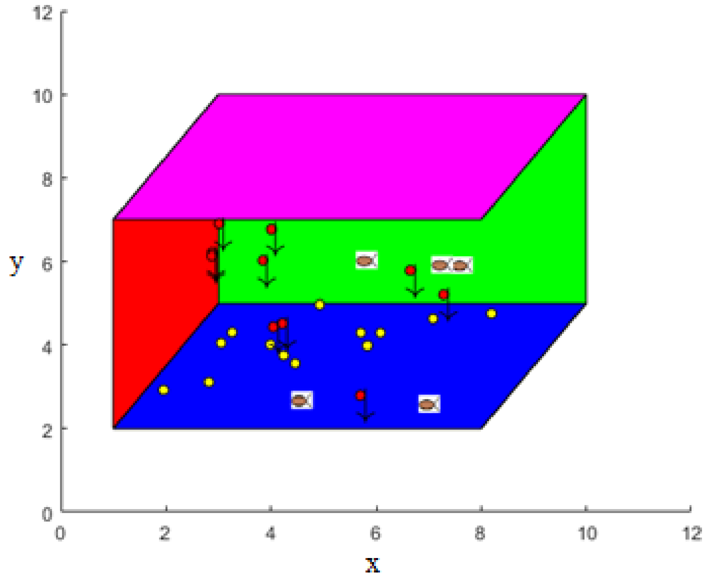

Figure 4.6: Deployment of autonomous underwater vehicle

The trajectory of these AUV are shown in Figure 4.7.

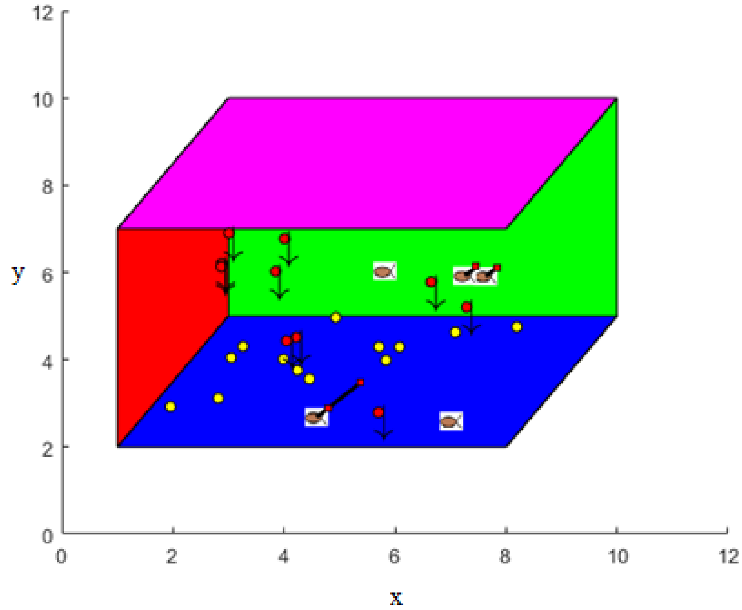

Figure 4. 7. Trajectory of these AUV

4.1.5 Deploy Sink Node

Here the sink node are deploying. After deploying the AUV in the place, the sink nodes will deploy in this place. About 12 nodes deployed in this place. The number of these sink nodes are select randomly. Figure 4.8 shows the sink nodes which deployed in the proposed area. These sink nodes shown as ship shape.

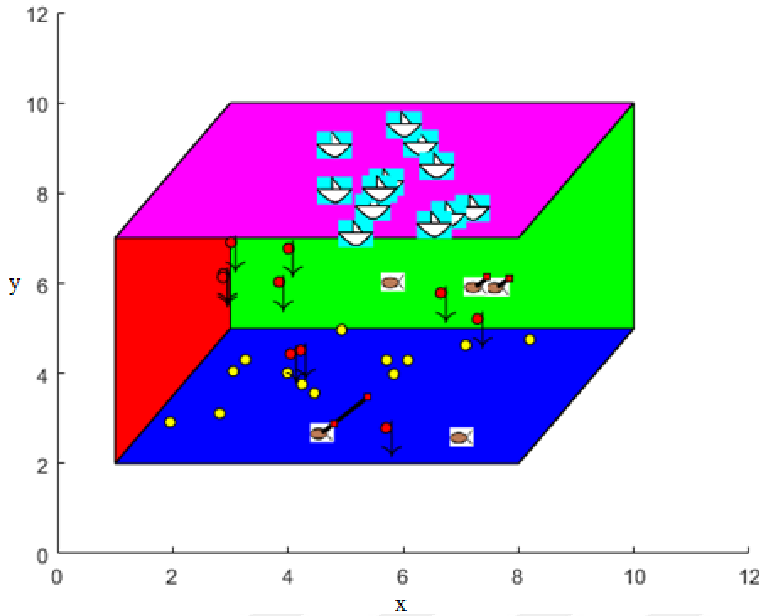

Figure 4.8: Deploy sink nodes which shown as ship shape

4.1.6 Network Deployment

After deploying the sink nodes in the place, the network deployment will done in this place. This item is illustrated in figure 4.9. In this thesis the cube deployment is done. About 6 node for cube deployment are selected.

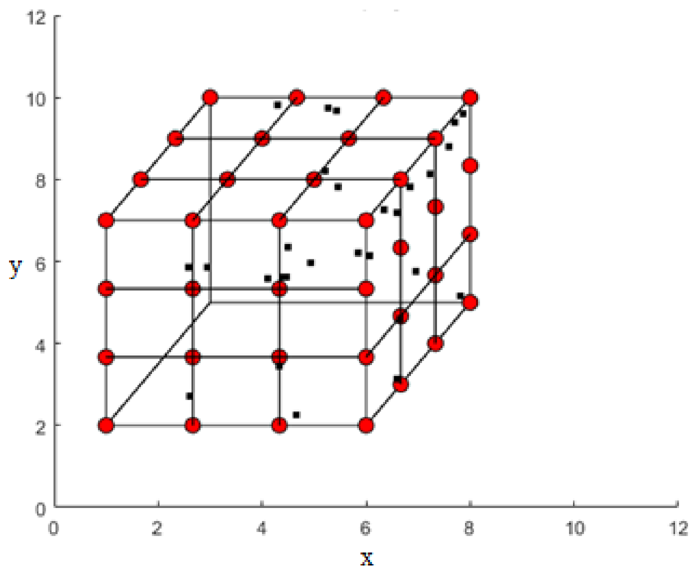

Figure 4.9: Network deployment

4.1.7 Topology

In this step the topology of network will design. In topology Anchor nodes and ordinary nodes are deployed. This state is shown in Figure 4.10. As shown in this figure the red stare shapes shown the Anchor nodes and blue circle shapes are shown as ordinary nodes.

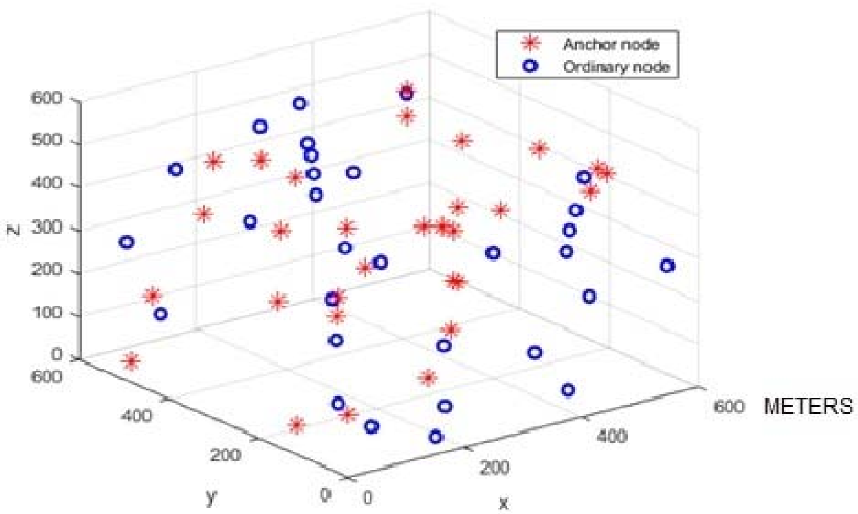

Figure 4. 10. Topology deployment.

4.1.7.1 Topology of the random deployment scheme

The connection between first Anchor node and the ordinary nodes is shown in Figure 4.11. The connection is shown by line green color.

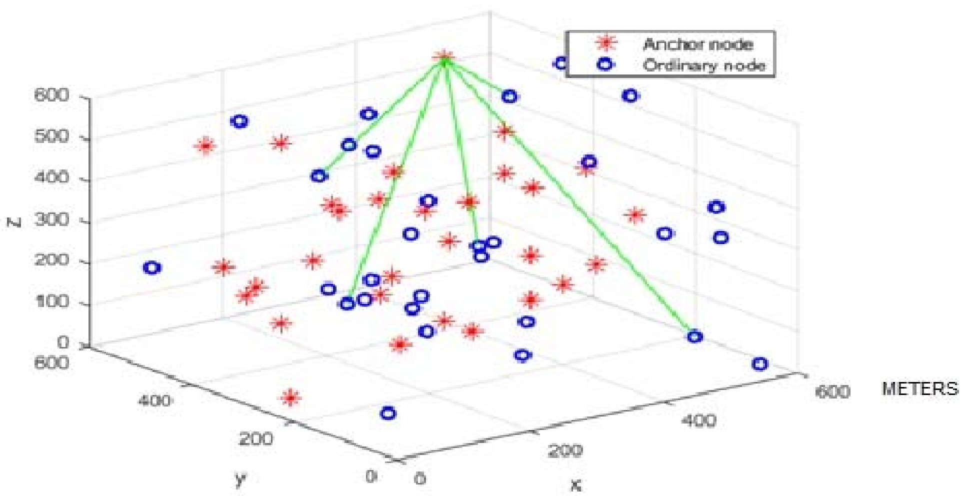

Figure 4.11: Connection between one anchor node and the ordinary nodes

The connection between all Anchor nodes and the ordinary nodes is shown in Figure 4.12. The connection is shown by line green color.

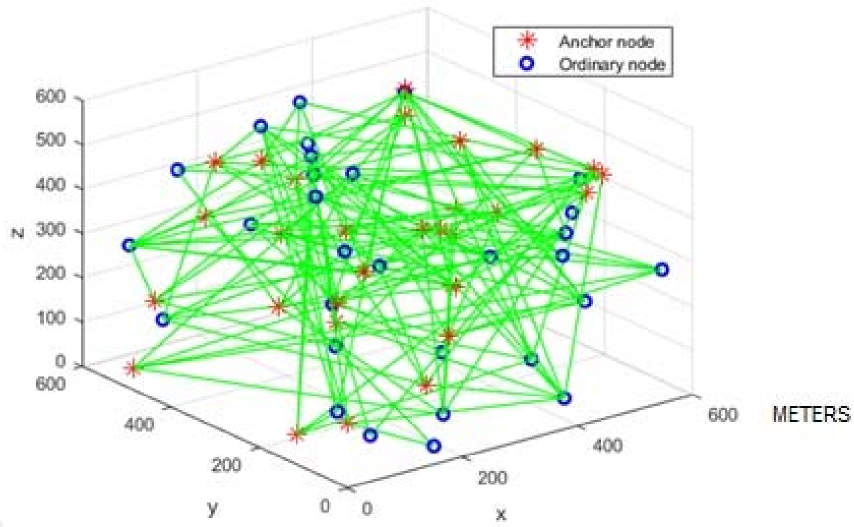

Figure 4.12: Connection between all anchor nodes and the ordinary nodes

4.1.7.2 Topology of the cube deployment scheme

In this step the Average number of neighboring anchor nodes is calculated. The Anchor nodes, ordinary nodes and the estimated nodes are shown in Figure 4.13.

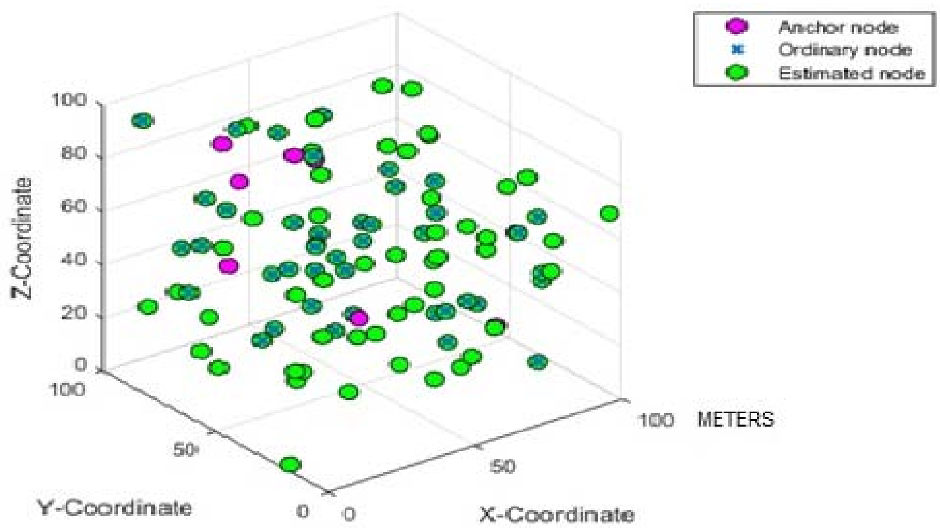

Figure 4.13: Collection of the anchor nodes, ordinary nodes and the estimated nodes

The topology of the Cube Deployment Scheme for first Anchor node is shown in Figure 4.14.

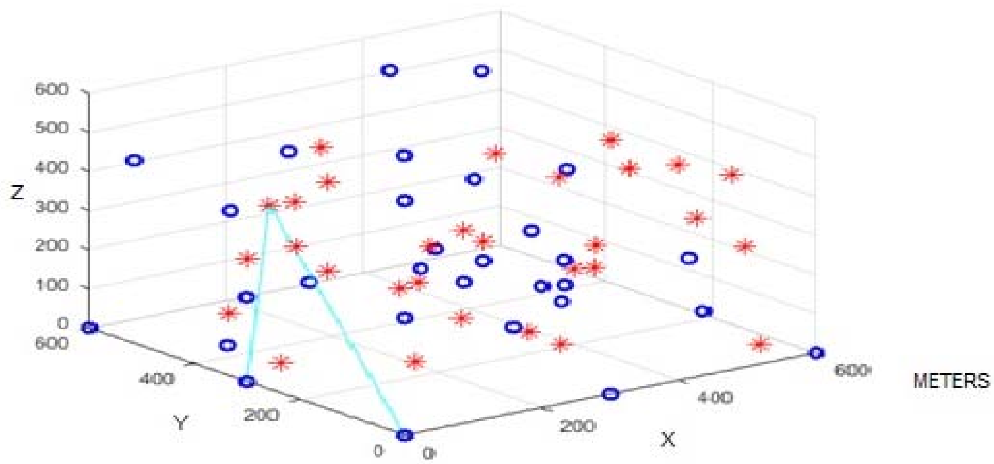

Figure 4.14: Topology of the cube deployment scheme for first anchor node

The topology of the Cube Deployment Scheme for all Anchor node is shown in Figure 4.15.

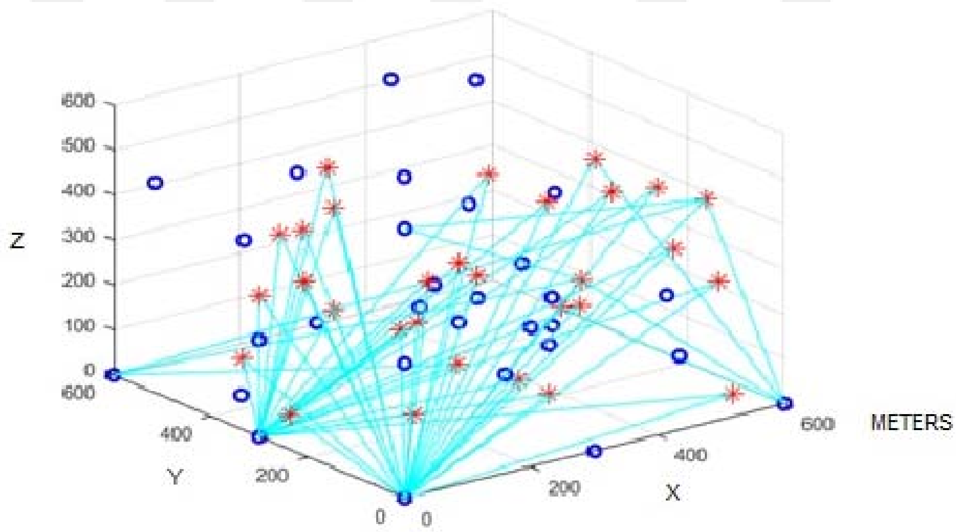

Figure 4.15: Topology of the cube deployment scheme for all anchor node

4.1.7.3 Topology of the regular tetrahedron deployment scheme

Topology of the Regular Tetrahedron Deployment Scheme for first Anchor node is shown in Figure 4.16.

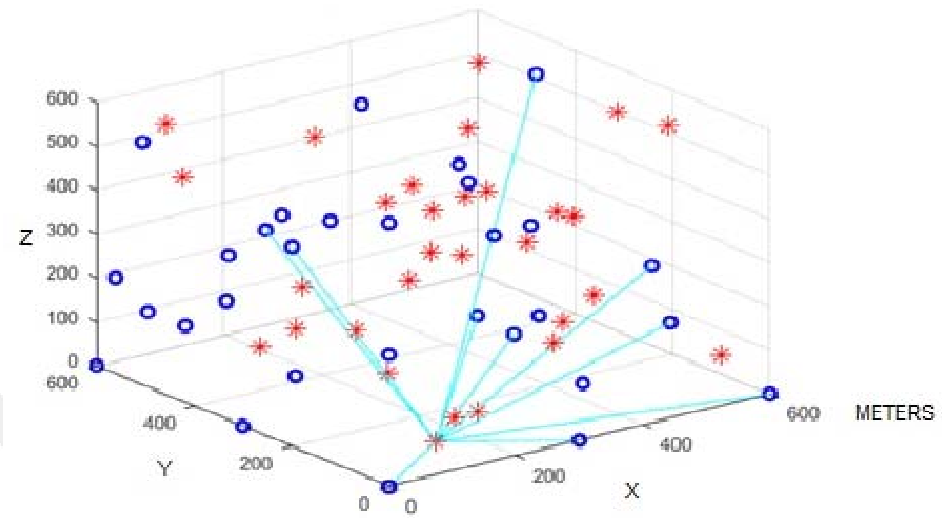

Figure 4.16: Topology of the regular tetrahedron deployment scheme for first anchor node

Topology of the Regular Tetrahedron Deployment Scheme for all Anchor node is shown in figure 4.17.

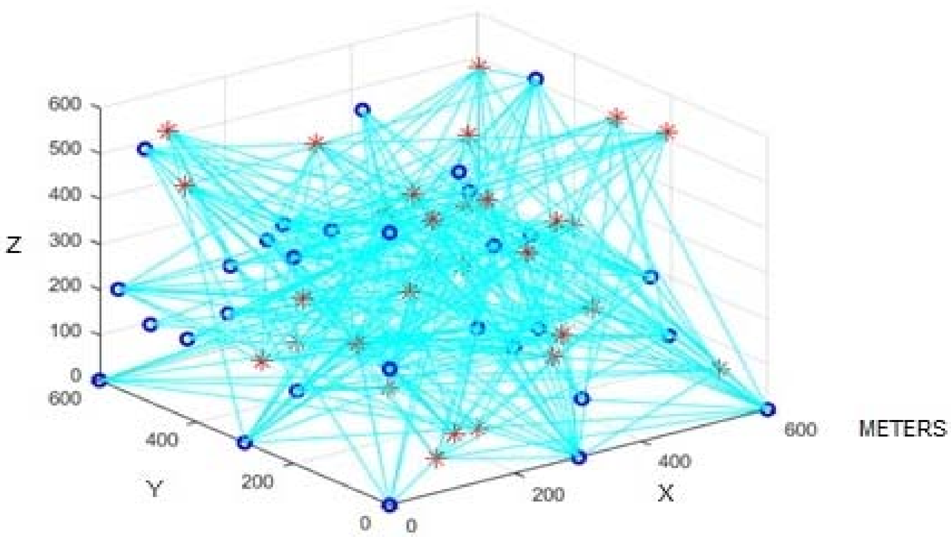

Figure 4.17: Topology of the regular tetrahedron deployment scheme for all anchor node

The network connectivity on the Anchor nodes for Random deployment, Cube deployment and Regular Tetrahedron Deployment is shown in Figure 4.18.

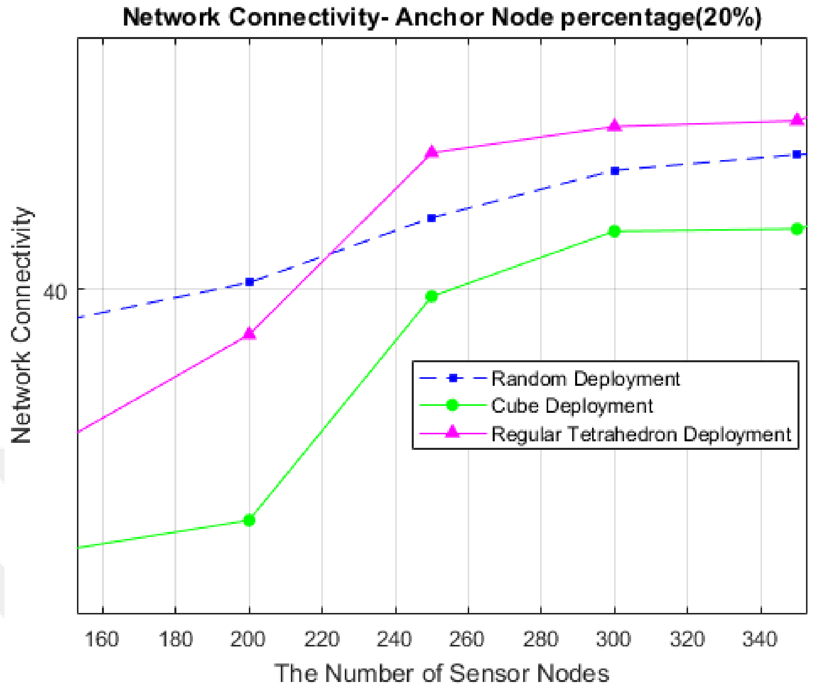

Figure 4.18: Network connectivity on the anchor nodes for random deployment, cube deployment and regular tetrahedron deployment.

The comparison between Random Deployment, Cube Deployment and Regular Tetrahedron Deployment are illustrated in table 4.1. The following value is not sorted. The result which shown in figure 4.18 is sorted from the minimum up to maximum value.

Table 4.1: Comparison between three methods

Number of Sensor	Random Deployment (%)	Cube Deployment (%)	Regular Tetrahedron Deployment (%)
100	**42.25**	36.25	23.5
150	**49.07692**	21.76923	47.76923
200	**43.66667**	30.22222	26.11111
250	32.65217	28.47826	**40.34783**
300	39.28571	49.5	**51.28571**
350	50.09091	**53.87879**	45.84848
400	44.84211	26.10526	**47.52632**

As seen in this table the network connectivity for three method is different and this difference is depended on the number of the sensors. For example in 100, 150 and 200 sensors the highest connectivity is obtain for the random deployment. When the sensor number is 250 and 300 the maximum network connectivity is achieved for Regular Tetrahedron Deployment. As seen in this table the cube deployment is the minimum one and only in one scenario is obtained the maximum network connectivity and this value for 350 sensor is 53.87879.

CHAPTER FIVE

CONCLUSION

5.1 Conclusion

To explore the depths of our oceans we need reliable and powerful means of communication. For wireless communication, communication via electromagnetic waves is only suitable for this purpose, since these have only limited range. Another and more suitable means of communication is the use of acoustic signals, which have been considered in this thesis. The physical principles and limiting factors were presented at the beginning, as were the influence factors on the range and speed of the acoustic signals. Due to the many undesirable influences on the quality of the transmission, special requirements apply to the type of signal transmission. Several modulation methods (ASK, FSK, PSK, QAM, OFDM) have been presented, all of which are applied under water. In order to complete the topic, two application scenarios for the application scenarios of subsea springs were briefly presented. Acoustic communication will continue to play an important role in communication under water. Especially in the context of global climate change the observation of the oceans is of great interest. In the course of these procedures, access control and collision avoidance were not considered. The interested reader is referred to the article, which deals with these topics and other aspects that are important in the design of network protocols under water.

Wireless sensor networks, widely used in terrestrial environments, have found areas of use in seas and oceans, thanks to technological advances in the late twentieth century, and the underwater environment, which is challenging for humans, can be more easily exploited by the use of sensors. In wireless underwater sensor networks, many sensor nodes located in a particular underwater region are obliged to transmit the necessary information to the data collector, usually located on the water surface, by collecting environmental information or detecting an anomalous situation according to the application. During the journey from the place where the donation is collected to the surface of the water, the routing protocols are fulfilled.

In this thesis we used the MATLAB 2014a version. For Localization ratio we got the 89.2473, for Localization error the 24.6079 is reached. Also for Average neighborhood and Network connectivity we got 5 and 141.29 respectively.

The parameter which we used in this thesis was as table 5.1.

Table 5.1: The parameter of the network

Parameter	Value
Number of Bottom Node	7
Number of Underwater Node	17
Number of AUV	5
Number of Sink Node	9
Node for Cube Deployment	6

The concept of referral is not a problem with (UWSN) and has been worked intensively in the terrestrial (WSN). However, when it comes to underwater, the communication environment is changing completely and the problem of orientation is emerging in a new way. Improved routing protocols for terrestrial networks are not available underwater, and improved underwater routing protocols are also evolving.

The Table 5.2 shows the result of Localization ratio, Localization error, Average neighborhood and Network connectivity.

Table 5.2: Result of network

Parameter	Values
Localization Ratio	89.2473
Localization Error	24.6079
Average Neighborhood	5
Network Connectivity	141.29

The ratio of the communication for number of sensor with other sensors are define as the Equation 5.1.

$$Network\ Connectivity = \frac{N_{communicate}}{N_{tot}} \tag{5.1}$$

where $N_{communicate}$ is the sensor nodes number which caninter connect through other nodes, also N_{tot} is the entire quantity of nodes.

The network connectivity is shown in table 5.1.

The average number for anchor nodes is define as:

$$A_{anchor} = \frac{N_{communicate\_anchorNode}}{N} \tag{5.2}$$

This average is the neighbor average.

where $N_{communicate\_anchorNode}$ is the sensor nodes which interconnect with anchor nodes, also N is defined as whole number of sensor.

Concentration error is the average distance between estimated coordinates and real coordinates. It is clear that the error localization is smaller, and will be better than the result of localization. The localization error can be calculated as follows:

$$ErrorLocalization = \frac{\sum \sqrt{(u_i - x_i)^2 + (v_i - y_i)^2 + (w_i - z_i)^2}}{N_l} \tag{5.3}$$

Where (U_i, V_i, W_i) are the actual coordinates of the typical node i, (X_i, Y_i, Z_i) are the typical node coordinates, and N_l is the number of normal nodes in the local area[41].

The rate of localization is the ratio of the number of common contract nodes to the total number of contract. Obviously, higher than the localization ratio, the more common local nodes can be localized. The localization rate is define as:

$$LocalizationRatio = \frac{N_l}{N_o} \tag{5.4}$$

where:

N_l : Number of localized nodes which is ordinary

N_o : Total number of nodes.

5.2 Future Work

In future we can use proposed method on the NS2 and we can convert our method to C++ and then we can use these codes on the devices and we can test in the underwater for controlling the earthquake or other problems which is available in the underwater world.

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