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Investigation of Underwater Sensor Networks Localization and Analysis the Performance

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Abstract: ***In this paper, the system related to the underwater communication system is defined, information about the parameters affecting the communication is given and the theoretical analyzes such as the behavior of the underwater environment is presented. The simulation work is performed for these parameters in the simulation environment. The most recent studies is evaluated and comments and analyzes is presented.***

1. Introduction

In 1490, Leonardo da Vinci wrote: 'If you cause your ship to stop and place the head of a long tube in the water and place the outer extremity in your ear, you will hear ships at a great distance from you.' This early statement contained features still important today in the use of passive sonar, da Vinci drawing attention to the following requirements: low self-noise, acoustic coupling to overcome impedance mismatch, a receiver transducer, and a recognition system. This system was used as late as the First World War when directivity was gained by the employment of a second tube.As will be seen shortly, of key importance to the deep acoustics is the speed of sound in the water. The first measurements of this were made by Swiss physicist whose Daniel Celadon and French mathematician whose Charles François Sturm in 1827 in Lake Geneva/ Leman. From the time interval between the observation of a light and the sound from a submarine, both signals having been generated simultaneously, they calculated the speed of sound in the lake to be 1435 m/s. The water temperature was 8°C. By the end of that century, knowledge of the sound speed in water allowed exploitation of such signals in navigation [1].

In the 1900's, a distance measuring system was used which consisted of a combination of lantern ships, an underwater bell and a fog hatch on the deck. Through this system, the crew on the approaching ships could hear both sounds. The sound from underwater reached a hydrophone mounted on two ship's boats and they were able to gauge their estimated distance to the lantern ship by measuring the difference between the two sounds.The first sonar systems were developed by the American, British and French during First World War to find submarines and icebergs. At that time, sonar system was called "ASDIC". In 1925, the depth measurement of sonar was carried out. Germans developed a series of sonar systems called GERAT. This is followed by improvements in the use of sonars at high power and low frequencies. Again, in the 1900's, studies of the application of signal processing techniques to sonar systems, sounding torpedoes, mines and scanning systems, sonar systems have been realized by the USA. After World War II, sonar, sea-based geological surveys, sunken ships, fish detection and so on. studies were carried out to make applications on topics [2].

Today; Acoustic methods are used in many studies such as depth measurement, removal of the morphology of seafloor, seismic stratigraphy, oil and natural gas exploration, determination of crustal properties and thickness, engineering and acoustical applications, fish stocks.

2. Sound Features and Definitions

The sound is the regular movement of molecules in a flexible environment. Since the environment is a flexible structure, the movement of particles in the environment occurs after the sound source has exited and is now connected to the particles around it. Because of sound wave contacts particles in the environment, it spreads out of the source at a rate that is equivalent to the speed of sound. For said propagation to take place, said flexible medium must be solid, liquid or gas. Particle movement in the liquid occurs parallel to the direction of propagation and back and forth. So, the sound waves are fluctuating longitudinally. Longitudinal waves can be expressed as sinusoidal waves. The sine wave is drawn by the pressure changes that occur due to time and distance. The peak of the sine wave indicates the compression phase, and the sine of the sine wave indicates the dilution phase. The distance between the two peak points is defined as the "wavelength" and is expressed by the symbol "λ". A wave motion from the hill and the pits is called a "cycle". The time required for this cycle to occur is called the "frequency of the wave". The unit is expressed as 1 / s or Hz.

The deviation of the sound wave from the mean pressure level is expressed as "amplitude" and is the measure of the amplitude of sound 3. The wavelength of a sound wave, as in (1), can be expressed in terms of the voice frequency and the speed of sound "c".

$$\lambda = \frac{c(m/s)}{f(1/s)} \quad (1)$$

In addition to this information, we can talk about the types of sounds. Sound types are divided into 3 types. These 3 types are:

- Sounds whose frequency is below 20 Hz are subsonic,
- Sounds whose frequency is between 20-15000 Hz are sonic, and
- Sounds whose frequency is above 15000 Hz are supersonic.

3. Sound of Speed and Features

The sound of velocity in water is found by the formula given by (2)

$$c = \sqrt{\frac{\beta}{\rho}} \quad (2)$$

Where β (Newton / m^2 or Pa) represents the elastic modulus of the water, ρ water density (kg / m^3), c sound velocity (m / sec). We can find the bulk modulus by the formula given by (3).

$$\beta = -V \cdot \frac{du}{dV} \quad (3)$$

Where V is the volume, u is the acoustic pressure. According to this;

- The sound velocity in air is approximately 330 m / s, with β = 1.42 × 10^5 (Newton / m^2) and ρ = 1.3 (kg / m^3)
- The sound velocity in seawater is about 1435 m / s with β = 2.06 × 10^9 (Newton / m^2) and ρ = 1 (kg / m^3).
- In the meantime, the electromagnetic wave propagation velocity in the air is 3 × 10^8 m / s which is the speed of light.

Sound velocity profiles are graphs showing the variation of sound velocity with respect to depth. SSP's related to weather conditions, season, salinity, etc. Salinity is often considered constant at 35 ppt.

The dependence of sound velocity on parameters such as temperature, depth, salinity is formulated in various forms based on experimental data. One of the most important of these formulas is shown in (4).

$$c = 1492.9 + 3(T - 10) - 6\times10^{-3} T - 10^{2} - 4\times10^{-2} T - 18 + 1.2S - 35 - 10^{-2} T - 18S - 35 + H/61 \quad (4)$$

Where T is the temperature, S is the salinity, H (m) is the depth. For example;

The sound velocity is 1490 m /s at a temperature of 10 degrees, at a depth of about 0 m and a salinity of 3S. Again, approximate coefficients are shown in (5), (6) and (7) define the temperature, salinity, and variation of sound velocity.

$$\frac{Dc}{DT} = 3.4 \ m/s \quad per \quad °C \quad (5)$$

$$\frac{Dc}{DS} = 1.2 \ m/s \quad per \quad ppt \quad (6)$$

$$\frac{Dc}{DH} = 17 \ m/s \quad per \quad 1000 \ m \quad (7)$$

As you can see here, the changes in all parameters cause the increase of sound speed [2].

4. The Importance of Underwater Acoustics

Ocean research studies over a 60-year period are steadily increasing. In this research work, the information gathered by underwater receivers should be transmitted to the water surface in the most efficient way. At this point, information may be sent to the information collection center via satellite. In acoustic waves, it is possible to generate signals underwater hundreds of kilometers away. The underwater acoustic channel is characterized as a multi-channel channel due to the reflection of the signal from the surface and the sea bottom. Because the wave movements also lead to signal losses due to the different propagation and different delay times of the signal components.

In recent years, underwater acoustic communication has grown rapidly as an area of engineering and research. Underwater acoustic communication technologies are used in the offshore oil industry as a remote control, environmental system to control the pollution control, collecting scientific data obtained from underwater stations, the use and development of man less underwater vehicles, use of underwater divers for tasks such as providing contact with each other, also are used in the detection of objects in an underwater ground and rescue operations.

It is great importance for such applications. Acoustic environment noises are crowded with shrimps, fish, ships and various mammals. In addition to the ambient noise, human-induced noises are also added near the harbor. It is possible to design efficient and highly accurate underwater acoustic communication systems for the transmission of digital signals against all these disturbing effects. It has been tried to use light wave, radio wave, and sound wave to propagate in water. As a result of these experiments, it was observed that light and radio waves were weakened and damped very quickly while propagating in water, but the water was the ideal environment for the propagation of sound waves. Marine scientists are constantly researching and applying underwater aquaculture over the years since the first hydrofoil was launched to determine the location of an enemy submarine. As a result of this process, the spread of the waves in the water has become one of the most important tools utilized in today's marine science studies.

5. Effective Basic Parameters in Underwater Communication

The ocean is an acoustic passage extending between the sea ground and the sea surface, and there are four main factors that play a role in the change of the speed of sound waves propagating in this region; temperature, depth, salinity, and pressure. The speed of sound means that the value of these values increases along with the increases, but the rate of uplift is different and at least the role of salinity increases [3].

- Temperature
- Salinity
- Pressure
- Density
- Depth
- Interaction with boundaries (surface and bottom)
- Volumetric interactions (substances in water, bubbles, etc.)
- Locations of transmitters and receivers
- Voice recording and distance detection
- Mobility

a) Temperature

The change in temperature is the most important factor to be mentioned in the change of sound speed because it affects the sound speed 5 times more than other factors. Temperature is a measure of the kinetic energy that molecules possess. In the measurement of water temperature, the potential energy generated by the compression and expansion of fluids must be accounted for [4].

Heat goes deeper in water than it is in the earth because the specific heat of the water is much higher than that of the earth, so the seas play an important role in balancing the heat. Most of the solar energy is absorbed within the first 10 meters, which is 83% in clear ocean waters and 99% in cloudy waters. For this reason, if other environmental factors are excluded, warming occurs within the first 10 meters. Except for some special cases, the temperature of the seawater is greatly reduced. The heat exchange between the hot surface waters and the cold water at the bottom causes the wind to mix with the surface waters and flow as a result.
Other factors that play a role in the warming of seawater can be listed as solar radiation, convection of the inner heat of the ocean from the ocean floor, heat resulting from chemical and biological events, conversion of kinetic energy into heat energy, and heat from condensation of water vapor. Factors such as evaporation and atmospheric heat convection and reflections from the sea surface are the factors that cause heat loss in seawater [3].

b) Salinity

One of the important characteristics of sea water is salinity. Salinity changes very little in deep water, and horizontal changes are too small to be neglected. But in the coastal regions, especially in the fjord and ice fields, the salinity effect is important. Many of the physical properties of seawater vary depending on the saltiness. The characteristics such as seawater density, electrical conductivity, viscosity, expansion coefficient, osmotic pressure and sound velocity increase with increasing salinity, while specific properties such as specific heat, vapor pressure, thermal conductivity, and expansion coefficient decrease.

There are some factors that reduce and increase salinity, and the most important ones are evaporation and raising. As evaporation increases saltiness, salinity decreases with precipitation and equation (8) is used for the relation of these two opposite factors to salinity. In this equation; E, evaporation, and P, show the precipitation heights in mm [4].

$$S(\text{in thousands}) = 34.6 + 0.0175\ (E - P) \qquad (8)$$

c) Pressure

Along with temperature and salinity, one of the parameters affecting the velocity of the sound underwater is the pressure. Due to the weight of the molecules in the liquid, a pressure acting perpendicular to the surface is formed and this pressure is called "Hydrostatic Pressure" and increases by about 1 desire per 1 meter depending on the depth in the seas. Decibar (0.1 bar); It is the most practical unit that expresses the press and is equal to the pressure of a meter of seawater on a surface of cm^2[3].

d) Density

The mass corresponding to the unit volume of a substance is called "density". Density can also be called volumetric mass density. The density of seawater is generally taken to be about 1.026 g / cm^3 and increases with a decrease in temperature or an increase in salinity and depth. As can be understood from this expression, the factors affecting the density distribution are the characteristics that cause these 3 effects to change. The temperature is the parameter that has the greatest effect on the density as well as the sound speed. The density is also related to the chemical structure of seawater [3].

6. Communication System Components

The intermediate components used in the communication system are:

- Information source
- Input transducer
- Output transducer

a) Information Source

The input message may appear in different properties as there are various sources of information in it.The information generated by the information source is divided into two parts. These are:

- Analog information
- Numerical information

Analog information is a quantity that represents quantities from another species that varies with time and that is itself a time-varying and continuous property. Analog information can be speech, sound, picture, music, and image.

Numerical information is binary codes consisting of discrete samples such as "0" and "1" that is used to transfer information between computers. Analog information can be Binary arrays, graphic symbols, microprocessor operation codes.

b) Input Transducer

Making a signal suitable for transmission means converting that signal into electrical signals, that is, an electrical current or an electrical voltage change. Energy converters are utilized for the purpose of obtaining electrical signals. Both input transducers and output transducers are found in many electronic devices used in the day. The most common name for the input transducers is the sensors. Examples of input transducers are:

- Using LDR to produce resistance to light,
- Using thermistors to generate resistance to heat,
- Using the microphone to turn the voices into voltage,
- Using the variable resistor to turn the angle to resistor [5].

c) Output Transducer

The electrical signals obtained by the receiver must be converted to appropriate information formats for the user to have a sense of meaning. Output Transducers are used to convert an electrical signal to an alternative amount. Examples of output transducers are:

- Using a lamp or led to convert electrical energy into light,
- Use the speaker to convert electrical energy to sound,
- Using the engine to convert electric energy into motion,
- Using the heater to convert electrical energy to heat [5].

7. Basic Components

Any communication system consists of three main parts. Each of these parts plays an important role in signal transmission. These parts are:

- Transmitter,
- Communication channel and
- Receiver

A General Model of All Communication Systems is shown in figure 1.

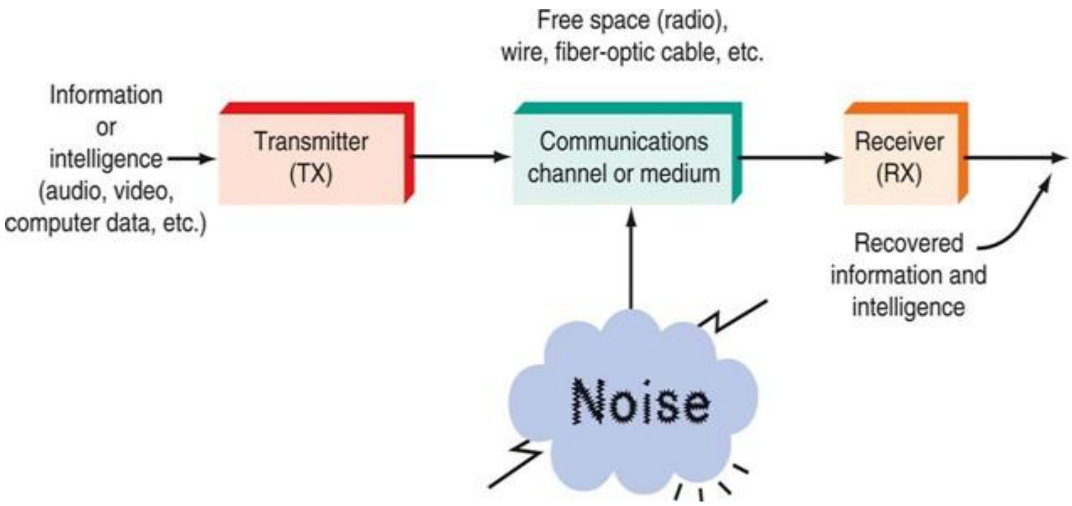

Figure 1: A General Model of All Communication Systems

a) Transmitter

The transmitter is a transducer if the word is interpreted literally. The transmitter processes the input signal to produce a signal that matches the characteristics of the communication channel and transforms it into a suitable format for transmission. They convert values such as heat, temperature, and pressure to voltage (0-10V) or milliampere (0-20mA). Conversion of information received by the input is called modulation. In the modulation process, such as simplicity of transmission, reduction of channel noise, and multiplication are performed. As a result, analog signals are transmitted directly via carrier modulation through a communication channel.

b) Communication Channel

There are many communication channels available, but we will deal with this issue as it is necessary to have underwater communication channel in this paper.

c) Underwater Acoustic Channels

Underwater communication is based on the transmission of acoustic waves. Radio waves are rarely used; because radio waves are seriously weakened due to ambient conditions. These transmission channels mentioned are generally not perfect. The bandwidth of these channels is rather limited. These channels cause the signals to be distributed both in frequency dimension and time dimension [6].

Underwater acoustic channels show time-related and environmental-related variability resulting from environmental characteristics and the nature of the transmission environment. In underwater acoustic channels, the speed of sound signal propagation is about 1.5 x 10^3 m / sec, which is a hundred thousand times less than the speed of light or radio propagation speed c (3 x 10^8 m/s). The bandwidth of underwater acoustic channels is limited and depends to a considerable extent on the transmission range and frequency. As the transmission range increases, the bandwidth of the channel decreases. Due to the absorption, most acoustic systems operate under 30 Goals. In addition to its unique features, it is possible to say that underwater acoustic channels are influenced by many factors in terms of performances and characters. Some of these factors are noise, path loss, multipath propagation and Doppler effect which cause error rates and delay changes as in all communication systems.

In addition, acoustic bonds are roughly classified vertically and horizontally according to the direction of the sound wave. The spreading characteristics of these two classes show differences due to the physical and chemical properties of the sea/ocean environment such as temperature, salinity, and density. Some of the characteristics of an acoustic channel can be briefly stated as high propagation delays and high latency variances, limited bandwidth and high error rates [7].

Acoustic waves can be emitted and perceived in water only with an aid. A transducer converts any energy to an energy source (source or projector), or any energy, usually audio, from the energy source (receiver).

Performance of converting two forms of energy into each other; It concerns the properties of the material called piezoelectricity and magnetostriction. Under pressure to gain electric charge between the surfaces; Some crystals such as quartz, ammonium, dihydrogen, phosphate-ADP, Rochelle salt are stressed when the voltage is applied. This type of material is piezoelectric.

Electro strictive materials are also of the same character, but they are polycrystalline ceramics and a high electrostatic field must be polarized optimally. These include; barium titanite and zirconated titanite. When a magneto strictive material is stretched, it changes the magnetic field around it, and when it is polarized, its performance improves because the frequency doubling phenomenon is lifted [8], [9], [10], [11].

8. Simulation Results

After initialization of the place, the nodes will deploy in this place. About 15 nodes deployed in this place. The number of these nodes are select randomly. Figure 2 shows the sensors which deployed in the proposed area.

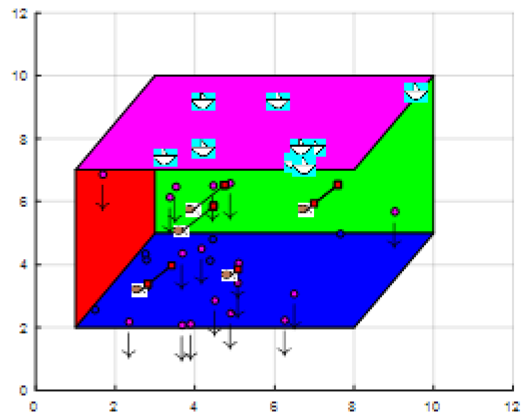

Figure 2: Number of Bottom Nodes which Deployed in the Proposed Area

After deploying the bottom nodes in the place, the underwater nodes will deploy in this place. About 12 nodes deployed in this place. The number of these nodes are select randomly.

In Deploy Autonomous Underwater Vehicle (AUV) step the Autonomous Underwater Vehicle (AUV) is setup. About 6 AUV are setup in proposed place.

In Deploy Sink Node step the sink node are deploying. After deploying the AUV in the place, the sink nodes will deploy in this place. About 14 nodes deployed in this place. The number of these sink nodes are select randomly.

After deploying the sink nodes in the place, the network deployment will done in this place. This item is illustrated in figure 3. In this thesis the cube deployment is done. About 6 node for cube deployment are selected.

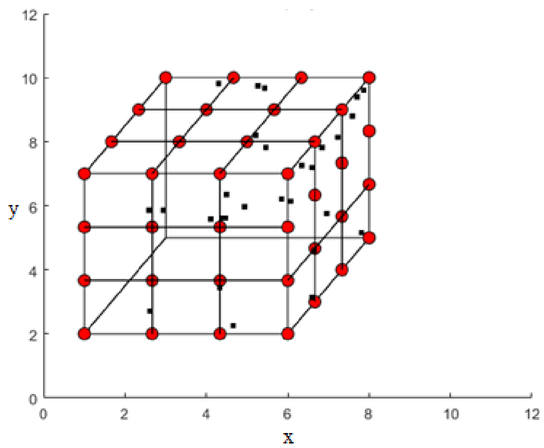

Figure 3: Network Deployment

In Topology step the topology of network will design. In topology Anchor nodes and ordinary nodes are deploy. This state is shown in Figure 4. As shown in this figure the red stare shapes shown the Anchor nodes and blue circle shapes are shown as ordinary nodes.

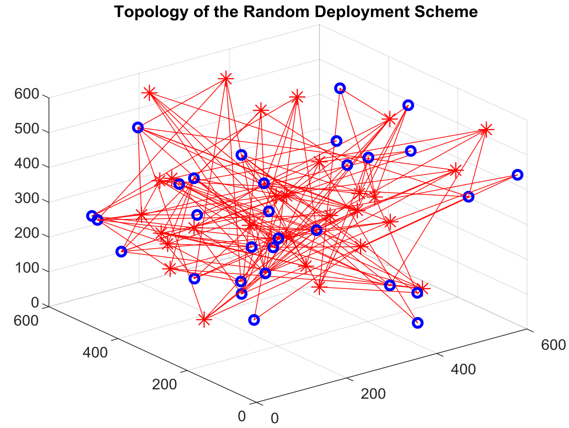

Figure 4: Topology Deployment and Connectionbetween One Anchor Node and the Ordinary Nodes

The connection between first Anchor node and the ordinary nodes is shown in Figure 4. The connection is shown by line green color.

9. 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 5.

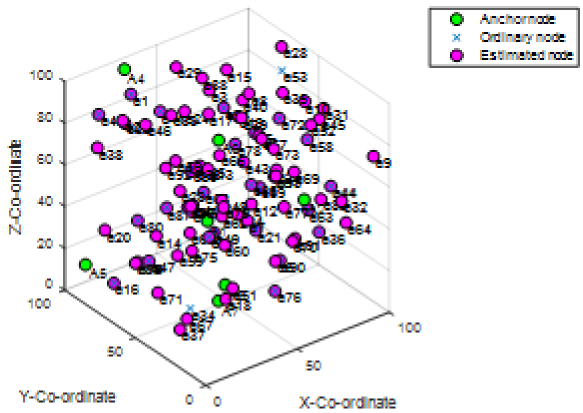

Figure 5: Collection of the Anchor nodes, ordinary nodes and the estimated nodes

The topology of the Cube Deployment Scheme for first Anchor node is shown in Figure 6.

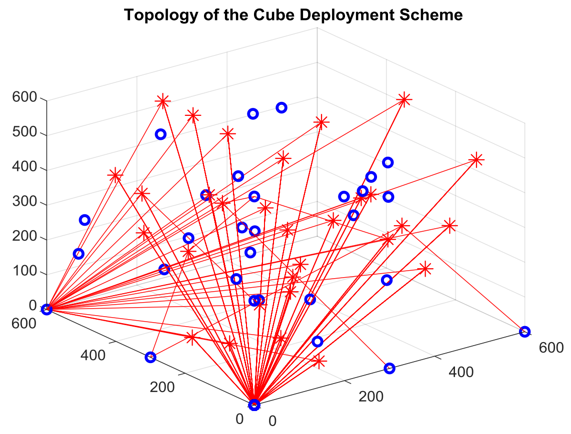

Figure 6: Topology of the Cube Deployment Scheme for first Anchor Node

The topology of the Cube Deployment Scheme for all Anchor node is shown in Figure 7.

Topology of the Regular Tetrahedron Deployment Scheme for all Anchor node is shown in figure 7.

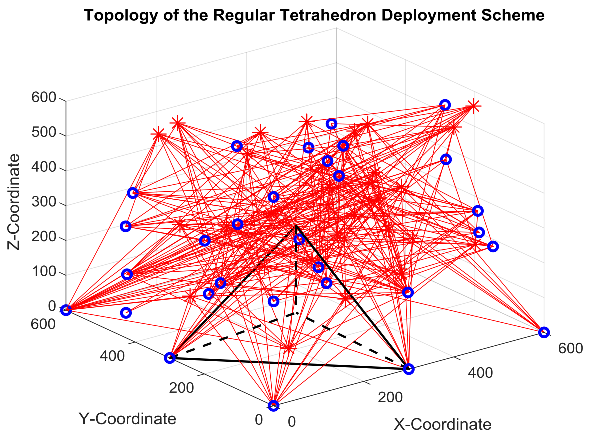

Figure 7: Topology of the Regular Tetrahedron Deployment Scheme for all Anchor Node

The network connectivity on the Anchor nodes for Random deployment, Cube deployment and Regular Tetrahedron Deployment is shown in Figure 8.

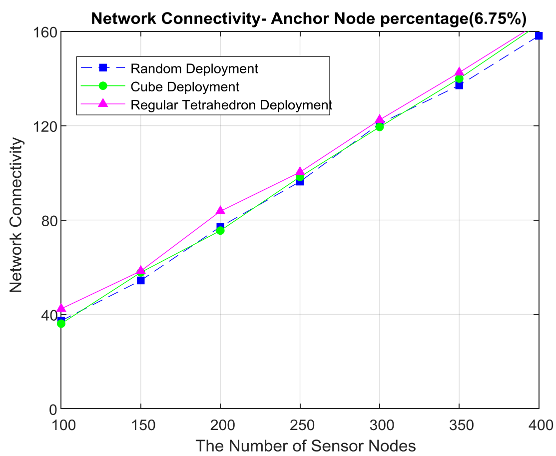

Figure 8: Network Connectivity on the Anchor Nodes for Random Deployment, Cube Deployment and Regular Tetrahedron Deployment

The comparison between Random Deployment, Cube Deployment and Regular Tetrahedron Deployment are illustrated in table 1. The following value is not sorted. The result which shown in figure 8 is sorted from the minimum up to maximum value.

Table 1: Comparison between three methods

Number of Sensor	Random Deployment	Cube Deployment	Regular Tetrahedron Deployment
100	**43.35**	35.225	24.15
150	**48.05692**	23. 693	48.73
200	**42.547**	31.322	27.141
250	33.787	29.426	**41.383**
300	38. 571	48.15	**52.71**
350	53. 091	**54.18**	44.648
400	45. 4211	27.126	**48.52**

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 get for the random deployment. When the sensor number is 250 and 300 the maximum network connectivity is got for Regular Tetrahedron Deployment. As seen in this table the cube deployment is the minimum one and only in one scenario is got the maximum network connectivity and this value for 350 sensor is 54.18.

10. Conclusion

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.

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