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# Under Water Acoustic: A 4D WSN Approach for Deep Sea Exploration

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**ABSTRACT**: The interconnection of sensor nodes by a communication network is known as Wireless Sensor Network (WSN). An underwater acoustic channel is one of the most difficult communication media found today in WSN. In this paper, a four dimensional approach is employed for deep sea exploration using under water acoustic channels. During transmission of signals in acoustics, there is a possibility of loss of data due to attenuation and spreading. In order to calculate the loss, we use four different path loss models. The different factors such as temperature, depth, salinity in underwater acoustic communication are considered during the propagation of signals. We have used QualNet Network Simulator to create the scenarios and coding language as VC++ to implement the path loss models. We have introduced 4D technology for under water acoustic communication and assured accuracy is obtained.

**KEYWORDS**: Acoustic channel, Attenuation, Spreading, Depth, Salinity, QualNet.

## I. INTRODUCTION

The interconnection of sensor nodes by a communication network is known as Wireless Sensor Network (WSN). The elementary components of a WSN are PAN coordinator, coordinator and devices. Using these components, we have developed a scenario of 4D WSN approach for deep sea using under water acoustics. This under water acoustic communication is communication under the water using acoustic signals. Under water acoustic communication network is formed by a collection of sensor nodes, devices like Autonomous under water vehicle (AUV), surface buoy and onshore station. These are networked via acoustic channels. Spreading and attenuation determines path loss, which increases with distance.

Thorp formula is adopted in order to simulate seawater absorption properties, on the basis of which, the path loss is solved by using simulation. Fisher and Simmons model or Francois and Garrison model are also used to improve the results and to approach the noise model of underwater acoustic channel better.

The rest of the paper is organized as follows. Section II briefs about the survey related to previous work. Section III gives details about existing system and proposed system. Experiment results are briefed out in Section IV. Conclusion is given in Section V.

## II. PREVIOUS WORK

Survey related to acoustic communication is discussed. Susan Joshy et al have proposed capacity of underwater wireless communication channel with different acoustic propagation loss models [1]. They have performed a comparative assessment of the influence of various acoustic transmission loss models on the acoustic bandwidth and the capacity. Ian F. Akyildiz et al have discussed the challenges for efficient communication in underwater acoustic sensor networks [2]. Several fundamental key aspects of underwater acoustic communications are investigated and two-dimensional and three-dimensional underwater sensor networks are discussed. Ethem M. Sozer et al have proposed

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underwater acoustic networks [3]. They have surveyed the existing network technology and its applicability to underwater acoustic channels. They have also presented shallow-water acoustic network example and outline some future research directions. John Heidemann et al have discussed research challenges and applications for underwater sensor networking [4]. This paper explores applications and challenges for underwater sensor networks. Milica Stojanovic et al have proposed underwater acoustic communication channels [5]. They have considered the propagation models and statistical characterization. Yu Luo et al have discussed challenges and opportunities of underwater cognitive acoustic networks [6]. They have comprehensively investigated the unique characteristics and their impact on the UCAN design. Ian F. Akyildiz et al have proposed state-of-the-art in protocol research for underwater acoustic sensor networks [7]. This paper details the overview on the current solutions for medium access control, network, and transport layer protocols and open research issues are discussed.

In our proposed model, an attempt is made to develop a scenario of 4D WSN approach for deep sea using Under water acoustics by implementing necessary path loss models.

## III. PROPOSED MODEL

### A. *Existing system*

Traditional systems for exploration involved human divers or Remotely Operated Vehicle (ROV) using wired connection and controlled by the station on the shore. This system is shown below. Figure 1 shows existing wired system for underwater exploration. ROV collects the data from the wreckage and transmits to the control centre which is above the sea surface.

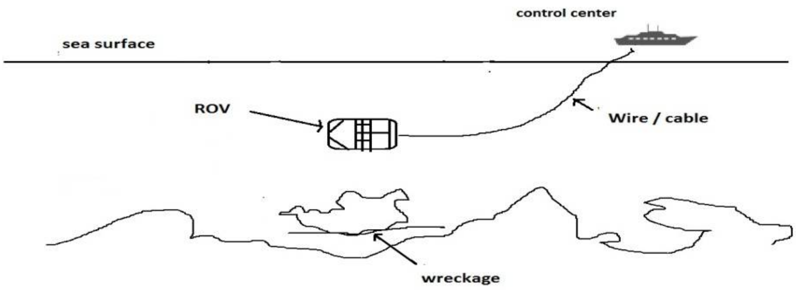


Fig.1: Existing wired system for underwater exploration

The limitation of existing system

- Since ROV's were operated by the cable , any damage to the ROV will go out-of-control and will not be recoverable.
- ROV's were preferred in situations where deep sea investigation was required. UWSN can be used both deep and shallow waters.
- The power requirements for ROV's are high compared to UWSN.
- UWSN can tolerate more faults than the existing tethered solution.
- This system suffers from single point of failure.

### B. *Proposed system*

The architecture shown in figure 1 can be built using wireless sensor networks which is shown in figure 2.

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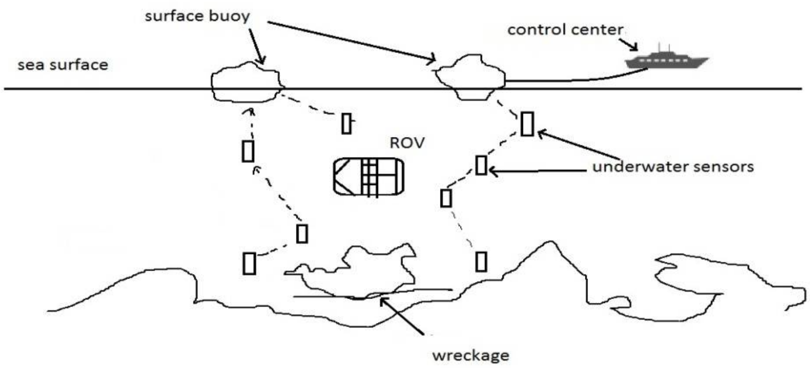


Fig.2: Proposed system architecture

In this architecture, Under Water (UW) sensors are used to collect the information related to objects. The data from each node is relayed by intermediate nodes and finally reach the gateways, that is the surface buoys. The surface buoys in turn are in communication with the control centre. During transmission of signals in acoustics, there is a possibility of loss of data due to attenuation and spreading. In order to calculate the loss, we use acoustic path loss model.

**Acoustic path loss**

Path loss is Cumulative value of geometrical spreading and attenuation. Analytical models for UW Acoustic path loss are introduced. Acoustic Transmission Loss (TL) is the accumulated decrease in acoustic intensity as the sound travels from the source to the receiver. Path loss occurs due to spreading and attenuation.

**1. Spreading**

Spreading is the expansion of wave fronts. Geometrical spreading for acoustic in underwater is mainly of two types.

1. Cylindrical Spreading: This spreading occurs in horizontal direction. It is preferred for shallow water exploration.
2. Spherical Spreading: This spreading is omni directional. It is preferred for deep sea exploration.

**2. Attenuation**

This is mainly provoked by absorption due to the conversion of acoustic energy into heat. The attenuation increases with distance and frequency. The Attenuation is also caused by scattering and reverberation, refraction, and dispersion. Attenuation is a variable component of path loss since it is different for different frequency, temperature and pressure. Different types of attenuation models are there for underwater channels and are discussed below.

1. Thorp model
2. Fisher and Simmons model
3. Francois and Garrison model

**1. Thorp model:**

This model is independent of temperature and depth of the water body. It depends only on the frequency, it is measured in db. Attenuation values= 0 to 63.5 db

Alpha=1.0936[(0.1f2/1+f2) + (40f2/4100+f2)]

Where

Alpha= absorption coefficient in db km-1

f= frequency in Hz.

**2. Fisher and Simmons model**

This model takes in account the effect of temperature of sea water, the pressure exerted at certain depth and the frequency. The empirical formula is shown below

$a = (A_1P_1 (f_1*f^2) / (f_1^2 + f^2) + A_2P_2 (f_2*f^2) / (f_2^2 + f^2) + A_3P_3 f^2) \times 8686$

Where

A1 = 1.03 x 10-8 + 2.36 x 10-10 * T – 5.22 x 10-12 * T2

A2 = 5.62 x 10-8 + 7.52 x 10-10 * T

A3 = [55.9 – 2.37 * T + 4.77 x 10-2 *T2 - 3.48 x 10-4 * T3] * 10-15

F1 = 1.32 x 103 (T+273.1) $e^{-1700 / (T+273.1)}$

F2 = 1.55 x 107 (T+273.1) $e^{-3052 / (T+273.1)}$

P1 = 1

P2 = 1- 10.3 x 10-4 *P + 3.7 x 10-7*P2

P3 = 1-3.84 x 10-4 *P + 7.57 x 10-8*P2

T is temperature in $^oC$ and P is pressure in atmospheres.

In the above equation, the value 8686 is included so that attenuation can be obtained in dB/km, the frequency is in Hz. This model has some restrictions that the depth cannot exceed 8 km and Salinity and pH must and should have the values 35 and 8 respectively. For a given frequency , if salinity and pH are set to 35 and 8 respectively, then attenuation using Fisher model yields less value when compared to Francois and Garrison model discussed next.

**3. Francois – Garrison model**

The attenuation in this model is function of salinity, frequency, depth , pH and temperature. The empirical expression showing the relation is given below.

$\alpha = A1P1 (f_1*f^2) / (f_1^2 + f^2) + A2P2 (f_2*f^2) / (f_2^2 + f^2) + A3P3 f^2$

The first term is sound absorption due to boric acid. The second term is sound absorption due to magnesium sulphate. The third term gives sound absorption due to pure water.P1, P2, P3 are pressure dependent, f is frequency of sound, A1, A2, A3 depend on properties of water such as temperature, pressure etc.

Absorption due to boric acid

$A_1 = (8.86/c) * (10^{(0.78*pH – 5)})$ , $P_1 = 1$, $f_1 = 2.8 *(S/35)^{0.5} * 10^{(4-(1245/273+T))}$

Absorption due to magnesium sulphate

$A_2 = 21.44 *(S/c)*(1+0.025T)$ , $P_2 = 1- (1.37 * 10^{-4} *D) + 6.2 * 10^{-9} * D^2$

$F_2 = (8.17*10^{(8-(1990/273+T))})/(1+0.0018*(S-35))$

Absorption due to pure water

$A_3 = 4.937 * 10^{-4} – (2.59 *10^{-5} *T) + 9.11* 10^{-7} *T^2 – (1.50*10^{-8}*T^3)$ For $T \leq 20$ °C

$A_3 = 3.964 * 10^{-4} – (1.146 *10^{-5} *T) + 1.45* 10^{-7} *T^2 – (6.50*10^{-10}*T^3)$ For $T>20$ °C

For frequencies in 50-500 kHz where contribution due to magnesium sulphate dominates the limits of reliability are

| | |
|---|---|
| -2 < T < 22 °C | range of temperature |
| 30 < S < 35 ppt | range of salinity |
| 0 < D < 3.5 km | range of depth |

For frequencies greater than 500 kHz the attenuation due to pure water dominates

| | |
|---|---|
| 0 < T < 30 °C | temperature range |
| 0 < S < 40 ppt | salinity range |
| 0 < D < 10 km | depth range |

C. *Simulation in QualNet*

The architecture shown in figure 3 is developed using QualNet 6.2 network simulator. The scenario shown in figure 3 shows 4D perspective for deep sea exploration. The scenario consists of total 13 nodes of which two nodes lie on the surface, serving as the surface buoys, one node also on the surface acts the onshore station, and the rest 10 nodes are under the water. The above scenario has two nodes, node 2 and node 3, which are configured to have two interfaces, since those are present on surface, they have to communicate both with underwater nodes as well as the station present on the surface. One interface is used to communicate with nodes underwater which are configured with sensor network specification at physical and Mac layer i.e. IEEE 802.15.4.

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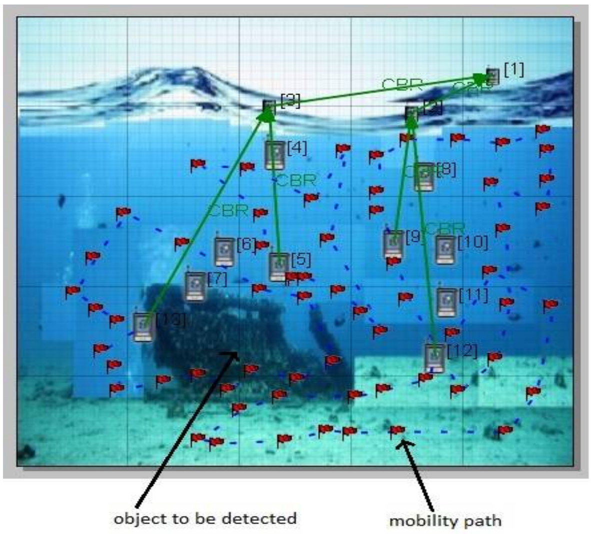


**Fig.3: System Architecture scenario created in QualNet**

The other interface is for communicating with terrestrial station which can be configured as Wi-Fi (802.11) or WiMAX (802.16) standard. The path followed during mobility is shown as red flags.

The implementation part basically includes implementing the path loss models considering different types of attenuation and spreading. There are two types of spreading and two types of attenuation we have considered here. This gives rise to four combinations of path loss types as mentioned below.

a) Spherical path loss considering Attenuation type 1
b) Spherical path loss considering Attenuation type 2
c) Cylindrical path loss considering Attenuation type 1
d) Cylindrical path loss considering Attenuation type 2

Here type 1 attenuation is based on Thorp model and type 2 is attenuation using either Fisher and Simmons model or Francois and Garrison model depending on the value of salinity and pH.

*D. Code Flow for Spherical Spreading*

Figure 4 shows the flowchart of our proposed system.

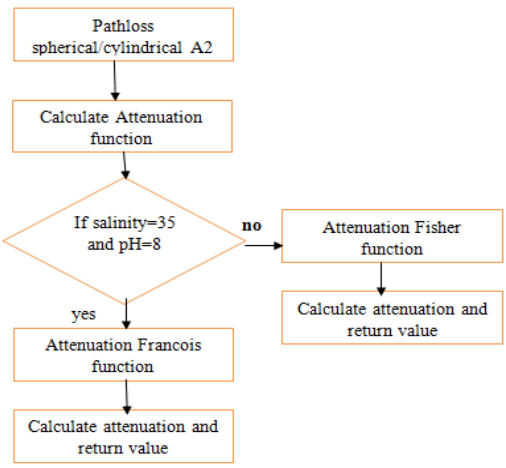


Fig.4: Code flow diagram of attenuation calculation for spherical spreading

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As shown in figure 4, attenuation is function of frequency and it depends on speed of sound. Here attenuation model is considered as Francois and fisher model. Speed of sound depends on the temperature, salinity and depth of sea. Speed of sound average value is 1500m/s, but it varies with respect to temperature, salinity and depth of sea. Cylindrical spreading is one type of geometrical spreading. This spreading due to sound wave loses its energy when propagating water from source sound. It increases with distance. Cumulative value of the Spreading and the attenuation gives path loss in channel.

## IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

Wireless sensor networks are an active topic in networking. There are many number of approaches discussed in the survey, but limited to only 3D. We have analysed and implemented 4D WSN approach for deep sea exploration using under water acoustics. We have used QualNet 6.2 Network Simulator to create the scenarios and VC++ for coding purpose. We have implemented Spherical path loss model considering Attenuation type 2. We have analysed the statistics related to number of packets sent, number of packets received, signal transmitted, signals detected, signals loaded on physical layer, signals received and forwarded to MAC. The main advantage of proposed system is better acceptability, eco-friendly and comparatively more effective for deep sea exploration as wireless architecture is used.

Table I shows the path loss variation with respect to distance and speed of sound. Table II shows the parameters and settings done in QualNet 6.2.

Table I Path loss Variation with Respect Distance and Speed of Sound

| Distance between nodes | Temperature ($^{o}$C) | Salinity (PPT) | Depth(m) | Speed of sound(m/s) | Spherical A2 Pathloss |
|---|---|---|---|---|---|
| 1 | 25 | 31 | 1 | 1530.15 | 0.044098 |
| 2 | 25 | 32 | 2 | 1531.4 | 6.108796 |
| 3 | 26 | 32 | 3 | 1533.95 | 9.67472 |
| 4 | 27 | 32 | 4 | 1536.6 | 12.217593 |
| 5 | 27 | 32 | 5 | 1537.83 | 14.199891 |
| 6 | 27 | 33 | 6 | 1537.99 | 15.82766 |
| 7 | 27 | 33 | 7 | 1537.99 | 17.2106 |
| 8 | 27 | 33 | 8 | 1538.15 | 18.4145 |
| 9 | 27 | 33 | 9 | 1538.31 | 19.481735 |
| 10 | 27 | 33 | 10 | 1538.47 | 20.440983 |
| 20 | 28 | 34 | 50 | 1547.54 | 26.902569 |
| 30 | 25 | 34 | 80 | 1546.06 | 30.8653 |
| 40 | 10 | 35 | 300 | 1537.98 | 33.8051 |
| 50 | 3 | 35 | 3000 | 1942.51 | 36.1844 |

In the above table, we can observe the different results produced for spherical A2 path loss model as the distance between two nodes increase along with different values of parameters such as temperature, salinity, depth and speed of sound.

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Table II: Parameters used in QualNet 6.2

| PARAMETERS | VALUES |
|---|---|
| Simulation Time | 300 |
| Terrain size | 500*500 |
| No. of nodes | 13 |
| Channel type | Wireless Channel |
| Traffic Type | CBR |
| Routing protocols | AODV |

Figure 5 shows the number of packets received from client to server. We can observe that, all three bars represent that they receive the data from two different nodes.

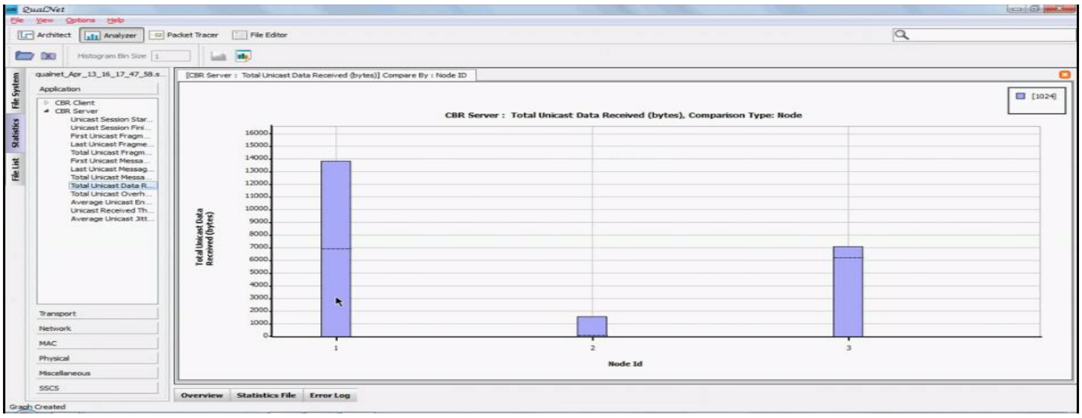


**Fig.5: Total Unicast data received**

Figure 6 shows the number of packets sent from client to server. We can observe the number of packets sent from each node.

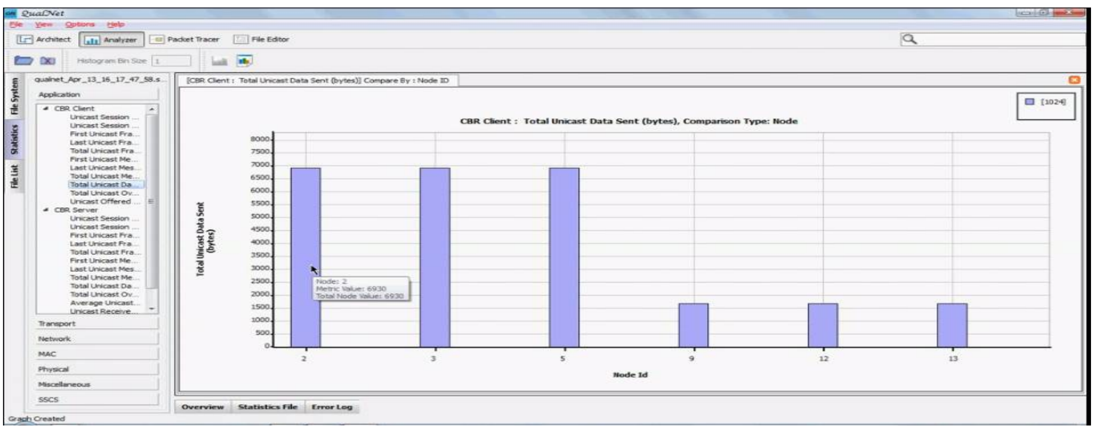


**Fig.6: Total Unicast data sent**

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Figure 7 shows the statistics for number of signals transmitted over the channel. In the same way, statistics can also be analysed for signal detected, signal loaded on by physical layer and signal received and forwarded to MAC layer for 802.15.4 standard.

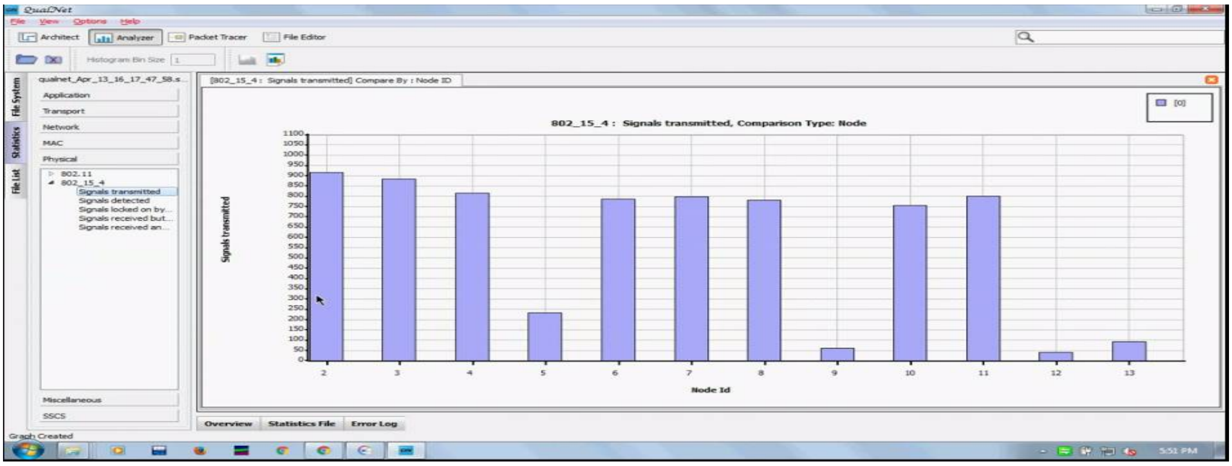


**Fig.7: Signals transmitted**

## V. CONCLUSION

In this paper, a four dimensional approach is employed for deep sea exploration using under water acoustic channels. The simulation results showed that the proposed model overcomes the most of the issues related to existing system. We have used QualNet Network Simulator to create the scenarios and coding language as VC++ to implement the path loss models. We have introduced 4D technology for under water acoustic communication and assured accuracy is obtained.

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