Acoustic Propagation Modeling Based on Underwater Wireless Sensor Communication - Research Challenges

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Abstract: In present paper, the analysis on the reliable performance of the acoustic wave based underwater wireless sensor network communication is done. Underwater wireless sensor network deployment is increasing day by day because of immense use in different applications such as earthquake and tsunami pre-warning, climate and ocean natural resources investigations, and water pollution monitoring etc. In this paper, A discussion will be done on system propagation channel modelling of acoustic communication network in underwater and its corresponding challenges. In ocean bottom and surface of oceans, the sensor nodes, surface stations, and global positioning system form underwater acoustic sensor network that serve as gateways and provide radio communication links to on-shore base stations. This force to characterize a path loss in underwater acoustic channel that can be calculated on basis of signal frequency travelling in oceans and transmission distance, absorption loss and attenuation, Signal to noise ratio. The signal frequency determines the attenuation, absorption loss, which increases with distance as well, with limited available bandwidth of acoustic network in underwater.

Keywords: UWSN (Underwater Wireless Sensor Node), Acoustic, Path Loss, Absorption Loss, Attenuation.

I. INTRODUCTION

Under water acoustic communication has widespread use because of its advantages such as high range communication and its functionality in the absence of line-of-sight (LOS) path between transmitting and receiving nodes. In ocean bottom and surface of oceans, the sensor nodes, surface stations, and global positioning system form underwater acoustic sensor network that serve as gateways and provide radio communication links to on-shore base stations [1] as shown in figure(1).This lead to characterize a path loss that can be calculated on basis of signal frequency travelling in oceans and transmission distance, absorption loss and attenuation. The signal frequency determines the attenuation ,absorption loss, which increases with distance as well [2,3]with limited available bandwidth of acoustic network in underwater.

On the earth, 78 % areas is covered with seas, canals. A large amount of natural resources are required to be explored in underwater. In this way, underwater wireless sensor network (UWSN) technology is emerging as scientific tools to explore the underwater natural resources. UWSN is wireless based communication which has sensing, intelligent computing, and communication capabilities. UWSN is a network of autonomous sensornodes [1] which are spatially installed in under water to sense the natural resources, water-quality, temperature, and pressure. The sensor nodes are connected wirelessly via communication configured modules to know different types of events of interest [4] and transfer that events noticed in underwater to surface station and base station [5].

In Underwater, different types of communication such as optical, RF (radio frequency), acoustic and ultrasonic can be focused to transfer the sensed events by sensor nodes to destination. Every emerging technology has its own properties with its advantages and disadvantages [6], physical and chemical constraints of the medium [7]. As, It can be known that high communication speed is possible of system with effective use of optical communication. But, in underwater some suspended particle become cause of back scattering .High turbidity of sea water affect more to optical communication and does not allow for long range of communication. On the other hand acoustic wave has less sensitivity to suspended particle and water turbidity as compared to the optical waves. Acoustic wave communication is possible to reach long distances (over 20 km [8]). Although acoustic communication is a proven technology, it presents some main drawbacks, like the low data rate (0 b/s to 20 kb/s), In previous years many researchers [7,8] has worked on acoustic and ultrasonic communications, in order to minimize the bad effects of reflections, and on achieving as high data rate as possible. When there is high requirements of high data rate, we pay attention to EM (electromagnetic waves) which are able to reach data rates of up to 100 Mb/s in very short distances. RF communication [9] is best emerging technology and good platform for underwater communication. EM waves have less sensitivity to refraction, reflection effects in shallow water than acoustic waves. In addition, there is little effect of suspended particles on EM wave's communication. The velocity of RF waves is150,000 times greater than that of acoustic waves. The speed of an EM wave is dependent upon some factors like permeability (μ), permittivity (ε), conductivity (σ) and volume charge density (ρ) [10].

II. RELATED WORKS

In advancement of technologies increasing day by day, underwater monitoring becomes important issue to find out precious natural resources. To take into consideration the monitoring process, there is important tool of deploying underwater wireless sensor network. In wireless sensor network (WSN) [4-5] as shown in above figure(1), deployments of different wireless sensing node are done to communicate from one place to another place in underwater. It is difficult for the one sensing node to communicate directly to base station. Then, there is need to use multi-hop transmission through which one node can forward and route the data with optimization path to another node to reach base station, then to destination.
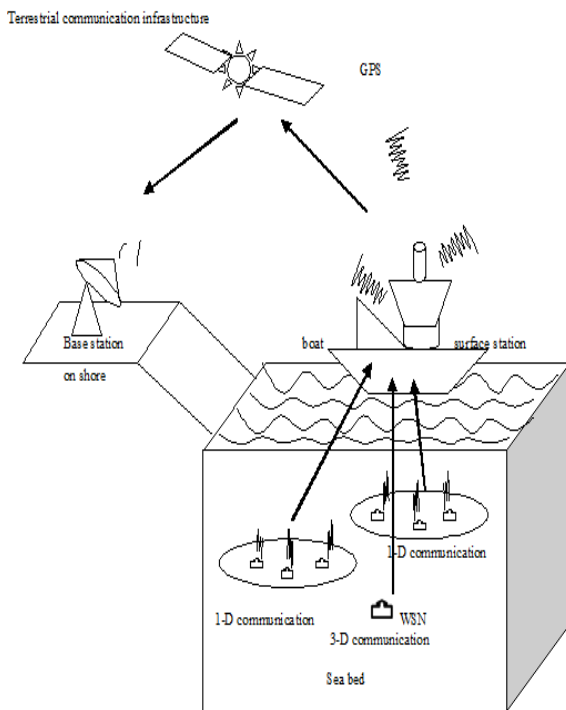
WSN (Wireless Sensor Node)

Fig. 1. Architecture of Underwater Wireless Sensor Acoustic Channel

In these networks, deployment of sensor node at various depth in underwater is done to communicate with other static, floating sensing node and other communication vehicles (e.g., ships, satellites)[11-12]Underwater wireless sensor network deployment is increasing day by day because of immense use in different applications such as earthquake and tsunami pre-warning, climate and ocean natural resources investigations, and water pollution monitoring etc. In oceans and seas, underwater wireless communication networks (UWCN) have to face different types of harsh environments such as fading, propagation delays, high bit error rates of signals, low bandwidth of acoustic channels. The unique characteristics of the underwater wireless communication channel and their underwater counterparts need development of effective, reliable, long range and better security techniques. As it is known that electromagnetic wave (EM) have high attenuation in underwater as compared to acoustic waves13]. we must use acoustic wave instead of EM wave. Now we will discuss about the system propagation model in which some factor like path loss , absorption loss, spreading loss, attenuation and velocity of propagation in acoustic channel.

III. SYSTEM PROPAGATION MODEL [14]

Underwater acoustics communication deals with the study of the propagation of sound in water and generated mechanical waves from sound making interaction with the water and its boundaries. The underwater acoustic propagation's frequencies defined are between 10 Hz and 1MHz.The propagation of sound in the ocean at frequencies lower than 10 Hz is usually not possible without penetrating deep into the seabed, whereas frequencies above 1 MHz are absorbed very quickly because of that they are rarely used. Underwater acoustics is sometimes known as hydro acoustic. A sound wave propagating underwater consists of alternating compressions and rarefactions of the water.

1. Challenges of Acoustic Underwater Wireless Sensor Networks:

Underwater wireless sensor networks have to face big challenges as following:

➢ Bandwidth is quite limited available.

➢ Underwater channel is associated by multi-path fading.

➢ Propagation delay in underwater is five times more than in radio frequency (RF) channels,

➢ High bit error rates

➢ Battery is constrained and typically batteries can't be energized, also because solar energy can't be misused.

➢ Underwater sensors sometime may fail and prone to corrosion.

Underwater wireless communication system can be categorized into three carrier wave system with different transmission distance, bandwidth and mode of communication. As, It can be known from Table (1) that Acoustic wave has long range of communication 100 km at low bandwidth with non line of sight mode of communication.

Table 1 Underwater Wireless Communication System [1, 9, 15]

Carrier	Transmission Distance	Bandwidth	Mode of Communication
Acoustic	100 km	<1khz	Non Line of Sight

Radio	<1m	1Mhz	Non Line of Sight
Optical	<10m	1Ghz	Line of Sight

Radio frequency wave can travel less than 1m distance at high frequency bandwidth 1MHz as compared to acoustic wave. Optical wave transmission distance is <10m at bandwidth 1Ghz with line of sight mode of communication.

The Thorp propagation model [14] is applied to explain the acoustic channel in underwater communications.

2. Velocity of Propagation:

The velocity of propagation is defined as distance travelled by acoustic wave passed through conductive medium within specified time given below in equation (1) [15].Acoustic wave's velocity is affected by salinity, temperature, depth of water. When Acoustic waves propagate through a conductive medium, they will influence the acoustic waves. The velocity of propagation increases with depth of water as shown in figure-2

$$C = 1412 + 3.2 \times T + 1.19 \times S + 0.0167 \times D \qquad (1)$$

Where C is velocity of propagation

T is temperature

S is Salinity

D is depth in meter

3. Absorption Loss:

Absorption loss[14] in equation (2) is amount of energy absorption of acoustic wave by underwater with variations of frequency. Absorption loss coefficient depends upon spread factor (k),distance (d) and attenuation coefficient k=1 for bounded and k=2 for unbounded communication.

$$A(d, f) = (d^k) \times (\alpha(f))^d \qquad (2)$$

Where k is spread factor

d is distance in meter

f is frequency(Hz)

$A(d, f)$ is absorption loss

$\alpha(f)$ is attenuation factor

4. Attenuation:

Attenuation [14] is decrease in signal strength of electromagnetic wave with some distance travelled. Here, attenuation of acoustic wave depends upon frequency Thus, attenuation in a medium has a direct relationship to frequency of signal i.e., with the increase in frequency greater than 0.4, attenuation will be increased and Acoustic waves will travel less distance [14].

$$\alpha(f) = \left(\frac{0.11 \times f^2}{1 + f^2}\right) + \left(\frac{44 \times f^2}{4100 + f^2}\right) + 2.75 \times 10^{(-4)} \times f^2 + 0.03 \leftrightarrow \leftrightarrow f \geq 0.4 \qquad (3)$$

$$\alpha(f) = \left(\frac{0.11 \times f^2}{1 + f^2}\right) + \left((0.11 \times f^2)\right) + 0.02 \leftrightarrow \leftrightarrow f < 0.4 \qquad (4)$$

Where $\alpha(f)$ is attenuation factor

f is frequency

5. Spreading Loss:

Spreading loss [14] can be defined as multiplication of spreading factor and range in underwater communication

$$Pl^{(spreading)} = k \times 10 \times \log(r) \leftrightarrow (db)$$

Where k is spread factor

r is range in meter.

6. Path Loss:

Path loss[14] has more significance for setup of robust UW system. After travelling with some distance acoustic wave degrade. In this way, Path loss can be defined as intensity of degradation of acoustic wave travelling from transmitter to receiver over a particular distance.Path loss is combination of absorption loss and spreading loss.

$$Pathlos = A(d, f) + pl^{(spreading)}$$

IV. RESUTS AND PERFORMANCE ANALYSIS

In figure (2), It can be known that velocity of propagation changes according to depth of underwater. Velocity of propagation increases as acoustic wave travel more deeply inside water, if temperature, salinity of water is kept fixed.
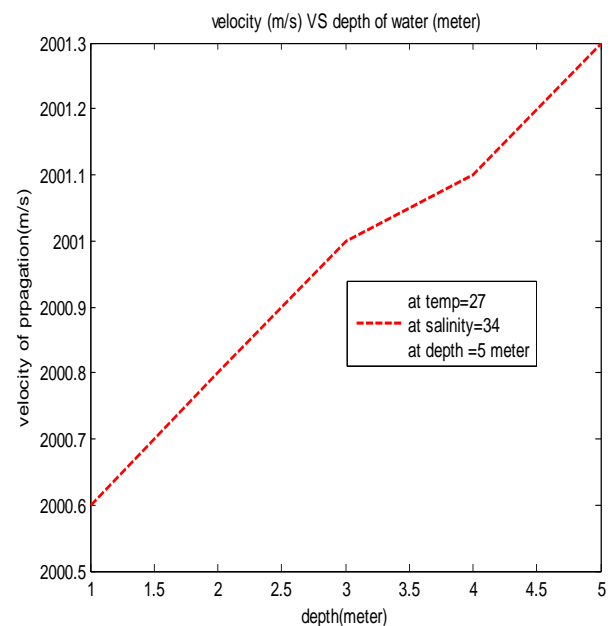

Fig. 2 Velocity of Propagation (M/S) Vs Depth (Meter)

In figure(3), Attenuation vary according to frequency. Initially, Attenuation decrease upto frequency of acoustic signal 0.4 Hz, beyond the frequency 0.4 Hz ,attenuation start to increases.
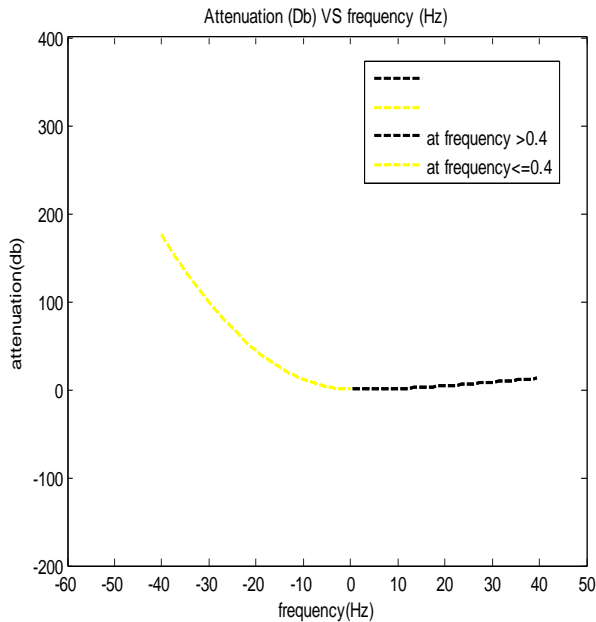

Fig. 3 Attenuation (Db) Vs Frequency (Hz)

Spreading loss in bounded and unbounded communication increases with range of communication. Spreading losses increases less in bounded communication at k=1 as compared to unbounded communication at k=2.This can be seen in figure (4).
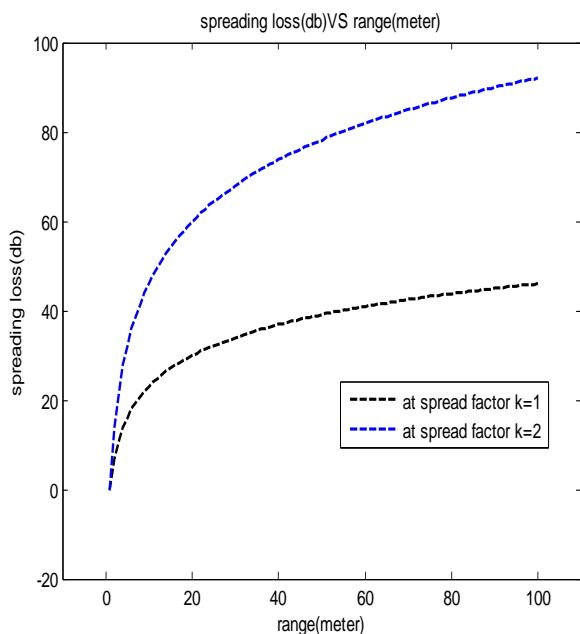

Fig. 4 Spreading Loss (dB) Vs Range (Meter)

As shown in figure (5), Absorption loss of signal, initially, remains constant but after travelling some distance in underwater, It start to increase. At k=1 for bounded communication, absorption loss increase less as compared unbounded communication at spread factor k=2.
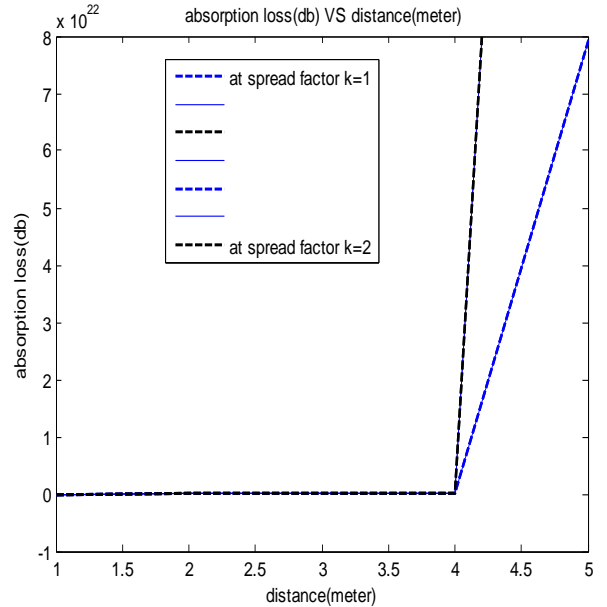

Fig. 5 Absorption Loss (Db) Vs Distance (Meter)

V. CONCLUSIONS

In present paper, the investigation is done on acoustic wave communication in underwater. Underwater wireless sensor network deployment is increasing day by day because of immense use in different applications such as earthquake and tsunami pre-warning, climate and ocean natural resources investigations, and water. pollution monitoring etc. In ocean bottom and surface of oceans, the sensor nodes, surface stations, and global positioning system form underwater acoustic sensor network that serve as gateways and provide radio communication links to on-shore base stations. In this paper ,It ia forced to characterize a path loss in underwater acoustic channel that can be calculated on basis of signal frequency travelling in oceans and transmission distance, absorption loss and attenuation, Signal to noise ratio.

VI. REFERENCES

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