UNDER WATER ACOUSTIC (UW-A) COMMUNICATION ARCHITECTURE AND THE KEY NOTIONS OF UW-A PROPAGATION

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Abstract

The study of the communication architecture for the underwater is very important due the wide applications based on these sensing devices. The more observed examples of applications are climate change monitoring, study of marine life, pollution control, and military purposes. It is observed the radio frequency (RF) electromagnetic waves [1], Optical electromagnetic waves, underwater Optical communication [2] waves all have been used for the underwater sensor networking. But these have shown with its slight disadvantages for the underwater related works. So this can be overcome by the usage of the acoustic communication as a means of transmission technology for the underwater networked system. It is also observed that the underwater acoustic signals are suffering from the some transmission loss, high propagation delay, limited bandwidth. So to eliminate these observed factors with respect to the underwater sensor networks the communication architecture has been developed to provide the point to point, having low data rate and high bandwidth signal and delay tolerant applications. Therefore this article has been written to give the details of how the communication architecture can be designed and for the underwater network and the key factors which relates to the propagation of underwater acoustic signals.

Keywords: *UW-A, Doppler Spread, Attenuation, Variance*

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1. INTRODUCTION

The study of the communication architecture for the underwater is very important due the wide applications based on these sensing devices. The more observed examples of applications are climate change monitoring, study of marine life, pollution control, and military purposes. It is observed the radio frequency (RF) electromagnetic waves [1], Optical electromagnetic waves, underwater Optical communication [2] waves all have been used for the underwater sensor networking. But these have shown with its slight disadvantages for the underwater related works. So this can be overcome by the usage of the acoustic communication as a means of transmission technology for the underwater networked system. It is also observed that the underwater acoustic signals are suffering from the some transmission loss, high propagation delay, limited bandwidth. So to eliminate these observed factors with respect to the underwater sensor networks the communication architecture has been developed to provide the point to point, having low data rate and high bandwidth signal and delay tolerant applications. Therefore this article has been written to give the details of how the communication architecture can be designed and for the underwater network and the key factors which relates to the propagation of underwater acoustic signals.

2. COMMUNICATION ARCHITECTURE FOR THE UNDERWATERNETWORKS

The underwater networks mean it is a collection of sensor nodes. Usually these nodes will be connected to the bottom of the ocean or sea. Internally these will be connected with a many underwater gateways through different wireless acoustic links [3]. The sensor networks are done with usually by selecting a multi hop paths because of its wide area to be covered by those sensing devices. The information will be taken from the bottom network of the ocean and connecting to a surface station. The gateways used for the underwater networking are equipped with three transceivers like vertical and horizontal transceivers and acoustic transceivers.

2.1 Vertical Transceiver

The Vertical transceiver in the underwater gateways is used to function as a relay data to the surface station. These are usually long rage transceivers.

2.2 Horizontal Transceiver

The horizontal transceiver is used to communicate with the sensor nodes and sends the commands as well as Configuration data to the sensors along with that it also collects the monitored data.

2.3 Acoustic Transceiver

These are present on the surface station to handle multiple parallel communications with the used and deployed underwater gateways. Acoustic transceivers may also communicate with the onshore sink or surface sink through a radio transmitter and satellite transmitter.

3. WORKING OF SENSOR NODES IN A COMMUNICATION ARCHITECTURE

Sensor nodes used for the communication in the underwater networks can float at different depths mainly to observe given phenomenon. Here each and every sensor node is attached to the surface buoy [3] by wires and the length is regulated to adjust the depth of each and every sensor node. This enables the quick deployment of the sensor networks. These floating buoys are usually vulnerable to the changes in the weather. The sensing devices are attached to the bottom of the ocean. The complete working of the UW-A communication network is shown in the fig 1.

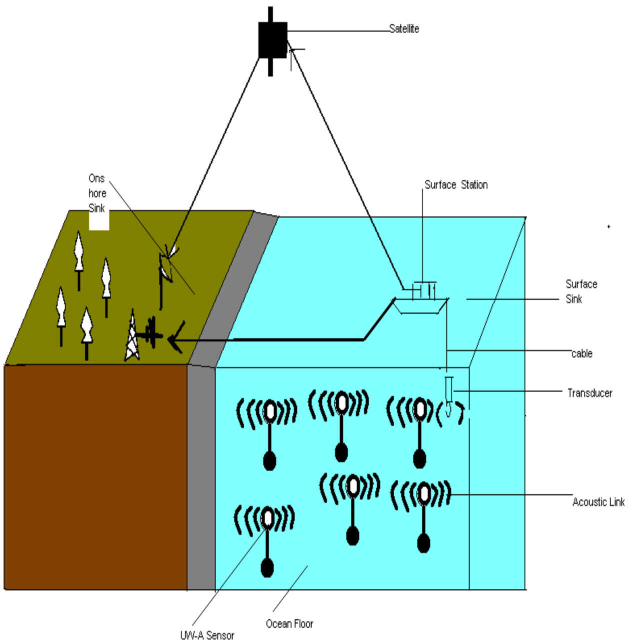

Fig.1 Communication Architecture for the UW-A Sensor Network

4. BASICS OF UNDERWATER ACOUSTICS COMMUNICATION

The main carriers of underwater communication are radio frequency electromagnetic waves, optical waves and acoustic waves. By some research work it is observed that radio frequency waves are affected by high attenuation [4] in water. These can be used only for short ranges of up to 10 to 15 meters. Optical waves are most rapidly scattered and very often observed by water. So there is lot of advantage in using the acoustic waves for the underwater communication over long range links.

These Underwater Acoustic (UW-A) communication is also being affected by noise, variable propagation delay [5], path loss. This UW-A communication works for any rage of systems with its varying frequencies based on the range of the system. This operates for mostly low bit rates.

Based on their range, UW-A communication links can be divided into some categories like long, very long, medium, short and very short. The corresponding bandwidth is also mentioned in the table below.

Table 1 Different types of UW-A Links with its range and bandwidth

Types	Range [km]	Bandwidth[kHz]
Short	0.1	> 100
Very short	0.1-1	20-60
Medium	1-15	10
Long	15-100	2-6
Very long	1000	< 1

5. FACTORS AFFECTING THE UW-A COMMUNICATIONS

5.1 Transmission Loss

The transmission loss is the major factor observed while using the underwater acoustics. This is caused mainly by two factors like geometric spreading loss and attenuation [5]. The transmission loss for any signal with a frequency of F [kHz] over a transmission distance of TD [m] can be expressed in decibels [db] as,

$$\mathbf{10 \log TL\ (TD, F) = N.10 \log (TD) + TD.\ \beta\ (F) + TA\ ,}$$

Where, N is the spreading factor, describes the geometry of propagation, β (F) [db/m] is the absorption coefficient and TA is the transmission anomaly which gives details about the multipath propagation, scattering, refraction. The shallow will be having higher values of attenuation compared to deep water UW-A channel. But the transmission loss increases with the distance and frequency for both.

Geometric Spreading Loss:

This is caused due to the spreading of acoustic energy to the very large surface with expansion of acoustic waves. The geometric spreading can be of two types they are Spherical and Cylindrical. The spherical for deep water communication and the cylindrical for shallow water communication.

Attenuation:

The Attenuation is mainly concerned about the absorption. It is caused due to the conversion of the energy of the acoustic wave into heat. The absorption coefficient can be expressed for any kind of frequencies in [kHz]. For the frequencies above few hundred Hz the absorption coefficient [3] can be,

$$\beta(f) = \left(0.11 \frac{F^2}{F^2+1} + 44 \frac{F^2}{F^2+4100} + 2.75 \cdot 10^{-4} F^2 + 0.003\right) . 10^{-3}$$

For lower frequencies, absorption coefficient can be considered as,

$$\beta(f) = \left(0.002 \frac{F^2}{F^2+1} + 0.11 \frac{F^2}{F^2+1} + 0.011 F^2\right) \cdot 10^{-3}$$

5.2 Noise

Acoustic noise for the underwater communication channel can be of natural or it might be manmade. The noise during the UW-A channel is caused mainly due to the machine parts like pumps, gears or power plants. If not due to machinery noise it may be due to the biological activities like tides, waves wind or rain. The noise sources can be expressed through some formulas, and that provides densities of source to the frequency F [kHz]. The noise may be generated for any kind of underwater acoustic communication.

Here each of the noise generated will have different range of frequencies. The shallow water will be generating a noise which is not predictable easily. But the deep water noise can be predicted easily compared to shallow water. Based on these factors the signal to noise ratio can be predicted based on the transmission loss (TL) and the noise power density,

$$SNR(TD, F) = \frac{P/TL(TD, F)}{N(F)B}$$

Where, B is the receiver noise bandwidth and 1/ (TL(TD,F), N(F))), is the factor which is defined as the effect of transmission loss and the noise present in any UW-A communication for any TD and F values.

5.3 Multipath

The multipath is the one of the factor which affects the UW-A channel. This is usually caused by the wave reflections generated from the surface and bottom. But the wave refraction is by means of wave sound, spread variation with depth. The geometry for the multipath may also depends on the link configuration. The UW-A channel as discussed is of two types. They are vertical channels and the horizontal channels. The vertical channels have less time dispersion compared to the horizontal channels.

5.4 Delay Variance

The speed of an acoustic signal is lower in magnitude compared to the electromagnetic signal. The througput of the system is reduced due to the high propagation delay. Usually the propagation speed for tan underwater acoustic can be considered as,

$$D(d, s, t) = 1449 + 45t - 5t^2 + 0.1t^3 + (1.3 - 0.1 + 0.00t^2) . (s - 30) + 16d + 0.1d^2$$

Where, t is the temperature, s is the salinity in ppt and d is the depth of water in km.

5.5 Doppler Spread

The Doppler Effect is due to some range of frequencies. When the Doppler power spectrum is nonzero then we say it as a Doppler spread of UW-A channel. This can be denoted by $D_{s.}$ This spread may be occurred due to the Doppler shifts caused by the motion in the source and destination. When the UW-A channel experiences with the Doppler spread having b bandwidth with some time t then it may have some BT samples. When BT is very less then we say the Doppler effect as under spread so that it can be ignored. With respect to the coherence time the Doppler spread can be denoted as,

$$\mathbf{T_{coherence} = 1/D_s}$$

Sometimes it is also possible that the Doppler Spread may be overspread. This Doppler spread is very important in the underwater acoustic and so it is leading to a degradation of the performance in the digital communication.

CONCLUSIONS

In this article we have given with the recent advances in the underwater acoustic communication by the sensor networking. We explained with the typical communication architecture of a sensor network. The article also describes about the key factors of UW-A propagation which is necessary to know the efficiency of the sensor networking.

The main objective of the article is to encourage the research work for the development of the communication technique for the underwater networking. As a part of future work we are planning to use effective protocols at the network layers to increase the efficiency of the underwater communication.

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