Under water Environment: a brief of explored work and future scope

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ABSTRACT
Due to the limitations of weather effects in the terrestrial environment, underwater communication has been chosen as a method of high efficiency and security. It has been emerged as a promising technique due to low power consumption, compact size and better data rate. Despite of the benefits it offers, this technique has various lagging effects like it has high bit error rate, battery power and bandwidth limitation and many more which are discussed in this paper and the means to combat those limitations have also been discussed.

Keywords
Underwater Communication, Coded Division Multiple Access (CDMA), Orthogonal Frequency Division Multiplexing (OFDM), Media Access Control (MAC), Field Programmable Gate Array (FPGA).

1. INTRODUCTION
With the advancement of technology man has shifted from road to air; similarly the communication is also seeing its future in underwater environment. Although there are limitations of this transmission but it is gaining huge acceptance due to high data rate, low latent rate and less energy consumption as compared to acoustic links. Since acoustic waves have low data transmission rate and it is sensitive to backward environment so a better option is to move to laser and radio frequency waves. As the optical ray has more directivity and has less dispersion compared to existing acoustic ray system, so this method is quite promising. Nowadays Wavelength Division Multiplexing (WDM) is used which has further increased the capacity. Wireless sensor network is employed for surveillance to safety purpose in underwater communication system. Though the marine world is not affected by the equipments used in underwater communication system but the problem lies in power supply issues, deploy-ability of sensors, misalignment of the optical link due to mobile nodes and many more. Thus the demand for underwater communication is increasing due to other human activities like off shore oil fields and underwater exploration [2]. Generally Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs) are used for this purpose. Although cables are used, but they have other limitations also despite offering high speed. Thus, optical communication in underwater environment would also be a boon like in terrestrial environment due to its large bandwidth and high data rate (Mbps to Gbps). The underwater optical communication uses the visible band of electromagnetic spectrum i.e. the range of 450-550 nm, while water is transparent to light and absorption is minimum. In this paper a discussion about various trends of underwater communication, its challenges, different topologies in use and their future scope is carried out. An overview of wireless sensor networks; its deploy-ability with the limitations they are facing and some key measures are also given in the end. In section II different trends of technologies have been discussed, section III deals with the study of different works and in the last section future work has been proposed.

2. TRENDS OF TECHNOLOGIES
Before concentrating on the experiments and advancements made till yet, it is more important to know about the waves which are used in underwater communication. Mainly, in this section three types of waves are focused on with their properties – acoustic, electromagnetic and optical waves.

Acoustic waves: These are the waves which are of the kind of longitudinal waves and propagate through adiabatic compression and expansion. Thus, they have same direction of propagation and vibration. These are used as the basic carrier in underwater communications. As it is known to us that speed of sound in water depends upon several properties of water such as temperature, salinity, pressure and this is the factor which plays an important role in communication. There is one another concept of absorption in these waves. There may be a change in wave energy while travelling so this can be converted to heat due to inelasticity which works as imperfection.

Electromagnetic waves: These are the waves which have electric field and magnetic field components which are perpendicular to each other and also to the direction of propagation of wave. Normally, electromagnetic waves travel with the speed of light. These are arranged in order of frequency or wavelength in a spectrum called electromagnetic spectrum. It is related to the theory of electrodynamics and properties of superposition are followed. It exhibits both wave and particle properties as per wave particle duality. The energy is deposited when light is absorbed although it is not showing particle but quantum nature as described in quantum electrodynamics.

Optical waves: These are the light waves used for communication. They have big advantage of high data rate but in underwater it has several disadvantages. These are readily absorbed by water and scattering is also prominent. Presently they have provided better communication up to a limited range. It has more speed than acoustic and thus better to utilize. Moreover, the use of other waves could lead to high latency and could affect marine life that is not possible with optical waves [3]. Thus for various underwater applications optical waves are preferred.

3. STUDY OF EXPERIMENTAL WORKS
The main aim to design underwater communication is to have an efficient and reliable network .There is various advantages

of underwater communication in today's world. It is not a new concept to explore the ocean but in 1912 and even earlier when titanic sank and system of detecting U-boats developed. The underwater data links can be combined with satellite links for real time operations. These can be used for disaster management process. Thus the transmitter and receiver for underwater are similar to Free Space Optics (FSO) link in terrestrial atmosphere but the only difference is with the wavelength of operation. Though there are a number of benefits of using underwater communications but there are some drawbacks also. The main disadvantage is the battery power required. The bandwidth available is also limited and the bit error rate is very high [4]. There is more multipath fading and propagation delay; the cost is also high. They are more prone to failure of system than terrestrial system. The difference between terrestrial and underwater communication is made clear in table 1.

Table 1. Comparison between terrestrial and underwater communications

Specification	Underwater	Terrestrial
Cost	More	Less
Deployment	More sparse	Less sparse
Power needed	High	Less
Spatial correlation	Uncorrelated due to mobility of sensors	Correlated

Despite of all the limitations we have better future in underwater communication due to more security and no weather affect disturbance unlike fog or smog in terrestrial communication [5].

3.1 Modulation formats and coding decoding schemes

Recently a transpacific cable system has given the range of terabit for 100 channel WDM network having a speed of 10Gbps with channel spacing of 0.3 nm and a spectral efficiency of 0.3 bits/s/Hz has been achieved [1]. This experiment has used a number of modulation formats like on-off keying, chirped return to zero and recently a new format is added i.e. Return to zero differential phase shift keying. The main problem is to improve spectral efficiency. Some coding and decoding schemes are also used in underwater communication system like CRC encoding and circular trellis check, viterbi decoding is also used. This paper has showed that error detection offered by Reed Solomon encoder gives better performance against noise [6]. The packet size of encoder should be fixed for better decoding and reduction in receiver complexity. The channel is provided with different schemes like turbo codes and reed Solomon [8]. The visible light spectrum has also been used for underwater applications [9]. The systems are using Infrared Radiations but visible light is also employable if used in place of IR [10]. Low Density Parity Check codes (LDPC) are also a good choice to have better results [11]. LDPC codes with code rate ½ , row weight 6 and column weight 3 are used. These are then compared with turbo code of ½ code rate. It is observed that if SNR is greater than 1.5 dB then LDPC codes are good in giving results [12]-[13]. The experimental block diagram is shown in fig 1 which uses BPSK modulator and demodulator with LDPC coding-decoding devices.

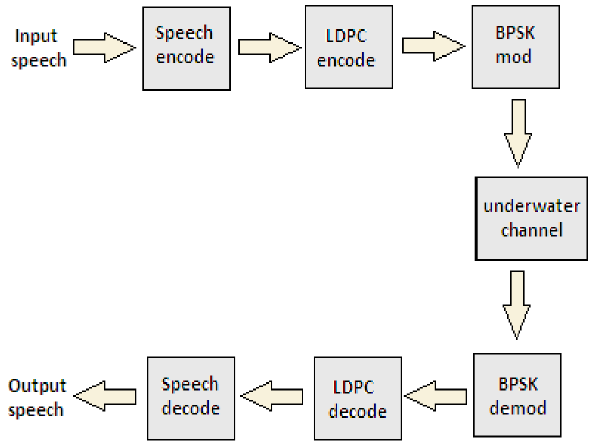

Fig 1: Block diagram for LDPC codes [11]

So better digital speech communication is achieved using this method. There is another method of joint iterative equalization and decoding scheme in combination with the joint synchronization and equalization scheme in order to cure the limitations of the underwater atmosphere [14]. This experiment basically involves physical layer but several higher layers are also involved if taken into account thus solving issues of signal distortion and other impairments [15]-[16]. But the use of this method is limited till very high and low signal to noise ratio is not achieved. The use of single carrier is an old technique. So nowadays multicarrier communication is used not only in terrestrial but also in underwater atmosphere thus ensuring high data rate and low bit error rate [17]. As the technology is advancing various multiple access schemes are also used for multi user communications. One technique is direct sequence code division multiple access (DS-CDMA) with multi user chip rate equalization algorithm as proposed [18]-[21]. Due to the limitations of Doppler spread and Inter Symbol Interference (ISI); the use of decentralized hypothesis feedback equalization algorithm is a secure method which continuously updates the coefficients at chip rate [22]. Keeping this in view another hypothesis of successive interference cancellation hypothesis feedback equalization (SIC-HFE) has been proposed which in turn increases the performance of the system.

3.2. System design and environment

The first and foremost step in the communication is to design the structure of the system. There are limitations to radio frequency and ultrasound waves so we prefer optical waves but its characteristics also depends on water [23] .Thus system design has more importance. The design of the system can be better decided by considering various factors like attenuation coefficient, absorption, scattering. The wavelength also affects the distance to be travelled. As it is reported that using 470 nm one can send information to more distance which is not with 660 nm and 525 nm. OFDM is normally used for multicarrier operations as it provides good data rate. Based on it a structure of transmitter and receiver is proposed and then implemented showing better stability and real time applications with the use of multi channel synchronous sample module at receiver and First In First Out at transmitter on FPGA. The experiment is conducted in a lake and results are cited [24].As far as transmitters are concerned using LEDs are better due to economical reason and also the latency rate is less in them. For receiver utilize tion of photo detectors due to better switching abilities. Since oil lines have their way through ocean so in oil and gas industry for internal check; an in-pipe communication system has been proposed [25]. The oil industries are suffering loss due to changes along the pipes, deposition of debris, valve issues and other configurable problems [26]. So a method of using a robot inside pipe is used and the robot would travel along the pipeline and interact with the base station. It would help to find out the issues that were earlier unrevealed. For this a master- slave architecture is utilized with master at one side of pipeline and slave with robotic device which would travel along the pipe. This system works better for 1km distance. The main issue is with the communication channel configurability. The property of self-configuration should be there in underwater sensors in order to automatically connect to the relevant one [27]. The sensors connected to buoys are not a better approach since it has defense threats. So use of wireless sensor connected to a heavy object to restrict its mobility is an efficient method keeping in view about the topology which should not be harmed. The use of rake receiver is better as proposed in as it reduces the post effects of multipath fading and hence increasing output by decreasing bit error rate [28]. But the synchronization of PN-sequence is not taken into account which is an important issue. A new method of micro-modem has been utilized for short range underwater communication systems and results are noted by conducting experiments in a pond and a lake taking different data rate and distance measures. Hence it is noticed that error free communication is obtained up to 100m and if distance increases up to 500m, degradation of signal occurs. The turbidity of water is also a matter of focus and various authors have conducted a series of experiments by varying the depth and distance between nodes [29]-[33]. A mathematical model is proposed to find the extinction coefficient variability with respect to depth. In the other one the slope and beam scattering effects are taken into account while establishing the link between source transmitter at surface and receiver which has been submerged. Thus the turbidity of water depends on pressure, temperature and nature of water surface. An experiment with monte-carlo simulations has been done and it is studied that except in turbidity conditions the performance of the system proposed is better [34]. In an another approach 80% communication has been observed with propagation loss of 2dB/m and attenuation of 1dB/m using laser communication but a problem of uplink sensitivity of satellite, used between land station and AUV, is solved using gap filters. This experiment has been performed for a depth of 1000m and a JPEG image is transmitted from underwater vehicle using both acoustic and laser waves. It is also noticed that in acoustic wave communication for Quadrature Phase Shift Keying error free communication is there [35].

3.3 Routing protocols and synchronization

Moreover if there is a direct link between source node and the target node; another system of using Transmission Control Protocol (TCP) over a link which is modulated by a USB CP2102UART is a better solution. Since the bandwidth is limited in underwater communication system. So using optical links with TCP would even open the doors to video transmission also. For this, broadcast MAC is employed and it gives better result. Another concept in underwater communication is the time synchronization which requires the proper information between two communicating nodes. But due to fluctuation in temperature and pressure, this factor varies [36]. Once it is achieved the rate of sending and receiving information can be controlled and the reliability would be more. There are a number of algorithms that can be used to have a better timing synchronization like maximum likelihood based on cyclic prefix, symbol synchronization based on Linear Frequency Modulation (LFM) and synchronization based on pseudo random noise sequence. A ten path fading channel is taken and un-coded Bit Error Rate (BER) is used to calculate performance with OFDM [37]. It is observed that performance of LFM is better than others. Moreover it has the ability to manage delay and fading thus providing better results for OFDM underwater communication. In addition to it, an adaptive pilot coarse timing synchronization method is used [38]. It utilizes Constant Amplitude and Zero Auto Correction (CAZAC) sequence which has flat frequency response [39]. To make the performance of OFDM underwater system more reliable by using comb type pilot with CAZAC preamble synchronization method. It improves accuracy and the acquisition time [40]-[41]. The system of OFDM with underwater communication system on FPGA has been carried out and the results are noted [42]. Another method of frequency hopping is also good in underwater communication system at multipath fading and strong noise conditions [43]. So overall it has better simulation results for multipoint communication. A method of Pulse Position Modulation (PPM) has also been introduced which has improved the synchronization complexities and increased the efficiency. Since high energy laser is required thus xenon lamp with adjusted Q laser is used in the experiment as described in fig 2 [44]. This experiment is more reliable than with modulators [45].

The signal travels through medium from one node to another, thus there should be proper alignment between receiving and transmitting nodes otherwise the loss of data could be there. Hence, high directivity is the main requirement though it is not possible while making connections with AUVs and ROVs. If the FOV is small then misalignment problems are more peculiar. Thus inserting the lens and scanning mirrors can solve the purpose but at the reception, the FOV becomes more sensitive so gives limiting performance. An array of LEDs at the transmitter side and photodiode array at the receiver side gives good results which also help in the alignment of transmitter and receiver by scanning or beam steering [46]-[48]. There are various measures which need to be considered while establishing link between the nodes. A model of prediction i.e. sampling based model predictive control is proposed for control and tracking. In AUVs which helps to find path out of local minima as described [49].

If the physical layer is utilized then better communication could be achieved till 100m but multipath propagation and Doppler spread is always there. In data-link layer, various multiple access schemes can be used but it is observed that only CDMA worth in giving results but the latency problem remains there. The network layer is an emerging method in which only the use of geographical routing is beneficial instead of proactive and routing protocols but there is a problem of uncertainty in it. In transport layer, the use of Event to Sink Reliable Transport (ESRT) is used as a tool to conserve energy.

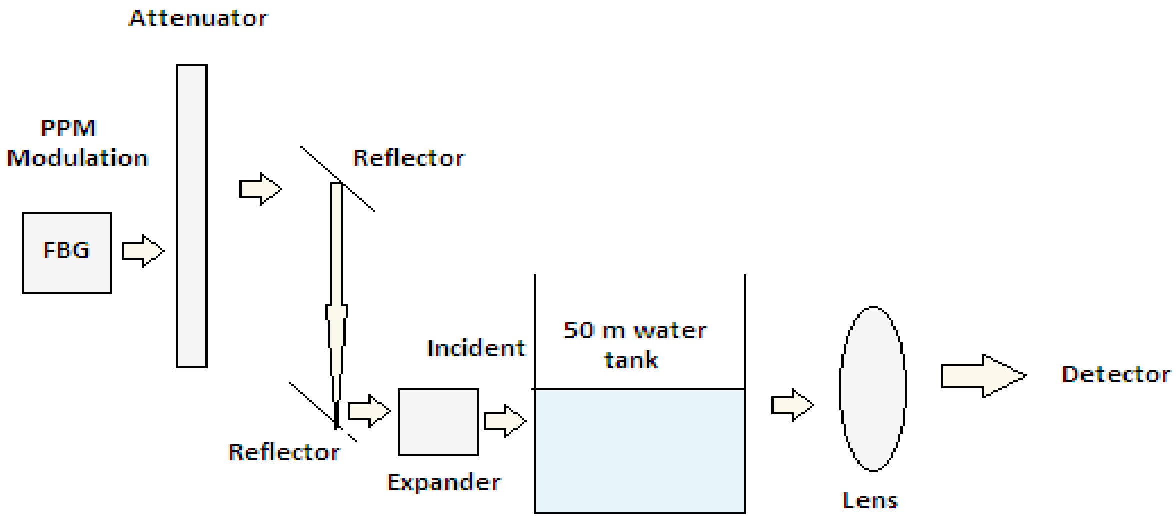

Fig 2: Setup of PPM utilization [44]

4. CONCLUSION

The underwater communication is a recent technology and is still in the developing phase. Many things have been discovered and much work has to be done in this field. The challenges of underwater communication can be overcome by regulating the sensors properly and using various CDMA spectrums since signal becomes resistant to frequency selective fading. By focusing on the routing schemes for 3-dimensional and considering present situation we can utilize this technique more efficiently. The use of Wavelength Division Multiplexing is also a revolutionary step in this direction.

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