

Modulation and Encoding of Underwater Communication

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Introduction

Underwater communication presents complex challenge since specialized devices and techniques are necessary to allow the generation of underwater sound. Difficulties experienced in sound travelling underwater include absorption electromagnetic influence and large attenuation. Transducers, audio amplifiers, and microphones are useful in allowing for communication of divers, submarines, and also surface interaction with the two. Distance is a factor that influences the transmission of communication, with additional factors including signal attenuation, available bandwidth, time variations of the channel, and multi-path propagation. Acoustic vibrations are used as opposed to electromagnetic or radio waves, which are improbable. Various research projects have focused on the techniques adopted for the modulation and encoding channels useful in underwater communication.

The concept of data transmission through the environment of water bodies that is subject to influence by a variety of wireless carriers including optical waves, radio-frequency waves, and acoustic waves presents the proper definition of underwater wireless communications (Pompili & Akyildiz, 2009). One technology that consequentially results in higher data rate and also much higher transmission bandwidth is the underwater optical wireless communication (UOWC). There are a variety of approaches that can be adapted in line with UOWC. However, many of such approaches are faced with challenges that pose issues against the implementation as well as design of the technology (Nasri, Kachouri & Andrieux, 2008).

With more than 70% of the earth's surface covered by water bodies, it is probable to carry out research exploring the bodies with a futuristic perception of the world. The continually growing interest brewed from such explorations has brought about revolutionary underwater

wireless communication technology, whose adoption is critically facilitating the awareness of various ocean exploration systems (Krishnamoorthy & Suriyakala, 2017). Consequentially, such revelations only lead to more explorations and interests.

Types and designs of waves

The designs and implementation developed that utilize wireless information technology whose transmission is through large water bodies brings about enabling technology that consequentially facilitates future endeavors that develop ocean sensor networks and their monitoring systems. The wireless systems adopted through underwater wireless technology also propagate for stand-alone controls that could be applicable for autonomous underwater vehicles (Berger et al, 2010). Additional applications of underwater networks have a variety of probable adoptions including terrestrial sensor networks. Such networks can be facilitated via several designs of underwater communication technologies inclusive of optical waves, radio-frequency waves, and also acoustic waves. However, each of the three technologies has their sets of merits and demerits considered prior to adoption.

Radio waves can exist either naturally, through astronomical objects or lightning, or can be generated artificially. The latter context is useful computer applications, communication satellites, navigation systems such as radar, broadcasting, fixed and mobile communication, and other several applications. The frequencies for radio waves are longer than infrared with frequencies spanning between 300 gigahertz and 30 hertz. The RF waves have loose pointing requirements, and a moderate data transmission rate particularly over short distance. The waves also experience relatively smooth transition through boundaries of air or water, and exhibit stronger tolerance to turbidity and water turbulence as compared to acoustic and optical waves.

However, RF exhibit high bit error rates, and short link range. Compared to optical waves, RF waves have consumers that consume more energy, and are bulky and costly.

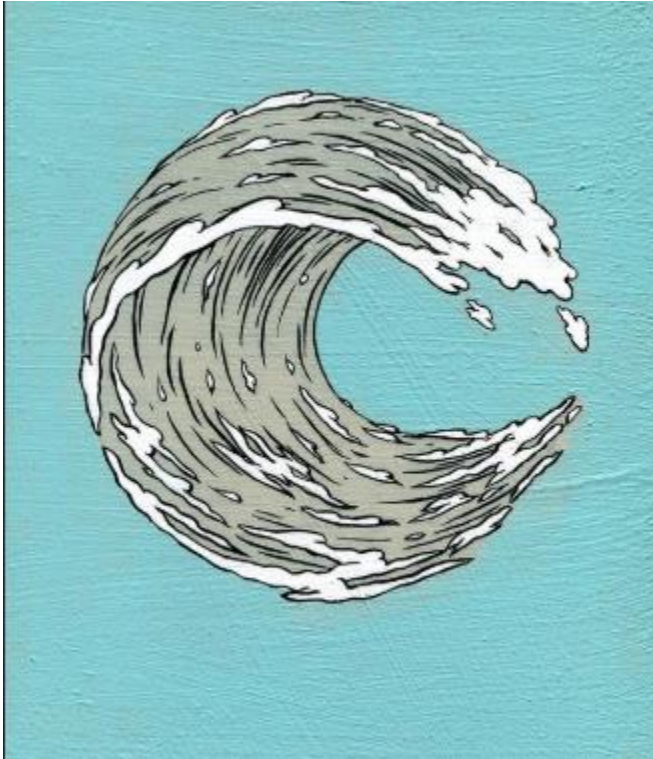


Figure: Circural wave

Acoustic waves describe longitudinal and mechanical energy propagation that result from oscillation of pressure travelling through liquid, solid, or gases. The pattern adopted by the oscillations has to be wave patterns. The oscillation of the waves assumes the same direction for vibration as it does for propagation. The traits of such waves are numerous including amplitude, period, frequency, and wavelengths. The means of travelling through a medium for acoustic waves can either be adiabatic compressions or decompressions.

The quantifiable measures for acoustic waves include acoustic intensity, particle displacement, particle velocity, and acoustic pressure. Acoustic waves exhibit low bit error rates,

and their communication range can span a long range of up to 20 kilometers. Additionally, acoustic waves present as the most widely adopted form of underwater communication technology. However, such technology also presents a significant danger to marine life, and while accounting for the order of seconds, exhibits large communication latency. The transceivers for acoustic wave also incur a lot of costs, are bulky, and consume a lot of energy. The technology also has low data transmission rate in kilobytes per second.



Figure: Wave print

Optical waves range from the infrared spectrum through the various visible to the ultraviolet light. They are combined high-frequency electrical and magnetic fields. Classical theories from Maxwell's equations on electromagnetic fields provide a means for mathematical treatment of optical waves. Optical waves communication transmits the information via light, and can be done either by use of electronic devices or visual elements. Optical waves have

various advantages such as its immunity to transmission latency, its ultra high data transmission, and minimum bit error rates. Additionally, the technology utilizes small volume and low-cost transceivers (Chitre, Shahabudeen, & Stojanovic, 2008). However, transmissions from optical waves cross the air and water boundary easily, and their link range is moderate. The technology also suffers from severe scattering and absorption of waves (Oubei, 2017).

The researches endeavors have resulted in the development of multiple techniques whose adoption would facilitate the sharing of resources between several different stations successfully. The sharing of resources is also probable while making use of differentiated signals with all of them coexisting within a common medium (Domingo, 2008). Acoustic channels exhibit highly peculiar characteristics, all of which have to be accounted for underwater networks while developing designs resource sharing systems. Domingo's overview highlights several detriments of the systems currently in place for acoustic signals to include relatively long reach, frequency-dependent attenuation, and long delays (2008).

Environmental conditions also contribute to the factors facilitating and limiting underwater communications. There are various influences that impact communication signals that propagate through the surf zone. Some include the absorption and scattering emanating from the reflective capabilities of the sea floor, the breaking surf also clouds of bubbles that cause scattering, and surface gravity (Sahu & Shanmugam, 2018). The wave front travel time are produced as systemic variations as a consequential product of focal regions that are brought about surface reflection from shoaling gravity.

Ciphering of Transmission

Further research on acoustic sensors as carried out by Manyi and Manjula takes account of the propagation times involved in underwater communication, and also nodes and their probable distances (2010). Their research also accounts for technological interference on the permissible forms of communications taking place underwater from climate and natural disasters. The channels adopted for underwater communications also involve several disadvantages inclusive of limitations in bandwidth, reduced battery power capacities, fouling, and also corrosion. Manyi and Manjula also specify that such traits highlight the various elements of acoustic sounds (2010). The trident platform also inculcates various elements whose addition to the acoustic links is probable, and they include text and also speech apart from data (Trubuil, Goalic, & Beuzelin, 2013).

Friedman and team also carried out additional research intended at the monitoring of liquid associated processes in cruising sensor nodes, and accounted for their application in industrial processes (2010). They assessed that one specific advantage is their capability to self-propel, which allows for adoption to be directed towards a specified target location for the collection of data. Within the established particular areas of interest, the network comprised of a variety of several nodes useful in cruising. Within a confined space, Wang and team found the presence of numerous reflections which brought about interference among the network of nodes. Lee, Jeon and Park agree with the assessment of Wang and team that the resultant scheme of the study demonstrated traits of robustness and efficiency for the spectrum, and hence would probably be effective in dealing with the underwater channels (2014).

Acoustic Underwater Communication

The sensors adopted for acoustic underwater communications also prove valuable when assessing for better means of monitoring the ocean. The efficiency of the monitoring is subject to influence by various factors including; small available bandwidth, greatly differing multipath, colossal propagation delays, noise, physical channel characteristics, and large power consumption. The determination of error rate for the communication channels also requires accounting for range of distance and the data rate. It is probable to note that increase in data rate results in a consequential increase in BER rate.

Li, Huang, and Wang also note the pulsing of IFR rates allows for the shaping of communication underwater (2012). An additional advantage is its capability to begin program, and also frequent modification also allows customization to suit specified needs (Li, Huang & Wang, 2012). The use of acoustic communication together with the unmanned vehicles also allows for further improvement to cater for the long-range restriction involved in underwater communication. The host and the unmanned vehicles provide additional limitation of transmission loss for underwater communication (Shen, 2006).

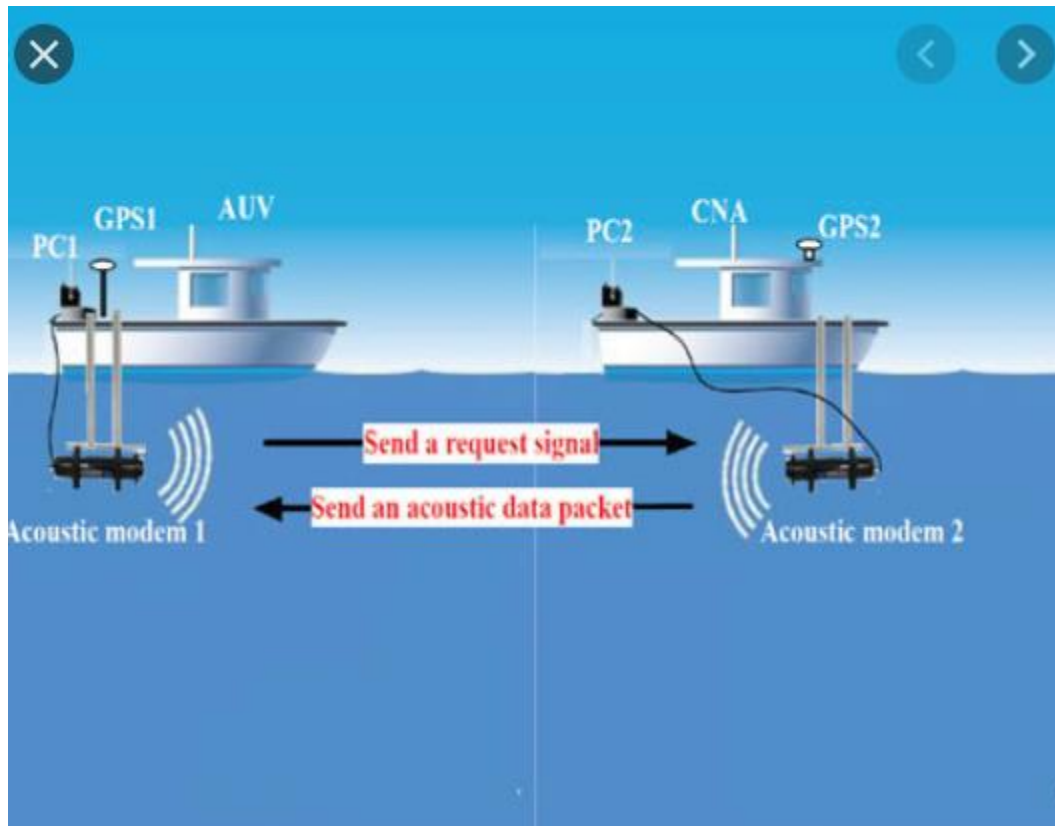


Figure: Acoustic Underwater Communication

Underwater acoustic sensors face a variety of multiple challenges. Some of the issues include power constraints, re=outing resource limitations, media access control, network path loss, 3D topology, high propagation delay, limitation for energy and memory, the small size of sensors with low bandwidth, and deployment to different layers. Such problems bring about a fall down in communication speed to as low as 1500m/sec. accounting for various routing protocols (Tuna & Gungor, 2017).

It is probable to come up with possibilities and solutions to such challenges. To accomplish and maintain a high successful data delivery ratio rate, it is conducive to reduce any form of congestion within the network for the routing algorithms, which will consequentially

make them more energy efficient. Vector based forwarding protocol was the first for underwater sensors. Its functionality allows for location tracing from every node, while each packet can pass on information about the location of the sender, sink, and the source.

Ibrahim and team discuss the research by Xie, Cui and Lao regarding VBF protocol (Ibrahim et al, 2014). For the nodes that lie within the routing pipe, the VBF protocol are known to apply the routing vector pipe with the source to sink vector that forward packet to source. VBF has attained higher success in data transference, scalability, energy efficiency and robustness. After various undertaking of simulations and accommodation of algorithms, Ibrahim and team agree that Xie, Cui and Lao were successful in proving that the protocol could grip node mobility with high productivity. Additionally, the self-adaption algorithms authorize every node to evaluate its significance and for saving energy by alterably forwarding packets.

Nicolaou, See, Xie, Cui, and Maggiorini proposed a new routing protocol called Hop-by-Hop vector-based forwarding (HH-VBF) based on some of the limitations from VBF. The former increases the ratio packet delivery in sparse networks (2007). There have also been additional inventions in the redundancy control measures incorporated under the self-adaption strategy. There is the probability of discovering more additional paths using the HH-VBF protocol for data transferring while scattering (Nicolaou, See, Xie, Cui, & Maggiorini, 2007). HH-VBF is also found to be more sensitive to the routing pipe as compared to VBF. The HH-VBF protocols were also adapted in NS-2 to simulate 3D underwater sensor networks and in broadcasting MAC protocols (Husain, Husain & Aslam, 2015).

Packets are passed from a single layer to another in a network due to medium access control layer (MAC), which is used up while entering the underwater acoustic channel.

Parameters were set up the resources of the physical layer of the MAC were regulated, whereby progression delay was observed. It is probable that the observation was due to the acoustic signals have transmission speeds that are lower than electromagnetic waves at 15000m/sec. Consequentially, the UAN's probability of bit error rate is also high. However, acoustic signals demonstrate an ability to transmit over long distances while underwater, which is probably why underwater communication adopts their signals.

There are also a variety of different routing protocols used in underwater acoustic communication, whose adoption is significantly directed at improving their qualities and issues. Localization based routing (LBR) and localization free routing (LFR) provide additional means with each having their issues and advantages. Consequentially, the researchers did not have success in establishing which of the better protocol from the two (Krishnamoorthy & Suriyakala, 2017).

Husain, Husain, and Aslam considered the option of merging the two routing protocols which would consequentially improve their qualities. Network simulator version 2 is an event-based simulator used for simulating underwater network. For the oceanic environment, Aqua-Sim is installed on the network simulator version, whose use is in the implementation. They function within a fixed timeline, with an animation-based simulation. There is another version of a network simulator whose event networks are discrete for the internet systems and they use an extension called AquaSim-NG. The last one supports both 2G and 3G topologies.

To transfer data wirelessly through underwater, one component that is widely used in the subsea application is called a modem. The device also implements physical layers for transmitting data and receiving data through the network. Modem is also necessary for data

processing in the application layer, transport protocol for the transport layer, routing protocol in network layer, and MAC protocol in link layer (Chitre, Shahabudeen, & Stojanovic, 2008). However, modems incur a hefty price. In the discussion of current issues such as Mac and routing challenges, and the comparison of current methodologies, the study of the current challenges and also environmental effects provide a base for further improvement of designs through new and better solutions.

Following the influence of the work by Abbas, Montandon, Orozco, and Villalba about the biggest challenges facing the underwater acoustic network, the team proposed a routing protocol called energy balanced vector-based forwarding (EBVBF) (2019). They used the third network simulator version for simulating this routing protocol, and used it in conjunction with an extension termed the AquaSim-NG. Further research also prompts the proposal of another new routing protocol called the diagonal and vertical routing protocol. The researchers successfully demonstrated that it has the capability to provide better performance as compared to the other routing protocols which are used in underwater acoustic networks. The diagonal and vertical routing protocol offers several advantages such as efficiency in end-to-end delays, reliability, scalability, and power consumption.

Sensor networks with autonomous underwater vehicles (AUVs) also have the capability to perform without the need for tether, cables, or even remote control. In oceanography, environmental monitoring, resource studies in underwater, there are a multitude of application, Pompili was among the tea who proposed a new network which required cooperation of algorithms. One is adaptive sampling and the other is self-configuration which would effectively integrate UW-ASN's with AUVs as required.

Conclusion

Through and comprehensive exploration of underwater sensing applications shows probable benefits of lower costs associated with cheap computing for advancements in acoustic sensing, communication and technology. Despite the advancements and developments on underwater sensor networks, there still are various challenges that future researches should focus on solving. The paramount and significance of such research should take account of integration and testing, effectiveness of analysis, and new approaches to communication.

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