Marine Information Technology Curriculum Report

Title： Underwater Wireless Communication

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1. Introduction

Underwater wireless communications play an important role in marine activities such as environmental monitoring, underwater exploration, and scientific data collection. Underwater wireless communications still remain quite challenging, due to the unique and harsh conditions that characterize underwater channels. These conditions include for example severe attenuation, multipath dispersion, and limited resource utilization. Advanced communication techniques using acoustic, electromagnetic and/or optical waves have emerged to tackle fundamental and practical challenges of underwater wireless communications.

The word acoustics originates from the Greek word meaning, “to listen.” The original meaning concerned only hearing and sound perception. The word has gradually attained an extended meaning and, in addition to its original sense, is now commonly used for almost everything connected with rapidly varying mechanical vibrations, from noise to seismic and sonar systems, to ultrasound in medical diagnosis and materials technology. Underwater wireless communication is the wireless communication in which acoustic signals (waves) carry digital information through an underwater channel. The signal that are used to carry digital information through an underwater channel are the acoustic waves.

Underwater acoustics is the study of the propagation of sound in water and the interaction of the mechanical waves that constitute sound with the water, its contents and its boundaries .Typical frequencies associated with underwater acoustics are between 10 Hz and 1 MHz. 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 rarely used because they are absorbed very quickly. Underwater acoustics is sometimes known as hydroacoustics. The field of underwater acoustics is closely related to a number of other fields of acoustic study, including sonar, transduction, acoustic signal processing, acoustical oceanography, bioacoustics, and physical acoustics.

2. History

Aristotle (384–322 BC) was among the first to note that sound could be heard in water as well as in air. Nearly 2000 years later, Leonardo da Vinci (1452-1519) made the observation quoted above that ships could be heard at great distances underwater. Almost 200 years after da Vinci's observation, the physical understanding of acoustical process was advancing rapidly with Marin Mersenne and Galileo independently discovering the laws of vibrating strings, which Mersenne published in his work *L'Harmonie Universelle* in the late 1620's. Mersenne's remarks regarding the nature and behavior of sound and his early experimental measurements on the speed of sound in air during the mid to late 1600's are considered to provide the foundation for acoustics. Several decades later, in 1687, Sir Isaac Newton published the first mathematical theory of how sound travels, in his great work, *Philosophiae Naturalis Principia Mathematica*. Although Newton focused on sound in air, the same basic mathematical theory applies to sound in water.

In 1743, Abbé J. A. Nollet conducted a series of experiments to settle a dispute about whether sounds could travel through water. With his head underwater, he reported hearing a pistol shot, bell, whistle, and shouts. He also noted that an alarm clock clanging in water could be heard easily by an underwater observer, but not in air, clearly demonstrating sound travels through water.

In 1877 Lord Rayleigh wote the Theory of Sound & established modern acoustic theory. In 1919, the first scientific paper on underwater acoustics was published. Many advances in underwater acoustics were made which were summarised later in the series Physics of Sound in the Sea,published in 1946. After world war two, the development of sonar systems was driven largely by the cold war, resulting in advances in the theortical & practical understanding of underwater acoustics ,aided by computer based techniques.

3. Necessity of Underwater Wireless Communication

Nowadays the need for underwater wireless communications is necessary for applications such as remote control, offshore oil industry pollution monitoring, in environmental systems, the collection of scientific data recorded at ocean-bottom stations, speech transmission between divers and mapping of the ocean floor for detection of objects as well as for the discovery of new resources. Transmission of acoustic waves can establish underwater wireless communications. Underwater acoustic communications are rapidly growing a field of research and engineering. Because of the applications are exclusively used in the military now extends into commercial areas also. So that without any physical connection of tethers, there is a possibility to maintain signal transmission which enables the gathering of data from underwater equipment without human interference and unhindered operation of unmanned or independent underwater vehicles.

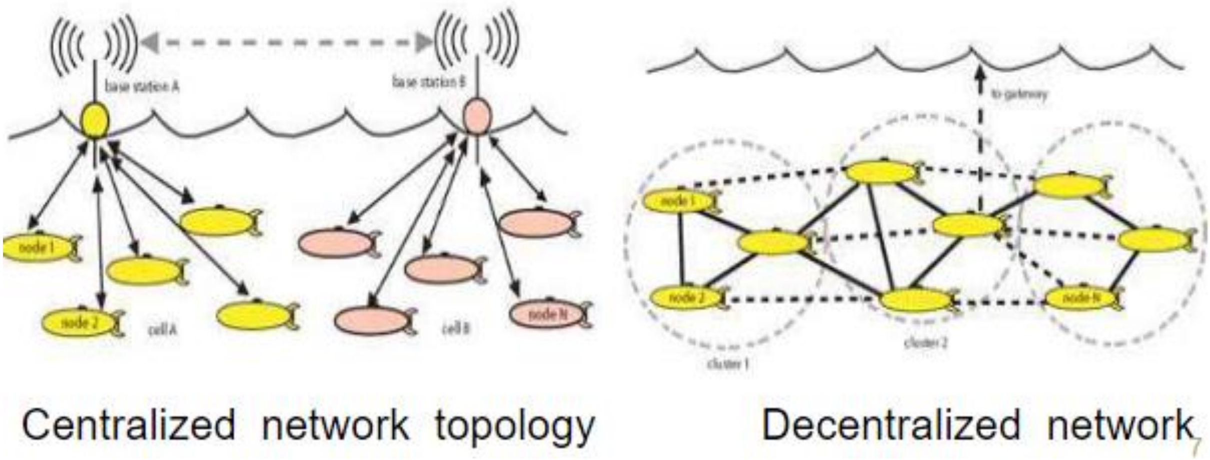
Underwater wireless transmission of signals depends not only on acoustic waves but also radio waves that will transmit any distance through conductive sea water. Optical waves do not suffer so much from attenuation, but they are affected by scattering. Consequently, transmission of optical signals requires high precision in pointing the narrow laser beams. When the laser technology is still perfecting for practical use, the acoustic waves remain solely the best solution for communicating with marine applications where tethering is unacceptable.

Wired underwater is not feasible in all situations as shown below-: Temporary experiments, Breaking of wires, Significant cost of deployment, Experiment over long distances. To cope up with above situations, we require underwater wireless communication.

4. Underwater Acoustic Wireless Communication Technology

Acoustic communication is the most versatile and widely used technique in underwater environments due to the low attenuation (signal reduction) of sound in water. This is especially true in thermally stable, deep water settings. On the other hand, the use of acoustic waves in shallow water can be adversely affected by temperature gradients, surface ambient noise, and multipath propagation due to reflection and refraction. The much slower speed of acoustic propagation in water, about 1500 m/s (meters per second), compared with that of electromagnetic and optical waves, is another limiting factor for efficient communication and networking. Nevertheless, the currently favorable technology for underwater communication is upon acoustics.

Among the three types of waves, acoustic waves are used as the primary carrier for underwater wireless communication systems due to the relatively low absorption in underwater environments. We start the discussion with the physical fundamentals and the implications of using acoustic waves as the wireless communication carrier in underwater environments. Radio waves do not propagate well underwater due to the high energy absorption of water.Therefore, underwater communication are based on acoustic links characterized by large propagation delays. The signal that are used to carry digital information through an underwater channel are acoustic channel. Acoustic channels have low bandwidth. The propagation speed of acoustic signals in water is typically 1500 m/s.As per the applications, the underwater network topologies are two types and they are as follows. Centralized network topology, Decentralized network topology.



5. Factors Influencing Acoustic Communication

Due to the high radio frequency which quickly immersed in water, the WSNs are being applied in marine applications which are the main problem and a large antenna is required by small radio frequency. Moreover, the optical waves are not efficient in marine environments because they may be speckled. An excellent performance of acoustic waves is very apt for marine environments, and so these are utilized as a path loss, low bandwidth and high-energy applications in comparison with radio waves. The flow of water, there exists high and constant movement of sensor nodes which create other demands, is an added issue to be taken into account for the inapplicability of global positioning system (GPS) to this atmosphere. The complexity is getting raised due to the 3D nature of the marine environment. The networks route the sensing data and deliver it successfully to the sinks, and so it considered as the major issue.

Path loss: Due to attenuation and geometric spreading. Noise: Man-made noise and ambient noise(due to hydrodynamics)Doppler frequency spread.

Multi-path propagation and High propagation delay.

Acoustic Modem

Employ advanced modulation scheme and channel equalization for improved signal to noise ratio. Employ high performance error detection and correction coding scheme which reduces bit error rate to less than 10- Parts of an acoustic modem: DSP Board AFE(Analog Front End) Board DC/DC Converter

Data Transmission in Modem

When no data is being transmitted, the modem stays in sleep mode, it periodically wakes up to receive possible data being transmitted by far end modem.When the data is to be transmitted , the modem receives data from its link in sleep mode and then switches to transmit mode and transmit the data.

6. Applications

- Autonomous Underwater Vehicle (AUV)
- Pollution monitoring
- Ocean currents monitoring
- Equipment monitoring and control
- Seismic monitoring
- Remotely operated vehicle(ROV)
- Acoustic navigation technology for multiple AUVs. Solar Powered AUVs
- Disaster detection & early warning
- Defence

7. Advantages

Can be used to provide early warnings of tsunamis generated by undersea earthquakes.

- It avoids data spoofing.
- It avoids privacy leakage.
- Pollution monitoring.

8. Disadvantages

Battery power is limited and usually batteries cannot be recharged also because solar energy cannot be exploited .

- The available bandwidth is severely limited.
- Channel characteristics including long and variable propagation delays. Multipath and fading problems.
- High bit error rate.

9. Conclusion

- There is still an immense scope so more research as major part of the ocean bottom yet remains unexploded.
- The main objective is to overcome the present limitations and implement advanced technology for oceanographic research.
- To cope up with the environmental effects on the noise performance of acoustic systems to compete with the future challenges like effective transmission of audio and video signals etc.

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