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Communication in Underwater Wireless Sensor Networks

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Abstract: As is well known, the ocean covers approximately 70% of the Earth's surface area. Currently, human exploration of the ocean remains at less than 5%. Therefore, continuous exploration and development of marine resources are of great significance. In recent years, underwater wireless communication technology has rapidly developed. However, the harsh and constantly changing underwater environment has also posed many technical challenges.

Keywords: Underwater Wireless Communication; Wireless Sensors Networks.

1. Introduction

The ocean is not only the main body of the Earth but also the cradle of life and the source of human civilization. The total surface area of the Earth is approximately 5.1×10^8km2, divided into land and sea. Calculated according to Geoid, the land area accounts for 1.49×10^8 square kilometers, approximately 29.2% of the total surface area, while the ocean area accounts for 3.61×10^8 square kilometers, approximately 70.8% of the total surface area. This gives a land-to-ocean ratio of 2.5:1. The world's oceans are usually divided into four parts, namely the Pacific, Atlantic, Indian, and Arctic oceans. Within these vast bodies of water, there exists an abundance of marine biological resources. It is estimated that the ocean's ability to provide food for humans is equivalent to 1000 times the world's arable land.

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2. Application Scenario

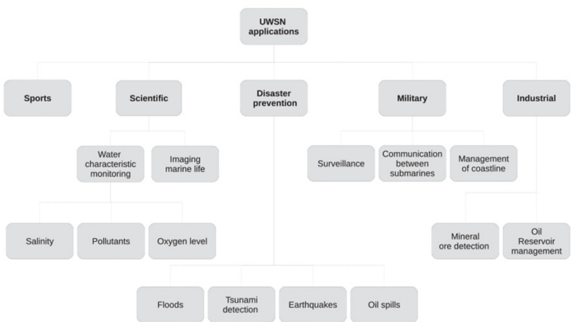

Figure 1. Examples of underwater wireless sensor network applications

In recent years, the emergence of compact sensors has led to the exploration of various application scenarios for underwater wireless sensor networks. Figure 1 presents several common application scenarios.

2.1. Environmental Monitoring

The application of underwater wireless sensor networks in marine environmental monitoring is crucial for maintaining the balance of nature and protecting the marine ecosystem. These networks can collect a large amount of real-time marine parameter data, such as water quality, temperature, salinity, dissolved oxygen, and more. This provides valuable information for scientists and environmental protection agencies to understand changes in the marine environment, control marine pollution, and respond quickly to ecological damage.

2.2. Underwater Resource Development

During marine energy development, sensor networks can monitor tides, currents, and waves to optimize energy collection and utilization. Additionally, in mineral resource exploration, sensor networks can monitor seabed mineral deposits in real-time, thereby improving mining efficiency and resource utilization.

2.3. Marine Disaster Monitoring

The sensor networks can monitor natural disasters, including tsunamis, earthquakes, and ocean storms in real-time, providing accurate warning information to help reduce disaster losses and ensure people's safety.

2.4. Marine Military Applications

Underwater wireless sensor networks have a wide range of applications in the maritime military domain. They can facilitate communication between submarines and surface combatants, enabling information sharing and military command. Additionally, sensor networks can monitor enemy activities and track underwater targets, enhancing the Navy's intelligence collection and military combat capabilities.

3. Networks Architecture

Different types of sensor networks have varying topological structures, and Figure 2 illustrates the fundamental network architecture of cluster communication.

The entire network comprises ordinary sensor nodes, cluster head sensor nodes, water surface float nodes, water surface sink nodes, land sink nodes, and communication satellites.

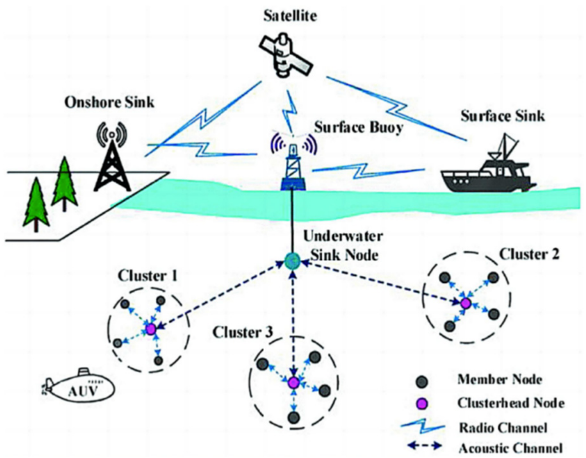

Figure 2. An underwater wireless sensor network working model

4. Communication Medium

Underwater wireless communication refers to the use wireless channel for data transmission underwater. It mainly relies on three media for implementation. Sound waves. light waves and radio frequencies. The following is a brief introduction to these three methods.

4.1. Acoustic Waves Communication

Underwater acoustic communication refers to the technology that uses sound waves as carriers to transmit information underwater. in a communication process, it is necessary to first convert the transmitted information into electrical signals through an electrical transmitter. and then perform digital processing through an encoder. After processing. the underwater acoustic transducer converts electrical signals into acoustic signals. The acoustic signal is transmitted in water and received by the underwater acoustic transducer at the receiving end. then. the acoustic signal carrying the information is converted back into an electrical signal. After the decoder decrypts the digital information. The receiver can obtain the original sent information.

4.2. Optical Waves Communication

Due to the low attenuation of light waves with frequencies from 450 nm to 550 nm in seawater, it corresponds to the Teal spectrum. Most underwater optical communication transmitters use Teal laser sources. Underwater optical communication has the advantages of high transmission bandwidth. fast communication rate. low link delay. small size. low cost. and high security. With the rapid development of digital technology, there is an increasing demand for affordable and practical underwater communication technology in various industries. The field of underwater optical communication has also achieved significant development. However, the communication quality of underwater optical wireless communication (UOWC) is closely related to the clarity of water. Optical signals are easily absorbed and scattered in complex underwater environments.

4.3. Underwater Radio Frequency Communication

While the application of radio frequency waves in the air is already quite mature, they attenuate severely in seawater. Super low frequency electromagnetic wave from 30Hz to 300Hz can penetrate more than 100 meters of sea water. Due to the size of the receiving antenna is proportional to the wavelength, and it requires a longer receiving antenna. Considering this reason.it cannot be achieved with a small sensor node. Therefore. wireless waves can only achieve high-speed communication over short distances.

5. Conclusion

Underwater wireless sensor network communication has made significant progress, but challenges still exist. This article introduces the characteristics and limitations of various communication methods. The demand for underwater communication technology is constantly increasing due to the rapid development of digital technology. Therefore, future research should focus on better adapting and addressing these challenges, and proposing more innovative and efficient solutions. Conduct in-depth research on energy management, topology control, and network optimization to enhance the performance and reliability of underwater wireless sensor networks.

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