Marine Information Technology

Curriculum Report

Title： The application of underwater wireless communication (UWC) in marine biology and aquaculture

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I declare that the assignment here submitted is original except for source material explicitly acknowledged, and that the same or related material has not been previously submitted for another course. I also acknowledge that I am aware of University policy and regulations on honesty in academic work, and of the disciplinary guidelines and procedures applicable to breaches of such policy and regulations.

Signature:

Date: 5th June 2020

Abstract

Recently, the wireless communication technology has become a basic tool for communication and tremendously useful in human life. In the past few decades, scientists have been on the quest to find a way to deploy the wireless technology underwater, so as to comprehensively understand the ocean, its processes and its characteristics, as it is impractical to have a sea surface and ocean floor with connect cables as means of communication.

Presently, UWC is employed in several applications, including coastal surveillance systems, marine environmental research, autonomous underwater vehicle (AUV) operations, oceanographic data collection, scientific ocean sampling, pollution, and environmental monitoring, climate and climate change recording, coastal and offshore exploration, disaster prediction and prevention, assisted navigation systems, distributed tactical surveillance, and mining exploration. However, this report highlights and introduces the primary applications of UWC in the field of marine biology and aquaculture with a significant focus on the mode of operation, functionality, and its related challenges.

1 Introduction

Wireless communication is a way of communication with no physical link involved between two or more devices, the connection between the devices is only achieved and established wirelessly. In the past few decades, the idea of wireless underwater communications (UWC) was seemingly impossible, thanks to research and the development of technology, scientists are now publishing out breakthroughs on underwater wireless communication. The quest and interest to comprehensively understand the oceanic environment and its processes has been the key driver for such novelties.

Presently, the use of UWC has improved and enhanced our exploration and research activities in the ocean. UWC is now used in a wide range of marine applications, to mention a few, coastal surveillance systems, marine environmental research, autonomous underwater vehicle (AUV) operations, oceanographic data collection, scientific ocean sampling, pollution, and environmental monitoring, climate and climate change recording, coastal and offshore exploration, disaster prediction and prevention, assisted navigation systems, distributed tactical surveillance, and mining exploration.

To date, UWC uses acoustic, optical, and radiofrequency waves wireless carriers in underwater communication and transmissions, it is essential to note that all the three have both strengths and weaknesses. Radio Frequencies enable high data rate over short ranges, the optical signal transmission achieves high bandwidth and data rate too. However, acoustic waves are widely used as the primary carrier for underwater wireless communication systems due to the relatively low absorption in marine environments (Ali et al.,2019).

During the operation, the underwater wireless communication (UWC) network can be linked with several configurations such as floating devices, AUVs, seafloor-attached sensors, on land processing towers, submarines, and ships depending on purpose and mode of operation.

While acknowledging the vast applications of UWC, this report highlights and introduces the primary applications of UWC in the field of marine biology or science and aquaculture with a significant focus on the mode of operation, functionality, and faced challenges.

2 The application of underwater wireless communication (UWC) in marine science and aquaculture

2.1 Wireless sensors in marine and aquaculture monitoring

The development of UWC has enabled state-of-the-art developments in the field of aquaculture and marine biology, for example, the introduction of underwater monitoring systems that deploy wireless sensor network (WSN) technology in underwater monitoring. A wireless sensor network (WSN) is defined as self-organized wireless network used to monitor physical or environmental conditions to mention a few, temperature, sound, vibration, pressure, motion or pollutants, etc. and pass their data through a network. A wireless sensor network (WSN) usually consists of numerous sensor nodes, which can sense and monitor the parameters and transmit the collected data to a central location using wireless communication technologies (Xu et al.,2014, Shetty et al., 2018). Some of these underwater sensors, on the other hand, operate individually, they operate by sending the collected data from *in situ* to a network or phone or personal computer in real time, enabling a continuous flow of data from *in situ* (figure 2).

According to Xu et al. (2014) most underwater monitoring and surveillance system deploy wireless sensors as their core component of the monitoring system. These monitoring systems are usually configured and installed as demonstrated in (figure 1). Conferring to Xu et al. (2014) and other studies, the settings usually consists of sensor nodes, sink nodes, a base station, a server, and user terminals. Sensor nodes are used to monitor in-*situ* environmental parameters such as water temperature, salinity, turbidity, pH, oxygen density and chlorophyll levels, and then transmit the collected data to sink nodes via wireless communication. Usually, a sink node is used to collect data from a group of sensor nodes and subsequently send the collected data to the base station via the GPRS network, meanwhile the server is used to store and process the received data from the base station. And finally, the users get access to the data by connecting to the server over the Internet.

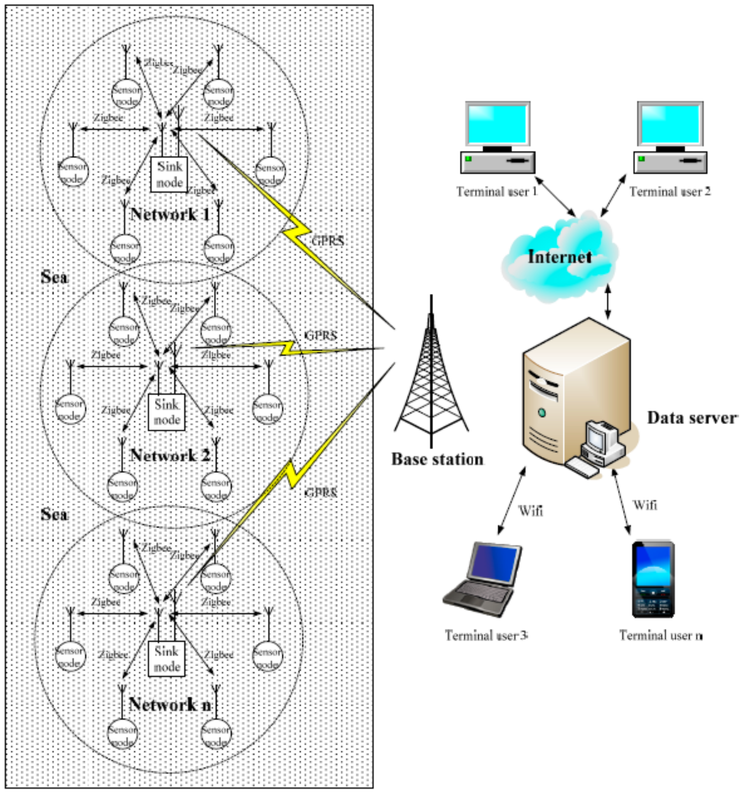


Figure 1. The typical WSN configuration in marine and aquaculture monitoring as illustrated by (Xu et al., 2014)

WSN has a broad spectrum in marine environment monitoring, including but not limited to water quality monitoring, coral reef monitoring, and aquaculture operations. Wireless sensors are of various types and configurations depending on the given application and purpose.

- Water quality monitoring

A water quality monitoring system is configured to monitor water conditions such as temperature, pH, turbidity, conductivity, and dissolved oxygen, etc. (figure 2).

Figure 2, Some of the examples of Individual configured sensors for water quality monitoring (innovasea.com)

In some cases, a fish farm or aquaculture monitoring system is also configured to monitor fecal waste and uneaten feed for a fish within the system (Xu et al.,2014). Numerous studies have also explained the modality of wireless sensor networks including a study by Wang et al (2012) that designed an automated remote monitoring system operating in open-ocean-aquaculture cages, the configuration was designed to incorporate the 3G wireless communication platform and the ARM-Android system simultaneously. The whole configuration consisted of three parts, including the aquaculture-cage detection and surveillance terminal, portable monitor terminal, and remote data centers. The detection terminals and the surveillance system are used to collect real-time seawater parameters and video surveillance data in real time. Afterward, the data was transferred to a portable monitor terminal by 3G wireless networks.

- Coral reef monitoring system

On the other hand, a coral reef monitoring system is typically configured to monitor coral reef habitats, processes and interactions with their ecosystem, in most case this kind of monitoring system is often embedded with a camera for visualization (figure 3). All the settings and configuration are usually independent, real-time, and operate wirelessly.

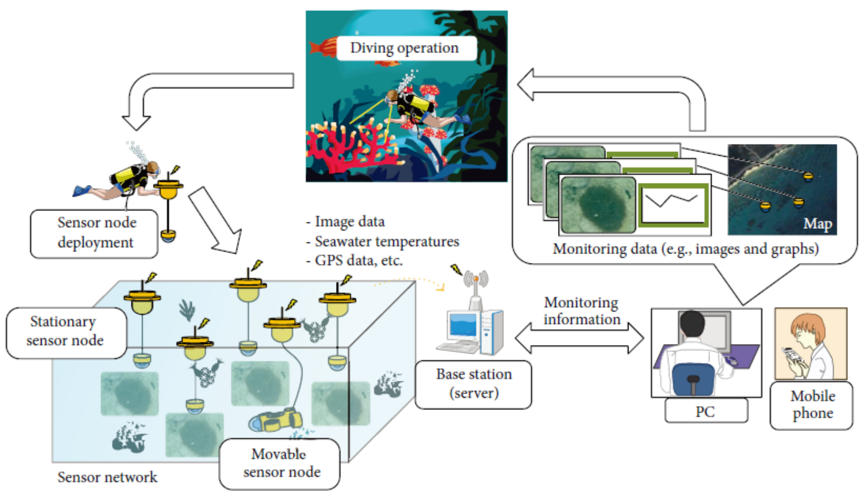


Figure 3, Coral reef monitoring wireless sensor network system as demonstrated by (Suzuki et al.,2014)

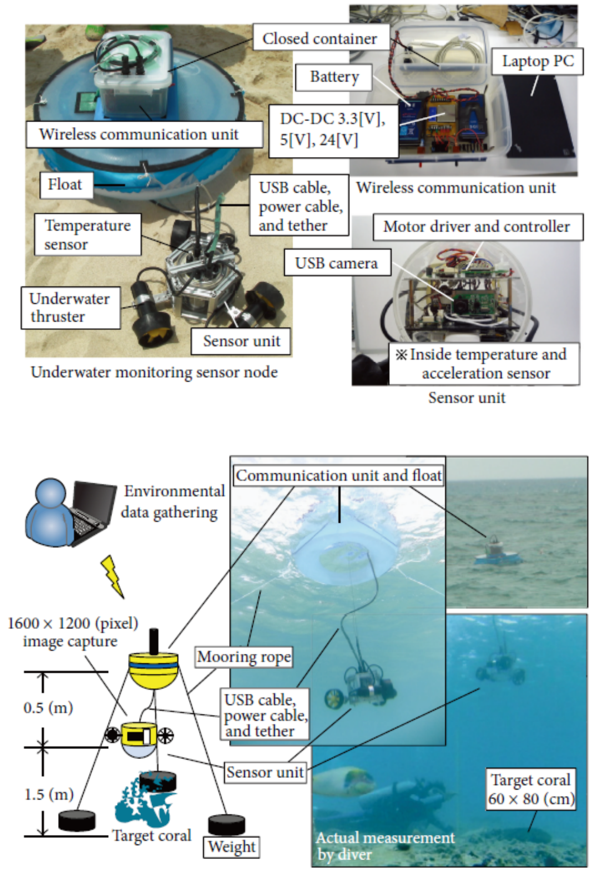
2.2 Enhanced and convenient diving and surveillance

For a long time, divers have been using traditional and considerably unsafe and impractical means of communication during diving such as hand signals, writing slates or carrying a long-cabled wire with them as means of communication with the crew members at the surface. However, Recent developments of underwater wireless communication have enhanced and smoothen communication during diving, the divers have now the freedom of free-swimming without carrying a long-cabled wire to the surface. One diver can wirelessly communicate with another diver underwater meanwhile simultaneously communicating with the crew member on the surface.

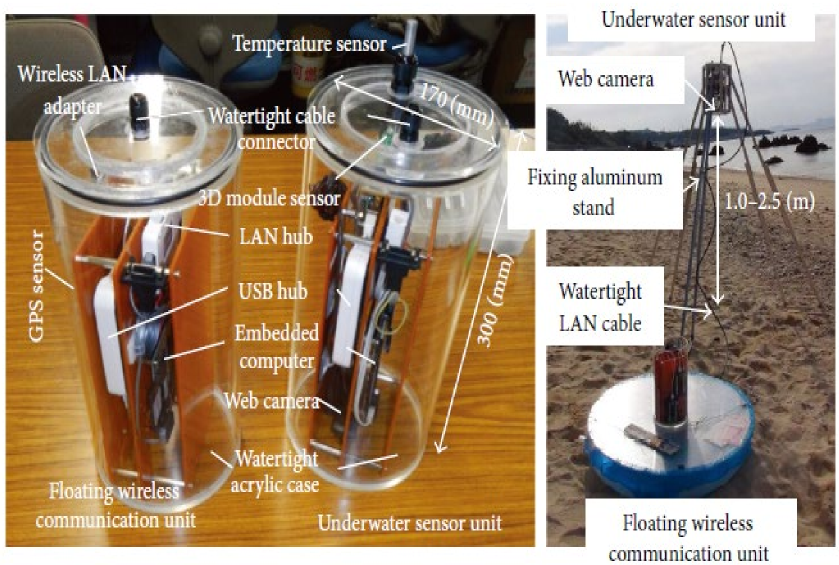
Wireless communications during diving employs water to carry an acoustic signal from one transceiver to another, for example, when the divers are wirelessly communicating, the speech is picked up via the microphone installed in the helmet and then sent to the communication unit. Afterward, the speech is then sent into water via transducers before another receiver's transducer picks up the speech and sends it up to the earphone for that diver to listen.

The diving experience has been made more exciting by the introduction of autonomous, wireless and smart camera underwater drones. These cameras enhance the diving experience by filming the adventure and wirelessly sending it to the networks, for future memories and sharing with friends and colleagues. Nevertheless, these cameras can be used for underwater surveillance and real time monitoring of underwater biota.

Figure 4, Wireless communicating underwater and deployment of underwater wireless camera drones (I bubble cameras)



(a)



(b)

Figure 5, Underwater coral reef monitoring system showing suspended (a) and fixed (b) communication and sensor unit by (Suzuki et al.,2014)

2.3 Advanced wireless transmission CTDs

CTD is an acronym for Conductivity, Temperature, and Depth. CTD is a device used for the detection of conductivity, temperature-depth, and salinity in the marine environment, especially in the deep ocean. This device is one of the most common gadgets used by marine scientists and oceanographers to determine oceanic water characteristics. CTDs can be used to give a physical and chemical profile of a body of water through numerous mechanisms. There are traditional CTDs that work offline without deploying wireless communication systems while the modern, sophisticated CTDs deploy wireless communication systems without actually using a direct (cable) connection. The advanced wireless CTDs are one of the examples of gadgets that deploy underwater wireless communication.

The advanced CTD is configured to record different water characteristics and changes, then wirelessly transmit this data to a network or a personal computer. The modern CTDs provide critical information on the ocean water characteristic by monitoring the entire water column. This particular information helps marine biologists and scientists to understand the effect of the chemical and physical environment on the biota distribution in the ocean.

3 Challenges of underwater wireless communication

UWC is costly, knowledge, and resource-demanding and requires more sophisticated communication devices. In most cases, self-configured underwater wireless sensors, communication nodes and camera drones are powered through batteries, which makes them unreliable for long periods of time before their source of power is fed up. Moreover, the oceanic and water environment is considerably challenging, factors such as salt concentration, pressure differences, temperature fluctuation, poor light, and wind significantly affect underwater wireless communication (Gussen et al., 2016). For example, when the means of communication is an optical wireless transmission, the quality of data transmission and reliability will depend on the physio-chemical properties of the water environment and the physical characteristic of optical signals (Liu et al., 2008)

Dissolved salts such as NaCl, $MgCl_2$, etc., tend to absorb light and induce scattering effects, but also detrital and mineral components such as sand, metal oxides significantly contribute to both absorption and scattering. Furthermore, colored dissolved organic matters such as fulvic and humic acids tend to affect absorption, while organic substances, for example, viruses, bacteria, phytoplankton, and organic detritus, results in backscattering.

On the other hand, when the wireless communication is acoustic, there is a relatively delay of data as compared to optical carriers, because the speed of sound is lower than the speed of light between underwater wireless communication nodes. Furthermore, extreme changes in water characteristics such as dramatic changes in temperature at a thermocline can create a potential barrier to wireless transmission. The presence of biological noise can significantly affect the quality of wireless transmission underwater. For example, a large moving fish can emit sound at the same frequency as wireless communications. The implication is that anything emitting at the same frequency as your wireless connections is heard on your communication devices hence interpreted as loud static noise (Liu et al., 2008).

In the presence of mechanical noise, let say, a kind of noise generated by a moving boat or motors, the risk of transmission alteration is very high, which impairs the ability to communicate wirelessly. The presence of a lot of air in the water is likely to reduce underwater wireless transmissions because the air tends to kill the signal, implying that air in the water will critically affect your wireless communication.

4 Conclusion

Despite the few mentioned applications of underwater wireless communication, there are a vast more applications that are directly and indirectly linked to marine biology and aquaculture. The ocean as we know it, on the other hand, is yet to be fully explored, comprehensively understood and more discoveries to be made. Therefore, calling upon the development of more advanced and strong communication systems underwater to enhance the oceanic exploration and more discoveries.

References

1) Ali, M., Jayakody, D.N.K., Chursin, Y.A. *et al.* (2019) Recent Advances and Future Directions on Underwater Wireless Communications. Archives of Computational Methods in Engineering. https://doi.org/10.1007/s11831-019-09354-8
2) Gussen C, Diniz P, Campos M, Martins WA, Costa FM, Gois JN (2016) A survey of underwater wireless communication technologies. J Communications Inf Sys 31(1):242–255
3) Lanbo Liu, Shengli Zhou, Jun-Hong Cui (2008) Prospects and problems of wireless communication for underwater sensor networks. Wireless Communication Mobile Computer 8(8):977–994
4) Shreema Shetty, Radhika M Pai & Manohara M. M. Pai. (2018) Design and implementation of aquaculture resource planning using underwater sensor wireless network, Cogent Engineering, 5:1, 1542576
5) Wen Ding and Yinchi Ma. (2011) The Application of Wireless Sensor in Aquaculture Water Quality Monitoring. 5th Computer and Computing Technologies in Agriculture (CCTA), Oct 2011, Beijing, China. pp.502- 507, ff10.1007/978-3-642-27275-2_56ff. ffhal-01361177f
6) Xu, G.; Shen, W.; Wang, X. (2014), Applications of Wireless Sensor Networks in Marine Environment Monitoring: A Survey. *Sensors*, *14*, 16932-16954.
7) Yanle Wang, Changsong Qi, Hongjun Pan, (2012), Design of Remote Monitoring System for Aquaculture Cages Based on 3G Networks and ARM-Android Embedded System, Procedia Engineering, Vol.29, pp. 79-83, 2012
8) www.innovasea.com.aquasolutions built for life, aquameasure.
9) https://ibubble.camera/product/ibubble-evo-autonomous-underwater-drone/