Abstract

The need for real-time monitoring of water bodies requires a technology that can provide remote monitoring and control of underwater activities. Underwater internet of things (IoT) has gained popularity in the last decade due to the potential of the technology to monitor underwater environments remotely and continuously. Underwater IoT systems comprise different sensors such as temperature, salinity, pH level, camera, and motion that monitor the aquatic environment, guide navigation, and prevent disasters. However, wireless optical communication or radio wave communication is not suitable for the underwater environment. It is because underwater optical wireless communications suffer from the problems of scattering. Further, radio wave communication requires a suitable configuration of antennas, high transmission power, and less coverage range. Therefore, acoustic or ultrasonic waves are suitable for achieving high data rate and coverage under water due to their long-range coverage and significant bandwidth. Also, multi-path fading is a primary concern associated with sound wave-based communication. It is caused by reflection and refraction in water due to varying sound speeds at different depths resulting in inter-symbol interference (ISI) on the receiver side.

Further, there is an ever-growing interest in real-time multimedia operations, including transmission of pictures and videos. However, the development and deployment of underwater acoustic communications are challenging due to the low data rate, vulnerability to jamming, high-energy requirements, and susceptibility to self-interference. Acoustic waves are considered the most reliable form of communication in underwater channels. A Medium Access Control (MAC) protocol holds tremendous responsibility for efficiently utilizing acoustic communication channels and resources. Moreover, network and infrastructure management are challenging due to the mobility of the stations and uncertain communication characteristics. In this work, to address the issues such as low data rate, less coverage range, high mobility of nodes, and inefficient energy consumption, we propose five schemes for use in underwater multimedia streaming and medium access in ideal lab-scale still water environments. We explicitly focus on acquiring and assessing how to implement underwater acoustic sensor networks using low-cost, off-the-shelf, open hardware electronics and transducers. The proposed system can support direct communication between two nodes at a data rate of $2.4Kbps$ within a communication range of $65m$ in still shallow water. With the adoption of some minor modifications, the data rate is then enhanced to $3.5Kbps$ over a range of $70m$. We also focus on medium access control (MAC) protocol design, which facilitates efficient energy management, reduced overhead, and controlled traffic flow. These nodes' deployment can take place over much longer distances by incorporating more relay nodes.

We evaluate the performance of our system towards supporting multimedia data transmission and even attempt multimedia streaming through our deployed underwater IoT network using video compression and reduced sampling of the video frames. Our rigorous study based on test-bed experiments and simulations using underwater acoustic parameters shows improved performance. We observe that the system successfully supports multi-hop network configurations and undertakes multimedia transmission by compromising the data quality. The system demonstrate a clear trade-off between data quality, transmission range, and transmission delays.

In summary, we present AquaStream, a multi-hop multimedia streaming solution over acoustic channels in severely resource-constrained IoT networks, as the first work. The second work introduces an infrastructure-based multimedia streaming network for improved reliability and energy efficiency in underwater IoT. After that, in our third work, we present a reliable and efficient MAC protocol, RE-MAC, to overcome the multimedia data transmission issues in an acoustic network. In the fourth work, we highlight a Reinforcement Learning (RL)-based underwater MAC protocol, RL-MAC, to overcome multimedia data transmission issues. Finally, in our fifth work, we introduce the programmable approach to reconfigure all types of underwater nodes for resource-constrained networks while considering the mobility of stations and relays.

Keywords: Internet of Things (IoT), Underwater Acoustic Network, Internet of Underwater Things (IoUT), Underwater Multimedia Streaming, MAC Protocol.