Towards a Fully Cooperative Multi-Agent Reinforcement Learning based Media Access Control Protocol for Underwater Acoustic Wireless Sensor Networks

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ABSTRACT

Underwater Acoustic Sensor Networks (UWASNs) has gain a widespread recognition recently due to some technological break- through, and thus, beginning a new era of research in the industry with potential for vast applications that are important to our livelihood. Despite all these potentials, deploying a reliable UWASNs based systems still remain very far from perfect and there are only limited experimental trials at the moment. This is due to challenges of reliabilty, QoS and energy efficiency, which is due to inherent characteristics of underwater acoustic channel. These pose signif- icant challenges for the design of network protocols, especially, the Media Access Control (MAC) protocol for UWASNs. Various MAC protocols have been developed for UWASNs and some few adopted from Wireless Sensor Networks (WSNs). However, most of these protocols do not provide acceptable QoS in terms of delay, throughput, fairness and energy efficiency. This paper presents a review of some of the prominent MAC protocols for UWASNs and adaptable WSNs based MAC protocols for UWASNs and propose a Fully Cooperative Multi-Agent Reinforcement Learning based MAC protocol for UWASNs. The proposed scheme will apply Multi-Agent based Reinforcement Learning (RL) to ALOHA MAC scheme to create a dynamic contention-free-like slotted MAC to aid nodes cooperation and interactions within themselves and the underwater environment to significantly achieve "self-organization" and "self-adaptability" to changes in the environment which would provide means for coping with long and variable propagation delay, low data rates and energy efficiency and in turn can significantly improve the QoS of UWASN systems by having better convergence time and Energy efficiency.

CCS Concepts

• **Networks → Network components → Wireless access points, base stations and infrastructure**

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Keywords

Reinforcement Learning, MAC protocol, ALOHA, QoS, Self-organization, UWASN, Multi-Agent

1. INTRODUCTION

Increased researches in WSNs has made a plethora of real life applications possible, particularly in underwater scenario. UWASNs is recently becoming an important area of research with promising potential for various applications ranging from underwater oil and gas extraction (seismic imaging), pipeline and infrastructure monitoring, marine life monitoring and control, monitoring of underwater Carbon(IV)Oxide (CO2) storage facility, border control, Fish farming, freshwater reservoirs management, Autonomous Underwater Vehicles (AUVs), Naval Network centric warfare- mine reconnaissance etc. to tsunami and seaquake early warning systems [1–4]. Despite all these promising applications, Underwater Sensor Networks remain quite limited as compared to the terrestrial Sensor Networks technologies. Thus, this makes underwater operations limited to remotely controlled submersibles which are large, very costly and are almost temporarily deployed [1] as com- pared to sensor network nodes which are relatively cheaper and can be permanently deployed on the sea flow for real time communications.

Radio based communication for terrestrial sensor networks is not suitable for underwater usage because of extremely limited propagation delay as current mote radios transmit between 50 to 100cm and within 30-300 Hz of frequency underwater. The implication is that extraordinary transmission power and very large antennas are required for deployment [1, 5]. Therefore, establishing communication in UWSN effectively largely depends on acoustic communications. However, Underwater Acoustic communications bring about new challenges due to unique characteristics of under- water acoustic communication channels such as: High propagation delay caused by low speed of acoustic signals (speed of sound is approximately 1500 m/s) which is by 5 orders of magnitude slower than radio waves (3x108m/s) for terrestrial Wireless Sensor Net- works (WSN) [1, 3], low data rate (between 5-20Kb/s) due to limited channel bandwidth, high error rates, highly dynamic environment and high energy consumption (typical consumption between 50 to 100 W) [3, 6–8].

UWASNs is made up of a large number of sensors deployed underwater with capability to communicate via acoustic links.