An Experimental Testbed for Underwater Acoustic Sensor Network Protocol Dedicated to Offshore Wind Turbines

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ABSTRACT

Offshore wind turbine monitoring is crucial to reduce maintenance and operating costs of safety-critical components and systems, and to optimize the design of future wind turbines. Monitoring has four objectives: the acquisition of structural response data, local interrogation of collected measurement data, and wireless transmission of that data or analysis results to a underwater acoustic sensor networks (UASN). These sensing units require the design of dedicated UASN networking protocols. In this context, we implement the TDA-MAC protocol for data collection in UASN which needs any clock synchronization. The preliminary experimental results have successfully demonstrated the effectiveness of this MAC protocol on very low speed and long-range transmission devices.

KEYWORDS

Medium Access Control, Sea Trials, TDA-MAC, Underwater Acoustic Network, Wireless Sensing, MATS-LT

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1 INTRODUCTION

Wireless sensor networks (WSNs) have tremendous potential in monitoring aquatic environments by detecting, collecting and transferring wireless data to users in real time [1] [2]. In this context, the "Blue IoT Eolia R&D" project has also addressed such an issue, in particular through the development of a solution capable of both monitoring the fatigue of the power cable and a precise analysis of the complex dynamic behavior induced by offshore wind turbines as illustrated in an example in Figure 1. The main objective of the system is to develop a solution for the networking of underwater sensors whose purpose is to ensure a continuous monitoring of environmental and operational parameters, maintenance as well as supervision of the underwater infrastructure, [3]. for the proper functioning of offshore wind turbines.

Therefore, this paper explores the performance of the experimentation of the underwater TDA-MAC protocols [4] implemented on the MATS-LT acoustic micro-modem [5]. The experiments were conducted in July 2021 at Port de la Grimaudière, Nantes, France. Various network scenarios and packet delivery ratio (PDR), energy consumption were used to study the performance of the TDA-MAC protocol in different contexts. one objective of this work is to produce and compare experiments from [4] in the context of a wind turbine farm.

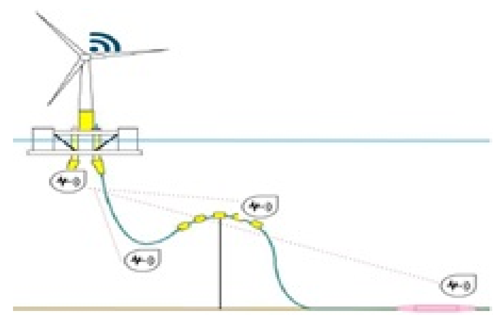

Figure 1: Monitoring of a floating wind turbine with possible acoustic modems locations along the dynamic cable [3].

Recently, underwater MAC protocols have been tested in real sea experiments [5] [6] [7]. In this study the TDA-MAC Protocol was tested in real-world offshore experiments in Fort William, UK. They focused on practical challenges and mitigation strategies related to TDA-MAC to increase its robustness in real-world deployments. Its main advantage over other MAC protocols found in the literature is that it can achieve network throughputs close to the channel capacity without clock synchronization or any other advanced functionality at the sensor nodes. Therefore, it has great potential as a practical solution for efficient data collection in UASN. The main draw-back of TDA-MAC is that it requires a centralized single-hop topology, which cannot accommodate nodes outside the gateway's cover-age. In this paper we propose to reproduce an experiments in another context and scenarios with different commercial equipment's.

2 EXPERIMENTAL SETUP

This section describes how we took the initial hardware concepts of the Blue-Iot-Eolia project and modified/enhanced them with the goal of creating an affordable, low-power, adaptable remote aquatic monitoring system capable of providing data in near real-time, for our testbed, we use the underwater acoustic micro-modem from the French company Sercel. Each of the beacons and gateways in the testbed is equipped with a MATS-LT acoustic micro-modem [5]. The specifications show an acoustic bit rate up to 40bps using multiple

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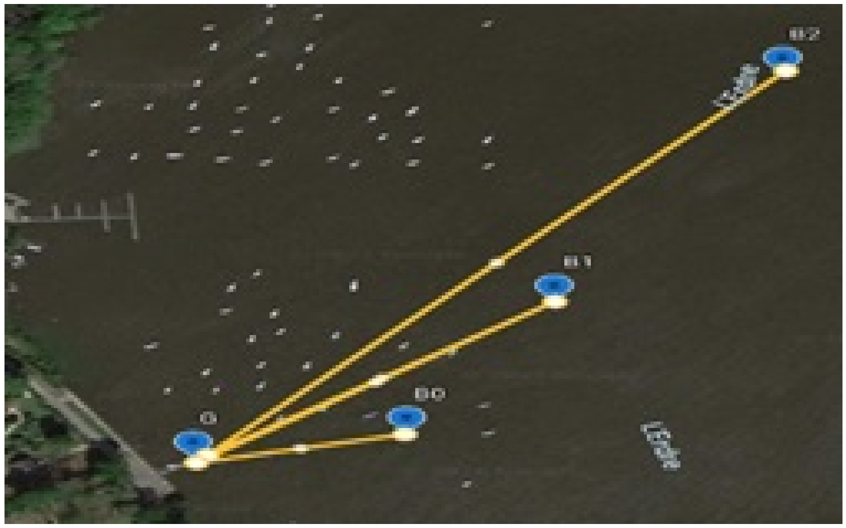

Figure 2: Deployment in Port de la Grimaudière

Table 1: Experimental results at the Testbed

Distance	PDR %		
	Beacon 0	Beacon 1	Beacon 2
30m	100	100	100
100m	100	100	100
200m	93.34	93.34	85
300m	94.45	77.76	0

frequency shift keying (FSK). This MATS-LT acoustic micro-modem is controlled by a stm32 type microcontroller (Cortex-M0) for the beacons and a raspberry pi 3 for the Gateway.

3 EXPERIMENTS RESULTS

This section describes the experimentation of the underwater acoustic network in a natural environment, the river Erdre, beginning of July 2021. In this experimentation, we perform an experimental evaluation of the TDA-MAC protocol with 3 nodes and a Gateway. To evaluate the mixed and maximum communication range and energy consumption, we placed the beacons in the river Erdre at a distance of 30m, 100m, 200m and 300m. From these points, we establish links with Gateway and variable distances. We use a reference point for Gateway, as illustrated in an example in Figure 2

Table 1 shows the PDR obtained by Gateway from each beacon.

In real experience, the PDR is constant (100%); this occurs because the distance is short. For first and second test the throughput is 5.08bps and 6.93 packets/min. For the third scenario (200m). It is possible to observe that beacon 0 and beacon1 keep a similar behavior, with a PDR is higher than 93% and beacon2 at a loss of 15%. The PDR of B2 is 85%. We explain simply this by the fact that B2 is farthest from the Gateway. This leads to minimizing the throughput to 4.35bps. A fourth scenario to check the maximum range. In just this scenario the majority of the packets were also successfully delivered to the gateway from beacon 0 and beacon 1, on the other hand beacon 2 did not deliver any packets. TDA-MAC is efficient in terms of packet deliveries in range of 200m for the same reasons explained in the previous table.

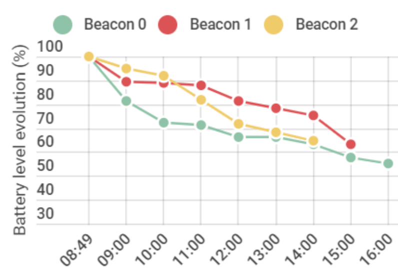

Figure 3: Battery level evolution

In Figure 3, we see that the battery level of the beacons decreases during the test. This is due to the number of acoustic communications. We also notice that the amount of energy consumed by beacon 0 is more than beacon 1. This is due to the number of data trans-missions made by the beacons, and it ran for 190 min, as shown in table.1.

4 CONCLUSIONS AND FURTHER WORK

In this paper, we have studied the results of experiments collected during a river trial. The objective is to analyze the performance of the TDA-MAC protocol using the MATS-LT acoustic micro-modem and its capability for real communication. We analyze three scenarios to study the impact of distance on communication, collecting data for real experiments to analyze and compare the PDR level and the battery level. Nevertheless, these results provided good information for future research. The next experiments will be conducted at the aquatic environment that has fewer particles, and improve flight time calculators, reduced packet loss and transmission delays. Additionally, we intend to deploy in multi-hop and other topology.

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REFERENCES

[1] K. Fekher, P. Benoît, R. Jean-Marc, d. Hervé et G. Thierry, «Internet of Underwater Things to monitor offshore wind turbines fields,»chez 31th European Safety and Reliability Conference, Angers, France, Sep 2021.

[2] J. TREVATHAN, S. SCHMIDTKE, W. READ et S. Abdul, «An IoT General-Purpose Sensor Board for Enabling Remote Aquatic Envi-ronmental Monitoring,»Internet of Things, vol. 16, p. 100429, 2021.

[3] Cruciani et Michel, L'éolien offshore flottant dans sa dimension industrielle et technologique, Etude de l'Ifri. Ifri, juillet 2019

[4] M. Nils, M. Paul D, Z. Yuriy, M. Rahul, P. Yvan R, G. Tyler, D. Mauro, S. Benjamin, N. Jeffrey A, T. Charalampos C et S. Mohammed E, «Robust TDA-MAC for practical underwater sensor network deployment: Lessons from USMART sea trials,»chez Proceedings of the Thirteenth ACM International Conference on Underwater Networks & Systems, Shenzhen, China., 2018.

[5] Pascal coince, Acoustic MATS-LT Modems User's Manual, Brest, france: https://blog.sercel.com/blog/sercel-launches-a-micro-acoustic-modem-mats-lt, 2021.

[6] P. Lina, L. Yu, M. Haining, L. Son, P. Zheng, C. Jun-Hong et J. Zaihan, «Comparing underwater MAC protocols in real sea experiments,»Computer Communications, vol. 16, pp. 47-59, 2015.

[7] R. PETROCCIA, C. PETRIOLI et J. POTTER, «Performance evaluation of underwater medium access control protocols: At-sea experiments.,»IEEE Journal of Oceanic Engineering, vol. 43, n° %12, pp. 547-556, 2017.