An Implementation of MAC Protocol for Underwater Cellular Networks

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***Abstract*—In this paper, we propose a communication system that implements a Medium Access Control (MAC) protocol for underwater acoustic cellular networks. To evaluate the network's performance between the underwater base station controller (UBSC) and the underwater base stations (UBS), we implemented a protocol stack on the commercial ARM Linux based hardware platform. We implemented the physical layer interface considering underwater channel characteristics and designed underwater MAC protocol on the data link layer. By testing the implemented system, we can evaluate the network performance and eventually can optimize the protocol performance.**

Keywords- Medium Access Control Protocol; Underwater Networks; Underwater Acoustic Communication.

I. INTRODUCTION

For reliable underwater communications, acoustic waves are preferred over Radio Frequency (RF) waves owing to the extensive attenuation and fading losses experienced by the RF waves imposed by the unique underwater channel characteristics [1]. However, underwater acoustic channel is limited in operational bandwidth, higher Bit Error Rate (BER), and introduce a relatively large propagation delay compared to terrestrial RF channel [2]. Therefore, to achieve better performance in underwater acoustic network, it is pertinent to consider the underwater channel characteristics in the design of an efficient underwater Medium Access Control (MAC) protocol [3].

In this paper, we present a commercial-platform based communication system to implement an underwater MAC protocol designed for underwater acoustic cellular networks.

II. PROTOCOL DESIGN

We consider an underwater cellular network which consists of an underwater base station controller (UBSC) and underwater base stations (UBS). Figure 1 shows the network architecture. The UBSC is deployed on the surface of the ocean while the UBSs are deployed underwater. UBSC registers and controls the UBSs and thus, each UBS is connected through acoustic wireless links to the UBSC. That is, the network has a UBSC centric cellular network configuration.

The proposed MAC protocol comprises of the three phases— network initialization, parameter setting, and data-transfer. In the network initialization phase, UBSC discovers the UBSs and estimates the distance by exchanging control

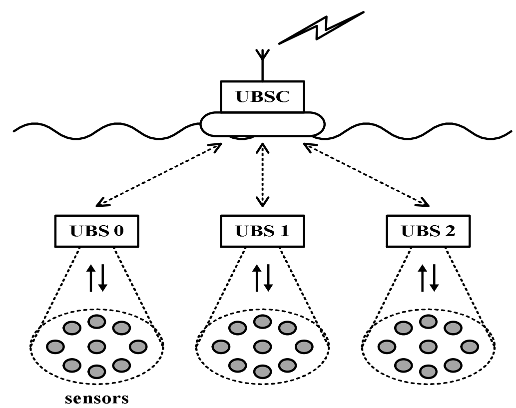

Figure 1. Underwater cellular network architecture.

messages. This is followed by the parameter setting phase where the UBSC, based on UBS information and following data transfer mode, allocates the suitable up/down link frequency channels for each UBSs and forwards system parameters that are used to specify the communication between UBSC and UBS.

On the completion of the parameter setting phase, the data-transfer phase begins immediately. Data-transfer phase consists of three modes: mode 1, 2, and 3, depending on call procedure. Data-transfer mode 1 uses a 4-way handshaking method to start the uplink or downlink session and delivering data frames. In this mode, if there are no uplink and downlink sessions for a period of time, the UBSC orders UBS to enter the sleep mode in order to save energy consumption. UBS which enters the sleep mode, cannot receive or transmit any frames during that time duration. Data-transfer mode 2 operates similar to mode 1, however there is no procedure for sleep mode setting. Thus, all the UBS remain in the active mode, allowing them to deliver the data immediately. Data-transfer mode 3 creates an ad-hoc communication between the UBSC and an underwater mobile node (e.g., diver, Autonomous underwater vehicle). In this mode, the UBSC and the mobile node transmit the data frames continuously and simultaneously through the uplink and downlink channel after call setup procedure.

III. PROTOCOL IMPLEMENTATION

To evaluate the performance and verify the operation of underwater MAC protocol, we implemented the protocol on the commercial platform. Xilinx Zynq 7000 series DSP board based on ARM Linux system was used as the hardware platform.

 ISBN: 978-1-61208-596-8

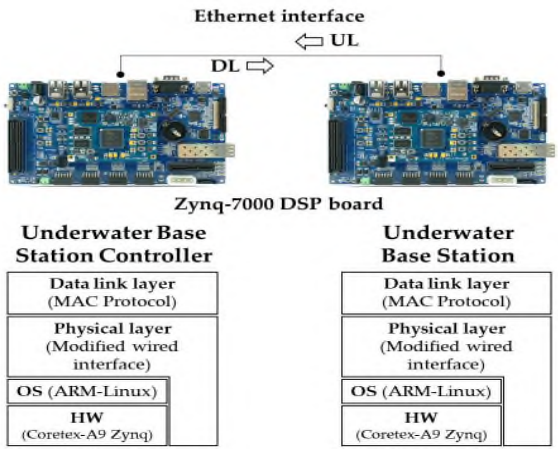

Figure 2. Architecture of the system

Figure 2 shows the architecture of the system. We implemented the protocol stack, which consists of physical and data link layer, on the Linux operating system. As a physical layer, a modified wired interface was used to replicate the underwater acoustic channel characteristics. To apply the realistic underwater channel such as available bandwidth and propagation delay depending on internodal distance, we modified the frame transmission time and the propagation delay by using a delay function. This physical layer interface is designed to be replaced by OFDM based underwater acoustic modem, which will be our final version of the implementation.

As a data link layer, we implemented the proposed MAC protocol mentioned in section 2. Data link layer operates on one downlink and multiple independent uplink channels. Each channel is separated in the frequency domain; hence, there are no inter channel interference or collision and it supports full duplex communication.

A node plays a role as one of UBSC, UBS, or mobile node according to user's input parameters that include node type, unique node ID and underwater channel specification. As a data traffic for testing, we used an image on both up- and downlinks. And, as a way of diagnosing the procedure, we made every event happening during the call procedure displayed on the monitor. In addition, for the purpose of further examination later, all events along with timing information are logged.

IV. PERFORMANCE EVALUATION

System parameters used for performance evaluation are listed in Table I. We tested communication scenario between UBSC and mobile node which sends 51.4kb size image data to each other by using data transfer mode 3. Considering underwater acoustic OFDM PHY frame, transmission time of control and data frames are set to 7s.

Figure 3 shows the call procedure diagram and event time figured out based on the event log. By analyzing the event log, we can verify that it takes 30s for network initialization and parameter setting. In data transfer phase, it takes 287s for the call setup procedures, 102.8kb data transfer and call terminates.

TABLE I. SYSTEM PARAMETERS

Parameter	Value
Iinternodal distance	1km
Propagation speed	1500m/s
Data rate	214.29bps
Payload size	1500bits

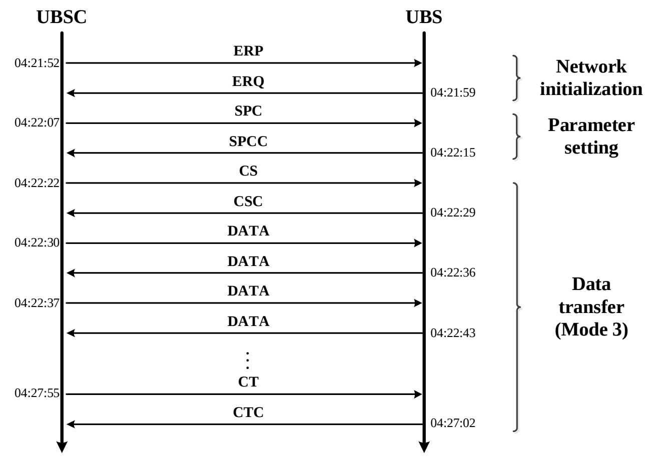

Figure 3. Protocol procedure of data-transfer mode 3

Thus, total network throughput is 358.2bps.

V. CONCLUSION

In this paper, we presented a commercial platform based communication system to implement an underwater MAC protocol designed for underwater acoustic cellular networks. By using the proposed system, we evaluated the network's performance, such as throughput or latency, which can be used to improve or optimize the protocol performance.

For further work, we will verify the designed protocol operation and measure the network performances in real underwater environment by using an underwater OFDM based modem physical layer interface.

ACKNOWLEDGMENT

This research was a part of the project titled "Development of Distributed Underwater Monitoring & Control Networks," funded by the Ministry of Oceans and Fisheries, Korea.

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