A MAC Protocol Design for Underwater Acoustic WiFi Network

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ABSTRACT
Underwater acoustic WiFi (UWA-WiFi) network is similar to the traditional terrestrial WiFi network, which provides wireless access services for underwater nodes (e.g., marine engineering equipment, underwater vehicles, divers, sensors, and so on). MAC protocol design is an essential issue for UWA-WiFi network. Due to the natures of low available bandwidth, long and variable propagation delay, and time varying on acoustic channel, the existing MAC protocols for terrestrial WiFi network can’t be directly applied to UWA-WiFi network. In this paper, we introduced customized Slotted-FAMA protocol for UWA-WiFi network. Furthermore, we did a pool experiment to testify the practicability of customized Slotted-FAMA protocol. The results of the experiment show that customized Slotted-FAMA can significantly reduce the probability of collisions and enhance the performance.

KEYWORDS
UWA-WiFi network, MAC protocol

1 INTRODUCTION
In recent years, underwater acoustic networks have attracted growing attention in academia and industry. In order to enable underwater mobile nodes and static nodes to be networked in a flexible manner, we proposed the UWA-WiFi network architecture, which is shown in Figure 1 and Figure 2. Underwater wireless access point (UW-AP), e.g. surface buoy equipped with RF and acoustic modems in Figure 1 or submarine base station connected to shore-based/onshore control platform through marine cable in Figure 2, provides wireless access services for underwater nodes, collecting the packets from UWA-WiFi network and forwarding them to the onshore control platform. The radius of UWA-WiFi network is the UW-AP’s maximum communication range. Proper use of these two networking architectures can achieve complete coverage in vertical direction from the sea surface to the seafloor. To accomplish UWA-WiFi network, designing a practical MAC protocol is vital. Nevertheless, owing to typical characteristics of underwater acoustic channel, the MAC protocols designed for terrestrial WiFi network [1] are not applicable for UWA-WiFi network. This paper introduced customized Slotted-FAMA protocol to settle collision issue. Unlike Slotted-FAMA in [2], the customized Slotted-FAMA optimizes the acknowledgment mechanism and specifically tailors the slot length for UWA-WiFi network.

The remainder of this paper is organized as follows. In section 2, the customized MAC protocol is described briefly. In section 3, the experimental settings and results are detailed. Finally, we summarize the work and describe future work.

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Figure 1: UWA-WiFi network combining RF communication

Figure 2: UWA-WiFi network combining wire communication

2 THE MAC PROTOCOL FOR UWA-WIFI NETWORK
The mechanism of customized Slotted-FAMA protocol is shown in Figure 3. The slot length is set to $\tau + \delta$, where $\tau$ is the maximum propagation delay from UW-AP to all terminal nodes and $\delta$ is the transmission duration of a CTS packet. In view of the impact of clock drift, a guard time is inserted into the slot. A terminal node that has data to send to UW-AP first transmits an RTS packet (carrying the number of DATA packets to be sent to figure out which packet isn’t be successfully received afterward) at the beginning of the next slot. This packet is received by UW-AP and other terminal nodes in UWA-WiFi network within the time slot. After receiving the CTS packet, the source node has reserved the sharing acoustic channel successfully, so it will start sending DATA...
packets (carrying the packet number) at the beginning of the next slot. If UW-AP succeeds in receiving all DATA packets, it sends an ACK packet to inform all terminal nodes that the transmission has been completed. If UW-AP fails to receive all DATA packets successfully, it sends a NACK packet containing the sequence number of the lost packets and then the source node retransmits the lost DATA packets. When UW-AP is the source node, it also goes through the abovementioned procedure. A bystander overhearing an RTS/CTS/NACK can defer its transmission until receiving an ACK, or if it doesn’t overhear an ACK, it can also backoff based on the number of DATA packets in the received RTS/CTS.

Figure 3: The mechanism of customized S-FAMA
After the end of a transmission, all terminal nodes that have data to send choose a random number of slots to back off so as to prevent many nodes from sending RTS packets at the same time. When a node doesn’t receive a CTS packet in response to its previously sent RTS packet, it also goes to back-off state.

In consideration of mobility, we assume that if the three-time handshake between a mobile node and the UW-AP fails, the mobile node is out of the communication range of the UW-AP currently. Taking into account channel utilization, if UW-AP receives multiple RTS packets within one time slot, it selects the first received RTS to reply. UW-AP is set to the highest priority. That is to say, if it has data to send after a transmission, UW-AP will send RTS first without going to back-off state. Since the CTS transmission is followed by the data transmission, the CTS packet is set to the highest priority.

3 EXPERIMENT AND RESULTS

3.1 Experimental Settings
We implemented customized Slotted-FAMA in SeaLinx [3], a protocol stack architecture for underwater networking, and tested it with ALOHA technique in a pool experiment. In this experiment, we deployed 3 nodes equipped with Smart-Ocean modems in the pool, one of which, as the UW-AP, was placed in the center of the pool, and the other two of which, as terminal nodes, were laid around UW-AP randomly. Because of the limitation of test environment, Smart-Ocean modems ran at lowest transmission power, and the slot length was estimated to be around 5.6s by control packet duration and the pool size. Besides, the DATA packet is set to 50 bytes. Test data were collected in the form of protocol log files. Then we drew these data into a graph, showing them intuitively.

3.2 Experimental Results
We compared customized Slotted-FAMA with ALOHA in terms of the performance of end-to-end packet delivery rate. The experimental results are shown in Figure 4, which depicts the relation between end-to-end packet delivery rate and network load (i.e., the number of packets sent per second). The more packets sent per second are, the more collisions there are, so the packet delivery rate decreases gradually. As Figure 4 shows, the packet delivery rate of customized Slotted-FAMA is much higher than that of ALOHA, because the handshake method of customized Slotted-FAMA lessens conflicts evidently.

Figure 4: End-to-end packet delivery rate

4 CONCLUSION
In this paper, we introduced customized Slotted-FAMA protocol for UWA-WiFi network. The customized Slotted-FAMA protocol optimizes the acknowledgment mechanism of Slotted-FAMA to reduce the average delay and specifically tailors the slot length for UWA-WiFi network. A pool experiment was performed to compare the method presented in this paper with ALOHA. Experimental results show that customized Slotted-FAMA can dramatically reduce collisions by the mechanism of channel reservation to enhance the performance of the network.

5 FUTURE WORK
In the future, we will do the following work: 1) seeing that UWA-WiFi network is a kind of central networks, an efficient synchronization means should be studied; 2) a more advisable back-off algorithm needs to be thought out; 3) energy-saving approaches ought to be considered; 4) network capacity is supposed to be researched; 5) how to combine reservation-based methods with scheduling-based methods to design a MAC protocol with higher performance should also be deeply researched.

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