충돌회피 다중접속을 위한 동적 타임아웃 연구

쩐티민콰*, 오승현*
*동국대학교 전자계산학과
e-mail : {ttmk84,shoh}@dongguk.ac.kr

A Study on Dynamic Timeout Over Multiple Access with Collision Avoidance

Tran Thi Minh Khoa*, Seung-Hyun Oh*
*Dept. of Computer Science, Dongguk University

Abstract

Underwater Wireless Acoustic Sensor Networks have become an important area of research over the recent decades. Designing an underwater network, especially a media access control (MAC) protocol, faces many challenges due to the peculiarities of underwater environment. One of the most important problems is resulted from long and variable propagation delay of the acoustic wave. In this paper, we propose a new method, namely Dynamic Timeout over Multiple Access with Collision Avoidance (DT/MACA), which is designed to handle long and high variable propagation delay in underwater acoustic sensor networks. In this proposed method, the difference timeout intervals are evaluated and applied to each network transmission. Simulation results show that our work not only improves the network throughput, but also decreases the unnecessary retransmission and end-to-end delay.

1. Introduction

The Oceans cover over three quarters of earth's surface. The ever growing requirements to acquire data from beneath the ocean's surface have been demanded. Underwater Wireless Acoustic Sensor Networks (UWASNs) have to be the ideal system for efficiently observing and exploring the oceans. UAWSNs are used in oceanographic data collection applications, pollution monitoring, undersea exploration, disaster prevention, assisted navigation, tactical surveillance applications, and mine reconnaissance [1, 2, 3, 7]. However, there are various challenges in the design of UWASNs because of the characteristics of underwater environment, such as long and variable propagation delay, limited bandwidth, high bit error rates, multipath and fading effects, etc [1, 2, 3, 7]. All these given challenges posed by the very specific environment, thus the solutions from terrestrial cannot be applied directly to UWASNs.

The focus of our paper is on Medium Access Control (MAC) which designed for underwater networks. A MAC protocol allows a node in a network to share the network channel. The main task of a MAC protocol is to resolve data packet collision and to prevent simultaneous transmissions while providing energy efficiency and fairness among competing nodes.

In general, the MAC protocols are classified into two categories: contention-free protocols and contention-based protocols [2, 3, 7, and 9]. Contention-free protocols include TDMA, FDMA, and CDMA, where communication channels are separated in time, frequency and code domain, respectively. Contention-based protocols include random access protocols (ALOHA, Slotted-ALOHA), carrier sense access (CSMA), and collision avoidance protocols with handshaking access (MACA, MACAW).

In this paper, we work on contention-based MAC protocols, especially on collision avoidance protocols with handshaking access. A handshaking-based approach can help in guarantee packet transmission reliability, reducing the network collision, and thus improve the network throughput as well. However, a long propagation delay in UWASNs (around 0.67s/km) poses a huge challenge for MAC protocols design, especially for the contention-based MAC protocols due to intolerable delay caused by the uncertain number of retransmissions in UWASNs [12]. In this work, we proposed a method which uses the dynamic timeout duration for each transmission. This method not only reduces the packet retransmission, but also improves the throughput of UWASN.

The remainder of this paper is organized as follows: In Section 2, we take an overview of some related researches. Section 3, we explain our proposed method in detail. Next, section 4 describes the simulations that were carried out to compare the results of the proposed method with the original MACA protocol. Lastly, we give our conclusions and discuss our future works in Section 5

2. Related Works

Nitthita, et al. [11] proposed two Aloha-based protocols, namely, Aloha with collision avoidance (Aloha-CA) and

Aloha with advance notification (Aloha-AN). In these protocols, each node tries to make use of the sender-receiver information that it picks up from those packets that it overhears, so as to help avoid collisions and lead to better throughput performance.

There are also various handshaking-based protocols which representative contention-based schemes such as MACA for Underwater, MACA-based MAC protocol with packet train to multiple neighbors, and MACA-based MAC protocol with Delay Tolerant.

In reference [5], Hai-Heng Ng, et al examined how an existing asynchronous handshaking-based protocol called MACA can be adopted for the use in multi-hop underwater networks. Three areas of the MACA protocol are modified, namely, the state transition rules, the packet forwarding strategy and the back-off algorithm. Their resulting MAC was named as MACA for Underwater (MACA-U).

Chirdchoo, et al [6] proposed an asynchronous random access MAC protocol, namely, MACA-MN. This protocol utilizes a handshaking-based approach in order to help avoid collisions and alleviate the hidden terminal problem in multi-hop underwater networks. In addition, the MACA-MN can overcome the low throughput problem suffered by typical handshaking-based protocols (such as original MACA), by transmitting a train of packets during each round of handshake.

Wen Lin, et al [9] also proposed an asynchronous random access MAC protocol based MACA protocol, which is called MACA-DT (MACA with Delay Tolerant). This protocol can overcome the low throughput and the long end-to-end delay problems of typical handshaking-based protocol by using adaptive silent time and simultaneous handshake technique.

3. The Proposed Dynamic Timeout Over MACA

In (Multiple Access with Collision Avoidance) MACA protocol [4], transceiver nodes exchange their control packets before they start to communicate. A timeout interval is an amount of time which is used for waiting a response packet. After timeout interval, if a node does not receive a response packet, it will do the retransmission. Hence, unnecessary retransmission can be decreased when a reasonable timeout is applied. Primarily, the timeout duration equals twice the transmission delay plus propagation delay. Unlike terrestrial wireless sensor networks where the propagation delay is negligible, the long propagation delay in UWASNs must be taken into the consideration. For example, in some sub-sea wireless sensor networks, the distance between two adjacent sensor nodes can be longer than 1.0 km such as 1.5 km. Thus, in a 1.5 km x 1.5 km area network range, the propagation delay between two adjacent sensor nodes is about 0.01s and 1s if their distance is 15 m and 1500 m respectively (propagation speed is about 1500 m/s). Such a long propagation delay demands that the reasonable timeout should be measured so that unnecessary can be avoided.

Due to the negligible variation in terrestrial propagation delays, the original MACA protocol uses the static delay value to calculate the timeout duration. Therefore, all transmissions are applied using the same timeout values. However, this becomes a disadvantage whether original MACA protocol is applied in underwater network. When the timeout is not large enough, a large of unnecessary retransmission will be performed. Therefore, we propose a method, namely dynamic timeout interval over MACA in order to solve the problem of fixed timeout interval used in original MACA. Here, the dynamic timeout means that sender node sets a different timeout for each transmission to its neighboring nodes. Depend on the distance to a receiver node, sender node calculates the propagation delay and then estimates the timeout duration need to wait for a response. Figure 1 below shows the two concepts of timeout interval. The figure above is for the fixed timeout and the beneath one is for the dynamic timeout.

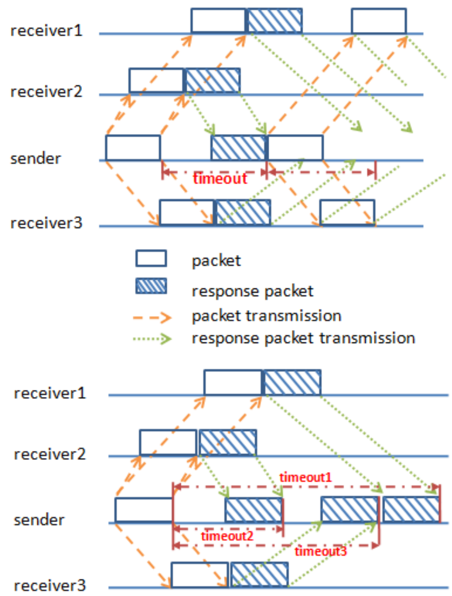

Fig. 1: Fixed timeout interval vs. Dynamic timeout interval

In this section, we describe our proposed method. We make clear how we evaluate the timeout duration waiting for a response packet. Each sender node sets the first timeout duration waiting for a response packet equals two times of transmission delay and propagation delay. And the propagation delay of each transmission is different depends on their distance.

Related to the well known MACA protocol, we utilize a three-way handshake (RTS/CTS/DATA). If a node wishes to transmit its data packets, it first initiates a handshake to its intended neighboring nodes by broadcasting an RTS packet. However, unlike to the MACA protocol, our sender node also records the time at which it broadcast RTS and sets timeout duration waiting for CTS. Then, sender node records the time at which it receives the response CTS packet from the receiver node. From the exchange RTS/CTS packets, sender node gets the value of round trip time, duration from time RTS packet is sent until CTS packet is received.

Moreover, the underwater environment is constantly changing. This causes the variable round trip time (RTT) for underwater network. Thus, it is also valuable to have a measure of the variability of the RTT. For estimating the timeout interval, in our work we attempt the timeout/retransmit mechanism of TCP. In TCP's method [8], firstly a sample RTT for every transmitted segment is measured. Then, TCP maintains an average value called estimated RTT and evaluates the retransmission timeout interval. Two differences between TCP and our method are following: Firstly, instead of measuring a sample RTT for every transmitted segment, most TCP implementations take only one sample RTT measurement at a time [8]. In our work, we use the actual RTT given from previous transmission. Secondly, TCP only computes a sample RTT for segments that have been transmitted, but it is not for a segment that has been retransmitted. We use previous RTT from both transmission and retransmission.

Upon obtaining an RTT from previous transmission, sender node updates the estimated round trip time. Obviously, the timeout duration should be greater or equal to the estimate round trip time, or unnecessary retransmission would be performed. But the timeout interval should not be too much larger than the estimated round trip time while it should not be smaller than estimated round trip time as well. This is taken into consideration to set timeout duration equal to the estimated round trip time plus some margin. The margin means the deviation between RTT and estimated RTT. As well, it is updated after every transmission.

Correspondingly, our proposed method with a dynamic timeout interval for each pair of sender-receiver sensor node can decrease the number of retransmission which is caused by the distance between the two sensor nodes. By attempting evaluated dynamic timeout interval from the previous round trip time, we can get reasonable amount of time waiting for response packets. This is suitable for the further sensor nodes. Thus, network performance is increased significantly.

4. Simulations and Results

4.1 Simulation Scenario and Setting

We simulate our proposed method in Qualnet 5 and multi-hop networks are investigated. As shown in Fig. 2, we have conducted our simulation model in which we have used 50 random sensor nodes in a grid topology. With scenario dimension of 10 km x 10 km, for each simulation 10 minutes time is set, and channel frequency is set by 20 KHz. There are 30 CBR (Constant Bit Rate) applications between 50 sensor nodes with 64bytes fixed packet size for all transmissions. In abstract Physical Model, we applied Signal-to-Noise Ratio (SNR) based reception with SNR threshold of 10. All nodes operate at a fixed data rate and maximum transmission power of 20 Kbps and 80 dBm (or 10650m in our simulation topology), respectively. Also, it is assumed that all nodes are equipped with a half duplex omni-directional antenna. For routing protocol, we focused on AODV (Ad-hoc On-Demand Distance Vector) which allows nodes to pass messages through their neighbor nodes if they cannot directly communicate. Channel is assumed to be error free, so that the lost packets are wholly due to the MAC protocol's performance.

The acoustic propagation speed is used in this performance study is 1500 m/s. Offered load and Throughput are employed to measure the performance of various protocols in this paper, which are define by the two following formula [10].

$$Offered\ load = \frac{\dfrac{total\ data\ packets\ transmitted}{simulation\ time}}{\dfrac{signalling\ rate}{data\ packet\ size}}$$

$$Throughput = \frac{\dfrac{total\ data\ packets\ received}{simulation\ time}}{\dfrac{signalling\ rate}{data\ packet\ size}}$$

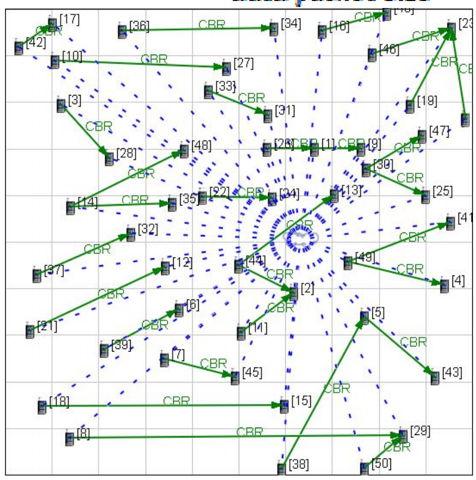

Fig. 2: Scenario for 50 sensor nodes

4.2 Simulation Results

The simulation's objective is to demonstrate how the dynamic MACA (MACA with dynamic timeout interval) protocol effects to the network performance. Note that reasonable timeout interval is an important factor which influences the network throughput. The less timeout occurs the less retransmission happens, and thus the more throughputs are. The graph in the Figure 3 describes the number of retransmissions occurs between original MACA and our dynamic MACA. The diamond lines show result of original MACA protocol and the triangle line shows the result of dynamic MACA protocol. As can be seen from the graph, there is less number of retransmissions in our dynamic MACA protocol. The number of retransmissions was decreased by 50 percent compared with that of original MACA protocol. This decrease can be attributed to the following reasons: timeout interval was calculated upon the distance and its own round trip time.

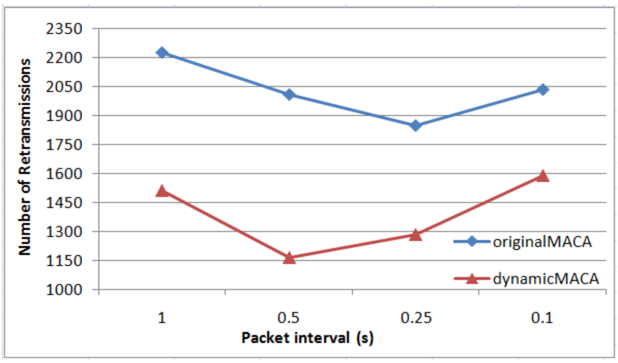

Fig. 3: Number of retransmissions

In the Figure 4, the diamond line presents the throughput of original MACA protocol and the triangle line presents throughput of our dynamic MACA protocol. The graph shows that the dynamic MACA protocol always gets higher throughput than the original one regardless of few or many packets are generated. Whereas the throughputs of original MACA protocol are not stable, throughput of our dynamic MACA protocol increases steadily with the number of generated packets. From this graph, we can conclude that the high number of timeouts causes the low throughput of underwater network. Since our dynamic MACA was applied, the network performance was increased noticeable. This graph also shows reasonable increase of throughput when packet intervals are different.

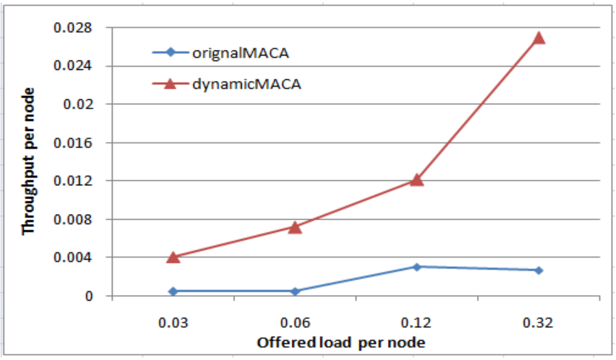

Fig. 4: Throughput

Next, as shown in Figure 5, we observe that modified protocol has lower end-to-end delay than original protocol. By employing dynamic timeout interval dynamic MACA protocol reduces delay well.

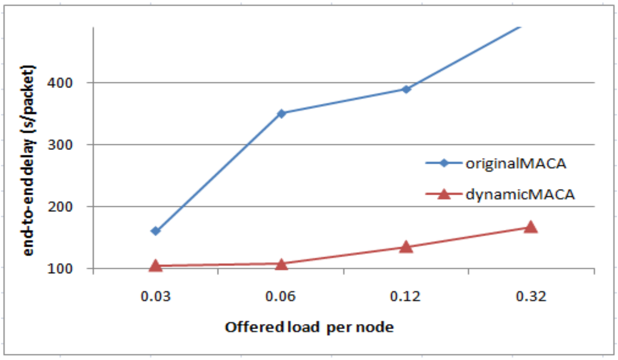

Fig. 5: End-to-End delay

5. Conclusions and Suggestion Future Works

In this paper we applied the dynamic timeout interval to the original MACA protocol. Due to the large propagation delay of underwater environment, it is not useful to use the same timeout interval for every sensor node. By calculating the propagation delay between each pair of end-to-end nodes and then evaluating the timeout interval, our proposed method shows a better network performance of underwater network. The less number of timeout occurs the better network throughput will be. Our method can efficiently be applied not only to solve impracticality of original MACA but also helped to improve the underwater network performance.

Our future works will be the stimulation of our proposed method with larger number of nodes. As the variant of underwater environment, this method will be tested with mobile nodes and error bit rate. Additionally, we will consider how to decrease the number of timeout as much as possible. We also want to take into consideration transmitting multiple packets in each single handshake. As it was shown in [6], the long propagation delay has less detrimental effect on the network as fewer handshakes need to be activated while transmitting multiple packets per each handshake.

Acknowledgment

This work was supported by National Research Foundation of Korea (NRF) grant funded by the Korean government (MEST).(Grant code: 2011-0014375)

References

[1] I. F. Akyildiz, D. Pompili, and T. Melodia, “Underwater acoustic sensor networks: research challenges,” Ad Hoc Networks (Elsevier), vol. 3, pp. 257-279, May 2005.

[2] I. F. Akyildiz, Dario Pompili, and Tommaso Melodia, “State-of-the-art in protocol research for underwater acoustic sensor networks,” In Proceedings of the 1st ACM international workshop on Underwater networks (WUWNet '06). ACM, New York, NY, USA, 7-16.

[3] I. F. Akyildiz, D. Pompili, T. Melodia, “Challenges for Efficient Communication in Underwater Acoustic Sensor Networks,” ACM Sigbed Review, Vol. 1, Number 2, July 2004.

[4] P. Karn, “MACA – A New Channel Access Method for Packet Radio,” ARRL/CRRL Amateur Radio 9th Comp. Network Conf., Sep. 1990.

[5] Hai-Heng Ng, Wee-Seng Soh, Motani M., "MACA-U: A Media Access Protocol for Underwater Acoustic Networks," Global Telecommunications Conference, 2008. IEEE GLOBECOM 2008. IEEE, vol., no., pp.1-5, Nov. 30 2008-Dec. 4 2008

[6] Chirdchoo, N., Wee-Seng Soh, Kee Chaing Chua, "MACA-MN: A MACA-Based MAC Protocol for Underwater Acoustic Networks with Packet Train for Multiple Neighbors," Vehicular Technology Conference, 2008. VTC Spring 2008, IEEE, vol., no., pp.46-50, 11-14 May 2008

[7] G. A. Shah, "A Survey on Medium Access Control in Underwater Acoustic Sensor Networks," International Conference on Advanced Information Networking and Applications Workshops, 2009. WAINA '09, vol., no., pp.1178-1183, 26-29 May 2009

[8] James F. Kurose and Keith W. Ross, Computer Networking: A Top-Down Approach Featuring the Internet, Fourth Edition, Addison Wesley Press, ISBN 978-0-321-51325-0

[9] Wen Lin, En Cheng, Fei Yuan, “A MACA-based MAC protocol for Underwater Acoustic Sensor Networks,” Journal of Communications, vol. 6, no. 2 (2011), pp. 179-184, Apr 2011.

[10] Shahabudeen.S, Chitre.M.A, “Design of networking protocols for shallow water peer-to-peer acoustic networks,” In Oceans 2005 - Europe, vol.1, pp.628-633, June 2005.

[11] N.Chirdchoo, WS.Soh, KC.Chua, “Aloha-Based MAC Protocols with Collision Avoidance for Underwater Acoustic Networks,” In 26th IEEE International Conference on Computer Communications, pp: 2271-2275, May 2007.

[12] Peng Guo, Tao Jiang, Guangxi Zhu, and Hsiao-Hwa Chen, “Utilizing acoustic propagation delay to design MAC protocols for underwater wireless sensor networks”. Wirel. Commun. Mob. Comput. (October 2008), 1035-1044.