Fixed Backoff Contention Window (FBCW) for CSMA-CA in Ad-Hoc Underwater Acoustic Networks

Omar O. Aldawibi [1*]
[1] Department of Electrical and Electronics Technology
The Higher Institute for Engineering Technology
Zliten – Libya.
[1] omar.aldawibi@hpiz.edu.ly

Salah A. Daw [2]
[2] Department of Electrical and Computer Engineering
Faculty of Engineering Elmergib University
Elmergib - Libya
[2] salahalidaw@gmail.com

Abstract— **Ad-Hoc underwater acoustic networks have become very important in the field of defense industry, rescue operations and etc. But this technique faces some big challenges such as high end to end delay, bandwidth limitation and battery consumptions. The performance of the backoff contention window is the main factor for CSMA-CA that determines the efficiency in sharing and utilizing the limited bandwidth and power consumption in Ad-Hoc underwater acoustic networks. In this paper , practicable distributed backoff contention algorithm, which is named Fixed Backoff Contention Window (FBCW) for CSMA-CA in Ad-Hoc underwater acoustic networks. The FBCW for CSMA-CA is presented in Ad-Hoc underwater acoustic networks. Simulation results show that the proposed technique gives remarkable improvement in terms of average end to end delay, throughput and power consumption.**

Keywords— **Underwater Communication, Ad-Hoc networks, Carrier Sense Media Access protocols**

I. INTRODUCTION

These days, the acoustic waves are the most widespread in media for underwater communication networks. The is because it has a low attenuation, compared with the electromagnetic underwater acoustic communication the only viable option for a range of hundred meters of underwater wireless channels. However, the underwater acoustic channel encounters unique challenges for communication protocols [1]. The speed of sound in underwater is around fifteen hundred meters in a second, resulting in propagation delays 200,000 times longer than those encountered by terrestrial radio communication networks. Therefore, the propagation delay in underwater channels is five times higher of magnitude than that of terrestrial radio frequency [2] [3].

This paper discusses the new model named Fixed backoff window for Carrier Sense Media Access with Collision Avoidance CSMA-CA, applied on Ad-Hoc Underwater Acoustic Network in terms of the number of sources versus to the throughput, average end-to-end delay and the power consumption. a two-ray ground channel has been applied in the NS2 simulator for the achieved results.

This paper is organized as follows: Section 2 describes the Carrier Sense Media Access with collision Avoidance CSMA-CA, backoff contention window mechanism and the proposed fixed backoff window. The simulation module parameters and evaluation matrices are carried out in section 3 and 4 respectively. The discussion of the results, in terms of evaluation matrices has been analysed in an individual section, which is, section 5. The obtained results are concluded in section 6 and followed with the references that have been cited in the paper.

II. CARRIER SENSE MEDIA ACCESS PROTOCOLS (CSMA)

One of the most important components of wireless ad-hoc networks is the Medium Access Control technics. It is important to designing due to the need to access a fairly distributed method. The IEEE 802.11 is called Distributed Coordination Function (DCF) protocol, which is a common choice for medium access control (MAC), because it satisfies the needed requirements [4].

A. CSMA with Collisions Avoidance (CSMA/CA)

The Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) was designed for the popular Wi-Fi wireless network technology (IEEE 802.11). CSMA/CA also senses the transmission channel before transmitting a frame. Furthermore, CSMA/CA tries to avoid collisions by carefully tuning the timers used by CSMA/CA devices.

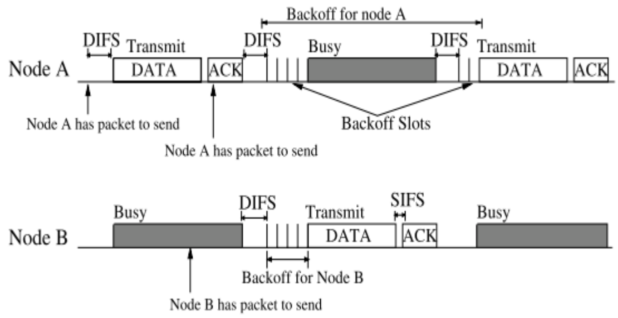


Fig. 1 CSMA/CA Protocol Mechanism [5]

Received-August 2020, Accepted-October 2020, and Published-December 2020

B. Backoff Contention Window Algorithm

All researches studying and investigating the performance of the IEEE 802.11 DCF Medium Access Control Protocol assuming the network under node-saturated conditions and all nodes have a packet and ready to be transmitted all the time. This assumption is suitable to investigate the medium access contention and time delay without adding the packet delay time while waiting in a node's queue. This assumption was changed to satisfy more realistic conditions such as the environment being unsaturated. All studies concentrated on both single-hop and multi-hop networks. Although, multi-hop networks are influenced by hidden nodes and hence these type of networks give different performance than single-hope networks. G. Bianci [6], has widely worked and deeply explained the IEEE 802.11 DCF protocol in analytically module. It is based on Markov chain to model the situation of the back-off contention window with the assumption of the number of retransmission that are associated with a constant probability of transmission collision nevertheless to the number of successive retransmissions packets by the transmission node. There are several researches. Some of them are considering the allowed number of retransmission attempts, and others considered transmission probability according to the status of previous time slot in Markov model. E. Felemban [7] study modified the probability of backoff counter in Markov chain, and took into account the channel states (Successful-Collision-Idle).

This paper studies a multi-hop underwater ad-hoc network, where the IEEE 802.11 DCF protocol is implemented in NS2 simulator and modified to adapt the underwater acoustic channel. The network consists of n nodes with the transmit queue. Also, assumed that all nodes are identical, in saturated condition and all error packets are due to the multiple access collisions. Randomly, the backoff counter choose the number from its range determined by the backoff window. The backoff window size is fixed (i.e. Cmin=Cmax) and chosen manually to achieve optimum performance.

III. SIMULATION MODULE PARAMETERS

In order to evaluate the proposed FBCW module , the technique has been implemented in the NS-2 network simulation for underwater acoustic channel [8]. As a comparison between the proposed FBCW module and custom backoff contention that implemented in Carrier Sense Media Access with collision Avoidance CSMA-CA, the nodes have been distributed randomly in area (250x250 m2) . The PHY layer parameters in simulation are shown in table_(1).

TABLE I
SIMULATION PARAMETERS

Parameter	FBCW Module	Custom BCW Module
Simulator	NS2.27	NS2.27
Area of Simulation	2500x2500 m^2	2500x2500 m^2
Max Propagation Delay	0.86 sec	0.86 sec
Simulation time	10000 sec	10000 sec
Traffic Type	UDP	UDP
Initial Energy	1000 Jules	1000 Jules
Node placement	Stationary	Stationary
MAC Protocol	802.11	802.11
Default Data Rate	15 kbps	15 kbps
Phy Preamble	144 bits	144 bits
Phy Header	48 bits	48 bits
MAC header	272 bits	272 bits
RTS	160 bits	160 bits
CTS	112 bits	112 bits
ACK	112 bits	112 bits
SIFS	0.962 sec	0.962 sec
DIFS	2 x SIFS + slot_time	2 x SIFS + slot_time
Slot_time	0.1 sec	0.1 sec
Packet Payload	8184 bits	8184 bits
CW_{min} - CW_{max}	255 – 255 slots	7 – 1023 slots
Routing Protocol	AODV	AODV

IV. EVALUATION MATRICES

To evaluate the performance of Fixed backoff contention window FBCW module, there several important matrices have been analysed versus to the number of sources. The matrices as shown below [9] [10]:

A. Throughput

Throughput can be defined as the data transferred over a period of time expressed in bits per second (bps). The formula for the throughput is as follows:

$$\text{Throughput (bps)} = \frac{Pkt\ (bits) \times Total\ Pkt_{succ}}{Total\ T_{succ}} \quad (1)$$

where
Pkt (bit) is the packet size per bits
Total Pkt_{succ} *is total successful packets.*
Total T_{succ} *is the total successful time.*

B. Average End-to-End Delay

End-to-end delay can be defined as the average time taken for all packets that transmitted across a network from source to destination. The formula for the average end to end delay is as follows:

$$\text{Average } T_{del}\ (s) = \frac{\sum (T_{recived} - T_{sent})}{\text{Total } Pkt_{recived}} \quad (2)$$

where:
Average T_{del} *is average end to end delay [sec].*
$T_{recived}$ *is the receiving packet time.*
T_{sent} *is the sent time for the packet.*

Received-August 2020, Accepted-October 2020, and Published-December 2020

C. Power Consumption

With increasing number of retransmissions, the energy use increases as well. This increased energy use is a price to pay for increased throughput. So one interesting aspect is to review the amount of energy needed to deliver one bit successfully. The power consumption formula can be expressed as follows:

$$E = \frac{\sum_0^n E_n}{n} \qquad (3)$$

where:

E is the Energy Consumption in (Jules).

n is the number of nodes.

V. Results and Discussion

The figures 2,3 and 4, show that there are three graphs showing the throughput corresponding to the number of sources. The first graph when Offered load is 1 pkt/sec, the second when Offered load is 4 pkt/sec, and the third when Offered load is 8 pkt/sec. There is a significant difference in the throughput between custom BCW and the FBCW module. The FBCW module gains a higher than custom BCW about 30% or more. But when the offered load is more than 4 pkt/sec, the FBCW module remains the same in throughput as when the offered load is 4 pkt/sec.

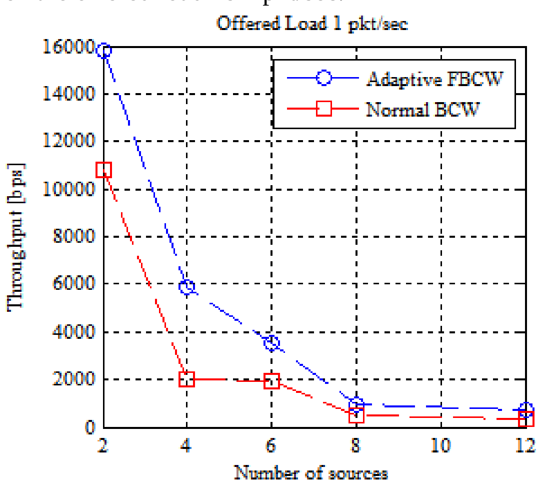


Fig. 2. Throughput for FBCW versus Custom technique

when 1 pkt/sec offered load.

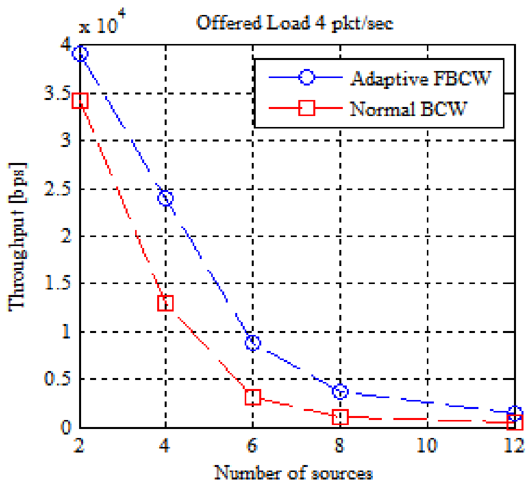


Fig. 3. Throughput for FBCW versus Custom technique

when 4 pkt/sec offered load

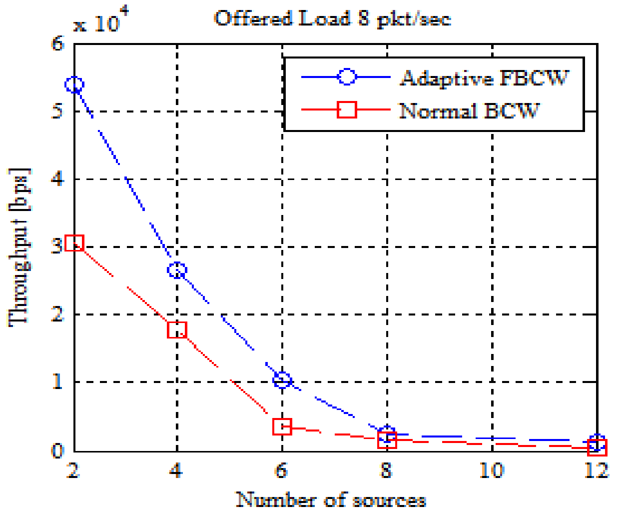


Fig. 4. Throughput for FBCW versus Custom technique

when 8 pkt/sec offered load

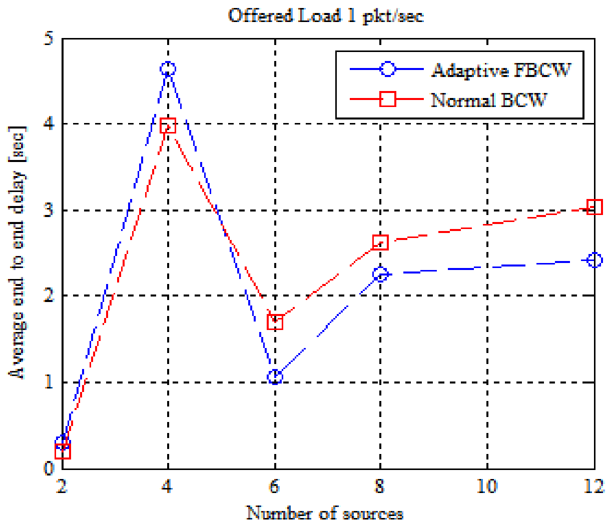
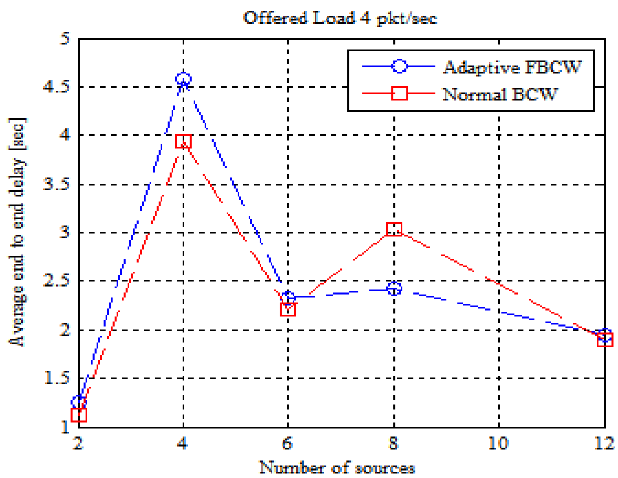


Fig. 5. Average to end delay for FBCW versus Custom technique

when 1 pkt/sec offered load.



Received-August 2020, Accepted-October 2020, and Published-December 2020

Fig. 6. Average to end delay for FBCW versus Custom technique

when 4 pkt/sec offered load.

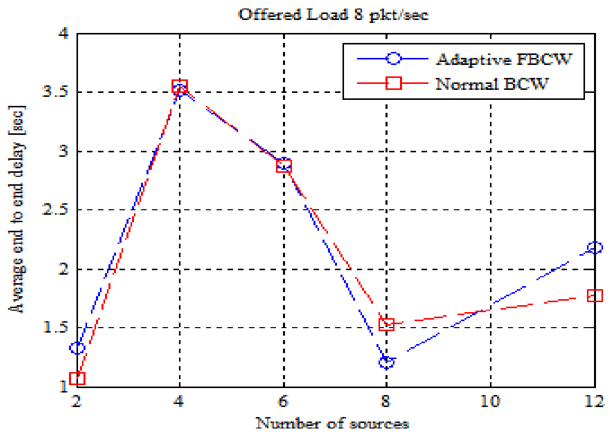


Fig. 7. Average to end delay for FBCW versus Custom technique

when 8 pkt/sec offered load.

Figures 5,6 and 7, show that there are three graphs, showing the average end to end delay corresponding to the number of sources. The first graph when Offered load is 1 pkt/sec, the second when the offered load is 4 pkt/sec, and the third when the offered load is 8 pkt/sec.

The FBCW module follow the same trend of custom BCW in all graphs and sometime better achievement. But, when the offered load is less than 4 pkr/sec, the adaptive module gains better results when number of sources is high. Although, when the number sources are small the FBCW module give higher in average end to end delay than custom BCW. It can be concluded that, the optimum offered load for FBCW module is 4 pkt/sec.

Figure 8 shows that the power consumption is corresponding to the number of sources.

Moreover, FBCW module does not use more power to gain these substantial improvements in the throughput and in the average end to end delay. Also, can be conclude that the optimum offered load for FBCW module is 4 pkt/sec.

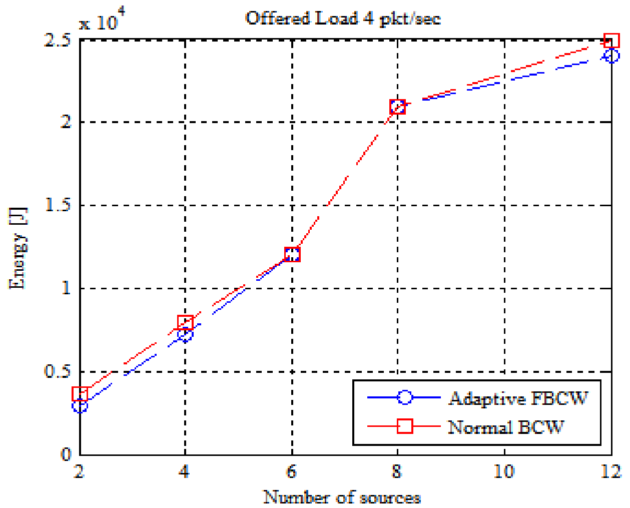


Fig. 7. Power Consumption for FBCW versus Custom technique with

when 4 pkt/sec offered load.

VI. Conclusions

In this paper, the fixed backoff contention window FBCW module for CSMA-CA using 200 meters propagation rang in underwater. The throughput of the Ad-Hoc underwater acoustic networks has been analysed in the given simulation environmental, and it gives better results than the custom backoff contention window. But the average end to end delay is slightly higher. Although the results show the power consumption in both techniques are almost the same. This results was in a static Ad-Hoc acoustic.

References

[1] C. D. Gurav and V. S. Dr.S, "Performance evaluation of routing protocols for wireless sensor networks," International Journal of Scientific Engineering and Applied Science (IJSEAS), vol. 2, pp. 147-151, July 2015.

[2] S. KuluChuku, D. C. Idoniboyeohu, O. Sunny, and O. T.Lewis, "Improved Underwater Wireless Communication System Using OFDM Technique," American Journal of Engineering Research (AJER), vol. 7, pp. 82-95, 2018.

[3] W. Lin, E. Cheng, and F. Y. M.-b. M. P. f. U. A. S. Networks, "A MACCA-based MAC Protocol for Underwater Acoustic Sensor Networks," Journal of Communication, vol. 6, April 2011.

[4] P. A. K. Acharya, U. Madhow, and E. M. Belding-Roy, "Sticky CSMA-CA: Implicit synchronization and real-time QoS in mesh networks," Ad-Hoc Networks, vol. 5, pp. 744-768, August 2007.

[5] N. Shenoy, J. Hamilton, A. Kwasinski, and K. Xiong, "An Improved IEEE 802.11 CSMA/CA Medium Access Mechanism Through the Introduction of Random Short Delays," 13th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt) pp. 331-338, 2015.

[6] G. Bianci, "Performance Analysis of the IEEE 802.11 Distributed Coordination Function," IEEE Journal on Selected Areas in Communication, vol. 18, pp. 535–547, March 2000.

[7] E. Felemban and E. Ekici, "Single Hop IEEE 802.11 Analysis Revisited: Accurate Modeling of Channel Access Delay and Throughput for Saturated and Unsaturated Traffic Cases," IEEE Transactions on Wireless Communications, Vol. 10, no. 10, pp: , October 2011," vol. 10, pp. 3256–3266, October 2011.

[8] O. O. Aldawibi and E. M. Ashmila, "Developing and validation underwater acoustic channel in NS2 simulator," presented at the 4th Computer Science and Electronic Engineering Conference (CEEC), Colchester, 2012.

[9] S. Alahmar and O. Aldawibi, "Influence of Initial Backoff Contention Window on Mobile Ad-Hoc Network," Journal of Electrical and Electronic Engineering and Information Technology, Bani-Walid, vol. 1, pp. 55-58, July 2020.

[10] S. Alahmar and O. Aldawibi, "Optimum Routing Protocol for Static Wireless Ad-hoc Network," presented at the Libyan International Conference on Electrical Engineering and Technologies (LICEET2018), Tripoli, March 2018.

Received-August 2020, Accepted-October 2020, and Published-December 2020