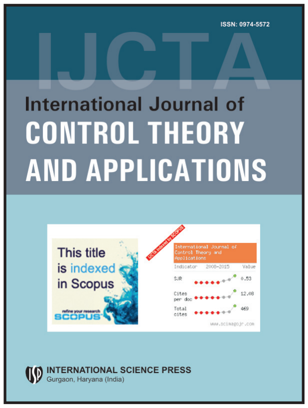

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Analysis of Contention Window MAC Protocol in Underwater Acoustic Sensor Networks

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Abstract: Underwater Acoustic Networks (UANs) uses acoustic communication for transmitting data. In this paper, we present the perception of Underwater Acoustic Sensor Networks (UWASNs), the features considered in designing the Underwater MAC protocol, classification of MAC protocols, study of the working of different protocols intended for the control of medium Access in UWASNs, and analysis of the performance of Underwater Acoustic Network Contention Window MAC (UAN-CW-MAC) protocol. The parameter considered for the assessment of the protocol is throughput, as it is important for a network to accommodate more number of user's communication. The Network Simulator NS3 is used to study the analysis of the protocol.

Keywords: UWANs, MAC protocols, Contention Window.

1. INTRODUCTION

The study of underwater communications and in particular about Underwater Acoustic Sensor Networks (UWASNs) is on the go over several decades. The researchers are vigorous in designing the various methods for transmitting wireless information through underwater. The Electromagnetic (EM) waves are not feasible to travel in water due to various physical constraints like high attenuation, low bandwidth and the factors like noise, refraction and multipath interference will increase bit error rate (Zaihan Jiang, 2008). Hence the acoustic waves are employed to transmit the information through underwater channel.

The available MAC protocols for terrestrial wireless communications which employ EM waves for their communications are incongruous for underwater environment. Due to huge antennae and high transmission power deployment of sensor networks will not be feasible in underwater communications. Nevertheless, using optical waves for underwater communication is not advisable as they suffer from considerable scattering. Consequently, optical waves for underwater environment are used only for short range communication. Hence to conclude communications in underwater environment are based on acoustic waves.

To ensure the successful operation of the network, a vital role is played by Medium access control (MAC) layer. The objectives of MAC protocol are as follows: The first objective is to avoid the collisions from the interfering nodes. The second objective is to create a wireless sensor network in underwater and to establish the fair and efficient communication among the nodes. The MAC protocols designed for underwater environment are wasting lots of energy due to idle listening and various physical constraints in underwater environment.

The following are the features considered in designing a MAC protocol for underwater environment.

1. ***Energy Efficiency:*** The sensor nodes which are deployed in underwater environment are battery powered. Due to various physical constraints it is hard to change or recharge the batteries. It is advantageous to substitute the sensor nodes rather than recharging them.

2. ***Latency:*** As the propagation delay in the short-range RF networks is negligible the delay can be estimated by considering just the transmit time. Due to the physical constraint like large propagation delay in acoustic media, the position of the receiver and potential interferers becomes crucial.

3. ***Throughput:*** The requirement of the throughput differs with various applications. The sensor network applications which require sampling the data with good temporal resolution, it is advisable that for such applications sink node receives more data.

$$\text{Throughput} = \frac{\text{Number of received data packet} \times \text{packet length}}{\text{Total tranmit packet length}} \quad (1)$$

4. ***Fairness:*** The bandwidth is one of the main physical constraints in many underwater sensor network applications. Hence it is essential to make sure that the sink node receives the data from all the sensor nodes fairly. The Authors in [24] have characterized the fairness using Jain fairness Index as defined below*:*

$$\text{Fairness Index} = \frac{\left(\sum x_i\right)^2}{n \cdot \left(\sum x_i^2\right)} \quad (2)$$

   Where the throughput of the node i is represented by x_i, and the number of nodes in the network is represented by n.

Our contributions in this paper are as follows: (1) analysis of contention window MAC protocol, (2) parameters like packet size, slot length, and boundary are taken into account to analyze the throughput. The earlier works on this type of protocol have considered only varying number of nodes to analyze throughput.

The rest of paper is arranged as follows. In Section II, we bring in few words on the classification of MAC protocols in underwater. In Section III, the list of selected MAC protocols for underwater sensor networks with their topology, throughput, energy consumption, delay, collision probability, advantages and disadvantages are compared and are briefly explained. Section IV discuses about the simulation tool followed by result analysis. We conclude the paper in Section V.

2. RELATED WORKS

The distinctive properties of UWASN demand the requirement of new well organized, consistent MAC protocols to gather up the challenge of delay in the propagations, multipath fading, path loss due to noise, attenuation etc. According to the authors Keyu Chen., Maode Ma, et. al., [29] existing MAC layer protocols can be classified into three categories: Contention based, Contention free Protocols and Hybrid as shown in Figure1.

A. Contention free Protocols

Considering various multiple access techniques, contention-free MAC protocols are categorized as frequency division multiple access (FDMA), time division multiple access (TDMA), and code division multiple access (CDMA). Although contention-free MAC protocol is an easy concept, its straight acceptance in underwater networks is not essentially a high-quality result.

B. Contention-based Protocols

Contention-based MAC protocols are further sub divided as follows: (a) MAC protocols with random access (b) MAC protocols with handshaking. Again enormous effort was made in categorization of handshaking MAC protocols in UWASNs. Finally the classifications of the MAC protocols are obtained based on the number of channels used for data transmission.

C. Hybrid Protocols

In conclusion, hybrid MAC protocols will bring in, the advantages of the contention-free MAC and contention-based MAC protocols.

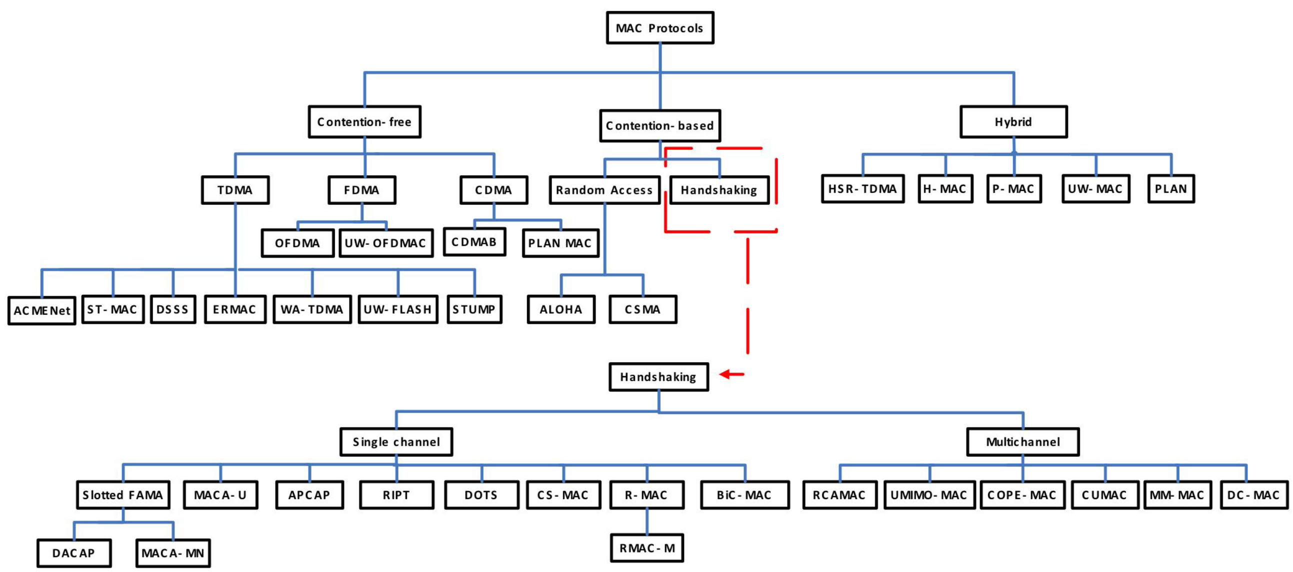

Figure 1: Classifications of MAC Protocols

3. WORKING OF THE MAC SCHEDULERS IN UWAN

This section describes the functionality and working principal of the MAC protocols used in UWAN. The authors Ansari, S., Gonzalez, J.P., Otero, P. et. al., [26] have provided the analysis of research on different MAC strategies. The parameters conceded for the performance measurements in ad-hoc-based/Cluster-head based MAC protocols are topology, throughput, propagation delay, collision probability, energy consumption, offered load, advantages and disadvantages are analyzed and the summary of comparative analysis is shown in Table 1.

UAN-CW-MAC

In UAN-CW-MAC protocol contention window is the new aspect introduced which plays a significant task in channel utilization and justice in sharing the bandwidth among stations. The frequency and the order of the channel access will also be decided by contention window. In order to improve the performance of the underwater acoustic communication widespread work has been carried out on CW control. The two distinct access modes

Table I
Comparative Analysis of Selected Mac Protocols in Underwater Acoustic Sensor Networks

Protocol	*Topology*	*Throughput*	*Energy consumption*	*Delay*	*Collision probability*	*Advantages*	*Disadvantages*
PURE ALOHA(14)	Adhoc based 2-D	0.45	High		High	Simplicity	More Collisions
CS-ALOHA(27)	Line and Star3-D	0.425(line) 0.002(star)		2.07s(line) 3.86s(star)	Low	Less collision of data packets	Over Conservative, Over hears
ALOHA-CA(21)	Adhoc based	0.45	High		Low	Better stability	High offered load is challengeable
Aloha-AN(21)	Adhoc-based	0.55	High		Low	Stability & high throughput	More memory
UWAN-MAC(18)	Adhoc-based	0.46	Medium	0.2s	Low	Mechanisms to solve synchronization problem, and tolerant propagation delay	Due to require a small duty cycle, it is difficult to achieve high throughput
UW-MAC(5)(6)	3-D shallow water	0.8	Less	1.5s	Low	Energy efficient	Require that all nodes know other nodes, multiple access interference
ACME net(9)	Cluster-head based	0.240	High		Low	Good scalability	Energy consumption is high due to idle listening
SBMAC(28)	Cluster-head based	0.275	Low		Low	Maintains an optimized transmission environment, Saves energy by minimizing the transmission of control frames	

which are defined in DCF are basic access mode and optional RTS/CTS (Request to Send/Clear to Send) access mode. In the basic access mode, prior to a frame transmission, using carrier sensing the medium status is made sure for each station. The transmission carries out immediately if the medium is idle for longer than IFS (Inter Frame Space); the station will be postponing its transmission, if the medium is sensed busy waiting for the medium determined to be idle.

4. SIMULATION RESULTS

The NS3.25 is the Network simulator used to assess the effective performance of UAN scenario. The C++ based framework, waf, is used for configuring, compiling, installing and running the developed UAN scenario. GNU-Plot is the utility used to plot the graphs. The analysis of the throughput for the UAN-CW-MAC protocol is considered in the scenario. The various parameters like number of nodes, range, packet size, slot time and simulation time which are effecting on the throughput of the protocol are varied and analyzed. UAN module is also downloaded and installed on NS3.25. The MAC protocol UAN-CW-MAC is attached to the PHY layer which in turn will be returning the number of packets sent, MAC address, propagation delay by varying number of nodes in UAN scenario.

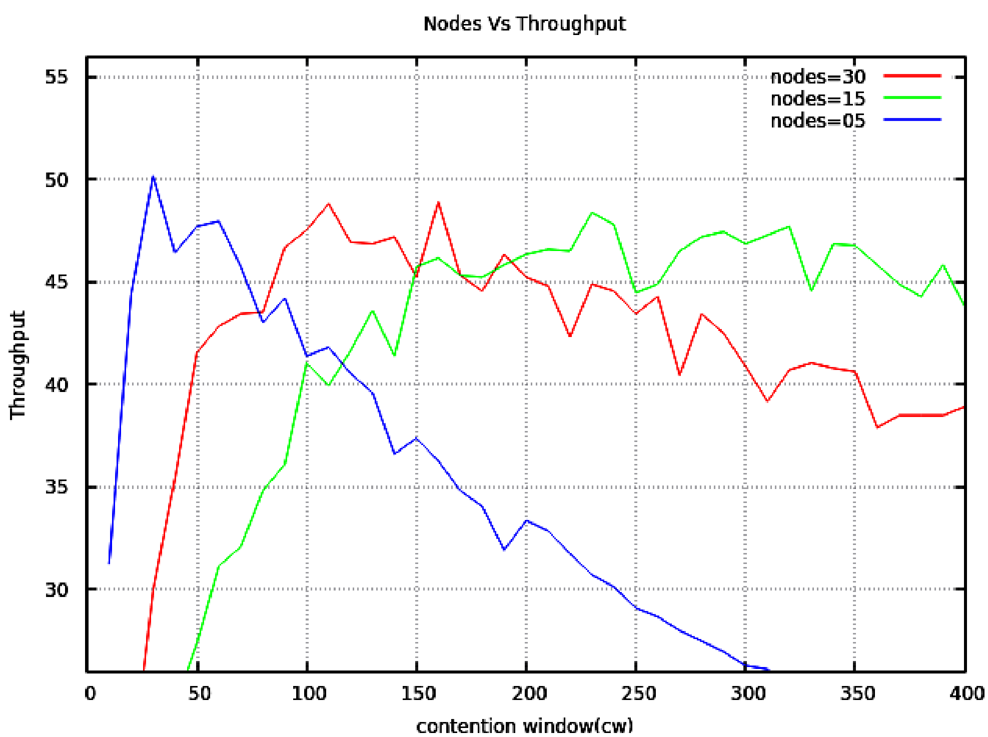

Figure 2: Throughput vs. CW for 05, 15, and 30 nodes in region of 500m × 500m

Remark 1: The nodes are deployed randomly in a uniform distributed square area of 500m × 500m. To show the variations in the throughout with respect to CW, the CW parameter is varied throughout the simulations. The throughput is increased to a maximum of 48,896 for CW = 160 for three runs. For higher values of CW the throughput are found to decrease slightly. The other parameters assumed in the protocol are as follows: Data rate is 80 Hz, Depth is 70 m, packet size is 32 bytes, CWmin is 10 and CW max is 400 in step of 10, slot length is 0.2 secs with simulation time of 1000secs. The entire throughput approximation is based on averaging of 3 simulation runs; to find the optimal value of CW the simulations are conducted for 05, 15, and 30 node networks. The results are given in Figure 2. The CW parameter will be tuned based on these results for additional simulations.

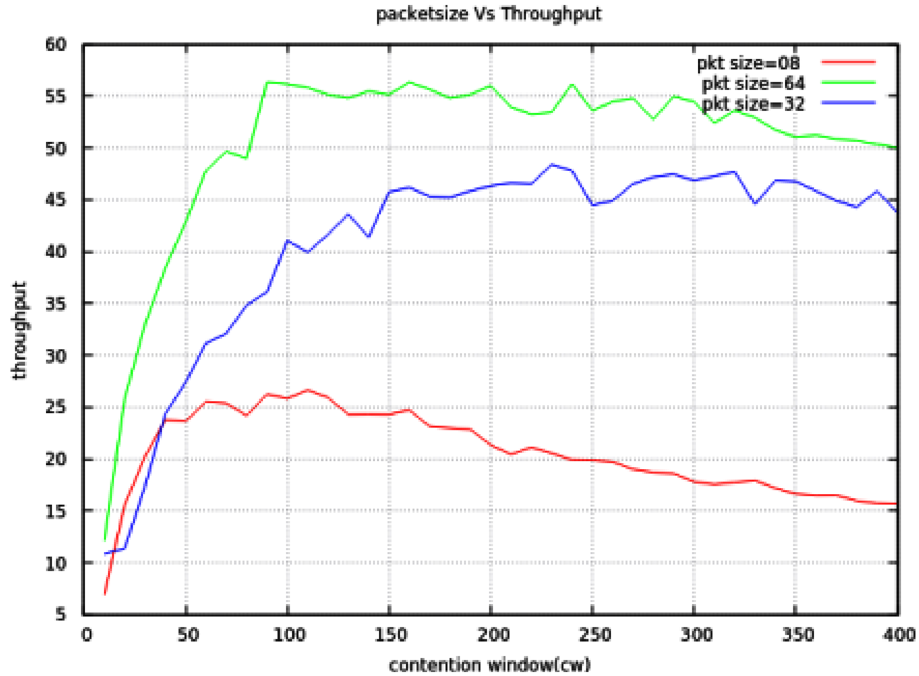

Figure 3: Throughput vs. CW for 08, 32, and 64 packet size deployed in region of 500m × 500m

Remark 2: The throughput is varying with different packet sizes as illustrated in the Figure 3. With 15 nodes in the region of 500m × 500m for CW = 76 the maximum throughput can be obtained.

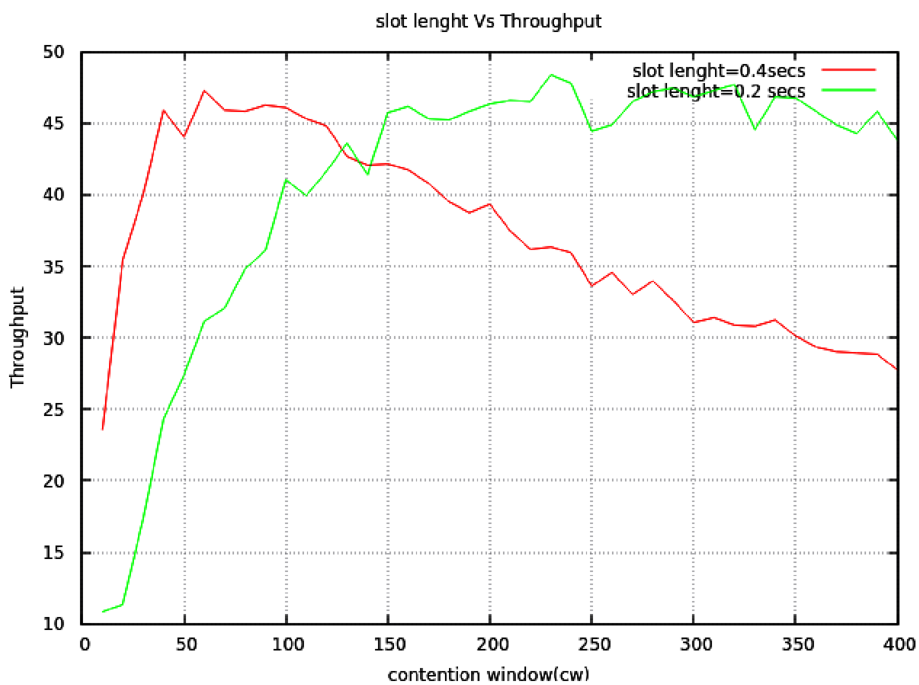

Figure 4: Throughput vs. CW for σ = 0.2sec and σ = 0.4sec deployed in region of 500m × 500m

Remark 3: Initially the throughput for the slot length (σ = 0.4secs) increases rapidly and reaches a maximum of 47, 2747 for CW = 60 but gradually drops down. Whereas for the slot length of (σ = 0.2secs) the throughput increases gradually remains constant after CW reaches 90 as shown in Figure 4.

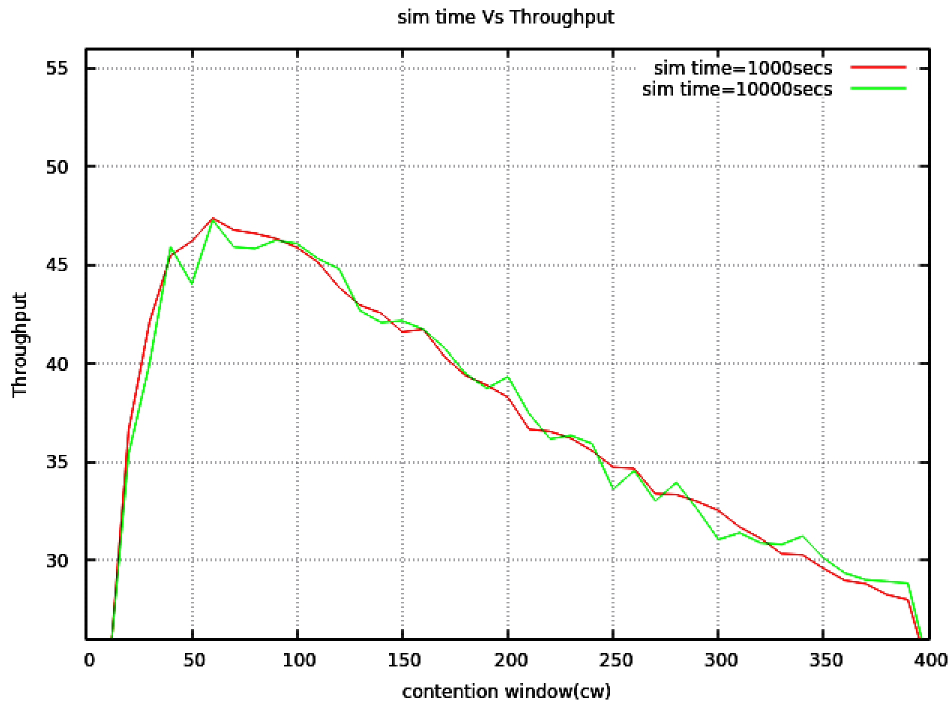

Figure 5: Throughput vs. CW for 1000secs and 10000secs simulation time deployed in region of 500m × 500m

Remark 4: The simulations are carried out considering a finite square region of 500m × 500m. The numbers of nodes are 15 and their positions are identified randomly. The times estimated for simulation are 1000secs and 10000 seconds. The results for throughput are almost same are shown in Figure 5.

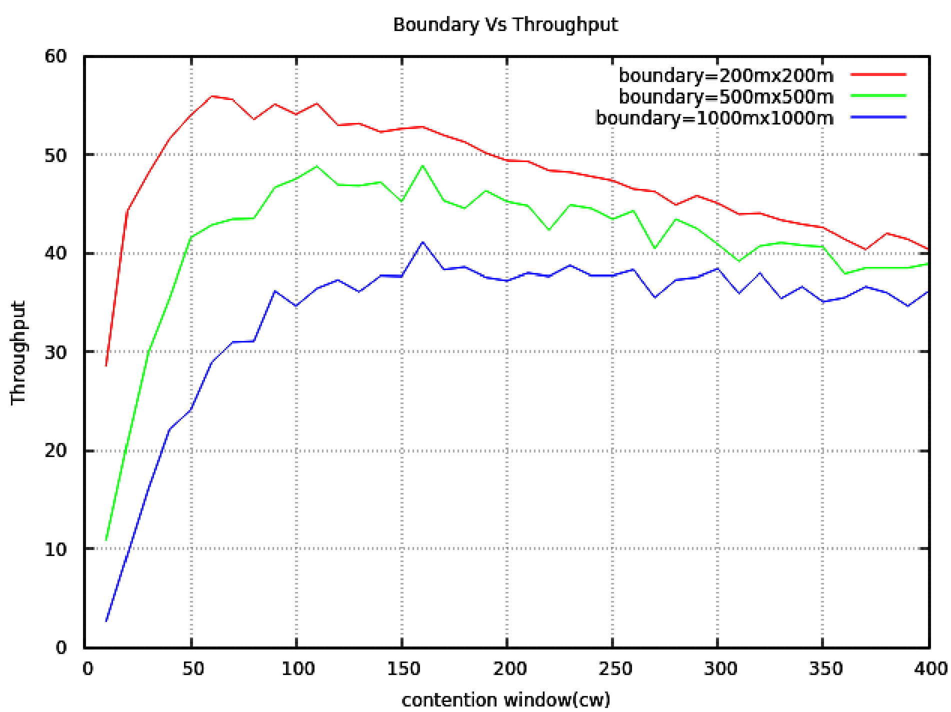

Figure 6: Throughput vs. CW for deployed in three different regions (1) 200m × 200m (2) 500m × 500m (3) 1000m × 1000m

Remark 5: As depicted in the Figure 6 the throughput for less boundary (200m × 200m) is high compared to other boundary areas like (500m × 500m) and (1000m × 1000m.). As there is increase in the area the throughput decreases.

5. CONCLUSION

In this paper, we present a throughput analysis of UAN-CW-MAC protocol for underwater acoustic sensor networks. In the future, we will think about additional situation to measure up this MAC protocol by considering the other factors like delay and energy efficiency for mobile ad-hoc networks. Our aim was to learn the different MAC strategies for UW applications and offer diagnostic study wherever required. A combined relative analysis on the performance of selected MAC protocols is also provided to have an imminent approach on the work done in [14] and [27].

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