Comparative Analysis of MAC Scheduling Algorithms in Underwater Acoustic Sensor Networks

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Abstract—**Underwater Acoustic Networks (UANs) uses acoustic communication for transmitting data. It is undoubtedly one of the most prevalent evaluation methodologies in the area of computer networks. In this paper we first bring in the perception of Underwater Acoustic Sensor Networks (UWASNs), and then study the working of different protocols intended for the control of Medium Access in UWASNs. Here the comparative assessments of three underwater Medium Access Control (MAC) protocols like CW-MAC, RC-MAC and UAN-ALOHA-MAC are conceded. The parameter considered for the assessment of these protocols is Throughput. The Network Simulator like NS3 is used to study the working of these protocols in underwater environment. The efficacy of the suggested means is examined through the achieved simulation results.**

Keywords—UWASNs, MAC protocols, CW-MAC, RC-MAC, ALOHA.

I. Introduction

Underwater acoustic sensor networks(UWASN) consist of variable number of sensors that are set up to perform combined monitoring of tasks over some specified area .UWASN has many applications some of them are monitoring pollution in lakes and rivers ,surveillance(coastline protection) ,detection of mines, identifying underwater threats and preventing ocean-disasters . Designing protocols for UWASN is quite challenging due to its harsh underwater environments, limited availability of bandwidth, long propagation delay. There are a few factors that affect the acoustic communication they are 1) Path loss 2) Geometric Spreading 3) Noise 4) Multi-path 5) High delay and delay variance

UWASN's limited channel bandwidth, high bit error rate because of the wireless channel, limited battery power of the sensor nodes may give an illusion that it is no different from the terrestrial wireless network but it is not so .The size and cost of underwater sensors is greater than terrestrial ones, deployment of sensors is sparse in underwater while in terrestrial the sensors are deployed densely and underwater sensors need a larger memory in comparison with terrestrial sensors.

To get a more clear idea let us have a look on the underwater scenario shown below.

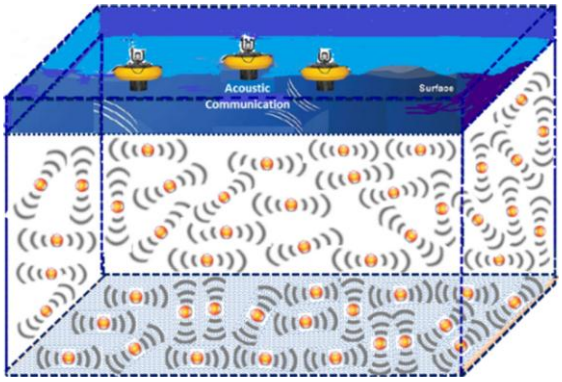

Figure1: Underwater Acoustic sensor network scenario.

The figure.1 shows a 3D-UWASN.It consists of 3 sinks furnished with both acoustic modems and radio frequency, nearly 50 sensor nodes distributed underwater. In UWASN the sensor nodes are connected using acoustic links which helps in collecting the underwater data. The sensor nodes reach the sinks on the surface of water through multiple hops. The acoustic signals are sent from the sensors to the sink, and then the packets from the sink are sent to the control centre present at the shore using the radiofrequency signals.

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 organization of the paper is as follows. We briefly introduce on works carried out in MAC layer in UWASN in section II.The working of three MAC protocols like CW-MAC, RC-MAC and UAN-ALOHA-MAC are briefly put in plain words in Section III. Section IV discuses about the simulation tool followed by result analysis. We conclude the paper in Section V.

II. RELATED WORKS

We referred a few papers and collected the information that follows below. The propagation delay changes significantly with distance because the propagation speed of acoustic signal is low. Hence synchronization between receiver-transmitter pair is crucial before starting up a communication. A few synchronization plans have been proposed. However, at the real time communication, the available synchronization may end up hard, due to spatial-temporal variation of propagation speed. Built in problems of multi-access system must also be considered. Here the main focus is on reducing collision of data packets. For this we have many schemes that are based on RTS/CTS handshake mechanism for example the multiple-access collision avoidance with multiple neighbors (MACA-MN) protocol which works through (RTS/CTS/DATA) handshake mechanism. The sender sends an RRTS packet to a receiver with recommended CTS and contention window. Once RTS is received, CTS will be sent to transmitter by the receiver and subsequently data packets are transmitted. By using the above transmission-delay reservation based approach, the collision of data is reduced, however this has low success rate as transmission of RTS packet is based on pure Aloha.

In reservation-based point-to-point communication approach which is driven by the receiver, four-way handshake is driven; the following parameters are included 1) RTR 2) Packet size by transmitters3) Packet ORDER by receiver and 4) DATA packet transmission. Here, the packets are received by the receiver in an order, as a result of biased network, network domination is possible and also delay is very high in this protocol, as the transmitter needs to wait for transmission of data until receiver's initiation. An additional protocol that falls under the reservation-based category which utilizes the four-way handshake mechanism is sender initiation which is initiated by sending notice in an order subsequently followed by data and reply. To avoid competition a sequence based "notice" message is being spread, which could constrain the clients number of a cluster. Here the uncertainty of delay during propagation has not been tended. In a many-to-one gateway-based RC-MAC protocol, the entire channel is divided into two one as control and the other as data. Accordingly nodes use pure Aloha to send RTS through control channel to reserve resource at the gateway. Gateway nodes react by sending CTS through the data channel. In this way, the node successfully transmits data through data channel and in case of unsuccessful transmission frames are retransmitted by the nodes.

In one of the algorithm based on reservation mechanism, the propagation delay and scheduling information of a node is known to its neighbors, the impact is anticipated beforehand to take necessary steps. A code division multiple-access (CDMA)-based MAC protocol has been proposed which utilizes RTS-CTS which is also transmitter oriented. Another distributed MAC protocol called Direct sequence CDMA was recommended which uses a closed-loop algorithm to optimize the power of transmission and length of code that reduces near-far effect. One more protocol has been proposed i.e. time-division multiple accesses (TDMA) for hybrid spatial reuse. As the spatial reuse TDMA protocol cannot be incorporated with the system, it is consolidated with CDMA. Multichannel MAC protocol, is associated with problems related to congestion are addressed. In T-Lohi, a frame based underwater multi-access protocol, adaptable frame size was considered. A frame comprises of data transfer with varying rounds of contention. The rounds of contention increases variably till an effective access occur. The duration of contention rounds varies predominantly resulting the three variants of T-lohi(either synchronous or asynchronous).

In terrestrial to satellite stations communication, distinctive reservation schemes are introduced. The data transmission in R-Aloha utilizes frames that are equally slotted. By utilizing S-Aloha protocol the transmitter retrieves a free slot. If the retrieval is successful then the data transmission takes place through the same slot until the data packets are completely transmitted. In satellite communication frames of fixed size are equally slotted. These frames are in-turn slotted which are used for randomized access. The mini-slots obtained by the transmitters has a chance to effectively transmit the information over the data slots. The packet reservation method can be used to dynamically allocate satellite channel. Each frame is divided into access and data slots where variable data slots are followed by fixed access slots. In another approach, packet reservation multiple access with dynamic allocation (PRMA/DA) ,considers a frame of fixed size but with variable number of access slots.

From the study of some of the available reservation based (RTS-CTS) protocols, we analyze that it has low success rate when its reservation mechanism uses most of the Aloha variants. Whereas in few other protocols that are frame-based we observe that the load-dependent inconstancy of access or data slots is considered while ideal equilibrium between these slots is not examined. In this present work we aim at comparing the various MAC scheduling algorithms for underwater sensor networks using NS3. The Reservation Channel Acoustic Media Access Protocol (UAN-RC-MAC), UAN-ALOHA-

MAC, and UAN-CW-MAC are already implemented in NS3; we have analyzed the performance of these protocols by designing the underwater sensor network application. The throughput for the designed application using these MAC protocols are computed and compared.

III. WORKING OF THE MAC SCHEDULERS IN UWAN

This section describes the functionality and working principal of the MAC protocols used in UWAN.

A. *RC-MAC*

Depending on RTS/CTS handshaking mechanism and channel reservation scheme the Reservation Channel Acoustic Media Access Protocol is developed.The accessible bandwidth is divided into control channel and main channel. Each time if any data need to be sent on the main channel, it is held in reserve by transmitting RTS packets on the control channel. This process will assist in reducing the possibility of collision in data packets. To brief in few words about RC-MAC dual channel protocol where in the obtainable bandwidth is divided into two channels specifically reservation channel and data channel. In the network it is assumed that the numerous non –gateway nodes are serviced by single gateway node. Time is divided into cycles. In the data channel preceding cycles' scheduled data transmission will be passed, while the non–gateway nodes transmit RTS packets on the reservation channel. The gateway node will be storing these requests for the duration of the cycle. On the brink of the next cycle a CTS packet which is transmitted by gateway node includes the information on bandwidth allocation in addition to packet transmission times for reserved packets. In the script a single gateway node is positioned at the middle of the region and the non gateway nodes are uniformly distributed between each node and the gateway.

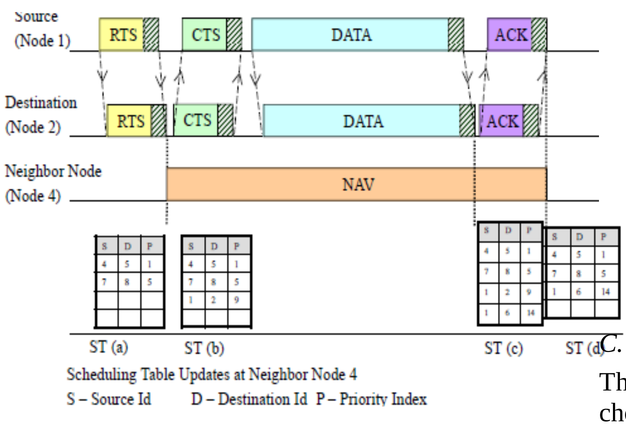

Figure 2: Working of RC-MAC

B. *UAN-ALOHA-MAC*

UAN-ALOHA-MAC is categorized under random access MAC protocol. With the purpose of improving the recital of classic Aloha in UWANs new features of automatic repeat-request (ARQ) and back-off schemes are engaged. As in TWNs the collisions are immediately sensed by the channel, but in underwater environment the collisions cannot be identified instantaneously due to its long propagation delay. Consequently, UW-Aloha adds in a feature of acknowledgment (ACK) to clearly update the sender whether the transmission is successful or not. Fig. 3 shows the work flow of UAN-ALOHA-MAC. Packets are randomly sent by a Sender without reservation or negotiation with other senders. Based on Stop and wait method UAN-ALOHA-MAC is designed to work. Meanwhile none of the outgoing packets are processed when the when the sender is waiting for the acknowledgement. If the ACK is not received by the sender in time, it specifies that either the data or the ACK is lost as a result of collisions or link errors. So the sender before retransmitting the packet will back-off. To conclude this back-off mechanism is used to slow down the process of packet transmission when collision occurs at high network traffic rate. If not, the sender will get ready for new data transmission following a reception of ACK.

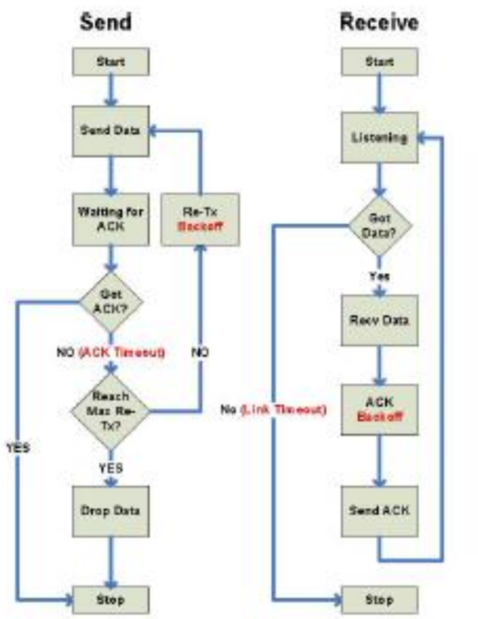

Figure3: Workflow of random access UAN-ALOHA-MAC

C. *UAN-CW-MAC*

The frequency and the order of the channel access is chosen by the contention window parameter, hence it plays a vital role in consumption of the channel and equality of the bandwidth divided among

stations. With the purpose of enhancing the recital of the underwater acoustic communication widespread work has been carried out on controlling CW.The basic access mode and the optional RTS/CTS (Request to Send/Clear to Send) access mode are the two access modes distinct in the DCF.
In the basic access mode, prior to the transmission of the frame every station verifies the status of the medium by sensing the carrier signal. The transmission starts away without delay if the medium is idle for more than IFS (Inter Frame Space) period: the station will adjourn its transmission if the medium is sensed busy and continues the process as soon as the medium is observed to be idle. One of the QOS parameter like throughput is defined by the equation (1)

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

IV. SIMULATION RESULTS

NS3 simulator is a discrete-event network simulator used for research and educational purpose. It is an open-source software .It mainly focuses on the working of internet protocol and networks but at the same time it can also be used to model non-Internet based systems.
UAN module is downloaded and installed on NS3.24.The foremost aim of the UAN Model is to allow various underwater network situations. The UAN model is divided into three major components: The channel, PHY, and MAC models. Ideal channel model, the Thorp propagation model and the Bellhop propagation model are the three propagation models. The Power Delay Profile (PDP) and the information lost in the path are proposed by these propagation models. UAN PHY models propose the parameters like Signal to noise ratio (SINR) and packet error rate (PER).The arrangement of the PER and SINR models verify successful reception of packets. The Transducer class assists in connecting the PHY model with the channel which is responsible in following the flow of all inward and outward packets over the period of events. UAN MAC models included RC-MAC, CW-MAC, protocols AUV mobility models are used to program AUV at various paths. It also controls the velocity, depth, direction, pitch of AUV. The energy handling is realized by combining together Energy Model and the UAN.

The different MAC protocols like UAN-CW-MAC, UAN-RC-MAC and UAN –ALOHA-MAC are 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.
The developed UAN scenario can be configured, compiled, installed and ran on C++ based framework called waf. The packet loss ratio can be analyzed through the trace file which gives the number of packets sent and received. The GNU-plot utility is utilized to plot the graphs for the analyzed values. The Throughput for the protocols is considered in the scenario. The simulations are carried out considering 06 nodes for sender and 04 nodes as receiver. The number of nodes and their positions are identified randomly. Poisson process is used to generate the traffic. The number of packets sent per second each sender is 0.02. The estimated time for the simulation is 1000 seconds and the simulation is repeated for 10 times. Figure 4 depicts the results for throughput.

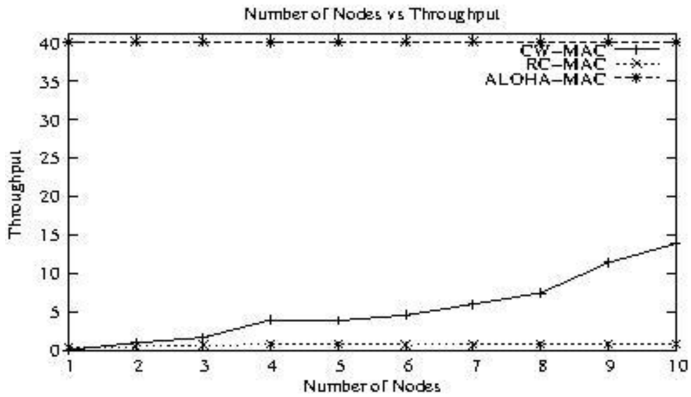

Figure4:Throughput in Bps Vs Number of nodes

V. CONCLUSIONS

In this paper, we present a comparative performance evaluation of three MAC protocols for underwater acoustic wireless sensor networks on basis of Throughput and number of nodes. The number of nodes is varied in X-axis with the throughput of each protocol on Y-axis. UAN-ALOHA-MAC protocol proved more efficient than CW-MAC and RC-MAC for short distance transmission of the packets as the delay factor is less. For longer distance transmission CW-MAC is more efficient than RC-MAC. In the future, we will think about additional situation to measure up to these three MAC protocols.

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