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# MAC Layer Communication Protocol Design for Underwater Fish Farming Technology: Stochastic Network Calculus

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***Abstract—The underwater communication channel usage and MAC layer protocol architecture are the most problematic aspects of a seawater wireless communication network. It introduces the underwater acoustic communications research challenges and opportunities, especially in terms of throughput and transmission delay. In this research work, we propose the MAC protocol with collision avoidance. Underwater Medium Access control and Collision Avoidance -Wireless protocol (UWMACA-W) is proposed for Underwater Fish Farming. This research work also has compared the performance of the UWMACA-Wireless protocol with and without SNC. The growth of the fishes inside the bubble can be exchanged to the base station by using the UWMACA-wireless protocol and also increases interface efficiency by taking account of the underwater acoustic channel's long delay time, as well as fixing the issues related to uncovered terminal issues. UWMACA-W method has higher performance than MACA-Wireless protocol, according to simulation testing on Riverbed modeler.***

***Keywords— Underwater Acoustic Wireless Communication, Delay, Backlog, Stochastic Network Calculus, Underwater agriculture forming.***

## 1. INTRODUCTION

Submerged structures grasp different applications such that the ocean oil industry, Aquaculture, Mining, and other business applications [1]. Nowadays Researchers are searching for new methods and strategies for underwater fish farming due to the world's population increase. Submerged aquarium structures of systematic fish farming are one of the open research forums related to the underwater or massive form of water. Deepwater fish farming utilizes aquatic cages that are equivalent to those encountered in the inshore but are submerged and down streamed into a deeper area of the ocean. The Figure 1. Illustrate the aquatic cage set up in the underwater region. Movable fish farms underwater also liberate up enough space for aquaculture to extend to satisfy rising fish demand. The fish reservoirs allow long-term breeding of various fish species in open habitats. The fish cage installations usually operated in the depth of the ocean offer security as well as ideal circumstances for fish farming. Physical monitoring of cage and fish movements is a tedious task for human beings. The remote control can make underwater farming more effective and smarter. Innovations like the development of a wireless sensor network system to tracks and feed the fishes automatically. Currently, the fish forming is controlled through buoy with wired communication for feeding and monitoring activities. Wireless acoustic communication is an effective method for monitoring the fish forming remotely. The growth rate, feeding, movement of cages, distance between the cages is a necessary activity for underwater aquaculture. Physically monitoring these factors in every moment is a difficult one as a human being. The underwater wireless acoustic communication is suitable to exchange the information between the nodes which are deployed inside the cage to the base station.

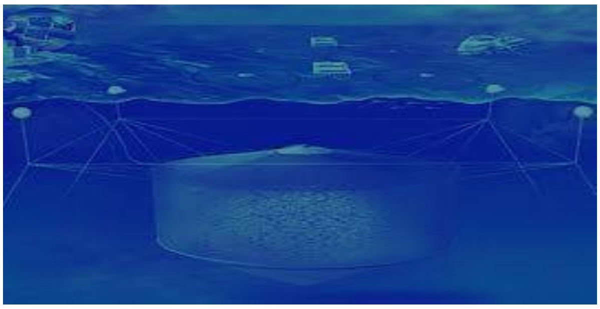

Figure 1. Framed structure of underwater Fish forming

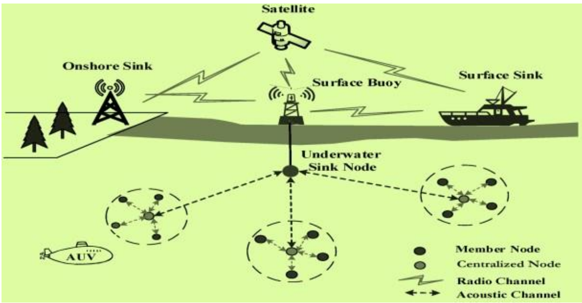


Figure 2. Illustration of sensor node setup inside the cage

The conversation is carried out in an aquatic channel of communication, it is not equivalent to the traditional terrestrial communication methods [2]. It's one of the difficult issues for the researchers to utilize the acoustic communication channel. An acoustic channel communication between the nodes and the base station is affected by the various characteristics of acoustic channels. The short distance communication can be received by the transceivers. Since the growth of the underwater system is not automated [3]. The MAC protocols need to test with underwater fish farming cages. This paper deals with the design of MAC layer communication protocol to monitor the feeding activities and the growth rate of the fish inside the cages to the outside base station. The wireless acoustic communication is illustrated in Figure 2, where the nodes are deployed inside the cage and all sensor nodes are connected with centralized control nodes like star topology. Centralized hub exchanges the information related to the movement of the cage, feeding information, location, and growth rate of fishes inside the cage to the base station.

Wireless underwater MAC protocols dealing with acoustic channel allocation and collision issues [4]. The lowered acoustic channel is difficult to receive the data due to crippling, multipath concealing, and time comparing ascribes [5]. The acoustic spread is often smaller than the radio channel, and also creating uncertainty [6] [15]. The transmission speed of acoustic signals in the seabed is around 1500m/s, which is below the range of radio propagating waves. Furthermore, the restriction in submerged channels, Frequency Division

Multiple Access (FDMA) is not ideal for submerged communications [7] [18]. Collision avoidance protocols are expected to minimize re-transmissions and improve the utilization of resources that are battery-powered. The unfavorable properties of submerged conditions make it difficult to design effective and efficient communication protocols [8].

In recent years, several MAC protocols have been invented and updated at the simulation level. Since there is no proper collision [11] [12] [13] avoidance method is encounter stochastically in the ALOHA or MACA (Collision Avoidance). A device can automatically relay a payload if it has something to transmit. Whereas the network's loading is heavy, the channel's performance degrades exponentially owing to the unavailability of any collision avoidance system [9] [14]. To minimize packet losses, CSMA allows nodes to listen/sense the channel, and it solves the issue of unseen and exposed terminals. Later Wireless-medium access collision avoidance inter-process communication protocols [10] are presented to overcome the CSMA issue, but they fail spectacularly when implemented underwater.

At this moment, propose a UWMACA (Underwater Wireless MAC Collision Avoidance) with Stochastic Network Calculus (SNC) based strategy for QoS examination. To enhance the efficiency of traditional hand-shacking, the UWMACA protocol with Stochastic Network [16] Calculus is invented to reduce the collision rate and increase the successful communication between the underwater fish farming to base Sink [17]. The rest of the investigation article is figured out as follows. Fragment II deals with the system model for underwater data flow. Section III deals with the Analysis and working of UWMACA for underwater fish forming. Portion IV explains the stochastic network calculus for the backlog, delay bound with obscuring channel. Section V discuss about the performance bounds in underwater wireless communication. Section VI focuses on the simulation results of the proposed scheme for underwater fish forming.

## 2. SYSTEM MODEL FOR UNDERWATER DATAFLOW

For this research, we have considered one relay and two relay topologies. One relay topology allows a system to exchange the information directly to the destination node without any hop communication shown in Figure 3. Two relay topology allows the source and destination system with one intermediate device shown in Figure 4.

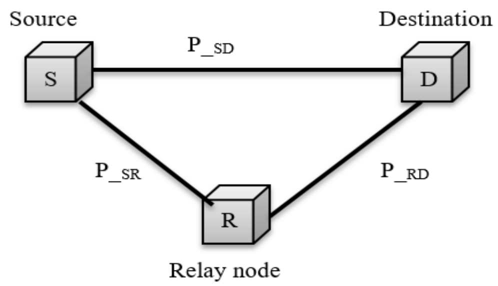


Figure 3. One relay topology

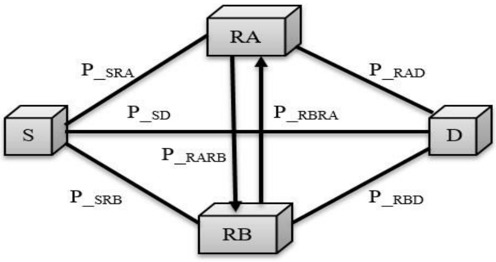


Figure 4. Two Relay Topology

We considered the wireless acoustic synchronized communication occurs with time multiplexing. In this paper, our work focused that one packet can transmit at the one-time slot of a frame | ţ |.

*In the Wireless acoustic channel model,* the time slot between source and next node is considered as u belongs to ţ (u∈ ţ). There is a limited channel between two nodes i, j, and time slot u. The channel probability is denoted as $P^{u}_{\cdot s,d}$ The channel is modeled with additive noise based on the packet error rate derived from the factors which the nodes tried to egress in the same time slot. Each node transforms the packet in the half-duplex mode and the node can"t perform both sending and receiving operations at a time.

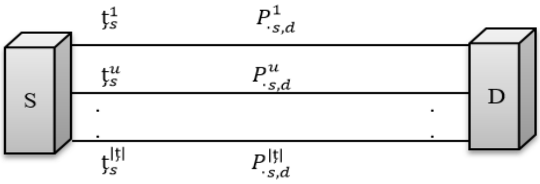


Figure 5. Channel and node model

*In the network model,* the finite number of a weighted graph is considered for one and two relay communication. The graph is denoted as $G_{|v|} = (vertives,\ edges,\ timeslot)$. The orthogonal limited acoustic channels | ţ| as shown in Figure 5. The edge (s,d,u) describes the channel between S and D in the „u" time slot. The weight of an edge is $P^{u}_{\cdot s,d}$. If the transmission is not possible, then the weight is assigned as $P^{u}_{\cdot s,d} = 0$. The transaction direction from and to of a node is denoted as $\underset{N\_s}{\rightarrowtail}$ and $\underset{N\_s}{\longrightarrow}$ for node S respectively.

## 3. ANALYSIS OF MACA AND WORKING OF UWMACA-WIRELESS PROTOCOLS

### *A. Analysis of MACA-Wireless protocol*

The wireless protocol MACA follows the R-C-D-A mechanism [R-RTS, C-CTS, D-Data, and A-ACK] to interchanges the data between the nodes. The RTS and CTS messages will help the node to avoid the collision occurrences between two intended devices.

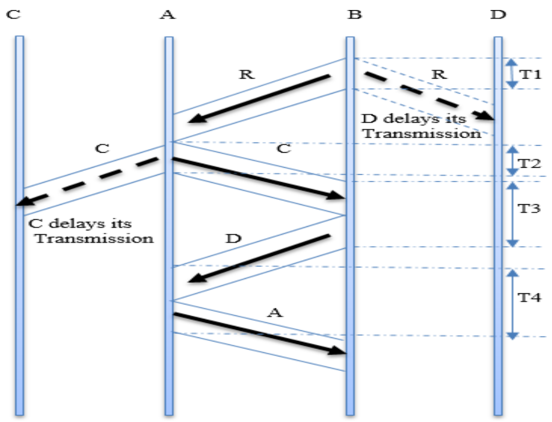


Figure 6. Information exchange using R-C-D-A in MACA-wireless protocol

Figure 6. Illustrates a controlled data flow between nodes. Node B willing to communicate with node A. Node B exchanges RTS messages to node A. But the same RTS can view by nearest node D and understand the communication occurrences [19]. Node D will go to waiting mode until the reception of the communication termination message. Node A sends a CTS message when the node is free. The CTS message can be viewed by nearest node C. node C will enter to waiting mode until the completion of communication between A and B. once the CTS message is received from node A, the data exchange will happen. For every successful data exchange the ACK will be shared by node A. Underwater channel has the less busy time due to long propagation delay, which means that most of the time the channel will be idle [20]. $Ti$ denotes the total amount of time for entire communication starts from RTS to ACK. The total communication time is expressed as,

$$Ti = \frac{P(rts) + P(cts) + P(data) + P\ (ack)}{R(rate)} + \frac{4 * Di}{S} \qquad (1)$$

Where $P(rts),\ P(cts),\ P(data),\ and\ P\ \ (ack)$ denotes the packet size of the R-C-D-A mechanism. Di represents the Distance between the nodes, $R(rate)$ denotes the data rate between nodes. Here for simulation, we have considered an equal rate for both nodes. S denotes the speed of the acoustic wave. The busy time $B_t$ of the channel evaluates as,

$$B_t = \frac{P(rts) + P(cts) + P(data) + P\ (ack)}{R(rate)} \qquad (2)$$

The ratio of busy duration ρ is denoted as,

$$\rho = \frac{Bt}{Ti} * 100\ \% \qquad (3)$$

The typical example for MACA – wireless protocol, let $P(rts), P(cts), P(data), and\ P\ (ack)$ has an equal length of a packet. (Ex. 100 bits), $P(data)$ =1024 B, Di=2000 meter, R(rate) =1000b/s, Speed S=1500m/s. substituting the values in (1), (2), and (3), it yields $Ti$ 6692 s , $B_t = 1.3215s$, ρ 19.91%. Hence $B_t < Ti$. It means that channel will be idle for the maximum amount of time. So MACA-wireless protocol is insufficient for the underwater environment. If the distance is increased between nodes. Another disadvantage is propagation delay will be less because it interleaved with the busy time.

*B. Working principle of UWMACA-Wireless protocol*

MACA-wireless protocol yields $B_t < Ti$. The channel utilization is very less and propagation delay interfered with the busy time. To overcome these issues, UMACA-wireless protocol giving much more attention to every packet that extracts the information of the sender, receiver, and busy state of neighbors during R-C-D-A.

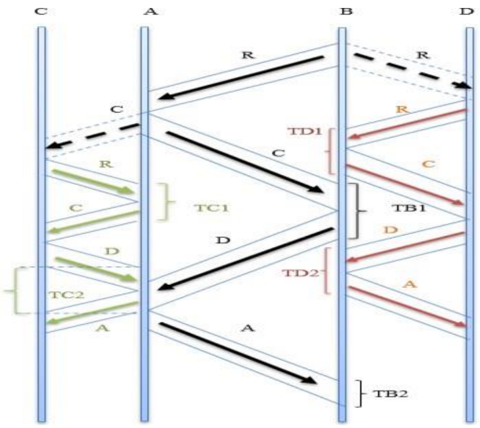


Figure 7. Information exchange using R-C-D-A in UWMACA-wireless protocol

According to the UMACA - Wireless protocol, every node shall listen to the connection and listen closely to every other package it gets to know, then collect details about both the nodes, as well as the active timeframes of strangers. UMACA - Wireless protocol utilize the channel's network latency time, allowing nodes to communicate with many other peers during the R-C-D-A exchange era. Crashes will never happen when active intervals of multiple nodes aren't overlapping at one another. Figure 7, illustrates the R-C-D-A messages in a three-way. A is conversing to B, and C will send messages to A through inter-leaving their active intervals TC and TA mostly during communication time of A and B. Likewise, B will send information to A and D in the same exchange time provided the active intervals TD and TB do not overlap.

The active periods are split into 2 parts, TB1 & TB2. TB1 is the time it takes from the start T1 and receiving the CTS to the final time T2 of transmitting data. TB2 has to be the time T3 required from the start of collecting ACK to the final time T4 of acquiring ACK. The transmission time can be computed as illustrated in Figure 7.

$$T1 = T_{BC} + T_{rts} + 2\,\partial BA \quad (4)$$
$$T2 = T1 + T_{cts} + Tdata$$
$$TB1 = [T1, T2]$$
$$T3 = T_{BC} + T_{rts} + T_{cts} + T_{data} + 4\ \partial BA \quad (5)$$
$$T4 = T3 + T_{ACK}$$
$$TB2 = [T3, T4]$$

Where,

$T_{BC}$ = Present time of the node B sending RTS

$T_{rts}$ = RTS, $T_{cts}$ = CTS, $T_{data}$ = DATA, $T_{ACK}$ = ACK

$\partial BA$= Propagation delay between A&B

During the busy time TB of node B exchange the message to A, it can be written as,

$$TB = TB1 \text{ y } TB2 \tag{6}$$

D, as A's neighbor, hears the RTS packet and is aware of the busy length TB. If D needs to send data to B, it must also calculate the busy durations TD1 and TD2, which are the output of a new message exchange between D and B. TD1 is the time between both the initial stage T5 of obtaining RTS D and the finish times T6 of transmitting CTS D, and TD2 is the time between both the initial stage T7 of obtaining DATA D as well as the end time T6 of transmitting CTS D.

$$T5 = T_{DC} + \partial DB$$
$$T6 = T5 + T_{rts} + T_{cts} \tag{7}$$
$$TD1 = [T5, T6]$$
$$T7 = T_{DC} + T_{rts} + T_{cts} + 3\ \partial DB$$
$$T8 = T7 + T_{data} + T_{ACK} \tag{8}$$
$$TD2 = [T7, T8]$$

Where,
$T_{BC}$ = Present time of the node D sending RTS
$\partial DB$= Propagation delay between D&B

During the busy time TD of node D exchange the message to B, it can be written as,

$$TD = TD1 \text{ y } TD2 \tag{9}$$

## 4. SNC – BASIC NOTATIONS FOR COMMUNICATION

On a very basic level, SNC has its root from the Queuing hypothesis [13]. In this part, the fundamental documentation and ideas of SNC are presented. A cycle is characterized as the capacity of time t. The different organization components are spoken to as a measure of traffic showing up to the organization Arrv(t) (Arrival or appearance measure), the measure of traffic leaving the organization Dept (t) (departure takeoff measure), the measure of administration gave by the organization Serv (t) (Service measure) and the measure of administration neglected to be given by the organization I (t) (Impairment measure). We expected all cycles are non-negative and exerted acoustic Gilbert-Elliot obscuring channels using stochastic framework investigation. Expanding capacities and by convention$t = 0$,

i.e. $\mathrm{Arrv}(0) = \mathrm{Dept}(0) = \mathrm{Serv}(0) = \mathrm{I}(0) = 0$.
For any$0 \leq \mathrm{s\ erv} \leq \mathrm{t}$, Let $\mathrm{Arrv}(\mathrm{s1}, \mathrm{t1}) \equiv \mathrm{Arrv}(\mathrm{t1}) - \mathrm{Arrv}(\mathrm{s1})$, $Dept(\mathrm{s1}, \mathrm{t1}) \equiv \mathrm{Dept}(\mathrm{t1}) - \mathrm{Dept}(\mathrm{s1}), (\mathrm{s1}, \mathrm{t1}) \equiv \mathrm{Serv}(\mathrm{t1}) - \mathrm{Serv}(\mathrm{s1})$and $\mathrm{I}(\mathrm{s1}, \mathrm{t1}) \equiv \mathrm{I}(\mathrm{t1}) - \mathrm{I}(\mathrm{s1})$.
Default value, $\mathrm{Arrv}(0) = \mathrm{Dept}(0) = \mathrm{Serv}(0) = 0$.

The non-negative wide detecting expanding capacity is indicating as $\not{f}$ the arrangement of non-negative wide-detecting expanding capacities, and $\not{\mathcal{F}}$ the arrangement of non-negative diminishing capacities,

$$\mathcal{f} = \{fun(.): \forall\ 0 \le x1 \le y1, 0 \le fun(x1) \le fun(y1)\}$$
$$\bar{\mathcal{f}} = \{fun(.): \forall 0 \le x1 \le y1, 0 \le fun(y1) \le fun(x1)\}$$

Variable with randomness is denoted as C1, its functional distribution is denoted by $Fun_c(C) \equiv Prob\{C \le c\}$, fits $\mathcal{f}$, and HDF- Harmonizing distribution function, $\bar{\mathcal{f}}_c(C) \equiv Prob\{C > c\}$, fits to $\bar{\mathcal{f}}$. For modeling, the bounding function needs a stronger requirement on the execution $\mathcal{f}$. Where $(.) \in \hat{G}$, $x1 \ge 0$ and $\hat{G}$ for $n1 \ge 0$, i.e.,

$$\hat{G} = \{\ (.): \forall\ n1 \ge 0, (\int_{x1}^{\infty} dy1)^{n1} \quad (y1) \in \hat{G}\} \tag{10}$$

*a. Operations in Stochastic Network Calculus*

The min plus functions are categorized under $(\min, plus)$, $(\min, plus)$, the *exertion* of f and $g$ have denoted as [14] [21]

$$(f \quad g)(x1) = \underset{0 \le y1 \le x1}{\text{infimum}}[f(y1) + g(x1 - y1)]$$

$(\min, plus)$, *deconvolution* of function f and $g$ is

$$(f ❾\ g)(t1) \equiv \underset{s1 \ge 0}{\text{supremum}}\{f(t1 + s1) - g(s1)\}$$

$$[x1]^{+} \equiv \text{minimum}\{x1, 0\}, [x1]_{.} \equiv \min\{x1, 1\}$$

The *lowest* of fand $g$ is

$$(f \wedge g)(x1) = \min imum[f(x1), g(x1)]$$

The *extreme* of function f and $g$ is

$$(f \vee g)(x1) = \max imum[f(x1), g(x1)]$$

In accumulation, the standard complication for autonomous case analysis [20], the *standard complication* of $f$ and $g$ is,

$$(f * g)(x1) = \int_{0}^{x} f(x1 - y1) d\, g(y1) \tag{11}$$

*b. Factors of Metrics, Traffic and Server Models*

The following factors have induced in the service assurance analysis under SNC [15], the backlog (BL) is expressed as $BL(t1)$ in the system at time $t1$ is defined as:

$$BL(ti) = Arrv(ti) - Dept(ti). \tag{12}$$

The delay $Del(ti)$ at time $t1$ is defined as:

$$Dept(ti + \tau 1)\} \tag{13}$$

SNC traffic incoming curvature and traffic service at every node drawn as curves implemented in SNC. The flow of data at the node has derived as the arrival. Sender based traffic models can be derived and a data flow at the node is denoted as arrival process $Arrv(ti)$, arrival curve for the stochastic process $\acute{\alpha} \in \acute{E}$ with function for calculating bounding values $\in \bar{\acute{E}}$

$Arr{\sim}ta1$ [ , ά1], $\forall ti \geq 0$ and $xi \geq 0$, it holds

$$Prob\,\{Arrv(si,ti) - ά(ti - si) > xi\} \leq \ (xi) \quad (14)$$

The node flow centric backlog bound (BB) for stochastic $Arrval$ is said to $a \in \mathcal{F}$ with bounding function $\not f \in \bar{}$, denoted by

Arrv~BB[$\not f$, ά], ∀ ti ≥ 0&∀xi ≥ 0, expressed as,

$$Prob\,\{\underset{0\leq si\leq ti}{\text{supremum}}[Arrv(si,ti) - ά(ti - si)] > xi\} \leq \not f(xi) \quad (15)$$

The maximum backlog curve using stochastic ά ∈ $\not f$ with bounding function $\not f$ belongs to $\bar{\mathcal{F}}$ it can be expressed as byArrv ~ maxbound[ $\not f$, ά ], If for all ti ≥ 0 and all xi ≥ 0, it holds

$$Prob.\{\underset{0\leq si\leq ti}{\text{supremum}}\ \underset{0\leq ui\leq si}{\text{supremum}}[Arrv(ui,si) - ά\,(si - ui) > xi] \leq \not f(xi)\} \quad (16)$$

*Weak_stochastic_service curvature is belonging to* $\beta'$ *contains* $\mathcal{F}un'$, *the bounded* components of a function are $h$ *belongs to* $\bar{\mathcal{F}}$ denoted by $Si\ \sim weakservice < \ gi, \beta i\ >$ , $\forall ti \geq\ 0 \& \forall xi\ \geq\ 0$, and then the probability is

$$Prob\{Arrv \otimes \beta'(ti) - Dept(ti)]\ greater\ than\ xi\} \\ \leq h(xi)$$

*Service rate curvature* $\eta$ *belonging to* with bounding function *belonging to* , the service of node expresses by $Ser \sim ser\_curve[g', \eta\ ]$, $\forall ti \geq 0$ **&** $\forall xi \geq 0$, then

$$Prob\,\{\underset{0\leq si\leq ti}{\text{supremum}}[Arrv \otimes \eta(si) - Dept(si)] > xi \leq g'(x)\}$$

In an acoustic organization framework, the time length including lost time from its start, when the service queue is full and the appearance rate is higher than the processing rate and it brings about the data loss. A packet (s,t) is a loss period, at that point the measure of misfortune during the time [si, ti],

$$P\{Loss(si,ti) > xi\} = Prob\,\{A_{\_pkt}(si,ti) - D_{\cdot pkt}(si,ti) greater\ than\ (xi)\} \quad (17)$$

The different properties of stochastic analytics for network c, including the stochastic overabundance bound and the stochastic, postpone bound have been constituted.

c. *Model of Acoustic Channel*

The channel representation underwater concerning the acoustic contains the fading effects [17]. The acoustic Channel model is utilized to communicate the double divert model in the bundle level [18]. The Markov Chain is the essential component to measure the activities of the fading channel and it is expressed in Figure 8. The twofold states 0 and 1 are utilized to denote the acoustic divert model at the packet level. 0 noted to the acoustic bundle misfortune or loss and 1 noted to the acoustic data got in the acoustic collector/reception side. This activity constitutes the transmission based on the acoustic is positive or negative.

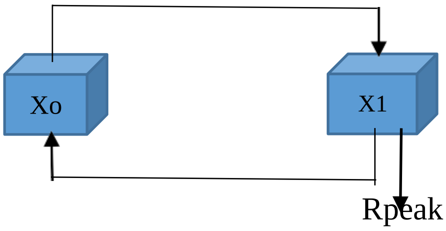


Figure 8. Markov Chain double divert channel Diagram

The MGF of states Markov Chain deals with stationary process Y (ti) concern of continuous-time ti. The states of the above diagram are represented as $X_0$ and $X_1$. The data rate between the Xo and X1 are denoted as $T_a$ and $T_b$. Markov representation in the matrix to evaluate average generation $M_x$ shown as,

$$M_x = \begin{pmatrix} -T_a & T_a \\ T_b & -T_b \end{pmatrix} \quad (18)$$

The homogenous process represented in the Markov chain process is as follows, the MGF is [19],

$$G_x(0, ti) \leq \exp^{\theta i\ \varphi(\theta i) ti} \quad (19)$$

Where $\theta i > 0, ti \geq 0$ and

$$\varphi = \frac{1}{(\theta i)^2}\left(\sqrt{(T_a - T_b + T)^2 + 4T_a T_b - T_a - T_b + T\ \theta i}\right) \quad (20)$$

T denotes the data rate of the process. The acoustic communication channel is represented as 0_Negative and 1_Positive states. These states switch alternatively based on the traffic between the nodes. The traffic rate switch from +ve to -ve is denoted as $T_{ba}$ and traffic rate switch from -ve to +ve is denoted as$T_{ab}$. The average data momentum matrix $K_A$along with Markov representation for the source models with traffic is expressed as [20],

$$K_A = \begin{pmatrix} -T_{ba} & T_{ba} \\ T_{ab} & -T_{ab} \end{pmatrix} \quad (21)$$

The vector of steady-state can be formed as,

$$\kappa_A = [\kappa_{+ve}, \kappa_{-ve}] \text{ are,}$$

$$\kappa_{+ve} = \frac{T_{ba}}{T_{ba} + P_{ab}}$$

$$\kappa_{-ve} = \frac{T_{ab}}{T_{ba} + T_{ab}}$$

The avg. arrival data flow rate is formed as,

$$\mu = \kappa_{+ve} T \quad (22)$$

The data flow rate with maximum bustiness is as follows,

$$\beta A = \frac{1}{T_{ba}} + \frac{1}{T_{ab}} \quad (23)$$

Consider the input and output representation of the system is expressed as $I(ti) \& P(ti)$ with time t1 $0 < ti <$ inf. The acoustic signal channel presents fading is $\varrho(t)$. The signal representation is as follows,

$$P(ti) = ą(ti)X(ti) + \sigma(ti) \quad (24)$$

Where $v = \sigma(ti)$ is the Gaussian form of external noise with an initial value of zero mean and variance. The fading component ą (ti) is initially zero-mean and it is variable during the process when the Gaussian noise is introduced. Channel wrap | ą (ti)| is over the limit level, the acoustic direct is in an acceptable state and if the channel encompasses is underneath the edge level, the acoustic divert is in a terrible state. This channel is quantized as the Rayleigh conveyance channel and the states X0, X1 can be supplanted with Markov chain and base channel states. The acoustic state channel relies upon the transmission rate $R_i$ picked by the transmitter and the acoustic channel limit of the acoustic submerged sensor networks is

$$L(ti) = (CBH) \lg_2 \left(1 + \frac{E|ą(ti)|^2}{N_0 (CBH)}\right) \quad (25)$$

Where E is the energy of the signal and CBH is the channel bandwidth, ᴦ is threshold derived as,

$$r = \sqrt{\frac{N_0(CBH)}{E}\left(2^{\frac{Ri}{(CBH)}} - 1\right)} \quad (26)$$

And the maximum throughput under these assumptions is given as,

$$R\_Pr\{|ą(ti) > r|\} = Ri \exp^{-r2} \quad (27)$$

## 5. ANALYSIS OF PERFORMANCE BOUNDS IN UNDERWATER WIRELESS COMMUNICATION

Let the channel service is self-determining random activity denoted as $Serv(si, ti)$. For $\forall\pi$, the MGF of the channel service is $G_{serv}(-\pi, ti)$.The exodus activity of node is $Dept(0, ti)$ in the server based on the handling rate is,

$$Dept(0, ti) \geq \underset{0 \leq si \leq ti}{infimum}[Arrv(0, si) + Serv(si, ti)] \quad (28)$$

The binary continuous representation of system states with Markov_model with +ve and -ve states [$\forall\ \tau > 0,\ t1 \geq 0$] & Delay_Bound depend on maximum work done $\mu_d$ of the acoustic channel under the delay guarantee is given as,

$$\mu_{del} = \max imum\{\mu | del^{\varepsilon psilon}\mu, D\_B \leq del^{g}\} \quad (29)$$

Where $del^{\varepsilon epsilon}\mu$, D_Bis following first come first serve basis &delay_ bound values derived through stochastic as follows,

$$Del(ti) = \inf imum\{\sigma \text{ greater than } 0: Arrv(0, t1) \leq Dept\ (0, t1 + \sigma)\} \quad (30)$$

Where, σ should be greater than or equal to 0.

if $\mathrm{del}(\mathrm{ti}) > \sigma$, $\mathrm{Arrv}(0, \mathrm{t1}) > Dept(0, \mathrm{t1} + \sigma)$. The process of $\mathrm{del}(\mathrm{ti}) > \sigma$and it belongs to $\{\mathrm{Arrv}(0, \mathrm{ti}) > Dept(0, \mathrm{ti} + \sigma)\}$ *noted as*

$$\mathrm{prob.}\{\mathrm{del}(\mathrm{ti}) > \sigma\} \leq \mathrm{prob.}\{\mathrm{Arrv}(0, \mathrm{ti}) > Dept(0, \mathrm{ti} + \sigma)\} \quad (31)$$

Simplified derivations are,

$$\mathrm{prob.}\{\mathrm{del}(\mathrm{ti}) > \sigma\} \leq \mathrm{prob}\{\mathrm{Arrv}(0, \mathrm{ti}) > Dept(0, \mathrm{ti} + \sigma)\}$$
$$= \mathrm{Prob}\{\mathrm{Arrv}(0, \mathrm{ti}) - \mathrm{Dept}(0, \mathrm{ti} + \sigma) > 0\}$$
$$= \mathrm{prob}\{\underset{0 \leq \mathrm{si} \leq \mathrm{ti}}{\mathrm{supremum}}\{\mathrm{Arrv}(\mathrm{si}, \mathrm{ti}) - \mathrm{Serv}(\mathrm{si}, \mathrm{ti} + \sigma)\} > 0\} \quad (32)$$

The presumption of appearances and the administration are viewed as Freecycle. Then the derivation is,

$$\mathrm{Prob}\{\mathrm{del}(\mathrm{ti}) > \sigma\} \leq \mathrm{prob.}\{\underset{0 \leq \mathrm{si} \leq \mathrm{ti}}{\mathrm{supremum}}\{\mathrm{Arrv}(\mathrm{si}, \mathrm{ti}) - \mathrm{Serv}(\mathrm{si}, \mathrm{ti} + \sigma)\} > Zero\}$$
$$\leq \sum_{\mathrm{si}-\mathrm{o}}^{\mathrm{ti}} \mathrm{R}[\exp^{\theta\mathrm{t}\,(\mathrm{Arrv}(\mathrm{si},\mathrm{ti}) - \theta\mathrm{t}\,\mathrm{Serv}(\mathrm{si},\mathrm{ti}+\sigma))}]$$
$$\leq \sum_{\mathrm{si}=\mathrm{r}}^{\mathrm{inf}} W_{\mathrm{Arv}}(\theta\mathrm{t}, \mathrm{si} - \sigma) \mathrm{W}_{\mathrm{serv}}(\theta\mathrm{t}, \mathrm{si}) \quad (33)$$

The RHS produces an equivalent to ϵpsilon and multiplied with log ln, the acoustic channel delay bound is represented as,

$$\mathrm{del}^{\varepsilon\mathrm{p}}\chi, \mathrm{BD} = \underset{\sigma \geq 0}{\mathrm{infimum}}\left\{\underset{\sigma \geq 0}{\mathrm{inf}}imum\left[\sigma: \frac{1}{\theta\mathrm{t}}\left(\log \ln \sum_{\mathrm{si}=\mathrm{ri}}^{\mathrm{inf}} \mathrm{W}_{\mathrm{Arrv}}\,(\theta\mathrm{t}, \mathrm{si} - \sigma)\,\mathrm{W}_{\mathrm{serv}}(\theta\mathrm{t}, \mathrm{si}) - \mathrm{logln}\,(\epsilon\mathrm{psi})\right) \leq 0\right]\right\}$$

## 6. SIMULATION AND PERFORMANCE BOUNDS

The performance assessment of the inferred numerical models utilizing recreations derived from the stochastic network calculus. The delay bound evaluation using SNC in the environment of Reverbed which simulates the underwater environment. A simulation arrangement for investigating the MAC layer with fading effects in an underwater acoustic network is deployed using nodes along with requirements shown in table 1. Shows the handshaking activities before the establishment of the communication. Initially, all the nodes have to verify whether the node is free or not. If an intended node wants to send any data to the particular node within the signal range, then the node has to send RTS (Request to Send) message exchanged by node B to all nodes within the range. The RTS messages have the MAC address of a node and its circulated to all nodes. Its received by all nodes that the intended Node A will send the CTS (Clear to Send) message for further communication. Other nodes discard the RTS message once its verified the IP. For every successful reception of the message, the ACK Acknowledgment will be shared. The delays occur due to the rigid properties of water. Other typical delays encountered due to the CTS messages from the intended node.

Figure 9. Shows the simulation node setup in the reverbed simulation atmosphere with fifteen nodes. The two halfway hand-off hubs screen the information appearance rate and the administration rate among the hubs. Reverbed is a medium that strengthens remote acoustic signal correspondence. For each pair of communication and channels, the remote transmission preparation can be portrayed by a progression of sub-transmission blocks. These transmission blocks are boundaries whose counts are identified with the remote connection. In particular, for each pair of transmitters and beneficiaries, reverbed paradigms the pipeline transmission stages. At the point when a frame section is prepared to send, the first bundle will consistently be replicated in any event once.

TABLE I
ATTRIBUTES FOR SIMULATION

| | |
|---|---|
| Bandwidth | 40 kHz |
| Power usage | 12W |
| Noise distribution | 5.5 DB |
| Spectrum for carrier | 40 kHz |
| Deployed node Count | 15 |
| Adjournment (delay) | 4s |
| Sim. Time | 30 ms |
| Trans. Time | 6.75 s |
| Distance of communication | 110 m |
| Data size | 1 MB |

The physical layer is displaying the remote beneficiary connections and the transmitter module. MAC layer discussing the allocation and access of the channel in the data link layer. It is isolated into 15 pipeline attributes. To display an acoustic channel, there is a need to change the coding that upholds acoustic channel correspondence. The radio transmitter hub credits and the radio collector ascribe are altered to comparing acoustic transmitter and acoustic recipient hubs. To simulate the acoustic communication channel, alterations should be done in the subsequent phases such that PD, Power, BER, Noise distribution, and channel allocation. Figure 10. Deals with the connection among the Probability of defilement and delay bound. The complete cycle of Simulation observation takes thirty minutes and the delay distribution with defilement probability substantiates the rigidity of the destined. The delay variations were encountered for 20 meters. The handshaking procedure has been followed for scheduled-based MAC with mechanisms of polling, reservation along fading effects.


Figure 9. Node arrangement in the reverbed environment

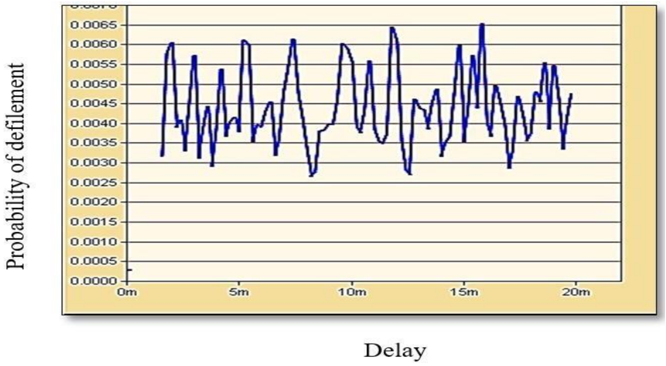


Figure 10. Probability of defilement vs. Delay

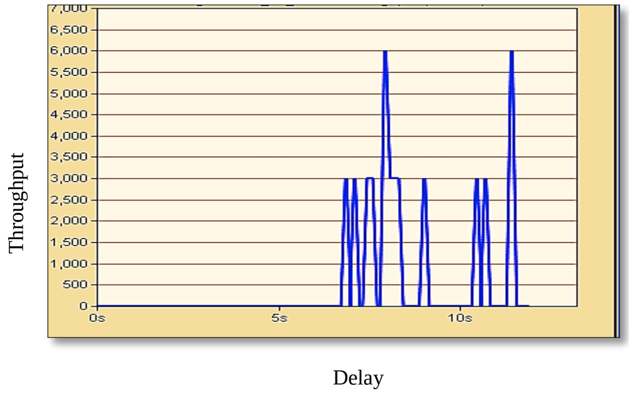


Figure 11. Throughput vs Delay

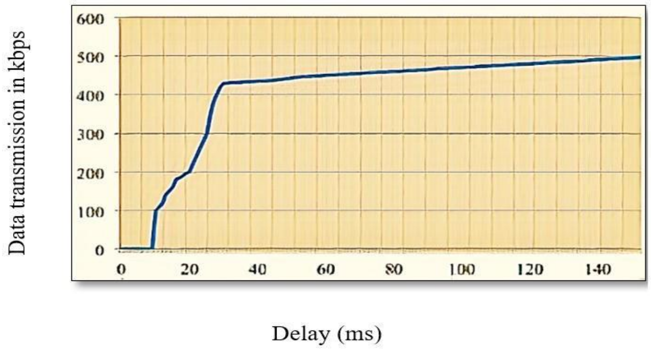


Figure 12. Delay vs Data Transmission

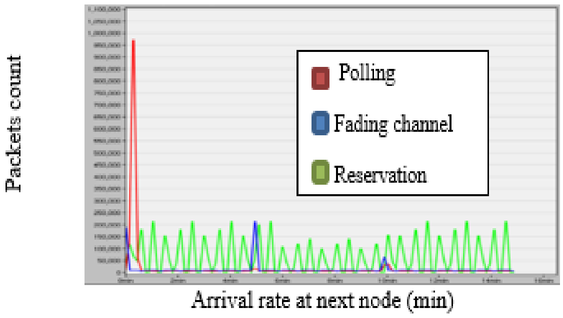


Figure 13. Packet Count vs. Arrival rate of next node

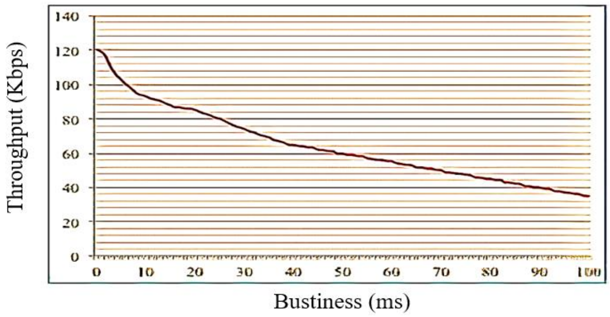


Figure 14. Bustiness vs. Throughput

Figure 11 shows the connection between the throughput and the deferral for a solitary hub. The postponement compelled throughput is determined dependent on the condition from (19) to (25). The interminable entirety in the postpone bound procedure is surrendered (25). The limitless entirety is determined for the initial 1000 units of time and postpones bound infringement likelihood. Overall work done process has been done for scheduled-based MAC along with other mechanisms like polling and reservation. Figure 12. Shows the connection between the postpone ensures on the deferral obliged throughput for various estimations of the defer infringement probabilities. The chart shows that rigid assistance ensures given by lower infringement probabilities will bring about a reduction in the throughput. If the packet counts increase then the delay also gradually increased in the scheduling-based operation. Figure 13. Represents the comparative analysis of various methods with time arrival rate protocols concerning packet count and Arrival Rate. The throughput will increment consistently after a certain point. This is because the appearance rate moves toward the framework limit restricted referenced in the mathematical outcome (23) and (24).

In Figure.15 the connection between the impact of business and the throughput is given. The diagram shows that there is an exponential rot of deferral obliged throughput with bustiness. The end-to-end delay between the SNC model, Scheduled based Mac, and Modified back off time MAC. Our outcomes propose that traditional exhibition measures are not appropriate to depict the throughput furthest reaches of the correspondence networks with postponing delicate sources. As we have demonstrated the postpone obliged throughput to defer infringement probabilities to quantify the traffic conveying limit of the group.

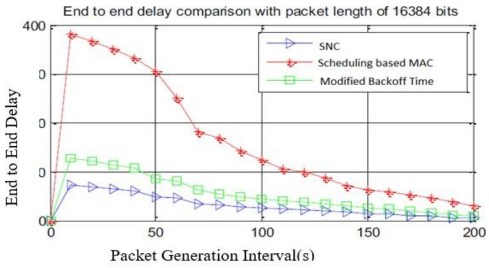


Figure 15. End to end delay vs Packet generation Interval

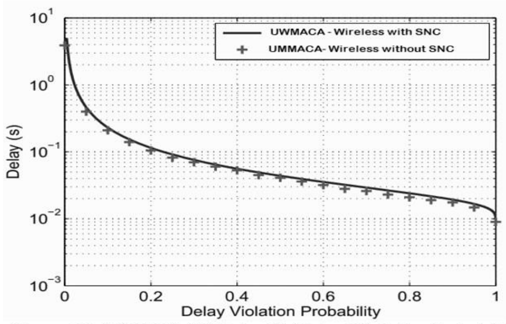


Figure 16. UWMCA-W Delay Vs Delay Violation Probability

Figure 16. Describes the delays in a simulation, where Source sent 1000 packets. From this, the packet deferrals are very dissimilar, unpredictable from 0.01 s to 5 s. Few packets experience high delays due to the distance and delay violation probability. From these simulation results, we can derive the delay bounds with corresponding violation probabilities. UWMACA-W simulated with and without SNC, the deferral rates are 5.19% (1000m), 9.88% (1500m), and 13.5% (2000 m), respectively.

## 7. CONCLUSION

In this exploration work, we have done simulation work for underwater fish forming. For communication purposes, we have presented random access and delay-tolerant MAC protocol (UWMACA-Wireless) to adapt to the ocean environment and avoid collision occurrences. Channel allocation and data transmission occurring with blurring impacts of the acoustic channel utilizing Stochastic Network Calculus. The variation with and without SNC shows the deferral rate between delay concerning delay violation probabilities. The control messages can occur between the devices when the propagation delay occurs during the R-C-D-A. Furthermore, message transfers based upon the neighbor's active timeframes limit the issue of concealed and uncovered nodes.

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