International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-5, March 2020

Stochastic Network Calculus for Delay Variation in UWAN Multichannel Communication

Saravanan M, Rajeev Sukumaran, M.R. Christhuraj, Manikandan TT

Abstract: ***The behavior of underwater acoustic wireless communication is challenging one compared to terrestrial communication due to the unpredictable changes in underwater. The multichannel communication needs to consider a lot of parameters at the time of modeling and investigation such as losses and noise. Thus, communication channel separation is curiously inflexible to investigate all properties of underwater. Compared with other modes of communication, acoustics waves afford the sturdy data delivery and receiving capability in underwater. The channel allocation and detachment appearing quite difficult in acoustic with respect to techniques that induce the transmission of data digitally, which compared with the major properties of attenuation variation in underwater. In this proposal, we concentrate on the numerical results for the transmission and receiver end delay variation with the help of stochastic network calculus to measure the deviation between the simulation and numerical results (SNC) with respect to multichannel(MC).***

Keywords: Stochastic Network Calculus (SNC), Underwater Wireless Acoustic Communication (UWAN), Medium Access Control (MAC), Delay Bound, SNR- Signal Noise Ratio.

I. INTRODUCTION

Research activities are increased in the discovery of new findings to improve the security, minerals finding in an acoustic environment due to security concerns. Many research organizations have deployed sensors, actuators and other communications devices in underwater for making the data transmission. RWN has utilized in earthbound wireless communication but radio signals are not adequate for submerged area ocean level communication. RWN rules and regulations for communication are unsuitable for UWAN due to the flow of data and processing the digital data is different in RWN protocols. The channel allocation in MAC is a complex task that has to satisfy real-time requirements to satisfy the pedagogy challenges, especially absorption, Doppler effects, propagation delays, speed of the signal, lower capacity of the channel, low channel quality and etc. High variation in delay (transmission/receiver) is an important factor that forcefully pulls down the performance of underwater areas.

Due to uncertainty in underwater, the characteristics always changeable. Characteristics of underwater such as the utilization of channel, medium, energy preservation and conservation for node efficiency, selection of protocol based on the situation to implement, QoS, mobility, and validation of protocol. The UWCN applications need to improve the quality and security such as environmental studies related to natural hazards, communication-related activities for marine, scientific research towards the mines, water content quality monitoring, finding oil resources and gas refinery resources availability, scientific applications, bottom image scanning and AUV communication for anomaly object identification.

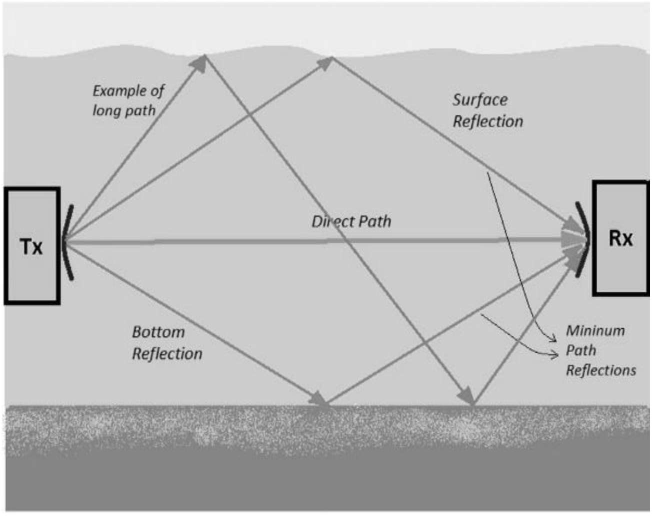

Figure 1. View of multipath communication in Underwater

Fig. 1 indicate the correspondence between the Tx and the recipient through various channels. The correspondence channels are differing dependent on the reflections. The underwater wireless acoustic correspondence framework is a two-way correspondence framework in which advanced information is changed over into a unique underwater sound signal [1]. At that point, these signals are gotten by another station and afterward changed over back to advanced information. This correspondence is done in the multipath proliferation of underwater wireless acoustic signals. As appeared in figure 1.1, underwater wireless correspondence comprises a transceiver with radio sensors appended to them. We can transmit EM or acoustic wave however acoustics is the principle decision as it gives better outcomes and better range. Because of attenuation, the transmitted signal transmits in a type of multipath.

Revised Manuscript Received on March 30, 2020.
* Correspondence Author
***Saravanan. M**, Research Scholar, CSE, SRM IST, Kattankulathur (Chennai), India.
Rajeev Sukumaran*, SRM-CARE, SRMIST, Kattankulathur (Chennai), India.
M.R.Christhuraj, CSE, SRMIST, Kattankulathur (Chennai), India
T.T. Manikandan, CSE, SRMIST, Kattankulathur (Chennai), India

II. RELATED WORK

Generally, Network calculus gives an idea about the systematic way of the design of networks and its numerical calculations, planning, and asset necessities. SNC is an extended version of network calculus for execution and investigation of properties which helps to analyze the different aspects of WSNs by a few specialists [22]. The network calculus [23] helps to analyze different flow designs of the networks along with topology. The tree-structured sensor networks have demonstrated and its optimistic scenario illustrated with sensor_networks. It focused on the delivery of streams with different limits, BW, tree structure mapped properties. The creators exhibited techniques to process the pessimistic delay scenario, memory-related to general-purpose register for buffering necessities [10]. SNC illustrates the capability of processing and arriving bits experienced knowledge helps to analyze the results in randomness in stochastic for packet size based networks.

The idea of probabilistic boundary values with respect to the bound values are drawn through the curvature values[24]. The curvature graphical representation is used to shows the variation of the processed streams. The DNC will give the static outcome related analysis results and SNC extended the features of DNC and included the randomness analyzed properties and bounds for the entire network outcome deviation occurred along with the bits and delayed activities which can reduce the current innovations. Christ [3] et al. proposed different fading techniques using SNC for packet loss over the acoustic medium. The server framework to encourage investigation and solicitation of the issues in the channel allocation, data faded with different terminologies measured in through SNC. There are many research article gives the idea about the theoretical needs of acoustic communication, however, not many of them discussed the simulation and mathematically derived results to map the issue with the rationale to all types of wireless communication.

III. MODELING MULTI-CHANNEL PROPAGATION

A. Multi-Channel design with SNC for UWN

UWN communication is possible with long-distance when the signal is transmitted as acoustic signals compared to other methodologies. Fig 2. Illustrate the propagation of acoustic signals in a different path and different channels. This model demonstrates the signal in the form of acoustic flow from one end to another communication device with multichannel support. The data is converted as a digital wave then it is given to a sound wave signal converter, then the data sent by the Tx to the multipath propagation or multi-channel communication from (Tx to Rx) from the source. The traffic flow may be generated with variable size of the datagrams originated to multipath traffic flow occurs in multi-dimension with respect to propagation, reflection, and fading. Finally, the Rx receiver gets the low powered signal after long propagation in a different path with different time duration or time to live values. Rx will deposit all received signals in-memory buffer for later analysis. The analysis includes the bits verification and duplication removal of data from a different path. Finally, it removes the duplication data by sequence values, if there is any data loss or sequence number is missing then it sends the negative ACK to resend the data's in a fast retransmission manner. These activities in terrestrial activities are hard to compare but the analytical comparison will help the researchers to enrich the quality transmission in the underwater asynchronous communication.

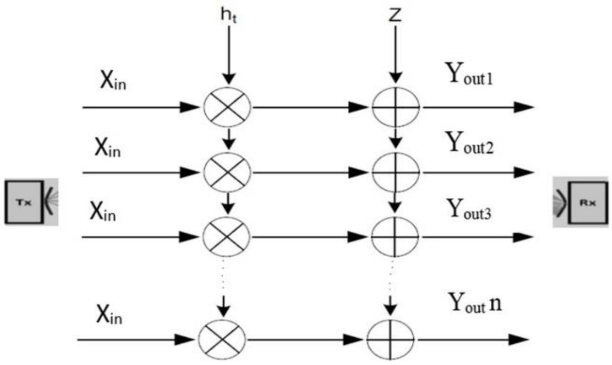

Fig 2: System model of multichannel with fading

The above fig 2. shows the multi-channel with the discrete flow with fading in Eqn. (1) & (2) by,

Output Y for single-channel is derived from the channel amplitude and uniform distributed input from Tx added with uniformly distributed Gaussian noise. That can be written as Y(single channel output)=[Amp] x [uniformly distributed input* channel gain] + Gaussian Noise

$Y_{(sco)} = |Ap\__{t}|\, e^{j\epsilon}\ TX_{in} + Gn$ (1)

For multi chaanel design, the output can written as

$Y_{(multi\ channel\ output)} = \{ Y_{1(sco)}\ \grave{U}\ Y_{2(sco)}\ \grave{U}\ \ldots..\ \grave{U}\ Y_{n(sco)} \}$

$Y_{(mco)} = |Ap\__{tn}|\, e^{j\epsilon}\ TX_{in} + Gn$ (2)

Where TX_{in} is denoted as input generated by Transmitter T_x, $Y_{(mco)}$ is denoted as output received by receiver R_x. Gn is Gaussian noise with uniformly distributed. $[Ap\__{tn}]e^{j\epsilon}$ is the gain value of the channel with amplitude $[Ap\__{t}]$ which is a dynamic generated g=during running time and ϵ is UD_phase interval of 0 to 2π. Sometimes $|Ap\__{tn}|$ denoted as |Rtn|

Assumptions for this model:

1. data distribution as a sound wave is carried out by both Tx and Rx.
2. intermediate device can record the state of information and can view the state information
3. data propagation in multi-channel faced slow fading
4. The signal can be transmitted in different paths within the available bandwidth, For this demonstration in the simulation, we considered the model P_{tx} is the required power for successful transmission and reception, BW is used to mention the bandwidth and N_0 is expressing density of the power variation noise. The cumulative capacity which derived for a channel can be calculated in Eqn. (3).

$$C = W\ \log_2(1 + 10^{\gamma t/10}) \qquad (3)$$

The Rayleigh Fading (FR) occurs during the transmission capacity derived for the channel in Eqn. (4)

$$C = Wn\ \log 2\left(1 + \frac{P_{tx}|Rtn|^2}{WN_0}\right) \qquad (4)$$

The SNR value is not introduced in the initial transmission. But it can be introduced in the number of trains and the analytical process completed, then it will be introduced during the number of cycle processed transmission.

The multi-channel with FR fading can be derived in Eqn. (5) as,

Prob. O/P =Prob.{Channel Capacity < Traffic Flow Data Rate(R)}

$$= Prob.\{W \log_2 (1+\frac{(Ptx|APtn|^2)}{No}*W) < Traffic\ Flow\ \ Data\ Rate(R)\} \quad (5)$$

Gain value for the different transmission in the multi-channel can be recorded F(x). it has pdf with FR fade denoted int (Eqn. (6))

$$F(x) = x * exponential\ (-x^2/2) \quad (6)$$

the density function for the equation 6 is expressed in the eqn.7

$$Density\ fun\ DF(x) = (0.5)\ exponential\ (-x/2) \quad (7)$$

the probability of output is derived and analyzed with the following Eqn. (8) as follows,

$$Prob.O/P=1-exp(\frac{1-2^{(\frac{datarate}{Bandwidth})}}{2*10^{(\frac{signalnoiseratio}{10})}}) \quad (8)$$

B.SSC service-related stochastic curve scheming

the design of different paths in the communication medium can be recorded as capability CH ={CH_1 V CH_2 V ….CHn} is dynamically distributed, DSC is convergence with the outcomes of the predefined trained I/P and O/P. the stochastic calculation is used to obtain the randomness of multi-channel properties used for the deviation calculation. Transmission rate (R) and error function € possible to derive the stochastic service curve. The multi-channel SSC is denoted as (δ(t) , €) expressed in Eqn. (9) with respect to FR characteristics, Where

$$\delta(t) = \sum_{q=1}^{q=n} \delta q(t)$$

$$€(R) = 1 - expon\,(1 - \frac{2^{\frac{R}{W}}}{(2*signal_{Noise_{Ratio}})}) \quad (9)$$

The EPF (err.Prob.fun) € expresses the upper limit and lower limit of the channel boundary limitation probability of MC. It strictly sick with the condition that the probability of data can not be lesser than the estimated value of €(R). R can be fixed by a technique used in the modulation of the transmitter.

IV. SNC FOR DELAY IN ARRIVAL PROCESS

This segment represents Infimum and supremum of the arrival bound limits and delays bound. Let the arrival of data from the source can assume as Arr(time)is tightly coupled by deterministic δ(t) curve.

Delay constraint bound: multi-channel communication acoustic medium is shown in section 2. SSC for the multichannel network N as (δ(t), €) for any time del >=0. The probability of delay bound can be written as DB(t) is expressed in Eqn. 10.

Prob{delay bound DB(t) > di}≤g(€(di))

where

Prob{ delay bound DB (t) > di}

$\leq$ P rob{Arr(t) – Del (t_i + di) > 0}

$\leq$ P rob{ $Supr_{(0<Ser<ti+d)}$ {Arr (ser, t_i) – € (ser, t_i + d_i)}

+ Arr x € (t_i + d_i) – Del (t_i + d_i) > 0}

$\leq$ P rob{$Supr_{(0<Ser<ti+d)}$ {recv(ser, t_i) – € (ser, t_i + d_i)}

+ Arr x € (t_i + d_i) – Del (t_i + d_i) > 0}

=P rob{Arr x € (t_i + d_i) – Del (t + d_i) > € (d_i)}

$\leq$ g(€ (d_i))

P rob{delay bound DB(t) > d} $\leq$ g(€(d_i))

DB(t) = $Maximum_{(1<No<r)}$Db(N_o,ceil(N_i*vioProb)) (10)

V. SIMULATION AND SNC RESULTS

This segment expresses the outcomes of simulated and SNC results. We used simulations and associated numerical results for evaluating the tight bond between the simulated outcomes and SNC outcome. For this evaluation, we considered a few parameters like bandwidth, SNR, frame size and simulation Period. The bandwidth value is W=30, the communication channel noise value is 0 dB, the frame size for every cycle is 1 kilobit. This range fixed for simulation is 40 runs with respect to the distinguished inputs. The source system generates an input packet per cycle. Every simulation takes is 10000 cycles. The Delay value registered for future jitter value calculation. For the above factors, the system cant calculates the error/ violation probability directly. So it needs to calculate the violation probability be encountering the differences in delays of every packet received at the receiver end.

The contribution towards this research compares the outcomes derived from the simulation, then it has to be mapped with delay bound values. Delay-bound value calculation takes no.of cycles completed runs is Ri=40 and packets count is Ni=10000; every packet has to be sent as proceeding with one per cycle. The DEL(No, S) where N_o is the input packets count has to be sent per one cycle execution. That is No=1,2….n; S denotes the simulation count (S=1,2,…..,m).

Let m = 40 is the no. of execution, and n = 10000 is the no. of packets can be transmitted in a single cycle with one sim_ run. Let d (i, j) where (1<=i <= m; 1<=j<= n) where i denotes no. of runs and j denote the delay. The calculation part shoes the descending order results with violation probabilities €(R). the delay_bound value can be derived from the Eqn. (10). Sample delay bound calculation is obtained from the Eqn. (9) and Eqn. (10). Let the sample €(3) = 0.1 , The delay bound value is, DEL(3) = $Maximum_{(1<No<r)}$Db(N_o,10000 * 0.1)

The arrival curve can be recorded through the curvature model equation arr_α(t) = data_rate_t + b, with b = constant (1 kb).

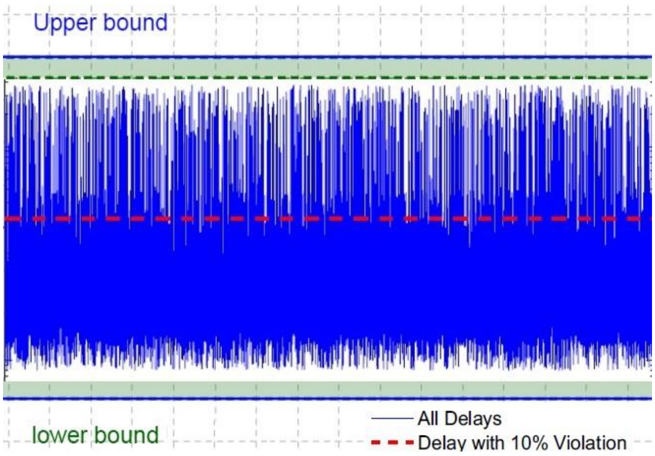

Fig. 3. Simulation: delay, Infimum bound and Supremum Bound

The above Fig.3 shows the simulation results with the packet transmission including 1000 packets in one complete transmission.

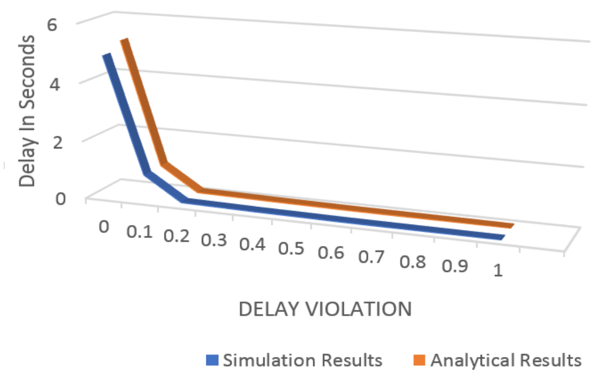

Fig. 4. Comparison of simulation and analytical results.

The delay of the packet transmission bounded between 0.013 seconds to 5.5 seconds, which is expressed in Fig. 4. The equation-10 helps to derive the analytical results for the delay bound values of the arrival packets. The outcomes induce to compare with simulated results show the heterogeneous outcomes. We got the differences between the simulated and analytical is 6.01% as the minimum difference and 15.4 % is the maximum difference for multichannel communication. This comparative analysis concludes the tight bound delay performance which derived by both simulation and analytical.

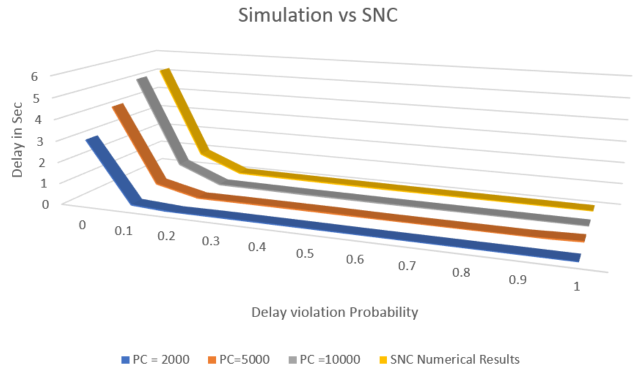

Fig. 5. Comparison of simulation and analytical results for various packet counts

The min & max delay variation can be encountered through the simulation and analytical outcomes with respect to underwater multi-channel communication have illustrated in Fig. 4 and Fig. 5. The different input packet count has taken for comparison results as 2000 packets, 5000 packets, and 10000 packets respectively. The avg. delay-variation between simulation and SNC analytical are encountered 8.75% & 15.9% respectively. The closely bounded value of delay bound in the arrival of packets is derived from the SNC. The SNC produces the best optimized tight bound values for both simulation and analytical results.

VI. CONCLUSION

In this model, we intend a scheme for modeling the delay bound variation in underwater wireless acoustic multi-channel communication. The uncertainty is a key challenge to analyze the characteristics of the underwater with fading in multi-channels. Mathematical model SNC is used to derive the model for delay bound variation calculation between simulation and mathematical model of an underwater wireless network with multichannel including FR fading. The comparison results of SNC and simulation gives the difference 8-12% variation and identify delay bound calculation. Future work, we would like to focus on modeling underwater wireless network with backlog value for multichannel for different types of data loss and data fading.

REFERENCES

1. Shengming Jiang, “SOA MAC Protocols for WAN: A Survey”, IEEE Comm, vol. 20. 2018
2. Eunbae et al. “p-BORE: Priori. Beacon_Repetition and CWS Based MAC Prot. in UWSN”. ICUFN, IEEE; 2017.
3. Christhuraj, Rajeev. “Stochastic Network Calculus for various Fading techniques in Underwater Wireless Communication”. Int. Jour. of Applied Math.and Stat., pp.0973-7545, 2016.
4. Markus Fidler, “A Guide to the Stochastic Network Calculus”, IEEE communication surveys & tutorials, vol. 17, no. 1, first quarter 2015
5. Xia Li, Dongxue Zhao, “Capacity Research in Cluster-Based Underwater Wireless Sensor Networks Based on Stochastic Geometry”, China Communications, June 2017
6. Huihui Zhang, “On Integrated Stochastic Channel Model for Underwater Optical Wireless Communications”, IEEE, 2018
7. C. Li et al., “FDCA: MAC_protocol for UWAN.”, IEEE Sensors Jour., pp.4638–4647, Jun. 2016.
8. Jiang et al., “A ref. model for MAC-prot. in UWAN”, Proceedings of the ACM Int. Conf. Underwater Network. Systems; Arlington, VA, USA, Oct. 2015.
9. Yang,Gao,Foh,J. F. Cai., “Hybrid collision-free MAC protocol for UWAN: Desn. and perf. Eval.”, IEEE Jour. Ocean. Engg., pp. 292–302, 2015;
10. Hu, Fei., “DSH-MAC based on decoupled and suppressed_handshaking for long_delay UWAN.”, Proceeding of IEEE Confer. Local Comp. Net, Australia, oct.2013.
11. Hsu, Kuo, Chou, Lin., “The elimination of ST uncertainty in UWAN”, IEEE Transac., pp. 1229–1242, Aug.2013.
12. Domingo, “An overview of the IOUT.”, J. Network. Comp. Appl., pp.1879–1890, 2012.
13. Preisig, “Acoustic propagation considerations for UWAN development”, WUW_Networks, 2006.
14. Etter., “UW-Acoustic Models Principles Techniques and Appln.”, 1996.
15. Catipovic., “Perf. limits in UW-acoustic Telemetry.”,IEEE Jour. Ocean. Engg. , pp. 205–216, 1990.
16. Kredo, Djukic, Mohapatra. Exploiting position diversity in the staggered TDMA UWN-MAC. IEEE infor.comm., pp.2961–2965, 2009.
17. Akyildiz, Pompili, “Melodia. Challenges for efficient Comm. in UWAN.”, ACM, pp.3–8, 2008.
18. Z. Li et al., “UD-TDMA: A dist. TDMA prot. UWAN”, Proc.of IEEE Inter. Conf. Mobile Adhoc-Sensor Sysm.; China, Oct. 2009.
19. Lin,Li, Chen, Sun, Wang., “A wave-like amendment_based TDMA slot allocn. mechanism for UWAN”, CyberC, Zhangijajie, pp.369–374, Oct. 2009.

AUTHORS PROFILE

M.Saravanan is a research scholar in SRMIST Chennai and received Bachelor's and Master's degrees in CSE from Anna University, Tamilnadu. Currently working in SRM Center for Applied in Research and Education, SRMIST, Chennai, India.

Rajeev Sukumaran is an Engineering Epistemologist and a Learning Researcher. He received his Ph.D in Computer Engineering and is an active researcher in Modeling Wireless Communication Networks and is with the Teaching Learning Centre, Indian Institute of Technology Madras, Chennai, India.

Christhu Raj is an enthusiastic researcher in Stochastic Network Calculus Models for Underwater Wireless Communication. He received his Ph.D. in CSE and is an active researcher. Currently working in SRM Center for Applied in Research and Education, SRMIST, Chennai.

Manikandan T T received a B.Tech in Computer Science and Engineering from SASTRA University, ME in Computer Science and Engineering from College of Engineering, Anna University and he is currently perusing Ph.D. in Computer Science and Engineering at SRM Institute of Science and Technology.