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Modeling Nakagami Fading channel in Underwater wireless sensor network using Stochastic Network Calculus

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***Abstract:** Underwater acoustic communication is growing famously day to day because of its important in many applications like offshore search, underwater search. In UWNS while signal is transmitting source to destination the signals are suspected by fading and noise. The QoS guarantees like small backlog, low packet delay are need to be in good condition for Real-time applications. Important role of this designing is Performance evaluation. Analytical models constructed by using (a) queuing theory, (b) effective bandwidth, and (c) deterministic network calculus. These were not adequate to sustain and assess the present packet switched networks. Stochastic Network Calculus is the solution for these issues. The SNC tool can be used to model and network performance assessment, especially for UWSN. In this paper, we have developed an underwater acoustic channel that is subjected to Nakagami fading channel based on SNC to arrive at Stochastic Arrival Curve and Stochastic Service Curve. Backlog bound and delay bounds stochastic performance are derived by using this model.*

***Keywords:** Backlog, Delay, Deterministic Network Calculus, Effective Bandwidth, Nakagami Fading, Queuing theory Stochastic Network Calculus, Underwater acoustics.*

I. INTRODUCTION

Acoustic signal is the medium which is used in acoustic wireless communication. There are three different types of mediums are used for wireless communication 1.Electromagnetic 2.ligh wave 3. Sound wave. The electromagnetic waves are used for minimum distance range communication only, because of its more attenuation and absorption effect. [1]. In the acoustic communication depends upon the multipath, path loss, doppler spread, propagation delay, noise [2]. The acoustic channel bandwidth is limited and it deponds upon the frequency and range. In acoustic communication the multipath fading is one of the common case This is due to a combination of constructive and destructive mixtures that have a number of paths obtained by random disparities and delays. The transmitted sound waves are disturbed by this fading. It also makes short-term signal variations. For defining statistical attitude of this case many models are referred. These are Rayleigh Fading model [3], Rician Fading Model [4], Nakagami Fading Model [5], Gilbert-Elliot Model [6], and Weibull Model [7]. Nakagami channel model is a common distribution, it can be model various fading situations. It has a much high flexibility and correctness in matching some testing data than the Rayleigh, Rician Distributions [8]. Nakagami fading is a more general fading model and whose parameters can be set to several different types of channel models.

Modeling any channel must consider the mathematical component in its simulation results. The research community is in need of modeling acoustic channels with appropriate mathematical tools Modern voice and video networks are seeking an exponential growth, and analyzing its performance guarantees is an uphill task. In-order to address modern networks, new analytical models are needed to analyze the performance and Stochastic Network Calculus is one such tool that addresses the performance evaluation of modern networks. Here we present the Mathematical model to UWA Nakagami fading channel by using mathematical tool(SNC). It was found that mathematical tools play an important role in modeling fading in acoustic communication networks. Presently to the author's knowledge, there is no model for acoustic Nakagami fading using SNC. This paper addresses the above issue by effectively constructing a model for Nakagami channel in acoustic communication using SNC. There are some of the mathematical techniques are avail but these are not adequate for packet switched networks. DNC, Queuing theory, effective capacity, effective bandwidth are the techniques. Constructing an appropriate mathematical model for acoustic fading communications is very crucial for evaluating the performance of acoustic networks. The significance of this research work is in creating mathematical model by using the SNC. It can be construct to model fading (Nakagami) in acoustic communication. And then this model is developed, deployed and simulated. SAC – stochastic arrival curve, SSC – stochastic service curve are analyzed by using this simulated model. This simulated model helps in analyzing the SAC and the SSC. The key purpose of these results are to derive

(a) PB – Performance bound

(b) SAC – Stochastic arrival curve

(c) SSC - Stochastic service curve, these are gives the guidelines to design the various transmission strategies in underwater acoustic communication

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We have found that SAC and SSC is vital is modeling the arrival and service process of the networks. This research has provided substantial analysis for underwater researchers in the field of designing and modeling fading in acoustic networks using stochastic network calculus. Presently there are no practical research findings that combine the SNC with acoustic communications; this article will provide fundamentals for the researchers working under mathematical modeling of acoustic physical layer communications using SNC. Form the mathematical and simulation result we can checks the tightness of the bound. The delay and backlog bounds of stochastic performance for underwater acoustic Nakagami fading are we can derived from this result.

II. STOCHASTIC NETWORK CALCULUS EVALUATION

A. Queuing Theory

The very first paper an queuing theory is published on 1909 by Erlang A.k[9]. After publishing his work Queuing theory gained much attention in performance evaluation and started applying in a wide variety of applications. Queuing theory commonly concerns about the mean quantities in stability at a stable state. In a stable state, the mean of quantities in equilibrium is typically concentrated on queuing theory. The customer inter arrival time is the service arrival process and customer service time is the service process. Mainly the queuing theory applied for circuit switch networks. The incoming packets are basically driven by the Poisson process similarly the size of packets by an exponential distribution, but with modern networks with increasing algorithms, applications, service expectations, user heterogeneity, queuing theory were found inapplicable to address the above issues. Modern networks were based on packet switched networks and queuing theory was able to address the issues in circuit switched networks. By this reason we get the motivation to develop a new model for packet switch network.

B. Markov-Modulated Fluid (MMF Model)

The perfect solution is derived by using markov – models for the probability of buffer overflow in a node fed by statistically independent flows[10]. In packet switched networks the main advantage is Statistical Multiplexing applied for voice sources and video sources are depends upon MMF Model. A fluid traffic model gives with packet notion and also it classified in the situation where the no of packet is highly comparative to a selection time scale. The MMPP is one of the model to analyze the bursty traffic. These two models are based on Markov Chain Model. The limitation of these models is that statistical multiplexing in packet switched networks cannot be captured accurately. This led to the research community need of a new mathematical tool for network performance analysis.

C. Effective Bandwidth

Effective Bandwidth was introduced around 1990 by Hui [11], this is motivated from requirement of resources allocation in packet switched network. Effective bandwidth is the traffic model. It has attractive properties; by these properties analysis of statistical multiplexing is easily exploited. The aggregated flow effective bandwidth is get from the sum of every flows. However Effective bandwidth was used for resource allocation for packet-switched networks and it failed in capturing statistical multiplexing. Moreover among these flows the dissimilar flows have dissimilar Qos necessities and alow arrangement. These flows aren't first in first out. Effective capacity model was reconstructed to overcome this issue for server model, but however applying effective capacity in real-time networks remained a major challenge.

D. Deterministic Network Calculus

A new approach was recomented by cruz for delay and backlog analyzing in network[15].This approach was proposed early 1990's. Network performance analysis is governed by network calculus by two decades. It is the two different tracks.

(1) - DNC (Deterministic Network Calculus)
(2) - SNC (Stochastic Network Calculus)

In DNC the process arrival and process services are derived with service curve and envelop functions. It was initially developed for worst-case analysis. In the cumulative data traffic in a time gap arrival curve is uses an upper bound this also called by envelop function. The summary of lot of DNC results shown [12]. Similarly service curve uses a service lower bound. In a particular time gap server system gives the cumulative number of services. We cannot accurately calculate the statistical properties of process arrivals by using dnc,that is the limitation of DNC. From the deterministic service and arrival curve the DNC analysis the worst case performance the acoustic underwater worst case performance can extent from this .The deterministic performance bound is very complicate and impossible become the underwater acoustic curve is unstable.

E. Stochastic Network Calculus

SNC tool used to design the acoustic network for give stochastic service guarantee. Because of time varying nature the fading channel have only stochastic service guarantee in underwater acoustic network. The arrival curve model extends to the probabilistic derivation of DNC. Similarly the service similarly service curve model is extended to the probabilistic derivation of DNC. These are called SAC and SSC. The server and traffic models of network calculus are satisfied to the concatenation property, service guarantees, and superposition property output characterization. In random (stochastic) service warrantees of packet networks, the SNC has the potential applications. The idea of SSC has been introduced as the possibility bound on the service getting by single flow or accumulated flow. Stochastic end to end delay and backlog bounds are can be calculate by network service formulation using stochastic network calculus. The internet work and our proposed model performance will be analyzed by this mathematical tool SNC.

III. BASIC NOTATIONS OF STOCHASTIC NETWORK CALCULUS

A. Basic Notations

Commonly the Queuing theory is the origin of SNC. The concept of SNC and its basic notations are addressed in this session.

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A(t)	Arrival (incoming) process
A*(t)	Departure process
S(t)	Amount of service supply by the network
I(t)	Impairment process

Suppose every process are non negative process and escalating functions by convene $t=0$, i.e., $A(0)=A^*(0)=S(0)=I(0)=0.$ For any $0 \le s \le t$, Let $A(s,t) \equiv A(t)\text{-}A(s), A^*(s,t) \equiv A^*(t)\text{-}A^*(s)$, and $S(s,t) \equiv S(t)\text{-}S(s)$ and $I(s,t) \equiv I(t)\text{-}I(s)$. By default, $A(0)=A^*(0)=S(0)=0$. We expressed by $\mathcal{F}$ the amount of positive wide-sensing growing functions, and $\bar{\mathcal{F}}$ the amount of positive wide-sensing declining functions, i.e.,

$$\mathcal{F}=\{f(.): \forall 0 \le x \le y, 0 \le f(x) \le f(y)\}$$

$$\bar{\mathcal{F}}=\{f(.): \forall 0 \le x \le y, 0 \le f(y) \le f(x)\}$$

The distribution function of X (X - random variable) is expressed by $F_X(x) \equiv Prob\{X \le x\}$ be suited to $\mathcal{F}$, and its balancing distribution function, $\bar{\mathcal{F}}_X(x) \equiv Prob\{X > x\}$, be suited to $\bar{\mathcal{F}}$ we have to give sustainable needs on the bounding functions for model the transform , expressed by $\bar{\mathcal{G}}$ the amount of functions in $\bar{\mathcal{F}}$ Where, for each function $g(.) \in \bar{\mathcal{G}}$, its nth-fold integration is bounded for any $x \ge 0$ and still be suited to $\bar{\mathcal{G}}$ for any $n \ge 0$, i.e.,

$$\bar{\mathcal{G}}=\left\{g(.): \forall n \ge 0, \left(\int_x^\infty dy\right)^n g(y) \in \bar{\mathcal{G}}\right\} \quad (1)$$

B. Operators in Stochastic Network Calculus

The bellow actions are described from the $(\min,+)$algebra and it can used in this work: The $(\min,+)$, *convolution* of function f and g is

$$(f \otimes g)(x)=\inf_{0 \le y \le x}[f(y)+g(x\text{-}y)]$$

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

$$\textbf{C.}\quad (f \oslash g)(t) \equiv \sup_{s \ge 0}\{f(t+s)\text{-}g(s)\}$$

also assume:$[x]^+ \equiv \min\{x,0\}, [x]_1 \equiv \min\{x,1\}$

The *statistical minimum* of f and g is

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

The *statistical maximum* of function f and g is

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

Add to this, the independent case analysis is need to the normal convolution:

For f and g

The *normal convolution* is,

$$(f * g)(x)=\int_0^x f(x\text{-}y)dg(y) \quad (2)$$

D. Performance Metrics, Traffic and Server Models

Service assurance Analysis below Network Calculus, the following activities are of interest:

$B(t)$ - backlog, in the time t is described as:

$$B(t)=A(t)\text{-}A^*(t). \quad (3)$$

$D(t)$ - Delay at time t is described as:

$$D(t)=\inf\{\tau \ge 0: A(t) \le A^*(t+\tau)\} \quad (4)$$

The main idea of STAC and SSC are there in SNC. The various explanation of SAC and SSC. For the traffic arrival models,

Definition 1: T.A.C - (traffic amount centric)

Suppose the flow $A(t)$ is told it has the *traffic-amount-centric* SAC $\alpha \in \mathcal{F}$ with bounding function $f \in \bar{\mathcal{F}}$, expressed by:

$A \sim ta < f, \alpha >$,

If for all $t \ge 0$ and $x \ge 0$, it holds

$$Prob\{A(s,t)\text{-}\alpha(t\text{-}s) > x\} \le f(x) \quad (5)$$

Definition 2: V.B.C(virtual-backlog-centric)

Suppose the flow $A(t)$ is said to have a virtual-backlog-centric SAC $\alpha \in \mathcal{F}$ with bounding function $f \in \bar{\mathcal{F}}$, expressed by $A \sim vb < f, \alpha >$,

if for all $t \ge 0$ and all $x \ge 0$, it holds

$$P\left\{\sup_{0 \le s \le t}[A(s,t)\text{-}\alpha(t\text{-}s)] > x\right\} \le f(x)$$

Definition 3: M.B.C (max-virtual-backlog-centric)

Suppose the flow $A(t)$ is said to have a maximum-virtual-backlog-centric SA $\alpha \in \mathcal{F}$ with bounding function $f \in \bar{\mathcal{F}}$, expressed by $A \sim mb < f, \alpha >$, if for all $t \ge 0$and all $x \ge 0$,

$$Prob\left\{\sup_{0 \le s \le t}\sup_{0 \le u \le s}[A(u,s)\text{-}\alpha(s\text{-}u) > x] \le f(x)\right\}$$

Definition 4: W.S (Weak stochastic model)

WSSC (Weak stochastic service curve).

Suppose the server confer a flow $A(t)$with a *weak stochastic service curve* $\beta \in \mathcal{F}$ with bounding function $g \in \bar{\mathcal{F}}$, expressed by $S \sim ws < g, \beta >$ if for all $t \ge 0$ and all $x \ge 0$,

$$Prob\{A \otimes \beta(t)\text{-}A^*(t)] > x\} \le g(x)$$

Definition 5: SSC (Stochastic service curve)

Suppose the server confer a flow$A(t)$with SSC $\beta \in \mathcal{F}$ with bounding function $g \in \bar{\mathcal{F}}$, expressed by $S \sim sc < g, \beta >$, if for all $t \ge 0$and all $x \ge 0$, it holds

$$Prob\left\{\sup_{0 \le s \le t}[A \otimes \beta(s)\text{-}A^*(s)] > x \le g(x)\right\}$$

Definition 6: SSSC (strict stochastic service curve)

Suppose the server confer a SSSC $\beta \in \mathcal{F}$ with bounding function $g \in \bar{\mathcal{F}}$, denoted by $S \sim ssc < g, \beta >$ when time $(s,t)$the total service $S(s,t)$ gives by the server satisfies

$$Prob\{S(s,t) < \beta(t\text{-}s)\text{-}x\} \le g(x)$$

By this explanations, thestochastic network calculus properties (with stochastic delay and backlog bound). The complete dioid $(\mathcal{F}, \wedge, \otimes)$ is proved, this is defined and in Lemma 1 listed all the properties.

Lemma 1. $(\mathcal{F}, \wedge, \otimes)$is a complete dioid having properties:

S No	Properties	Notation
1	Commutativity	$\forall f, g \in \bar{\mathcal{F}}, f \wedge g = g \wedge f;\ f \otimes g = g \otimes f$
2	Idempotency of addition	$\forall f \in \bar{\mathcal{F}}, f \wedge f = f$
3	Closure property	$\forall f, g \in \bar{\mathcal{F}}, f \wedge g \in \bar{\mathcal{F}}; f \otimes g \in \bar{\mathcal{F}}$
4	Associativity	$\forall f, g \in \bar{\mathcal{F}}, (f \wedge g) \wedge h = f \wedge (g \wedge h)$; $(f \otimes g) \otimes h = f \otimes (g \otimes h)$
5	Zero element	$\forall f \in \bar{\mathcal{F}}, f \wedge \bar{\epsilon} = f.$
6	Identity Element	$\forall f \in \bar{\mathcal{F}}, f \otimes \bar{e} = \bar{e} \otimes f = f$
7	Distributivity	$\forall f, g \in \bar{\mathcal{F}}, (f \wedge g) \otimes h = (f \otimes h) \wedge (g \otimes h)$
8	Absorbing zero element	$\forall f \in \bar{\mathcal{F}}, f \otimes \bar{\epsilon} = \bar{\epsilon} \otimes f = \bar{\epsilon}$

In added with followings we have ,

Lemma 2. $\forall f_1, f_2, g_1, g_2 \in \bar{\mathcal{F}},$

Comparison	$f_1 \wedge f_2 \leq f_1 \vee f_2 \leq f_1 \otimes f_2$
Monotonicity	$If f_1 \leq g_1 and f_2 \leq g_2, then f_1 \otimes f_2 \leq g_1 \otimes g_2;$ $f_1 \wedge f_2 \leq g_1 \wedge g_2;\ f_1 \vee f_2 \leq g_1 \vee g_2;$

By the above explanation, different properties of SNC, including the stochastic delay and backlog bounds have been proved.

IV. MODELING NAKAGAMI FADING OF UNDERWATER ACOUSTIC COMMUNICATION

SNC gives random service warranty to the packet networks for research and sound network applications. In the opinion of a service-oriented service curve of a potentially commitment in the service received by integrating the flow or single flow. A network service has the ability to calculate the final result-delay delay and feedback limits provided for various visits and service delivery in random network calculations by providing the product development curve. In [13], A server model serves a fixed service guarantee analysis. It also provides retreat guarantee, delay guarantee, output sorting and merging property. Though SNC theories have a variety of research, the theory is sometimes mapped for real-time network applications. In the closed form service curve is do not provide by it. But we need a stochastic service quality for fading that uses closed-form service curves.

A. Acoustic Channel Model

Nakagami fading model is a model of acoustic manipulation. Nagagami Channel is another kind of small-scale channel model. It is based on Rayleigh and Rican Fading. The delivery of electricity received is a high speed distribution. General assumption, the signal will come to the receiver with at least two different lines. [14]. The discrete time flat fading of acoustic channel can be taken as a sample system model. And it will be denoted by, $Y = |h_t| re^{j\varphi} X + Z$, where X, Y are input of the acoustic channel. Z is the independent. Also Z is identically distributed Gaussian noise; $|h_t| re^{j\varphi}$ - it is the channel gain with $|h_t|$ - amplitude . $|h_t|$ is a stochastic or random variable, and φ - phase is uniformly distributed in $[-\pi, \pi]$. Fig. 1 Shows acoustic fading channel model.

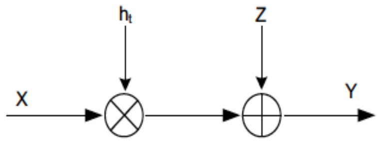

Fig. 1 System Model of a Fading Acoustic Channel

P_{tx}	Average transmission power
W	Channel bandwidth
N_0	Power spectral density of acoustic noise

the channel capacity can therefore be expressed a

$$C = W log_2 \left(1 + 10^{\gamma_t/10}\right) = W log_2 \left(1 + \frac{P_{tx}|h_t|^2}{W N_0}\right)$$

The sound transmitter does not know about instant Signal-to-Noise Ratio (SNR) γ_t (in dB).And its transmission power cannot be adjusted with respective of the sound channel condition.

Therefore, the data transfer rate can remain unchanged at the interval of the SNR of the received signal and there is probability of an outage.

The transmission data - R, the outage probability of an acoustic fading channel can be denote by,

$$p_{out}(R) = P_r\{C < R\} = P_r\left\{W\, log_2\left(1 + \frac{P_{tx}|h_t|^2}{N_0 W}\right) < R\right\}$$

$$= P_r\left\{|h_t|^2 < \left(2^{R/W}\text{-}1\right).\frac{N_0 W}{P_{tx}}\right\} \quad (9)$$

where, $|h_t|$ – channel gain has a distribution (with probability density function)

$$f(x) = \frac{2}{\Gamma(k)}\left(\frac{k}{2}\right)^k x^{2k\text{-}1} \exp\left(\text{-}\frac{x^2 k}{2}\right) \quad (10)$$

When $k = 1$, Nakagami becomes Rayleigh fading. The probability density function of Rayleigh Fading becomes

$$f(x) = x.\exp\left(\frac{-x^2}{2}\right)$$

From transformation theorem, $|h_t|^2$ has an exponential distribution (with probability density function),

$$g(x) = \frac{1}{2}\exp\left(\text{-}\frac{x}{2}\right)$$

so, the outrage probability can be denote as:

$$p_{out}(R) = 1\text{-}\exp\left(\frac{1\text{-}2^{R/W}}{2.10^{SNR/10}}\right) \quad (11)$$

Where $SNR = 10\log_{10}[P_{tx}/(N_0 W)]$ denotes the SNR in dB.

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B. Stochastic Acoustic Service Curve

Until the (C) capacity of acoustic channel is uneven we can no t capture the characteristics of deterministic service curve.
Because of this reason we use SSC for distinguish the acoustic channels service capture. It is expressed with two parameters.

1. R - data transmission rate R,
2. ϵ- error function

By the before analysis of the fading channel,
we can model the stochastic service curve $\langle\beta(t),\epsilon\rangle$,

$$\beta(t) = R.t \text{ and } \epsilon(R) = 1\text{-}\exp\left(\frac{1\text{-}2^{R/W}}{2.SNR}\right) \qquad (12)$$

The acoustic channels probabilities of channel crash is defined by the ϵ violation probability function. We should give the R – transmission rate is greater than $\epsilon(R)$. ϵ is affected by R and SNR. The transmitter's (acoustic transmitter) coding and modulation are decides the R value. SNR is decide by the transmission power and the channel condition.

V. PERFORMANCE BOUND ANALYSIS

By inspecting the sending data packets the performance bound is calculated. There are two different scenario are considered,

1. The data transmitting continuously and it can modeled by DAC.
DAC – Deterministic arrival curve.
2. The data transmitting randomly, and it can modeled by stochastic arrived curve.

A(t) - Arrival process
D(t) – Departure process

Deterministic arrival traffic

Theorem 1: We have refer the acoustic arrival process A(t) and it is bounded by the deterministic arrival cure $\alpha(t)$.
The arrival process $A(t)$ receives a stochastic service curve $\langle\beta(t),\epsilon\rangle$.
Because of these the performance bounds are,

1. Backlog bound: (SBB – stochastic backlog bound)
The $B(t)$ (stochastic backlog bound) is reveals by,

$$Pr\{B(t) \geq \alpha \oslash \beta(0)\} \leq \epsilon, \qquad (13)$$

Where $\alpha \oslash \beta(0) = \sup_{t\geq 0}\{\alpha(t)\text{-}\beta(t)\}$

2. Delay bound: (SUB – stochastic upper bound)
The delay bound $\mathrm{d}(t)$ (SUB for delay) is reveals by,

$$Pr\{d(t) \geq h(\alpha,\beta)\} \leq \epsilon, \qquad (14)$$

Where $h(\alpha,\beta) = \sup_{t\geq 0}\{\inf[\tau \geq 0: \alpha(t) \leq \beta(t+\tau)]\}$ it indicates the MHD (maximum horizontal difference) of arrival and service curve.
denotes
Since τ_0 is mhd between $\alpha(t)$ and $\beta(t)$,
we get $\alpha(t\text{-}s) \leq \beta(t\text{-}s+\tau_0)$.
For that reason,

$$Pr\{d(t) \geq \tau_0\} \leq Pr\{D(t) \leq A \otimes \beta(t)\} \leq \epsilon \qquad (15)$$

Stochastic arrival traffic

Beyond the scheduled arrival curve, an attendance process is similar to a rapidly defined explosion model.
The stochastic arrival curve model refers by follows (with parameters (ρ, a_1, a_2))

$$Pr\left\{\sup_{0\leq s\leq t}[A(t)\text{-}A(s)\text{-}\alpha(t\text{-}s)] \geq 0\right\} a_1 e^{\text{-}a_2\sigma} \qquad (16)$$

where $\sigma > 0, 0 \leq s \leq t$, and $\alpha(t) = \rho.t + \sigma$
Theorem 2:
The TAP - is refer by a SAC.
That is $A(t) \sim \langle\alpha(t), f(\sigma)\rangle$, where $\alpha(t) = \rho.t + \sigma$ and $f(\sigma) = a_1 e^{\text{-}a_2\sigma}$ A $\langle\beta(t),\epsilon\rangle$ stochastic service curve receivesA(t). we can derive the performance bounds as follows:
Backlog bound:
The B(t) - stochastic backlog bound is,

$$Pr\{B(t) \geq \alpha \oslash \beta(0)\} \leq \epsilon + f(\sigma) \qquad (17)$$

Delay Bound:
The $\mathrm{d}(t)$- stochastic upper bound for delay is,,

$$Pr\{d(t) \geq h(\alpha,\beta)\} \leq \epsilon + f(\sigma)$$

Since the probability is not greater than 1,
we derive $\epsilon + f(\sigma) = \min(\epsilon + f(\sigma), 1)$.
Proving of DB is mostly equal to the DAC.

$$Pr\left\{\sup_{0\leq s\leq t}[A(t)\text{-}A(s)\text{-}\alpha(t\text{-}s)] \geq 0\right\} = 0;$$

While for stochastic arrival curve,

$$Pr\left\{\sup_{0\leq s\leq t}[A(t)\text{-}A(s)\text{-}\alpha(t\text{-}s)] \geq 0\right\} \leq f(\sigma).$$

Therefore, the DB is given by

$$Pr\{d(t) \geq h(\alpha,\beta)\} \leq \epsilon + f(\sigma) \qquad (18)$$

VI. SIMULATION ANDN PERFORMANCE EVALUATION

The performance of derived model (Mathematical model) is evaluated by using simulation and results are shown as follows. The Riverbet simulator is used to simulate and validate the tightness of the band. Finally the simulation is compared with respective analytical result.

To inspect the nakagami fading channel effects in UW acoustic network the simulation setup is constructed by using transmitter and receiver nodes.

The simulation parameters are Channel Bandwidth -4 0 kilo Hertz, 2watts of Transmit Power, 1DB is NPSD.
(NPSD - Noise Power Spectral Density),
40 kilo hertz of CF, No. of Nodes – 9, 2 second for delay time, 1500 meter per second is the sound speed Sound - 1500 m/s, 0.09190 packets per second is the rate of Transmission, 7.75 second is the Transmission Time -,200 meter Range of transmission, 1024B size of Packet.
The Riverbet simulation environment is shown Fig. 2. (with 9 nodes).
Transmitter node – 4
Receiver node – 5.

Fig.2 Simulation Set up

Radio signal is the default communication channel in the Riverbet simulation tool so we need to change the coding for acoustic communication. Fig. 3 and Fig. 4 show the acoustic transmitter node attributes and the acoustic receiver attributes, in which the default node attributes are changed to acoustic node parameters. The following changes should done in the riverbet transiver stages.

1	Received Power
2	Bit error
3	Propagation Delay
4	Signal to Noise ratio
5	Background Noise
6	Channel Match

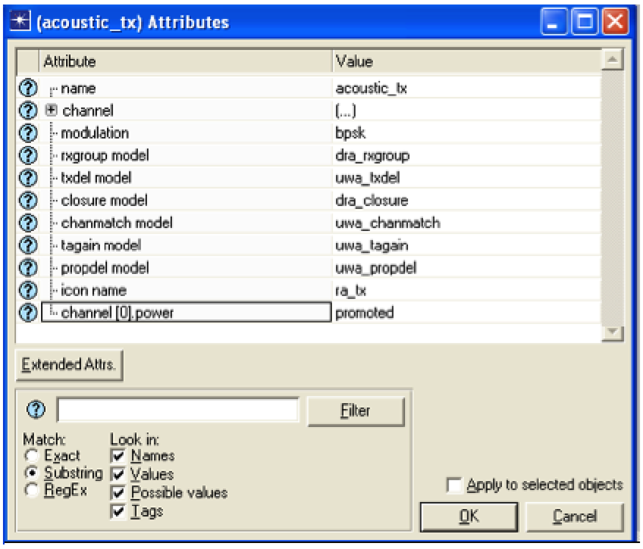

Fig. 3 Acoustic Transmitter Node Attribute

The Nakagami fading channel's PD (probability density) function is shown in fig.5. Nakagami channel fading is mainly dependent of the parameter k in the stochastic equation. If the value of k equals to 1, then Nakagami channel fading follows the Rayleigh distribution channel. If the value is non-negative and wide sense increasing (k value Less than 1), then Nakagami channel fading is said to follows AWGN channel and in the last case if the k value is greater than 2, then Nakagami channel fading is said to follow the Rician distribution. The sample code snippets in the receiver power stage to check the appropriate channel is given in Fig.6.

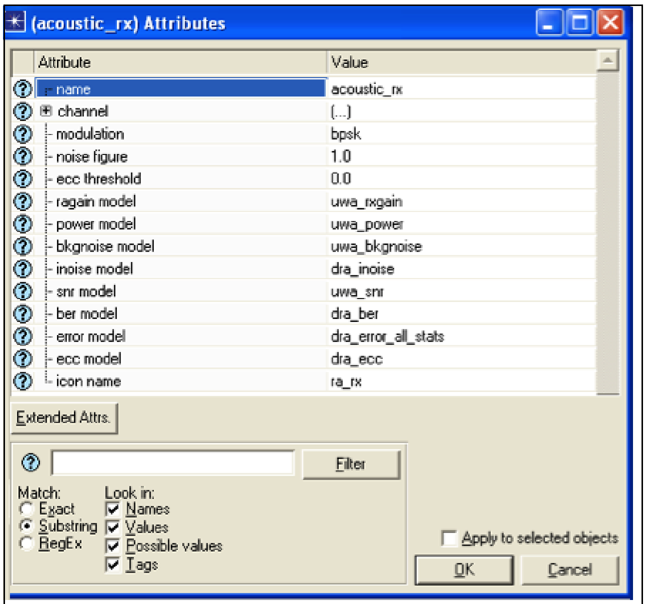

Fig. 4 Acoustic Node Receiver Attributes

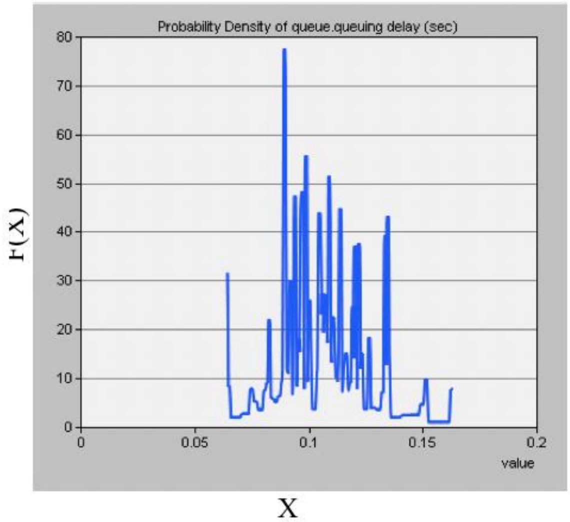

Fig. 5 Probability Distribution Function

Depends upon the modulator curve the BER (bit error rate) is shows in Fig.7. the attributes of modulation are relates to the channel model and also the attribute values are can be set various values. Clearly explains the SNR and BER ratio where each SNR value has a relative BER values. Depends upon the BER rate, by random manner the error bits are insert into the packets. The bit error probabilities are calculated by the particular method after that it compared with the random numbers from (0 to 1). The bit is called error bit when it is higher than random value. By using Riverbet simulation tool our Nakagami fading channel is validate and it is closely equal to our mathematical solution. At 1st simulation, the packets are send by the traffic models in periodically. data rate of these packets is $r = 40\ kbps$. The arrival process is modeled by using the arrival curve $\alpha(t) = rt + b$. We have also verified the loss and violation probability and the results were found to be satisfactory.

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/* Sample Coding to Relate Nakagami Model**/
/*If the value of k=1, it is Rayleigh Fading, if m=1.1 to 1.9 then
AWGN channel, if m>2 then it is Rician Fading**/
if(k==1) {
mean_rayleigh=rcvd_power;
dist_ptr=op_dist_load("gamma",mean_rayleigh,k);
rayleigh_fading_outcome=op_dist_outcome(dist_ptr);
rcvd_power-=Rayleigh_fading; }
else if((k>=0)&&(k<=0.99)) {
mean_awgn=rcvd_power;
dist_ptr=op_dist_load("gamma",mean_awgn,k,0);
awgn_fading_outcome=op_dist_outcome(dist_ptr);
rcvd_power=awgn_fading; }
else if (k>=2){
mean_=rcvd_power;
dist_ptr=op_dist_load("gamma",mean_rician/k,k);
rician_fading_outcome=op_dist_outcome(dist_ptr);
rcvd_power=rician_fading; }
else {
op_dist_outcome("invalid channel"); }
```

Fig.6 Nakagami Channel Fading sample code

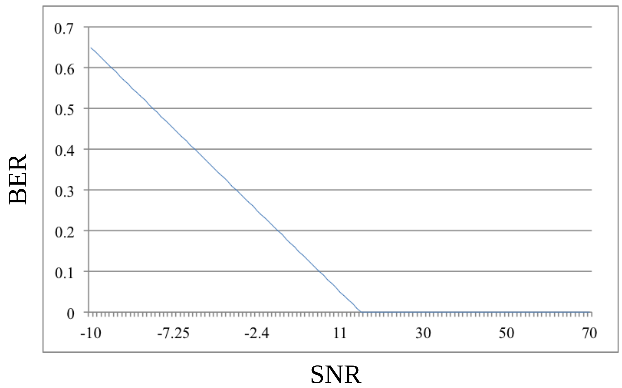

Fig. 7 SNR and BER Relationship in Nakagami Channel

VII. CONCLUSION

We developed the analytical and simulation model for the Nakagami fading channel of the acoustic communication using mathematical tool(SNC). By this analytical model we understand and model the effects of the acoustic nakagami fading channel. this analytical model validated through respective simulations. The solution is adequate to the expanse that our mathematical model very nearly constitutes bring about the real-time Nakagami channel fading consectary in underwater acoustic communication.

In later extenion of this work, we would look on large size network with various nodes and also by change the bandwidth of various channels as well as the power of transmission.

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