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Two Node Tandem Communication Network Model with Weibull Inter Arrival Times and Dynamic Band Width Allocation having Intermeadiatery Departures

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Abstract: Communication network models play a dominant role in design and monitoring of communication systems such as, Local Area Networks, Wide Area Networks and Metropolitan Area Networks. This paper addresses the development and analysis of a two node tandem communication network model with the assumption that the inter arrival times of the packets follows Weibull distribution. The transmission in both the nodes follows Poisson processes having dynamic band width allocation. It is further assumed that the packets after getting transmission from the first node may join the buffer connected to the second node or terminated with certain probability. This intermeadiatery departure of the packets have significant influence on the performance of the communication network. The performance of the network is evaluated by deriving explicit expressions for the network performance measures such as, the average content of the buffers, mean delay in the transmitters, the throughput of the nodes. Through numerical study, it is observed that the Weibull inter arrival time distribution parameters have significant influence on the performance measures. The dynamic band width allocation strategy reduces the congestion in buffers and improves the customer satisfaction. This model also includes some of the earlier models on particular cases. The time dependent nature of arrival rate of packets made the proposed model more flexible for analyzing several communication networks.

Keywords: communication network, performance evaluation, dynamic bandwidth allocation, performance measure.

1. INTRODUCTION

The communication systems deals with the problems of transmission, Packetization, assignment, statistical multiplexing, resource allocation, controlling and monitoring the delay. These issues are to be addressed for effective and accurate prediction of performance measures for the communication systems using network models. The mathematical theory of communication was pioneered by William cook and Charles Wheatstone (1939). In 1948 a significant event has been occurred for communication systems by introducing the concept of communication network modeling. There after considerable efforts are made by AT & T bell laboratories, USA Network group at MIT, IEEE communication systems and others for designing and developing efficient communication systems (IEEE communication systems 2002).

In general it is time consuming and highly complicated to conduct laboratory experiments under variable load conditions. Hence communication network models are developed and used for efficient design and monitoring of communication systems. Various communication network models have been developed with various assumptions on arrival processes, transmission processes, flow control and routing. It is know that packet switching gives improved quality of service than circuit switching, to reduce the delay in transmission through packet switching statistical multiplexing is extensively used.

Therefore, several of the communication networks are designed with a mix of dynamic engineering skills and statistical multiplexing (Gaujal and Hyon (2002), Parthasarathy et al(2001), SrinivasaRao et al (2000), Srinivasarao and Vijayakumar (2000), Suresh Varma P. et al (2007), NageswaraRao. K et al (2010)). In packet switching the messages are converted into small packets of random length and each packet will have a header for routing (Srinivasa rao (2006), Srinivasa rao (2010)). For effective design of communication network one has to consider congestion control strategies, for congestion control bit dropping is usually adapted. In bit dropping one has to discard certain portion of the traffic, ie., the least significant bits in order to reduce the transmission time without effecting the quality of service (Kin K Leung (2002), Klein rock (1976), YukuoHayashda (1993), Sriram K (1993)) and other have utilized queueing analogy for reducing

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Vol. 4, Issue 10, October 2015

congestion in buffers for communication systems. In these papers they assumed that the arrivals and transmission processes are independent. But in store and forward communication systems the messages generally preserve the long as they transfer to the network and the inter arrival and service processes have dependencies for optimal utilization of resources. These dependencies influence the system performance significantly (SrinivasaRao et al (2011)).

Recently, the dynamic band width allocation are load dependent transmission strategy is developed for improving the quality of service by utilizing the idle band width (Suresh Varma P et al (2007), Padmavathi et al (2009), Nageswararao K et al (2010)). In these papers the authors assumed that the arrival of packets to the buffers is homogeneous and time independent. Hence they used Poisson process for characterizes the arrivals. Modeling and analysis of network traffic based on Poisson process assume the arrival of packets are smoother and less bursty (Abry et al (2002), cappe et al (2002)). However, with the present day increases intensity on communication systems the aggregate traffic may not remain smooth and bursty. It is know that the actual traffic the Ethernet, LAN exhibits the property of Self-similar (burstness) and long range similarity, Leland et al (1994). This argument is further supported by Rakesh singhai et al (2007) who mentioned that the traffic at the MAN and WAN will have a variable bit rate and exhibit self-similarity.

The self-similar or burstness is due to the time dependent nature of arrivals. Hence, to have accurate prediction of performance measure of the communication network one has to deviate from the Poisson arrival process (Inter arrival times of packets) cannot be characterized by Poisson process (exponential distribution) is demonstrated by (Crovella et al (1997), Murali Krishna et al (2003), Feldmann A (2000)). There fore, Fisher et al (2001) has used weibull inter arrival time distribution for modeling the G/M/1 queueing system. Dinda et al (2006) has made several study and stated that " The traffic generate by many real world application exhibit a high degree of burstness (time varying arrival rates)". The time dependent arrivals can be well characterized by non-homogeneous Poisson processes with time dependent arrival rate. Very little work has been reported with respect to the communication network models with time dependent arrivals except the works of (M. V. Rama Sundari (2011), M. V. Rama Sundari (2011), TrinathaRao. P et al (2012), Suhasini, A. V. S. et al (2013a), Suhasini, A. V. S. et al (2013b)). Who have developed and analyzed communication network models with non-homogeneous Poisson process. In these papers they considered that the mean arrival rate is linearly dependent on time and inter arrival times of packets follow exponential distribution. But the linear dependence of time of the mean arrival rate is basic drawback in approximately the performance measures of the communication network is close to the reality. Hence to have available time dependent arrival rate we can characterize the inter arrival times of packets with a weibull distribution and the arrival process can be Duane process. The Duane process is generalization of the non-homogeneous Poisson process (RakeshSinghai et al (2007)). AraikTamazian and Mikhail Bogachev (2015), have analyzed the performance of WWW servers using weibull distribution for inter arrival times, assuming that there is a single server in an each queue and queues are independent. In many communication systems such as, The LAN, WAN, an MAN the output of one queue is input to the other queues are not independent. There is no work reported regarding tandem communication network models with weibull inter arrival times which model the Self-similarity network traffic with time dependent bursts. With this motivation in this paper, a two node tandem communication network model is developed and analyzed with the assumption that the inter arrival times of packets follow weibull distribution and the transmission strategy is dynamic band width allocation.

II. COMMUNICATION NETWORK MODEL AND TRANSIENT SOLUTION

In this section a communication network model having two nodes in tandem is considered. The arrivals to the buffer connected at node 1 are assumed to follow a non-homogeneous Duane process with mean arrival rate as power function of time t and it is of the form $\lambda(t)=abt^{b-1}$. The transmission process from node one to node two follows a Poisson with a parameter μ_1. After getting transmitted from node one the packets are forwarded to the second buffer for the transmission from second node and the transmission process of node two also follows a Poisson process with parameter μ_2 .There are no intermediate departure of packets after transmission from node1. The transmission strategy in both the nodes are dynamic band width allocation. That is the transmission rate of each packet in each node is adjusted just before transmission depending on the content of the buffer connected to it. The packets are transmitted through the transmitters by the first in first out principles. The schematic diagram representing the communication network model is shown in "Figure1".

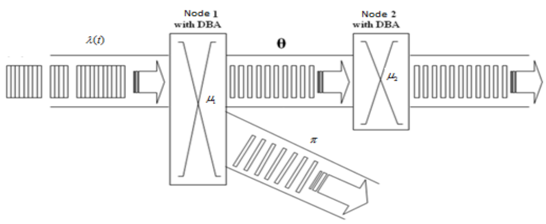

Figure1: Schematic diagram of the CNM model with two stage arrival

Let Pn1,n2(t) be the probability that there are n1 packets in the first buffer and n2 packets in the second buffer at time t. with this structure, the difference-differencial equations of the communication network are:

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$$\frac{\partial p_{n_1,n_2}(t)}{\partial t}=-\left(\lambda(t)+n_1\mu_1+n_2\mu_2\right)p_{n_1,n_2}(t)+\left(\lambda(t)\right)p_{n_1-1,n_2}(t)+(n_1+1)\mu_1\theta p_{n_1+1,n_2-1}(t)+(n_1+1)\mu_1\pi p_{n_1+1,n_2}(t)+(n_2+1)\mu_2 p_{n_1,n_2+1}(t) \quad (1)$$

$$\frac{\partial p_{n_1,0}(t)}{\partial t}=-\left(\lambda(t)+n_1\mu_1\right)p_{n_1,0}(t)+\left(\lambda(t)\right)p_{n_1-1,0}(t)+\mu_2 p_{n_1,1}(t)+(n_1+1)\mu_1\pi p_{n_1+1,0}(t) \quad (2)$$

$$\frac{\partial p_{0,n_2}(t)}{\partial t}=-\left(\lambda(t)+n_2\mu_2\right)p_{0,n_2}(t)+\mu_1\theta p_{1,n_2-1}(t)+(n_2+1)\mu_2 p_{0,n_2+1}(t)+\mu_1\pi p_{1,n_2}(t) \quad (3)$$

$$\frac{\partial p_{0,0}(t)}{\partial t}=-\left(\lambda(t)\right)p_{0,0}(t)+\mu_1\pi p_{1,0}(t)+\mu_2 p_{0,1}(t), \quad (4)$$

$$Let P(S_1,S_2,t)=\sum_{n_1=0}^{\infty}\sum_{n_2=0}^{\infty}P_{n_1,n_2}(t).S_1^{n_1}.S_2^{n_2}$$

be the joint probability generating function of $P_{n_1,n_2}(t)$.

Multiplying the equation (1) with S1n1 S2n2 and summing over all n1,n2 we get

$$\frac{\partial P}{\partial t}=-\sum_{n1=0}^{\infty}\sum_{n2=0}^{\infty}\left(\lambda(t)+n_1\mu_1+n_2\mu_2\right)P_{n1,n2}(t).S_1^{n_1}.S_2^{n_2}+\sum_{n1=0}^{\infty}\sum_{n2=0}^{\infty}\left(\lambda(t)\right)P_{n1-1,n2}(t).S_1^{n_1}.S_2^{n_2}+\sum_{n1=0}^{\infty}\sum_{n2=0}^{\infty}(n_1+1)\mu_1\theta P_{n1+1,n2-1}(t).S_1^{n1}.S_2^{n2}+\sum_{n1=0}^{\infty}\sum_{n2=0}^{\infty}(n_1+1)\mu_1\pi P_{n1+1,n2}(t).S_1^{n_1}.S_2^{n_2}+\sum_{n1=0}^{\infty}\sum_{n2=0}^{\infty}(n_2+1)\mu 2P_{n_1,n_2+1}(t).S_1^{n_1}.S_2^{n_2} \quad (5)$$

π = 1-Θ and after simplifying, we get

$$\frac{\partial P}{\partial t}=\mu_1\frac{\partial P}{\partial S_1}\left(1-S_1-\theta+\theta S_2\right)+\mu_2\frac{\partial P}{\partial S2}\left(1-S_2\right)-\lambda(t)P\left(1-S_1\right) \quad (6)$$

Solving the equation (6) by Lagrangin's method the auxulary equations are

$$\frac{dt}{1}=\frac{ds_1}{-\mu_1\left(s_1-1+\theta-\theta s_2\right)}=\frac{ds_2}{-\mu_2\left(1-s_2\right)}=\frac{dp}{\lambda(t)p\left(s_1-1\right)} \quad (7)$$

To solve the equation (7) the functional form of λ(t) is required.

The mean arrival rate of packets is $\lambda(t)=abt^{b-1}$

where, $\lambda>0$, a, b *are constants.*

Solving the first and third terms in equation (7), we get

$$A=\left(s_2-1\right)e^{-\mu_2 t} \quad (8)$$

Solving first and second terms in equation (7) we get

$$B=\left(s_1-1\right)e^{\mu_1 t}+\frac{\mu_1.\theta(S_2-1)}{\mu_2-\mu_1}e^{-\mu_1 t} \quad (9)$$

Solving the first and fourth terms in equation (7) we get,

$$C=P.\exp\left[a.b\left[\left(\left(s_1-1\right)e^{-\mu_1.t}\int_0^t e^{-\mu_1.t}.v^{b-1}.dv\right)+\left(\frac{\mu_1.\theta(S_2-1)}{(\mu_2-\mu_1)}e^{-\mu_1.t}\int_0^t e^{\mu_1.t}.v^{b-1}.dv\right)-\left(\frac{\mu_1.\theta}{(\mu_2-\mu_1)}\left(s_2-1\right)e^{-\mu_2.t}\int_0^t e^{\mu_2.t}.v^{b-1}.dv\right)\right]\right] \quad (10)$$

where A,B,C are arbitrary constants using the initial conditions P0,0 (0)=1 , P0,0 (t)=1, for all t>o.

The general solution of the equation (6) gives the Probability generating function of the number of packets in the first buffer and the number of packets in the second buffer at timet as P(S1,S2,t)

$$P_{s_1,s_2}(t)=\exp\left[a.b\left[s_1-1\left(e^{-\mu_1.t}\int_0^t e^{\mu_1.t}.v^{b-1}.dv-\frac{e^{\mu_1.t}}{\mu_1}\right)+\frac{(s_2-1).\theta}{(\mu_2-\mu_1)}\left(e^{-\mu_2.t}-e^{-\mu_1.t}\right)+(s_2-1).\theta\left[\frac{\mu_1}{\mu_2-\mu_1}\left(e^{-\mu_1.t}\int_0^t e^{\mu_1.t}.v^{b-1}.dv-e^{-\mu_2.t}\int_0^t e^{\mu_2.t}.v^{b-1}.dv-\frac{e^{\mu_2.t}}{\mu_2}\right)\right]\right]\right] \quad (11)$$

III. PERFORMANCE MEASURES OF THE NETWORK

In this section,we derive and analyse the performance measures of the communication network under transient conditions.ExpandingP(s1,s2,t) given in equation(11) and collecting the constant terms, we get the probability that the network is empty as

$$\left(P_{0,0,}(t)\right)=\exp\left[-a.b\left[e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv-\frac{e^{-\mu_1.t}}{\mu_1}\right]+\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right]+\left[\left[\left[\frac{\mu_1.\theta}{(\mu_2-\mu_1)}.e^{-\mu_1.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv-e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv\right]-\frac{e^{-\mu_2.t}}{\mu_2}\right]\right] \quad (12)$$

Taking S_2 =1,the probability generating function of the first buffer size distribution is

$$\left(P_{0,0,}(t)\right)=\exp\left[a.b\left[\left(s_1-1\right)e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv-\frac{e^{-\mu_1.t}}{\mu_1}\right]\right] \quad (13)$$

Expanding P(s1,t) and collecting the constant terms we get the probability that the first buffer is empty as

$$P_{0.}(t)=\exp\left[-\left[a.b\left(e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv-\frac{e^{-\mu_1.t}}{\mu_1}\right)\right]\right] \quad (14)$$

The mean numbers of packets in the first buffer is

$$L_1=E\left[N_1\right]=\sum_{n_1=0}^{\infty}n_1P_{n_1}(t)=a.b\left[e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv-\frac{e^{-\mu_1.t}}{\mu_1}\right] \quad (15)$$

The utilization of the first buffer is

$$U_1=1-P_0(t)=1-\exp\left[-a.b\left(e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv-\frac{e^{-\mu_1.t}}{\mu_1}\right)\right] \quad (16)$$

for computing the variability of the number of packets in first buffer, we compute

$$E\left(N_1^2-N_1\right)=E(N_1^2)-E(N_1)=a.b\left[e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv-\frac{e^{-\mu_1.t}}{\mu_1}\right]^2 \quad (17)$$

Therefore, the variance of the number of packets in the first buffer is

$$Var\left(N_1\right)=a.b\left[e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv-\frac{e^{-\mu_1.t}}{\mu_1}\right] \quad (18)$$

The throughput of the first transmitter is

$$Thp_1=\mu_1\left(1-P_{0.}(t)\right)=\mu_1\left[1-\exp\left[-a.b\left(e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv-\frac{e^{-\mu_1.t}}{\mu_1}\right)\right]\right] \quad (19)$$

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The mean delay in the first buffer size is

$$W_1 = \frac{L_1}{Thp_1} = \frac{E[N_1]}{Thp_1}$$

$$= \frac{a.b\left[e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - \frac{e^{-\mu_1.t}}{\mu_1}\right]}{\left[1-\exp\left[-\left[a.b\left(e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - \frac{e^{-\mu_1.t}}{\mu_1}\right)\right]\right]\right]} \quad (20)$$

Similarly by substituting s1=1,we get the probability generating function of the second buffer size distribution as

$$P_{s_1,s_2}(t) = \exp\left[a.b\left[\begin{array}{l}\frac{(s_2-1).\theta}{(\mu_2-\mu_1)}\left(e^{-\mu_2.t}-e^{-\mu_1.t}\right)+ \\ (s_2-1).\theta\left[\begin{array}{l}\frac{\mu_1}{\mu_2-\mu_1}.e^{-\mu_1.t}\int_0^t e^{\mu_1.t}.v^{b-1}.dv \\ -e^{-\mu_2.t}\int_0^t e^{\mu_2.t}.v^{b-1}.dv - \frac{e^{\mu_2.t}}{\mu_2}\end{array}\right]\end{array}\right]\right] \quad (21)$$

Expanding P(s2,t) and collecting the constant terms,we get the probability that the second buffer is empty as

$$P_{.0}(t) = \exp\left[-a.b\left[\begin{array}{l}\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right]+ \\ \left[\frac{\mu_1.\theta}{(\mu_2-\mu_1)}.e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv\right] - \frac{e^{-\mu_2.t}}{\mu_2}\end{array}\right]\right] \quad (22)$$

The mean number of packets in thesecond buffer is

$$L_2 = E[N_2] = a.b\left[\begin{array}{l}\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right]+ \\ \frac{\mu_1.\theta}{(\mu_2-\mu_1)}.e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - \frac{e^{-\mu_2.t}}{\mu_2}\end{array}\right] \quad (23)$$

The utilization of the second buffer is

$$U_2 = 1 - P_{.0}(t) = \left[1-\exp\left[-a.b\left(\begin{array}{l}\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right]+ \\ \frac{\mu_1.\theta}{(\mu_2-\mu_1)}.e^{-\mu_1.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - \frac{e^{-\mu_2.t}}{\mu_2}\end{array}\right)\right]\right] \quad (24)$$

For computing the variability of the number of packets in second buffer, we compute

$$E\left[N_2^{\,2} - N_2\right] = \left[a.b.\left[\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right] + \frac{\mu_1.\theta}{(\mu_2-\mu_1)}.e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - \frac{e^{-\mu_2.t}}{\mu_2}\right]\right]^2 \quad (25)$$

The variance of the number of packets in the second buffer is

$$Var2 = \left[a.b\left(\begin{array}{l}\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right]+ \\ \frac{\mu_1.\theta}{(\mu_2-\mu_1)}.e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - \frac{e^{-\mu_2.t}}{\mu_2}\end{array}\right)\right] \quad (26)$$

The throughput of the second transmitter is

$$Thp_2 = \mu_2\left[1-\exp\left[-a.b\left(\begin{array}{l}\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right]+\frac{\mu_1.\theta}{(\mu_2-\mu_1)}. \\ e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - \frac{e^{-\mu_2.t}}{\mu_2}\end{array}\right)\right]\right] \quad (27)$$

The mean delay in the second buffer is

$$W_2 = \frac{L_1}{Thp} = \frac{E(N_2)}{Thp}$$

$$\frac{a.b\left[\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right]+\frac{\mu_1.\theta}{(\mu_1-\mu_1)}.\left(e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - \frac{e^{-\mu_2.t}}{\mu_2}\right)\right]}{\mu_2\left[1-\exp\left[-\left[a.b\left(\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right]+\frac{\mu_1.\theta}{(\mu_2-\mu_1)}.\left(e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv\right)-\frac{e^{-\mu_2.t}}{\mu_2}\right)\right]\right]\right]} \quad (28)$$

From the equations (15) and(23) we obtain

$$E[N_1.N_2] = a.b\left[e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - \frac{e^{-\mu_1.t}}{\mu_1}.\left\{\begin{array}{l}\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right] \\ +\left(\frac{\mu_1.\theta}{(\mu_2-\mu_1)}.e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - \frac{e^{-\mu_2.t}}{\mu_2}\right)\end{array}\right\}\right] \quad (29)$$

The mean number of packets in the network at time t is L(t)
L(t)=E[N1]+E[N2]

$$L(t) = a.b\left[e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - \frac{e^{-\mu_1.t}}{\mu_1}\right]+$$

$$a.b\left[\begin{array}{l}\frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right]+ \\ \left(\frac{\mu_1.\theta}{(\mu_2-\mu_1)}.e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - \frac{e^{-\mu_2.t}}{\mu_2}\right)\end{array}\right] \quad (30)$$

The variability of the number of packets in the network is

$$Var[N] = \text{var}[N_1] + \text{var}[N_2] + 2Cov[N_{1,}N_2]$$

$$= a.b\left[e^{-\mu_1.t}\int_0^t e^{\mu_1.v}.v^{b-1}.dv - \frac{e^{-\mu 1.t}}{\mu_1}\right] + \frac{\theta}{(\mu_2-\mu_1)}\left[e^{-\mu_2.t}-e^{-\mu_1.t}\right]+$$

$$\left[\left[\frac{\mu_1.\theta}{(\mu_2-\mu_1)}.e^{-\mu_1.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv - e^{-\mu_2.t}\int_0^t e^{\mu_2.v}.v^{b-1}.dv\right] - \frac{e^{-\mu_2.t}}{\mu_2}\right] \quad (31)$$

IV.PERFORMANCE EVALUATION OF THE NETWORK

In this section, the performance of the proposed communication network is discussed through numerical illustration. Different values of the parameters are considered for bandwidth allocation and arrival of packets. After interactingwith the technical staff at internet providing station, it is considered the packet arrival rate parameter (a) varies from 8×10^4 packets/sec to 11×10^4 packets/sec, and b varies from 1.25 to 2 with an average packet size of 102 bytes. After transmitting from node 1, the packets may reach the node 2 at a rate of θ (θ=1-π) and some packets may be terminated at the rate (π). The forward transmission rate (μ_1) varies from 11×10^4 packets/sec to 14×10^4 packets/sec. The rate of transmission rate (μ_2) varies from 19×10^4 packets/sec to 22×10^4 packets/sec. In all these nodes, dynamic bandwidth allocation strategy is considered i.e., the transmission rate of each packet depends on the number of packets in the buffer connected to it at that instant.

Since performance characteristics of communication network are highly sensitive with respect to time, the transient behavior of the model is studied through computing the performance measures.

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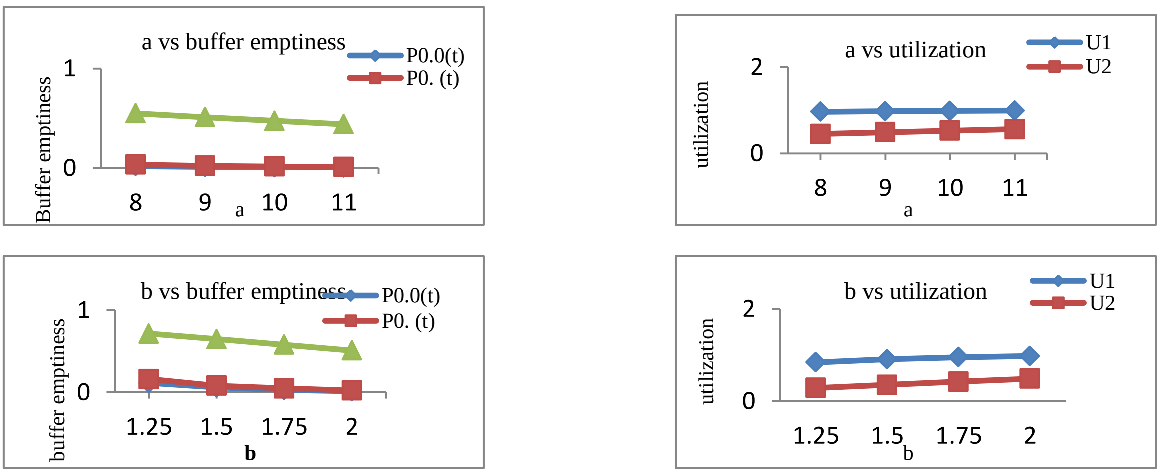
t = 0.5,1,1.5,2 Sec, a = 8,9,10,11(with multiplication to 10×10^4 packets/sec) b = 1.25,1.5,1.75,2,
μ_1 = 11,12,13,14(10×10^4 packets/sec),
μ_2 = 60,70,80,90 (10×10^4packets/sec),
θ = 0.6,0.7,0.8, 0.9, π = 0.4,0.3,0.2,0.1.

The probabilities of the network emptiness, buffers emptiness and Utilization of transmitters are computed for different values of t,a,b,θ,μ_1,μ_2 and presented in Table1 and Figure 2.

Table I : Values of network and buffer emptiness probability and utilization of the communication network with dynamic bandwidth allocation.

t	a	B	μ_1	μ_2	π	Θ	$P_{0.0}(t)$	$P_{0,}(t)$	$P_{.0}(t)$	U_1	U_2	L_1	L_2	LN
0.5	7	2	10	18	0.5	0.5	0.6604	0.7554	0.8742	0.2446	0.1258	0.2805	0.1345	0.415
1	7	2	10	18	0.5	0.5	0.2043	0.2837	0.7201	0.7163	0.2799	1.26	0.3284	1.5884
1.5	7	2	10	18	0.5	0.5	0.0312	0.0529	0.5928	0.9471	0.4072	2.94	0.5228	3.4628
2	7	2	10	18	0.5	0.5	0.0024	0.0049	0.4881	0.9951	0.5119	5.32	0.7173	6.0373
1.5	8	2	10	18	0.5	0.5	0.0191	0.0347	0.5502	0.9653	0.4498	3.36	0.5975	3.9575
1.5	9	2	10	18	0.5	0.5	0.0117	0.0228	0.5106	0.9772	0.4894	3.78	0.6722	4.4522
1.5	10	2	10	18	0.5	0.5	0.0071	0.015	0.4738	0.985	0.5262	4.2	0.7469	4.9469
1.5	11	2	10	18	0.5	0.5	0.0042	0.0099	0.4397	0.9901	0.5603	4.62	0.8216	5.4416
1.5	9	1.25	10	18	0.5	0.5	0.1141	0.1597	0.7144	0.8403	0.2856	1.8346	0.3363	2.1709
1.5	9	1.5	10	18	0.5	0.5	0.0591	0.0812	0.6477	0.9088	0.3523	2.3943	0.4344	2.8287
1.5	9	1.75	10	18	0.5	0.5	0.0277	0.0478	0.5794	0.9521	0.4206	3.0391	0.5458	3.5849
1.5	9	2	10	18	0.5	0.5	0.0117	0.0228	0.5106	0.9772	0.4894	3.78	0.6722	4.4522
1.5	9	2	11	18	0.5	0.5	0.016	0.0315	0.5083	0.9685	0.4917	3.4587	0.6768	4.1355
1.5	9	2	12	18	0.5	0.5	0.0209	0.0413	0.5063	0.9587	0.4937	3.1875	0.6806	3.8681
1.5	9	2	13	18	0.5	0.5	0.0263	0.052	0.5063	0.948	0.4953	2.9556	0.6838	3.6394
1.5	9	2	14	18	0.5	0.5	0.032	0.0636	0.5063	0.9364	0.4967	2.7551	0.6865	3.4416
1.5	9	2	13	19	0.5	0.5	0.0272	0.052	0.5063	0.948	0.4775	2.9556	0.6492	3.6048
1.5	9	2	13	20	0.5	0.5	0.0281	0.052	0.5063	0.948	0.4609	2.9556	0.6179	3.5735
1.5	9	2	13	21	0.5	0.5	0.0289	0.052	0.5063	0.948	0.4454	2.9556	0.5895	3.5451
1.5	9	2	13	22	0.5	0.5	0.0296	0.052	0.5063	0.948	0.4308	2.9556	0.5636	3.5192
1.5	9	2	13	20	0.4	0.6	0.0248	0.052	0.5063	0.948	0.5236	2.9556	0.7415	3.6971
1.5	9	2	13	20	0.3	0.7	0.0219	0.052	0.5063	0.948	0.579	2.9556	0.865	3.8206
1.5	9	2	13	20	0.2	0.8	0.0194	0.052	0.5063	0.948	0.6279	2.9556	0.9886	3.9442
1.5	9	2	13	20	0.1	0.9	0.0171	0.052	0.5063	0.948	0.6712	2.9556	1.1122	4.0678

*=Seconds, $=Multiples of 10,000 packets/sec



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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 10, October 2015

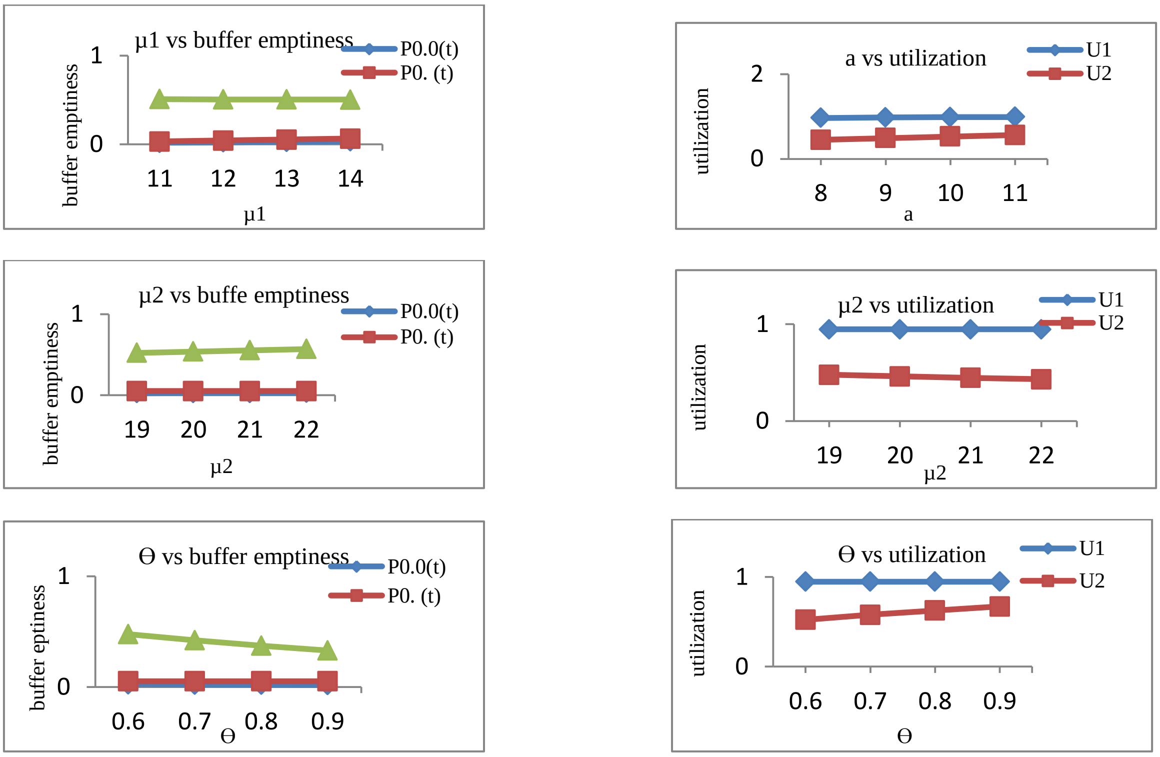

Figure 2: relationship between network emptiness, utilization and various parameters

It is observed that the probability of the emptiness in the entire communication network and in the two buffers are highly sensitive with respect to changes in time. As time (t) varies from 0.5 seconds to 2 seconds, the probability of the emptiness in the network reduces from 0.6604 to 0.0024 when other parameters are fixed at (7,2,10,18,0.5,0.5) for ($a,b,\mu_1,\mu_2,ɵ,\pi$). Similarly the probability for the emptiness in the 2 buffers varies from 0.7554 to 0.0048, 0.8742 to 0.4881 for node 1 and node 2 respectively. The decrease in the node 1 is more rapid when compared to node 2.

The influence of mean arrival rate of packets on the system emptiness is also studied. As the arrival rate parameter (a) varies from 8×10^4 packets/sec to 11×10^4 packets/sec, the probability of emptiness of the network decreases from 0.0191 to 0.0042 when other parameters are fixed at (1.5,2,10,18,0.5,0.5) for (t,b,μ_1, μ_2,μ2, ɵ,π).The same phenomenon is observed with respect to both nodes. This decrease is more than in first node and moderate in the second node. The influence of arrival rate parameter (b) varies from 1.25 to 2, the probability of emptiness of the network decreases from 0.1141 to 0.0117 when the other parameters remain fixed. The same phenomenon is observed for both the nodes. The decrease is more fast at node 1 and moderate in the next node. When the transmission rate (μ_1) of node 1 varies from 11×10^4 packets/sec to 14×10^4 packets/sec the probability of emptiness of the network increases from 0.016 to 0.0320 when the other parameter remain fixed.

Similarly the transmission rate (μ_2) of node 2 varies from 19×10^4 packets/sec to 22×10^4 packets/sec . The probability of emptiness of the network increases from 0.0272 to 0.0296 when the other parameters remain fixed. The same phenomenon is observed with respect to the emptiness of the two buffers. When the parameter (ɵ) increases from 0.6 to 0.9, the probability of emptiness of the network decreases from 0.0248 to 0.0171 when other parameters remain fixed. Similarly the probability of the emptiness in the first buffer remains at 0.052 and the emptiness of the second buffer decreases from 0.4764 to 0.3288 respectively when the other parameters remain fixed.

As the time (t) and arrival rate parameter (a) increases, the utilization of transmitters are increasing for fixed values of the other parameters. It is also observed that the as arrival rate parameter (a) increases the utilization of transmitters at both nodes are increasing for fixed values of the other parameters. As the transmission rate (μ1) increases, the utilization of the first node decreases when the other parameters remain fixed. Similarly as the transmission rate (μ2) increases the utilization of the second node decreases when the other parameters remain fixed. When the arrival rate parameter (ɵ) increases, utilization of the second node increases when other parameters remain fixed.

The mean number of packets in the buffers and in the network mean delays in transmission of both nodes are computed for different values are t,a,b,μ_1,μ_2,ɵ and π presented in Table 2 and "Figure 3".

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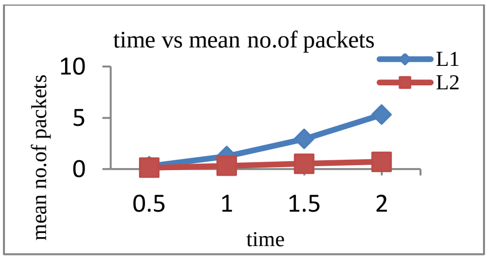
IJARCCE

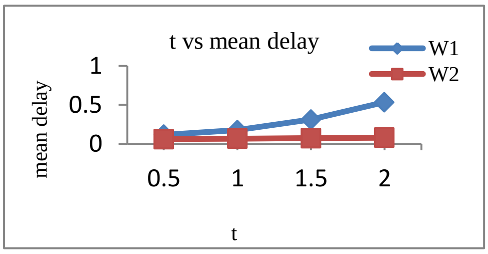
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 10, October 2015

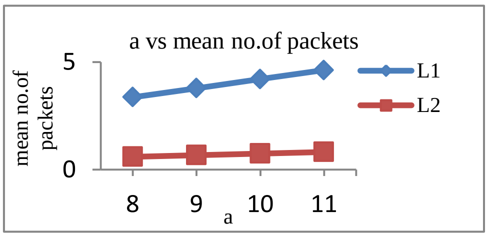
Table II: Values of mean number of packets and mean delay of the communication networks with dynamic band width allocation and Bulk Arrivals

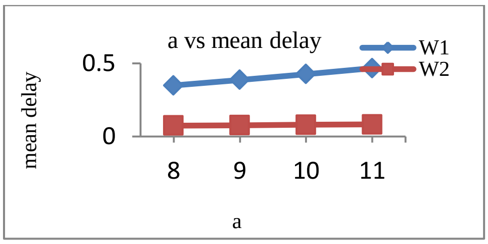
t	**a**	**b**	μ_1	μ_2	π	θ	L_1	L_2	**LN**	W_1	W_2
0.5	7	2	10	18	0.5	0.5	0.2805	0.1345	0.415	0.1147	0.0594
1	7	2	10	18	0.5	0.5	1.26	0.3284	1.5884	0.1759	0.0652
1.5	7	2	10	18	0.5	0.5	2.94	0.5228	3.4628	0.3104	0.0713
2	7	2	10	18	0.5	0.5	5.32	0.7173	6.0373	0.5346	0.0778
1.5	**8**	2	10	18	0.5	0.5	3.36	0.5975	3.9575	0.3481	0.0738
1.5	**9**	2	10	18	0.5	0.5	3.78	0.6722	4.4522	0.3868	0.0763
1.5	**10**	2	10	18	0.5	0.5	4.2	0.7469	4.9469	0.4262	0.0789
1.5	**11**	2	10	18	0.5	0.5	4.62	0.8216	5.4416	0.4666	0.0815
1.5	9	1.25	10	18	0.5	0.5	1.8346	0.3363	2.1709	0.2183	0.0654
1.5	9	**1.5**	10	18	0.5	0.5	2.3943	0.4344	2.8287	0.2635	0.0685
1.5	9	**1.75**	10	18	0.5	0.5	3.0391	0.5458	3.5849	0.3192	0.0721
1.5	9	**2**	10	18	0.5	0.5	3.78	0.6722	4.4522	0.3868	0.0763
1.5	9	2	**11**	18	0.5	0.5	3.4587	0.6768	4.1355	0.3246	0.0765
1.5	9	2	**12**	18	0.5	0.5	3.1875	0.6806	3.8681	0.2771	0.0766
1.5	9	2	**13**	18	0.5	0.5	2.9556	0.6838	3.6394	0.2398	0.0767
1.5	9	2	**14**	18	0.5	0.5	2.7551	0.6865	3.4416	0.2102	0.0768
0.5	0.5	0.5	0.5	**19**	0.5	0.5	2.9556	0.6492	3.6048	0.2398	0.0716
0.5	0.5	0.5	0.5	**20**	0.5	0.5	2.9556	0.6179	3.5735	0.2398	0.067
0.5	0.5	0.5	0.5	**21**	0.5	0.5	2.9556	0.5895	3.5451	0.2398	0.063
0.5	0.5	0.5	0.5	**22**	0.5	0.5	2.9556	0.5636	3.5192	0.2398	0.0595
0.5	0.5	0.5	0.5	20	**0.4**	**0.6**	2.9556	0.7415	3.6971	0.2398	0.0708
0.5	0.5	0.5	0.5	20	**0.3**	**0.7**	2.9556	0.865	3.8206	0.2398	0.0747
0.5	0.5	0.5	0.5	20	**0.2**	**0.8**	2.9556	0.9886	3.9442	0.2398	0.0787
0.5	0.5	0.5	0.5	20	**0.1**	**0.9**	2.9556	1.1122	4.0678	0.2398	0.0829

*=Seconds, $=Multiples of 10,000 packets/sec









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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 10, October 2015

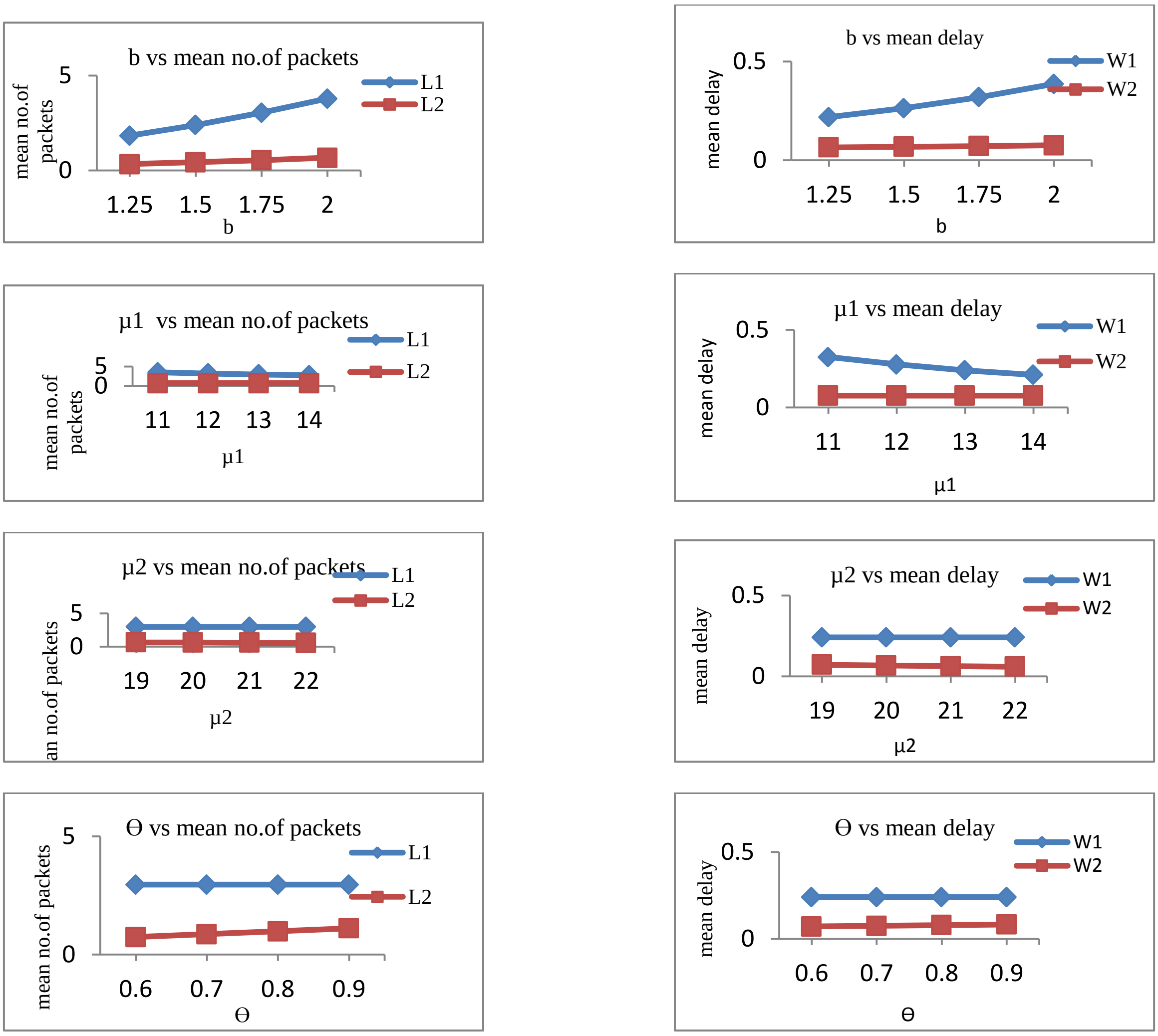

Figure 3: the relationship between mean number of packets, mean delay and various parameters

It is observed that at 0.5 seconds, the first buffer contains an average of 2805 packets, after 1 seconds it is rapidly increased to an average of 12600 packets. After of 1.5 seconds, the first buffer contains an average of 29400 packets and thereafter there is steady increase in the content of buffer for fixed values of other parameters(7,2,10,18,0.5,0.5) for (a,b,μ_1,μ_2, θ, π). It is also observed that as time (t) varies from 0.5 seconds to 2 seconds, the average content of the second buffer and in the network are increasing from 1345 packets to 7173 packets and from 415 packets to 6037 packets respectively when other parameters remain fixed.

When the arrival rate parameter (a) varies from 8×10^4 packets/sec to 11×10^4 packets/sec, the average content of the first buffer, second buffer and in the network are increasing from 33600 packets to 46200 packets, 5975 packets to 8216 packets, 39575 packets to 54416 packets respectively when other parameters remain fixed. The arrival rate parameter (b) varies from 1.25 to 2 the average number of packets in the first buffer, second buffer and in the network are increasing from 18346 packets to 37800 packets, 3362 packets to 6722 packets and 21708 packets to 44522 packets respectively when other parameters remain fixed.

When the transmission rate (μ_1) varies from 11×10^4 packets/sec to 14×10^4 packets/sec, the average content of the first buffer and in the network are decreasing from 34587 packets to 27551 packets from 41355 packets to 34416 packets and the average content in the second buffer increasing from 6768 packets to 6865 packets respectively when other parameters remain fixed. Similarly the transmission rate (μ_2) varies from 19×10^4 packets/sec to 22×10^4 packets/sec, the average content of the first buffer remains fixed at 29556 packets and the average content of second buffer and in the network are decreasing from 6491 packets to 5636 packets and 36047 packets to 35192 packets respectively when other parameters are fixed.

When the parameter (θ) varies from 0.6 to 0.9, the average content of the first buffer remains at 29556 packets and the average content of second buffer and in the network are increasing from 7415 packets to 11122 packets and 36971 packets to 40678 packets respectively, when other parameters are fixed.

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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 10, October 2015

It is observed that as the time (t) and the arrival rate parameter (a) are increasing, the mean delay in buffers is increasing from fixed values of the other parameters. When the transmission rate (μ_1) increases, the mean delay in the first buffer decreases when the other parameters remains fixed. Similarly, the transmission rate (μ_2) increases the mean delay in the second buffer decreases when the other parameter remains fixed.

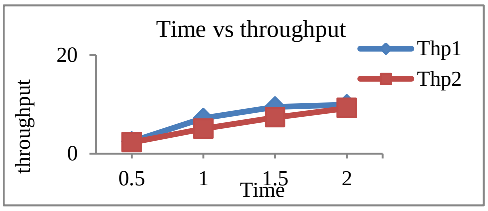
When the parameter (θ) increases the mean delay in the second buffer increases when other parameters are fixed.

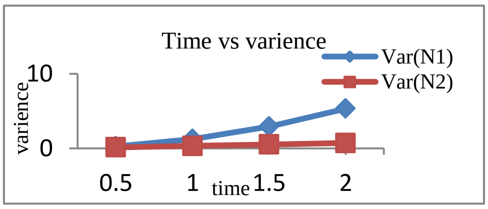
The variance of the number of packets in each buffer and throughput of each node are computed for different values of t,a,b,μ_1,μ_2,θ,π and presented in table 3 and "Figure 4".

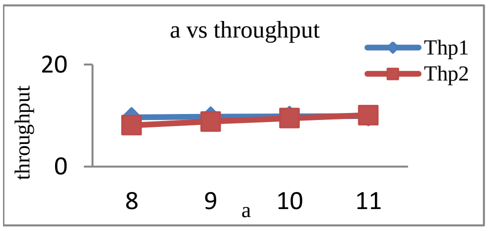
Table II: Effect of various parameters on Throughput and variance under transient state for communication network model with two stage arrivals.

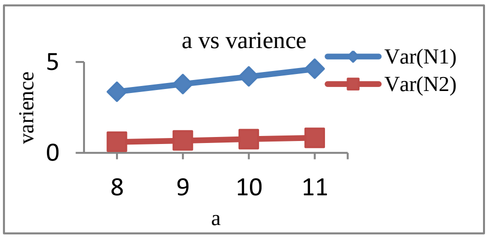
t	a	b	μ_1	μ_2	π	θ	Thp_1	Thp_2	$Var(N_1)$	$Var(N_2)$
0.5	7	2	10	18	0.5	0.5	2.4457	2.2649	0.2805	0.1345
1	7	2	10	18	0.5	0.5	7.1635	5.0386	1.26	0.3284
1.5	7	2	10	18	0.5	0.5	9.4713	7.329	2.94	0.5228
2	7	2	10	18	0.5	0.5	9.9511	9.2146	5.32	0.7173
1.5	**8**	2	10	18	0.5	0.5	9.6526	8.097	3.36	0.5975
1.5	**9**	2	10	18	0.5	0.5	9.7718	8.8097	3.78	0.6722
1.5	**10**	2	10	18	0.5	0.5	9.85	9.4711	4.2	0.7469
1.5	**11**	2	10	18	0.5	0.5	9.9015	10.0849	4.62	0.8216
1.5	9	1.25	10	18	0.5	0.5	8.4033	5.14	1.8346	0.3362
1.5	9	**1.5**	10	18	0.5	0.5	9.0877	6.3421	2.3944	0.4344
1.5	9	**1.75**	10	18	0.5	0.5	9.5212	7.5717	3.0391	0.5458
1.5	9	**2**	10	18	0.5	0.5	9.7718	8.8097	3.78	0.6722
1.5	9	2	**11**	18	0.5	0.5	10.6538	8.8514	3.4587	0.6768
1.5	9	2	**12**	18	0.5	0.5	11.5047	8.886	3.1875	0.6806
1.5	9	2	**13**	18	0.5	0.5	12.3234	8.9151	2.9556	0.6838
1.5	9	2	**14**	18	0.5	0.5	13.1096	8.94	2.7551	0.6865
1.5	9	2	13	**19**	0.5	0.5	12.3234	9.0728	2.9556	0.6492
1.5	9	2	13	**20**	0.5	0.5	12.3234	9.2183	2.9556	0.6179
1.5	9	2	13	**21**	0.5	0.5	12.3234	9.3531	2.9556	0.5895
1.5	9	2	13	**22**	0.5	0.5	12.3234	9.4782	2.9556	0.5636
1.5	9	2	13	20	**0.4**	**0.6**	12.3234	10.4717	2.9556	0.7415
1.5	9	2	13	20	**0.3**	**0.7**	12.3234	11.5793	2.9556	0.865
1.5	9	2	13	20	**0.2**	**0.8**	12.3234	12.5582	2.9556	0.9886
1.5	9	2	13	20	**0.1**	**0.9**	12.3234	13.4233	2.9556	1.1122

*=Seconds, $=Multiples of 10,000 packets/sec









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Vol. 4, Issue 10, October 2015

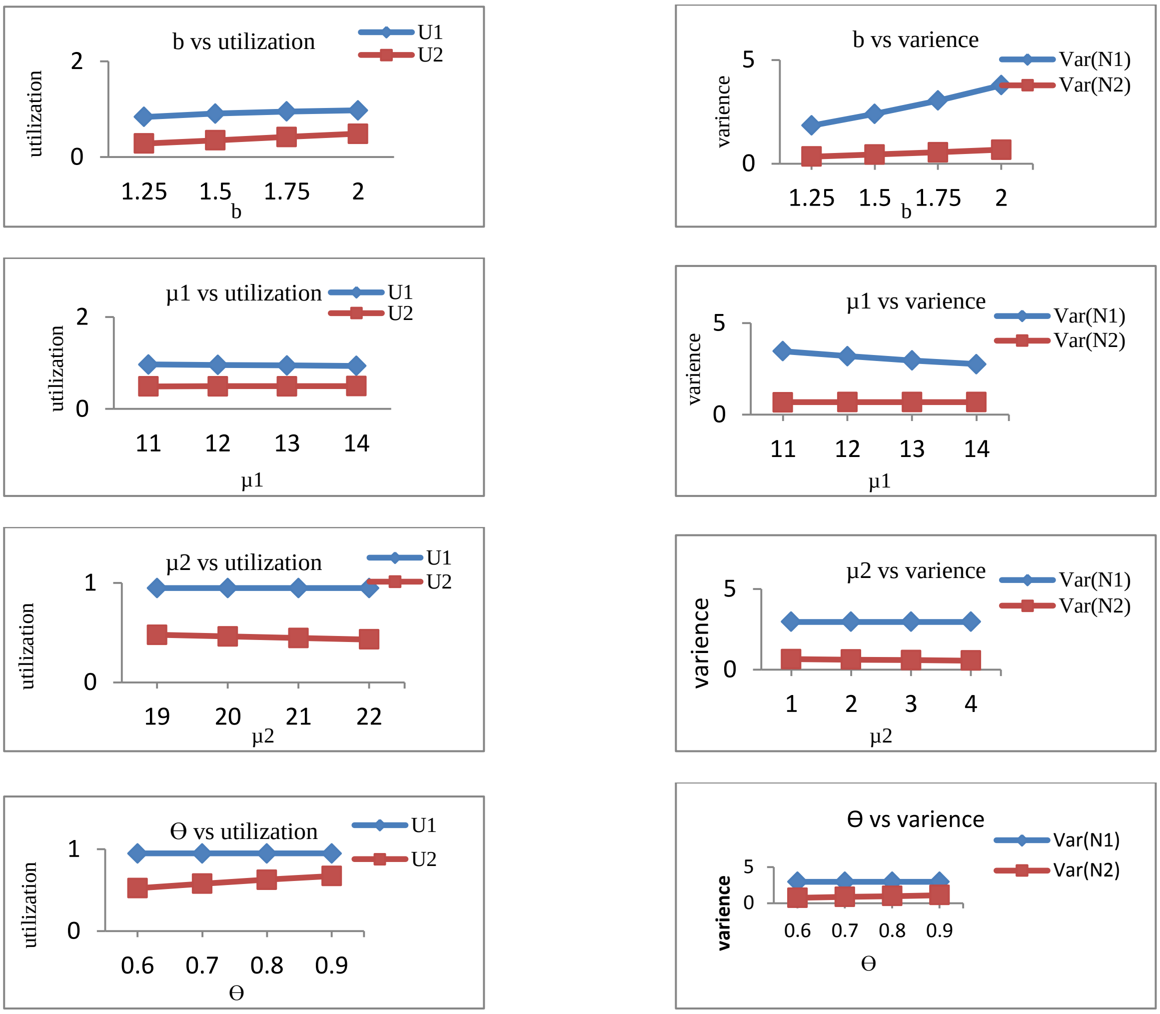

Figure 4: the relationship between throughput, variance and various parameters

It is observed as 't' increases, the throughput of first and second nodes are increasing from 24457 packets to 99511 packets and from 2.2649 packets to 92146 packets respectively for fixed values of the other parameters. As the arrival rate parameter (a) varies from 8×10^4 packets/sec to 11×10^4 packets/sec, the throughput of the first buffer and the second buffer are increasing form 96526 packets to 99015 packets, 8097 packets to 10084 packets respectively, when other parameters remain fixed. When the arrival rate parameter (b) varies from 1.25 to 2, the throughput of the first buffer and the second buffer are increasing from 84033 packets to 97718 packets, 51400 packets to 88097 packets respectively when the other parameters remain fixed.

When the transmission rate (μ_1) varies from 11×10^4 packets/sec to 14×10^4 packets/sec, the throughput of the first buffer and the second buffer are increasing from 106538 packets to 131096 packets, 88514 packets to 89400 packets respectively when other parameters remain fixed. Similarly, the transmission rate (μ_2) varies from 19×10^4 packets/sec to 22×10^4 packets/sec, the throughput of the first buffer remains at 123234 packets and the throughput of the second buffer increases from 90728 packets to 94782 respectively when the other parameters remain fixed. When the parameter (θ) varies from 0.6 to 0.9, the throughput of the first buffer remains at 12323 packets and the throughput of the second buffer increases from 10471 packets to 13423 packets when the other parameters remain fixed. If the variance of the number of packets in each buffer increases then the burstness of the buffers will be high. Hence, the parameters are to be adjusted in such a way that the variance of the content of each buffer is becomes small. The coefficients of variation of the buffer sizes are computed for each buffer which will help us to understand the consistency of the traffic flow through buffers. If this coefficient of variation is large then the flow is inconsistent and the requirement to search the assignable causes of high variation. It also helps us to control the smooth flow of packets in nodes.

It is, also observed that the dynamic bandwidth allocation strategy has a significant influence on all performance measures of the network. It is further observed that the performance measures are highly sensitive towards smaller values of time. Hence, it is optimal to consider dynamic bandwidth allocation under and non-homogenous Poisson arrivals and evaluate the performance under transient conditions. It is also to be observed that the

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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 10, October 2015

congestion in buffers and delays in transmission got reduced to a minimum level by adopting dynamic bandwidth allocation. This phenomenon has a vital bearing on quality of transmission.

V. SENSITIVITY ANALYSIS

Sensitivity analysis of the model is performed with respect to the t, a, b, μ1, μ2, θ, and π on the mean number of packets, the utilization of nodes, the mean delay and the throughput of the first and second buffers. The following data has been considered for the sensitivity analysis:
t = 1 sec, a=9 $\times 10^4$ packets/sec,b=2,μ_1=13 $\times 10^4$ packets/sec,μ_2=60$\times 10^4$ packets/sec , θ = 0.6.

The sensitivity analysis for the mean number of packets, the utilization of nodes, the mean delay, and the throughput of the first and second buffers are computed and presented in the table 4 with variation of - 15%,-10%,- 5%,0%,+5%,+10% and +15% on the model parameters.

As arrival rate parameter (a) increases from -15% to +15% the average number of packets in the two buffers and the total network increase along with the average delay in buffers, the utilization and the throughput of the two nodes.

As arrival rate parameter (a) increases to +15% the number of packets in the two buffers and total network are increasing along with the average delay, the utilization and the throughput of the two nodes. Similarly, for the arrival parameter (b), the utilization and the throughput are increasing in the communication network. When the parameter (θ) increases to +15% the mean number of packets in the two buffers, the utilization of the two nodes , the mean delay of the two buffers and the throughput of the two transmitters also increase. Overall analysis of the parameters reflects that the dynamic bandwidth allocation strategy for congestion control will tremendously reduce the delay in communication and improve the voice quality by reducing burstness in buffers.

Table IV: Sensitivity Analysis of the communication network with Dynamic Bandwidth Allocation

Parameter time(t) sec	Performance measure	% change in parameters						
		-15%	-10%	-5%	0%	5%	10%	15%
t=1	L1	0.90985	1.02568	1.14843	1.27811	1.4147	1.55822	1.70867
	L2	0.32539	0.34789	0.37039	0.39288	0.41538	0.43788	0.46038
	U1	0.5974	0.6414	0.6829	0.7214	0.757	0.7895	0.8189
	U2	0.2778	0.2938	0.3095	0.3249	0.3399	0.3546	0.369
	Thp1	7.7664	8.3388	8.8773	9.3787	9.841	10.2634	10.6456
	Thp2	5.555	5.8764	6.1906	6.4978	6.7983	7.092	7.3792
	W1	0.1172	0.123	0.1294	0.1363	0.1438	0.1518	0.1605
	W2	0.0586	0.0592	0.0598	0.0605	0.0611	0.0617	0.0624
a=9	L1	0.08639	1.1503	1.2142	1.27811	1.34201	1.40592	1.46982
	L2	0.33395	0.3536	0.37324	0.39288	0.41253	0.43217	0.45182
	U1	0.6626	0.6835	0.7031	0.7214	0.7387	0.7549	0.77
	U2	0.2839	0.2978	0.3115	0.3249	0.338	0.3509	0.3635
	Thp1	8.6134	8.8849	9.1397	9.3787	9.6028	9.8132	10.0102
	Thp2	5.6782	5.5968	6.23	6.4978	6.7605	7.0181	7.2706
	W1	0.1261	0.1295	0.1328	0.1363	0.1398	0.1433	0.1468
	W2	0.0588	0.0594	0.0599	0.0605	0.061	0.0616	0.0621
b=2	L1	1.11191	1.16815	1.22355	1.27811	1.33185	1.38481	1.43698
	L2	0.34739	0.36298	0.37814	0.39288	0.40723	0.42119	0.43477
	U1	0.6711	0.6891	0.7058	0.7214	0.736	0.7496	0.7624
	U2	0.2935	0.3044	0.3149	0.3249	0.3345	o.3437	0.3526
	Thp1	8.7239	8.9578	9.1756	9.3787	9.5682	9.7452	9.9106
	Thp2	5.8694	6.088	6.2973	6.4978	6.6902	6.8746	7.0517
	W1	0.1275	0.1304	0.1333	0.1363	0.1392	0.1421	0.145
	W2	0.0592	0.0596	0.06	0.0605	0.0609	0.0613	0.0617
μ_1=13	L1	1.48154	0.1407	1.33948	1.27811	1.22207	1.17072	1.12348
	L2	0.38678	0.38904	0.39106	0.39288	0.39453	0.39603	0.3974
	U1	0.7727	0.7551	0.738	0.7214	0.7054	0.6899	0.6749
	U2	0.3208	0.3223	0.3237	0.3249	0.326	0.327	0.3279
	Thp1	8.5385	8.8349	9.1147	9.3787	9.6285	9.8649	10.089
	Thp2	6.4152	6.4458	6.4733	6.4978	6.5201	6.5403	6.5587
	W1	0.1735	0.1593	0.147	0.1363	0.1269	0.1187	0.1114
	W2	0.0603	0.0604	0.0604	0.0605	0.0605	0.0606	0.0606

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 10, October 2015

μ_2=20	L1	1.27811	1.27811	1.27811	1.27811	1.27811	1.27811	1.27811
	L2	0.45755	0.43376	0.41232	0.39288	0.3752	0.35903	0.34419
	U1	0.7214	0.7214	0.7214	0.7214	0.7214	0.7214	0.7214
	U2	0.3672	0.3515	0.3379	0.3249	0.3128	0.3016	0.2912
	Thp1	9.3787	9.3787	9.3787	9.3787	9.3787	9.3787	9.3787
	Thp2	6.2418	6.3348	6.4198	6.4978	6.5698	6.6362	6.6977
	W1	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363
	W2	0.0733	0.0685	0.0642	0.0605	0.0571	0.0541	0.0514
Θ=0.6	L1	1.27811	1.27811	1.27811	1.27811	1.27811	1.27811	1.27811
	L2	0.40074	0.42432	0.44789	0.47146	0.49503	0.51861	0.54218
	U1	0.7214	0.7214	0.7214	0.7214	0.7214	0.7214	0.7214
	U2	0.3302	0.3458	0.361	0.3759	0.3905	0.4047	0.4185
	Thp1	9.3787	9.3787	9.3787	9.3787	9.3787	9.3787	9.3787
	Thp2	6.6036	6.9151	7.2205	7.5182	7.809	8.093	8.3704
	W1	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363
	W2	0.0607	0.0614	0.062	0.0627	0.0634	0.0641	0.0648

VI. COMPARATIVE STUDY

The comparative study between the proposed communication network models with homogenous Poisson arrivals it's carried in this section. The computed performance measure of both models are presented in the Table 5 for different values of t = 1, 1.5, 2, 2.5 seconds. As t increases, the percentage variation of performance measures between the models also increase. For the proposed model with non-homogenous Poisson arrivals with dynamic bandwidth allocation has more utilization compared to that of the model with homogenous Poisson arrivals under dynamic bandwidth allocation. It is also observed that the assumption of non-homogenous Poisson arrivals has a significant influence on all the performance measures of the network.

Table v: A comparative study of homogeneous and non homogeneous Duane arrivals

time(t) sec	perameters measured	Model with Poisson arrivals	Proposed Model	Difference	% of Variation
t=1	L1	0.7	1.26	0.56	80
	L2	0.1944	0.3284	0.134	68.93004115
	U1	0.5034	0.7163	0.2129	42.2924116
	U2	0.1767	0.2799	0.1032	58.4040747
	Thp1	5.034	7.1635	2.1295	42.30234406
	Thp2	3.1805	5.0386	1.8581	58.42163182
	W1	0.139	0.1759	0.0369	26.54676259
	W2	0.0611	0.0652	0.0041	6.710310966
t=1.5	L1	1.05	2.94	1.89	180
	L2	0.1944	0.5228	0.3284	168.9300412
	U1	0.6501	0.9471	0.297	45.68527919
	U2	0.1767	0.4072	0.2305	130.4470855
	Thp1	6.5006	9.4713	2.9707	45.69885857
	Thp2	3.1807	7.329	4.1483	130.4209765
	W1	0.1615	0.3104	0.1489	92.19814241
	W2	0.0611	0.0713	0.0102	16.69394435

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ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 10, October 2015

t=2	L1	1.4	5.32	3.92	280
	L2	0.1944	0.7173	0.5229	268.9814815
	U1	0.7534	0.9951	0.2417	32.08123175
	U2	0.1767	0.5119	0.3352	189.7000566
	Thp1	7.534	9.9511	2.4171	32.08255907
	Thp2	3.1807	9.2146	6.0339	189.7035244
	W1	0.1858	0.5346	0.3488	187.7287406
	W2	0.0611	0.0778	0.0167	27.33224223
t=2.5	L1	1.75	8.4	6.65	380
	L2	0.1944	0.9117	0.7173	368.9814815
	U1	0.8262	0.9998	0.1736	21.01186153
	U2	0.1767	0.5982	0.4215	238.5398981
	Thp1	8.2623	9.9978	1.7355	21.00504702
	Thp2	3.1807	10.7671	7.5864	238.5135348
	W1	0.2118	0.8402	0.6284	296.6949953
	W2	0.0611	0.0847	0.0236	38.62520458

VII. CONCLUSION

This paper addresses for the first time a two node tandem communication network model with weibull inter arrival times and having dynamic bandwidth allocation, with intermediatery departures between two nodes. The arrival process is characterized by Duane process which is a generalization of the homogeneous Poisson process having mean arrival rate as a power function of time. Here two nodes are connected in tandem and transmission times in each node follow exponential distribution with different transmission rates. The dynamic bandwidth allocation strategy is adopted at each node. It is further considered that after getting transmission from first node the packet may join the buffer connected to the second node or may get terminated with certain probability. The time dependent arrival process characterizes the self-similarity networks.

This sort of statistical multiplexing smooths the traffic in buffers and avoids burstness. The performance of the network is evaluated by deriving the explicit expressions for mean content of the buffers and mean delay in transmission. Through numerical study it is observed the Duane arrival process has a significance influence on the performance measures. The dynamic bandwidth allocation strategy can reduce congestion in buffers and mean delay in transmission. This network model is useful for analyzing LAN, WAN and MAN where the traffic is time dependent. This model also includes some of the models as particular cases. This model can be extended to the case of bulk arrivals which will be taken up else ware.

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