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Performance Analysis of A Two Node Tandem Communication Network with Feedback

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PERFORMANCEANALYSISOFATWONODETANDEMCOMMUNICATIONNETWORKWITHFEEDBACK

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Performance Analysis of A Two Node Tandem Communication Network with Feedback

CH. V. Raghavendran [α], G. Naga Satish [σ], M. V. Rama Sundari [ρ] & P. Suresh Varma [ω]

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I. Introduction

A communication network has to transfer data/voice effectively with a guaranteed Quality of Service (QoS). Number of algorithms based on flow control and bit dropping techniques have been developed with various protocols and allocation strategies for efficient transmission by optimum utilization of the bandwidth [1] [2] [3] [4]. But utilization of the idle bandwidth by adjusting the transmission rate instantaneously just before transmission of a packet is more important to maintain QoS.

Utilization of the resources is another major consideration for a communication network. Congestion control and packet scheduling are the two major issues to be considered in designing a communication network. In communication network congestion occurs due to unpredicted nature of the transmission lines. Packet scheduling is a process of assigning users' packets to appropriate shared resource to achieve some performance guarantee. Packetized transmissions over links via proper packet scheduling algorithms will possibly make higher resource utilization through statistical multiplexing of packets compared to conventional circuit-based communications. Earlier these two aspects are dealt separately. But, the integration of these two is needed in order to utilize resources more effectively and efficiently. In [5] [6] Matthew Andrews considered the joint optimization of scheduling and congestion control in communication networks. The statistical multiplexing with load dependent strategy has been evolved through bit-dropping and flow control techniques to decrease congestion in buffers [7] [8].

From the literature, it is observed that in most of the papers it was assumed that the arrival and transmission processes are independent. But in store-and-forward communication systems this assumption is realistically inappropriate. Since the massages, generally preserve the length as they transfers the network, the inter arrival and service sequences at buffer, interval to the system are time dependent as they formulate a queuing process at each node of the network through which the packet are routed. These dependences can have a significant influence on the system performance [7].

Dynamic Bandwidth Allocation (DBA) strategy of transmission considers the adjustment of transmission rate of the packet depending upon the content of the buffer connected to transmitter at that instant [9]. This strategy has grown as an alternate for bit dropping and flow control strategies for quality in transmission and to reduce the congestion in buffers [8] [10] [11] [12]. The strategy of dynamic bandwidth allocation is to utilize a large portion of the unutilized bandwidth.

From the literature we found some work regarding communication networks with dynamic bandwidth allocation. In [11], P.Suresh Varma et al has studied the communication network model with an assumption that the transmission rate of packet is adjusted instantaneously depending upon the content of the buffer. In [13], Rama Sundari., et al have developed and analyzed a three node communication network model with the assumption that the arrivals are characterized by non homogeneous Poisson process. It is further assumed that transmission time required by each packet at each node is dependent on the content of the buffer connected to it. Tirupathi Rao et al [14] proposed a two node tandem communication network with DBA having compound Poisson binomial bulk

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arrivals for scheduling the Internet, ATM, LAN and WAN. Generally, conducting laboratory experiments with varying load conditions of a communication system in particular with DBA is difficult and complicated. Hence, mathematical models of communication networks are developed to evaluate the performance of the newly proposed communication network model under transient conditions.

In this paper we have developed and studied a communication network model with two nodes having homogeneous Poisson arrival and dynamic bandwidth allocation with feedback for both nodes. Here it is assumed that the packets arrive at the first buffer directly with constant arrival rate. After getting transmitted from the first transmitter the packets may join the buffer connected to the second transmitter in tandem with first transmitter or returned back to the first buffer for retransmission with certain probability. Similarly, the packets transmitted by the second transmitter may leave the network or returned back to the second buffer for retransmission with certain probability. Using difference-differential equations the transient behavior of the model is analyzed by deriving the joint probability generating function of the number of packets in each buffer. The performance measures like average number of packets in the buffer and in the system; the average waiting time of packets in the buffer and in the system, throughput of the transmitter etc., of the developed network model are derived explicitly.

II. Proposed Communication Network Model with DBA and Homogeneous Poisson Arrivals

Let us consider a communication network model with two nodes. A node consists of a buffer and a transmitter. Assume that the two buffers Q_1, Q_2 and transmitters S_1, S_2 are connected in series in Tandem model. It is assumed that the packet after getting transmitted through first transmitter may join the second buffer which is in series connected to S_2 or may be returned back to S_1 with certain probabilities. The packets delivered from the first transmitter and arrived at the second buffer may be transmitted out of the network or returned back to the second transmitter for retransmission. The arrival of packets at the first node follows homogeneous Poisson processes with a mean composite arrival rate λ. It is also assumed that the packets are transmitted through the transmitters; the mean service rate in the transmitter is linearly dependent on the content of the buffer connected to it. The buffers follow First-In First-Out (FIFO) technique for transmitting the packets through transmitters. After getting transmitted from the first transmitter the packets are forwarded to the second buffer for transmission with probability (1-θ) or returned back to the first buffer with probability θ. The packets arrived from the first transmitter are forwarded to the second buffer for transmission and exit from the network with probability (1-π) or returned back to the second transmitter with probability π. The service completion in both the transmitters follows Poisson processes with the parameters μ_1 and μ_2 for the first and second transmitters. The transmission rate of each packet is adjusted just before transmission depending on the content of the buffer connected to the transmitter. A schematic diagram representing the network model with two transmitters and feedback for both transmitters is shown in figure 1.

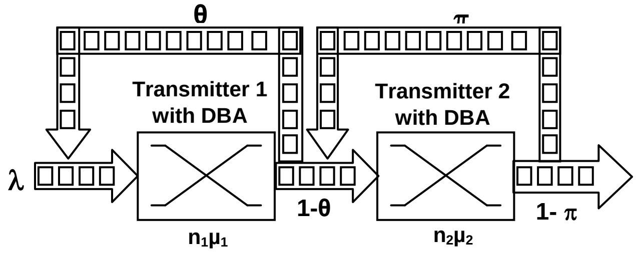

Figure 1 : Communication network model

Let n1 and n2 are the number of packets in first and second buffers and let $P_{n1,n2}(t)$ be the probability that there are n_1 packets in the first buffer and n_2 packets in the second buffer at time t. The difference-differential equations for the above model are as follows:

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

$$\frac{\partial P_{n_1,0}(t)}{\partial t} = -(\lambda + n_1\mu_1(1-\theta))P_{n_1 0}(t) + \lambda P_{n_1-1,0}(t)$$
$$+\mu_2(1-\pi)P_{n_1,1}(t)$$

$$\frac{\partial P_{0,n_2}(t)}{\partial t} = -(\lambda + n_2\mu_2(1-\pi))P_{0,n_2}(t) + \mu_1(1-\theta)P_{1,n_2-1}(t)$$
$$+(n_2+1)\mu_2(1-\pi)P_{0,n_2+1}(t)$$

$$\frac{\partial P_{0,0}(t)}{\partial t} = -\lambda P_{0,0}(t) + \mu_2(1-\pi)P_{0,1}(t) \tag{2.1}$$

Let P(S_1,S_2;t) be the joint probability generating function of $P_{n1,n2}(t)$. Then multiply the equation 2.1 with $S_1^{n_1}$ $S_2^{n_2}$ and summing over all n1, n2 we get

$$\frac{\partial P(s_1,s_2:t)}{\partial t} = -\lambda P(s_1,s_2:t) + \lambda \sum_{n_1=0}^{\infty}\sum_{n_2=0}^{\infty} P_{n_1-1,n_2}(t)s_1^{n_1}s_2^{n_2}$$
$$-\sum_{n_1=1}^{\infty}\sum_{n_2=0}^{\infty} n_1\mu_1(1-\theta)P_{n_1,n_2}(t)s_1^{n_1}s_2^{n_2}$$

$$
\begin{aligned}
&+\sum_{n_1=0}^{\infty}\sum_{n_2=1}^{\infty}(n_1+1)\mu_1(1-\theta)P_{n_1+1,n_2-1}(t)s_1^{n_1}s_2^{n_2}\\
&-\sum_{n_1=0}^{\infty}\sum_{n_2=1}^{\infty}n_2\mu_2(1-\pi)P_{n_1,n_2}(t)s_1^{n_1}s_2^{n_2}\\
&+\sum_{n_1=0}^{\infty}\sum_{n_2=1}^{\infty}(n_2+1)\mu_2(1-\pi)P_{n_1,n_2+1}(t)s_1^{n_1}s_2^{n_2}\\
&+\sum_{n_1=0}^{\infty}\mu_2(1-\pi)P_{n_1,1}(t)s_1^{n_1}
\end{aligned}
\qquad (2.2)
$$

After simplifying we get

$$
\frac{\partial P(s_1,s_2:t)}{dt}=\mu_1(1-\theta)(s_2-s_1)\frac{\partial p}{\partial s_1}+
$$

$$
\mu_2(1-\pi)(1-s_2)\frac{\partial p}{\partial s_2}-\lambda(1-s_1)\frac{\partial P(s_1,s_2:t)}{\partial t} \qquad (2.3)
$$

Solving equation 2.3 by Lagrangian's method, we get the auxiliary equations as,

$$
\frac{dt}{1}=\frac{-ds_1}{\mu_1(1-\theta)(s_2-s_1)}=\frac{-ds_2}{\mu_2(1-\pi)(1-s_2)}=\frac{dp}{\lambda P(s_1-1)}
$$

(2.4)

Solving first and fourth terms in equation 2.4, we get

$$
a=(s_2-1)e^{\mu_2(1-\pi)t} \qquad (2.5\text{ a})
$$

Solving first and third terms in equation 2.4, we get

$$
b=(s_1-1)e^{-\mu_1(1-\theta)t}+\frac{(s_2-1)\mu_1(1-\theta)e^{-\mu_1(1-\theta)t}}{(\mu_2(1-\pi)-\mu_1(1-\theta))}
$$

(2.5 b)

Solving first and second terms in equation 2.4, we get

$$
c=P(s_1,s_2;t)\exp\left\{-\left[\frac{(s_1-1)\lambda}{\mu_1(1-\theta)}+\frac{(s_2-1)\lambda}{\mu_2(1-\pi)}\right]\right\}
$$

(2.5 c)

Where a,b and c are arbitrary constants.

The general solution of equation 2.4 gives the probability generating function of the number of packets in the first and second buffers at time t, as P (S1, S2; t).

$$
P(s_1,s_2;t)=\exp\left\{
\begin{array}{l}
\dfrac{(S_1-1)\lambda(1-e^{-\mu_1(1-\theta)t})}{\mu_1(1-\theta)}+\\
\dfrac{(S_2-1)\lambda\left(1-e^{-\mu_2(1-\pi)t}\right)}{\mu_2(1-\pi)}+\\
\dfrac{(S_2-1)\lambda\left(e^{\mu_2(1-\pi)t}-e^{\mu_1(1-\theta)t}\right)}{(\mu_2(1-\pi)-\mu_1(1-\theta))}
\end{array}
\right\} \quad (2.6)
$$

III. PERFORMANCE MEASURES OF THE NETWORK MODEL

In this section, we expand P (S1, S2; t) of equation of 2.6 and collect the constant terms. From this, we get the probability that the network is empty as

$$
P_{00}(t)=\exp\left\{
\begin{array}{l}
\dfrac{-1}{\mu_1(1-\theta)}\lambda\left(1-e^{\mu_1(1-\theta)t}\right)+\dfrac{-1}{\mu_2(1-\pi)}\left(1-e^{-\mu_2(1-\pi)t}\right)\lambda+\\
\dfrac{-1}{(\mu_2(1-\pi)-\mu_1(1-\theta))}\left(e^{-\mu_2(1-\pi)t}-e^{-\mu_1(1-\theta)t}\right)\lambda
\end{array}
\right\} (3.1)
$$

Taking $S_2=1$ in equation 2.6 we get probability generating functions of the number of packets in the first buffer is

$$
P(S_1;t)=\exp\left\{\frac{S_1-1}{\mu_1(1-\theta)}\lambda\left(1-e^{-\mu_1(1-\theta)t}\right)\right\} \qquad (3.2)
$$

Probability that the first buffer is empty as (S1=0)

$$
P_{0.}(t)=\exp\left\{\frac{-1}{\mu_1(1-\theta)}\lambda\left(1-e^{\mu_1(1-\theta)t}\right)\right\} \qquad (3.3)
$$

Taking S1=1 in equation 2.6 we get probability generating function of the number of packets in the first buffer is

$$
P(S_2;t)=\exp\left\{
\begin{array}{l}
\dfrac{(S_2-1)\lambda\left(1-e^{-\mu_2(1-\pi)t}\right)}{\mu_2(1-\pi)}+\\
\dfrac{(S_2-1)\lambda}{(\mu_2(1-\pi)-\mu_1(1-\theta))}\left(e^{\mu_2(1-\pi)t}-e^{\mu_1(1-\theta)t}\right)
\end{array}
\right\} (3.4)
$$

Probability that the second buffer is empty as (S2=0)

$$
P_{.0}(t)=\exp\left\{
\begin{array}{l}
\dfrac{-1}{\mu_2(1-\pi)}\lambda\left(1-e^{-\mu_2(1-\pi)t}\right)+\\
\dfrac{-1}{(\mu_2(1-\pi)-\mu_1(1-\theta))}\lambda\left(e^{-\mu_2(1-\pi)t}-e^{-\mu_1(1-\theta)t}\right)
\end{array}
\right\} \qquad (3.5)
$$

Mean Number of Packets in the First Buffer is

$$
L_1(t)=\left\{\frac{1}{\mu_1(1-\theta)}\lambda\left(1-e^{-\mu_1(1-\theta)t}\right)t\right\} \qquad (3.6)
$$

Utilization of the first transmitter is

$$
U_1(t)=1-P_{0.}(t)=1-\exp\left\{\frac{-1}{\mu_1(1-\theta)}\lambda\left(1-e^{-\mu_1(1-\theta)t}\right)\right\}
$$

(3.7)

Variance of the no. of packets in the first buffer is

$$
V_1(t)=\left\{\frac{1}{\mu_1(1-\theta)}\lambda\left(1-e^{-\mu_1(1-\theta)t}\right)t\right\} \qquad (3.8)
$$

Throughput of the first transmitter is

$$
Th_1=\mu_1(1-P_{0.}(t))=\mu_1\left(1+\exp\left\{\frac{-1}{\mu_1(1-\theta)}\lambda\left(1-e^{-\mu_1(1-\theta)t}\right)\right\}\right) \qquad (3.9)
$$

Average waiting time in the first Buffer is

$$W_1(t)=\frac{L_1(t)}{\mu_1(1-P_{0.}(t))}=\frac{\left\{\frac{1}{\mu_1(1-\theta)}\lambda\left(1-e^{-\mu_1(1-\theta)t}\right)t\right\}}{\mu_1\left(1+\exp\left\{\frac{-1}{\mu_1(1-\theta)}\lambda\left(1-e^{-\mu_1(1-\theta)t}\right)\right\}\right)} \tag{3.10}$$

Mean number of packets in the second buffer is

$$L_2(t)=\left\{\begin{array}{l}\frac{1}{\mu_2(1-\pi)}\left(1-e^{-\mu_2(1-\pi)t}\right)\lambda+\\ \frac{1}{(\mu_2(1-\pi)-\mu_1(1-\theta))}\left(e^{-\mu_2(1-\pi)t}-e^{-\mu_1(1-\theta)t}\right)\lambda\end{array}\right\} \tag{3.11}$$

Utilization of the second transmitter is

$$U_2(t)=1-P_{.0}(t)=1-\exp\left\{\begin{array}{l}\frac{-1}{\mu_2(1-\pi)}\left(1-e^{-\mu_2(1-\pi)t}\right)\lambda+\\ \frac{-1}{(\mu_2(1-\pi)-\mu_1(1-\theta))}\left(e^{-\mu_2(1-\pi)t}-e^{-\mu_1(1-\theta)t}\right)\lambda\end{array}\right\} \tag{3.12}$$

Variance of the no. of packets in the second buffer is

$$V_2(t)=\left\{\begin{array}{l}\frac{1}{\mu_2(1-\pi)}\left(1-e^{-\mu_2(1-\pi)t}\right)\lambda+\\ \frac{1}{(\mu_2(1-\pi)-\mu_1(1-\theta))}\left(e^{-\mu_2(1-\pi)t}-e^{-\mu_1(1-\theta)t}\right)\lambda\end{array}\right\} \tag{3.13}$$

Throughput of the second transmitter is

$$Th_2(t)=\mu_2\left(1-P_{.0}(t)\right)$$

$$=\mu_2\left(1+\exp\left\{\begin{array}{l}\frac{1}{\mu_2(1-\pi)}\left(1-e^{-\mu_2(1-\pi)t}\right)\lambda+\\ \frac{1}{(\mu_2(1-\pi)-\mu_1(1-\theta))}\left(e^{-\mu_2(1-\pi)t}-e^{-\mu_1(1-\theta)t}\right)\lambda\end{array}\right\}\right) \tag{3.14}$$

Average waiting time in the second buffer is

$$W_2(t)=\frac{L_2(t)}{\mu_2(1-P_{.0}(t))} \tag{3.15}$$

Mean number of packets in the entire network at time t is

$$L(t)=L_1(t)+L_2(t) \tag{3.16}$$

Variability of the number of packets in the network is

$$V(t)=V_1(t)+V_2(t) \tag{3.17}$$

IV. Performance Evaluation of the Network Model

In this section, the performance of the network model is discussed with numerical illustration. Different values of the parameters are taken for bandwidth allocation and arrival of packets. The packet arrival (λ) varies from 2×10^4 packets/sec to 7×10^4 packets/sec, probability parameters (θ, π) varies from 0.1 to 0.9, the transmission rate for first transmitter (μ_1) varies from 5×10^4 packets/sec to 9×10^4 packets/sec and transmission rate for second transmitter (μ_2) varies from 15×10^4 packets/sec to 19×10^4 packets/sec. Dynamic Bandwidth Allocation strategy is considered for both the two transmitters. So, the transmission rate of each packet depends on the number of packets in the buffer connected to corresponding transmitter.

The equations 3.7, 3.9, 3.12 and 3.14 are used for computing the utilization of the transmitters and throughput of the transmitters for different values of parameters t, λ, θ, π, μ_1, μ_2 and the results are presented in the Table 1. Graphs in the figure 2 show the relationship between utilization of the transmitters and throughput of the transmitters.

From the table 1 it is observed that, when the time (t) and λ increases, the utilization of the transmitters is increasing for the fixed value of other parameters λ, π, μ_1, μ_2. As the first transmitter probability parameter θ increases from 0.1 to 0.9, the utilization of first transmitter increases and utilization of the second transmitter decreases, this is due to the number of packets arriving at the second transmitter are decreasing as number of packets going back to the first transmitter in feedback are increasing. As the second transmitter probability parameter π increases from 0.1 to 0.9, the utilization of first transmitter remains constant and utilization of the second transmitter increases. This is because the number of packets arriving at the second transmitter is packets arriving directly from the first transmitter and packets arrived for retransmission in feedback. As the transmission rate of the first transmitter (μ_1) increases from 5 to 9, the utilization of the first transmitter decreases and the utilization of the second transmitter increases by keeping the other parameters as constant. As the transmission rate of the second transmitter (μ_2) increases from 15 to 19, the utilization of the first transmitter is constant and the utilization of the second transmitter decreases by keeping the other parameters as constant.

It is also observed from the table 1 that, as the time (t) increases, the throughput of first and second transmitters is increasing for the fixed values of other parameters. When the parameter λ increases from 3×10^4 packets/sec to 7×10^4 packets/sec, the throughput of both transmitters is increasing. As the first probability parameter θ value increases from 0.1 to 0.9, the

Table 1 : Values of Utilization and Throughput of the Network model with DBA and Homogeneous Poisson arrivals

t	λ	θ	π	μ_1	μ_2	$U_1(t)$	$U_2(t)$	$Th_1(t)$	$Th_2(t)$
0.1	2	0.1	0.1	5	15	0.1488	0.0253	0.7438	0.3799
0.3	2	0.1	0.1	5	15	0.2805	0.0877	1.4026	1.3161
0.5	2	0.1	0.1	5	15	0.3281	0.1173	1.6403	1.7601
0.7	2	0.1	0.1	5	15	0.3465	0.1295	1.7325	1.9418
0.9	2	0.1	0.1	5	15	0.3538	0.1344	1.7692	2.0153
0.5	**3**	0.1	0.1	5	15	0.4492	0.1707	2.2460	2.5611
0.5	**4**	0.1	0.1	5	15	0.5485	0.2209	2.7425	3.3136
0.5	**5**	0.1	0.1	5	15	0.6299	0.2680	3.1495	4.0206
0.5	**6**	0.1	0.1	5	15	0.6966	0.3123	3.4831	4.6849
0.5	**7**	0.1	0.1	5	15	0.7513	0.3539	3.7566	5.3089
0.5	2	**0.1**	0.1	5	15	0.3281	0.1173	1.6403	1.7601
0.5	2	**0.3**	0.1	5	15	0.3763	0.1073	1.8816	1.6088
0.5	2	**0.5**	0.1	5	15	0.4349	0.0916	2.1746	1.3743
0.5	2	**0.7**	0.1	5	15	0.5052	0.0671	2.5258	1.0063
0.5	2	**0.9**	0.1	5	15	0.5872	0.0279	2.9360	0.4191
0.5	2	0.1	**0.1**	5	15	0.3281	0.1173	1.6403	1.7601
0.5	2	0.1	**0.3**	5	15	0.3281	0.1445	1.6403	2.1678
0.5	2	0.1	**0.5**	5	15	0.3281	0.1860	1.6403	2.7902
0.5	2	0.1	**0.7**	5	15	0.3281	0.2620	1.6403	3.9304
0.5	2	0.1	**0.9**	5	15	0.3281	0.3680	1.6403	5.5200
0.5	2	0.1	0.1	**5**	15	0.3281	0.1173	1.6403	1.7601
0.5	2	0.1	0.1	**6**	15	0.2921	0.1234	1.7527	1.8505
0.5	2	0.1	0.1	**7**	15	0.2620	0.1275	1.8342	1.9126
0.5	2	0.1	0.1	**8**	15	0.2368	0.1304	1.8941	1.9554
0.5	2	0.1	0.1	**9**	15	0.2154	0.1323	1.9388	1.9851
0.5	2	0.1	0.1	5	**15**	0.3281	0.1173	1.6403	1.7601
0.5	2	0.1	0.1	5	**16**	0.3281	0.1110	1.6403	1.7758
0.5	2	0.1	0.1	5	**17**	0.3281	0.1053	1.6403	1.7895
0.5	2	0.1	0.1	5	**18**	0.3281	0.1001	1.6403	1.8015
0.5	2	0.1	0.1	5	**19**	0.3281	0.0954	1.6403	1.8122

throughput of the first transmitter increases and the throughput of the second transmitter is decreasing. As the second probability parameter π value increases from 0.1 to 0.9, the throughput of the first transmitter remains constant and the throughput of the second transmitter is increasing. As the transmission rate of the first transmitter (μ_1) increases from 5×10^4 packets/sec to 9×10^4 packets/sec, the throughput of the first and second transmitters is increasing. The transmission rate of the second transmitter (μ_2) increases from 15×10^4 packets/sec to 19×10^4 packets/sec and the throughput of the first transmitter is constant and the throughput of the second transmitter is increasing.

Using equations 3.6, 3.8, 3.16 and 3.13, 3.15 the mean no. of packets in the two buffers and in the network, mean delay in transmission of the two transmitters are calculated for different values of t, λ, θ, π, μ_1, μ_2 and the results are shown in the table 2. The graphs showing the relationship between parameters and performance measure are shown in the figure 3.

It is observed from the table 2 that as the time (t) varies from 0.1 to 0.9 seconds, the mean number of packets in the two buffers and in the network are increasing when other parameters are kept constant. When the λ changes from 3×10^4 packets/second to 7×10^4 packets/second the mean number of packets in the first, second buffers and in the network are increasing. As the first probability parameter θ varies from 0.1 to 0.9, the mean number packets in the first buffer increases and decreases in the second buffer due to feedback for the first buffer. When the second probability parameter π varies from 0.1 to 0.9, the mean number packets in the first buffer remains constant and increases in the second buffer due to packets arrived directly from the first transmitter and packets for retransmission due to feedback from the second transmitter. When the transmission rate of the first transmitter (μ_1) varies from 5×10^4 packets/second to 9×10^4 packets/second, the mean number of packets in the first buffer decreases, in the second buffer increases

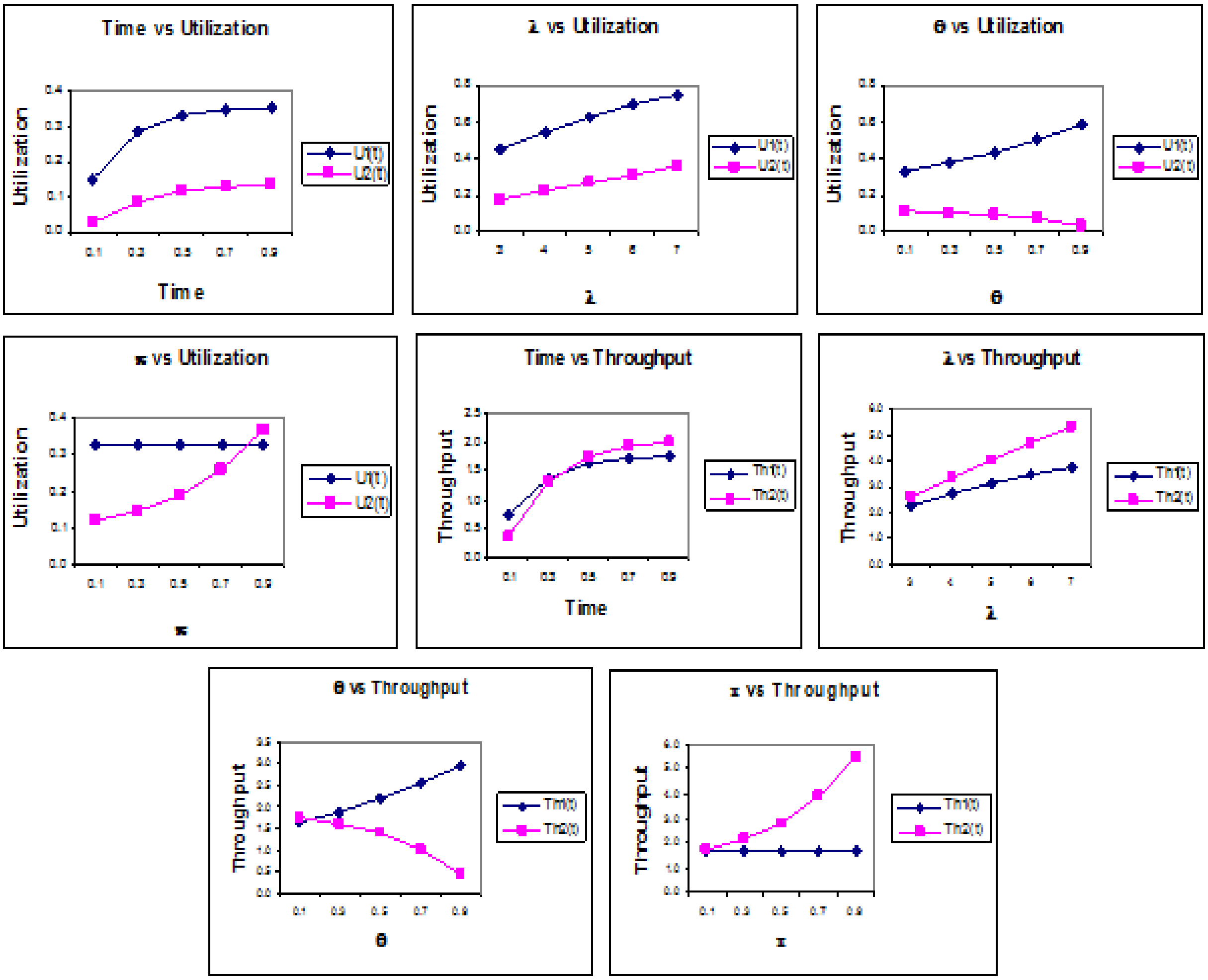

Figure 2 : Relationship between Utilization and Throughput and other parameters

and in the network decreases. When the transmission rate of the second transmitter (μ_2) varies from $15x10^4$ packets/second to $19x10^4$ packets/second, the mean number of packets in the first buffer remains constant and decreases in the second buffer and in the network.

From the table 2, it is also observed that with time (t) and λ, the mean delay in the two buffers are increasing for fixed values of other parameters. As the parameter θ varies the mean delay in the first buffer increases and decreases in the second buffer due to feedback for the first buffer. As the parameter π varies the mean delay in the first buffer remains constant and increases in the second buffer. As the transmission rate of the first transmitter (μ_1) varies, the mean delay of the first buffer decreases, in the second buffer slightly increases. When the transmission rate of the second transmitter (μ_2) varies, the mean delay of the first buffer remains constant and decreases for the second buffer.

From the above analysis, it is observed that the dynamic bandwidth allocation strategy has a significant influence on all performance measures of the network. We also observed that the performance measures are highly sensitive towards smaller values of time. Hence, it is optimal to consider dynamic bandwidth allocation and evaluate the performance under transient conditions. It is also to be observed that the congestion in buffers and delays in transmission can be reduced to a minimum level by adopting dynamic bandwidth allocation.

V. Conclusion

This paper introduces a tandem communication network model with two nodes with dynamic bandwidth allocation and feedback for both nodes. The dynamic bandwidth allocation is adapted by immediate adjustment of packet service time by utilizing idle bandwidth in the transmitter. The transient analysis of the model is capable of capturing the changes in the performance measures of the network like average content of the buffers, mean delays, throughput of the transmitters, idleness of the transmitters etc, explicitly. It is observed that the feedback probability parameters (θ, π) have significant influence on the overall performance of the network. The numerical study reveals that the proposed communication network model is capable of

Table 2 : Values of mean number of packets and mean delay of the network model with DBA and Homogeneous arrivals

t	λ	θ	π	μ_1	μ_2	$L_1(t)$	$L_2(t)$	$L(t)$	$W_1(t)$	$W_2(t)$
0.1	2	0.1	0.1	5	15	0.1611	0.0257	0.1867	0.2165	0.0675
0.3	2	0.1	0.1	5	15	0.3292	0.0918	0.4211	0.2347	0.0698
0.5	2	0.1	0.1	5	15	0.3976	0.1248	0.5224	0.2424	0.0709
0.7	2	0.1	0.1	5	15	0.4254	0.1386	0.5640	0.2455	0.0714
0.9	2	0.1	0.1	5	15	0.4367	0.1443	0.5810	0.2468	0.0716
0.5	**3**	0.1	0.1	5	15	0.5964	0.1872	0.7836	0.2655	0.0731
0.5	**4**	0.1	0.1	5	15	0.7952	0.2496	1.0448	0.2899	0.0753
0.5	**5**	0.1	0.1	5	15	0.9940	0.3120	1.3060	0.3156	0.0776
0.5	**6**	0.1	0.1	5	15	1.1928	0.3744	1.5672	0.3424	0.0799
0.5	**7**	0.1	0.1	5	15	1.3916	0.4368	1.8284	0.3704	0.0823
0.5	2	**0.1**	0.1	5	15	0.3976	0.1248	0.5224	0.2424	0.0709
0.5	2	**0.3**	0.1	5	15	0.4721	0.1135	0.5856	0.2509	0.0705
0.5	2	**0.5**	0.1	5	15	0.5708	0.0961	0.6669	0.2625	0.0699
0.5	2	**0.7**	0.1	5	15	0.7035	0.0694	0.7730	0.2785	0.0690
0.5	2	**0.9**	0.1	5	15	0.8848	0.0283	0.9131	0.3014	0.0676
0.5	2	0.1	**0.1**	5	15	0.3976	0.1248	0.5224	0.2424	0.0709
0.5	2	0.1	**0.3**	5	15	0.3976	0.1561	0.5537	0.2424	0.0720
0.5	2	0.1	**0.5**	5	15	0.3976	0.2058	0.6034	0.2424	0.0738
0.5	2	0.1	**0.7**	5	15	0.3976	0.3039	0.7015	0.2424	0.0773
0.5	2	0.1	**0.9**	5	15	0.3976	0.4589	0.8565	0.2424	0.0831
0.5	2	0.1	0.1	**5**	15	0.3976	0.1248	0.5224	0.2424	0.0709
0.5	2	0.1	0.1	**6**	15	0.3455	0.1317	0.4771	0.1971	0.0712
0.5	2	0.1	0.1	**7**	15	0.3039	0.1364	0.4403	0.1657	0.0713
0.5	2	0.1	0.1	**8**	15	0.2702	0.1397	0.4099	0.1426	0.0714
0.5	2	0.1	0.1	**9**	15	0.2426	0.1420	0.3846	0.1251	0.0715
0.5	2	0.1	0.1	5	**15**	0.3976	0.1248	0.5224	0.2424	0.0709
0.5	2	0.1	0.1	5	**16**	0.3976	0.1176	0.5152	0.2424	0.0662
0.5	2	0.1	0.1	5	**17**	0.3976	0.1112	0.5088	0.2424	0.0622
0.5	2	0.1	0.1	5	**18**	0.3976	0.1055	0.5031	0.2424	0.0585
0.5	2	0.1	0.1	5	**19**	0.3976	0.1002	0.4978	0.2424	0.0553

evaluating and predicting the performance of communication networks more close to the reality. This network model includes earlier models for limiting the values of the parameters. It is possible to extent this network model to non homogeneous Poisson arrivals.

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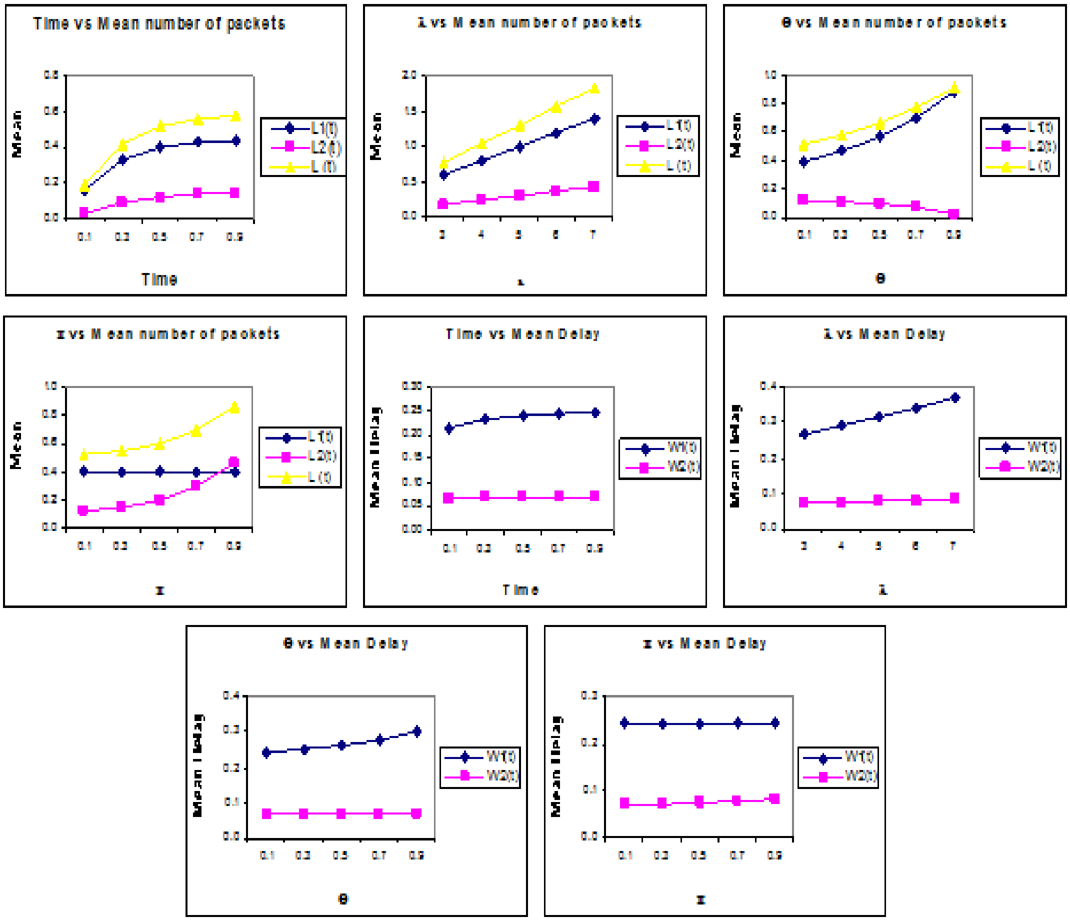

Figure 3 : The relationship between mean no. of packets, mean delay and various parameters

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