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Performance Evaluation of Three Node Tandem Communication Network Model with Feedback for First Two Nodes having Homogeneous Poisson Arrivals

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Abstract

In this paper we introduced the three node communication model with feedback for the first and second nodes assuming where every arrival makes homogeneous Poisson process one of the possible decisions by forwarding to the next node or to return back to nodes without taking service. Assuming such a decision to be entirely governed by the queue at the instant of the arrival, the transient solution is obtained using differenceâ??"differential equations; probability generating function of the number of packets in the buffer connected to the transmitter the System is analyzed. The dynamic bandwidth allocation policy for transmission is considered. The performance measures of the network like, mean content of the buffers, mean delays, throughput, transmitter utilization etc. are derived explicitly under transient conditions.

Index terms— dynamic bandwidth allocation, poisson process, three-node tandem communication network.

We consider an open queuing model of tandem communication network with three nodes. Each node consists of a buffer and a transmitter. The three buffers are Q1, Q2, Q3 and transmitters are S1, S2, S3 connected in tandem. The arrival of packets at the first node follows homogeneous Poisson processes with a mean arrival rate as a function of t and is in the form of ?. It is also assumed that the packets are transmitted through the transmitters and the mean service rate in the transmitter is linearly reliant on the content of the buffer connected to it. It is assumed that the packet after getting transmitted through first transmitter may join the second buffer which is in series connected to S2 or may be returned back buffer connected to S1 for retransmission with certain probabilities and the packets after getting transmitted through the second transmitter may join the third buffer S3 or may be retuned back to the buffer connected to S2 for retransmission with certain probabilities.

The packets delivered from the first node arrive at the second node and the packets delivered from the second node arrives at the third node. The packets delivers from the first and second may deliver to the subsequent nodes or may return to the first and second transmitters. The buffers of the nodes 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 Q2 for forward transmission with probability (1-?) or returned back to the Q1 with probability ? and the packets arrived from the second transmitter are forwarded to Q3 for transmission with probability (1-?) or returned back to the Q2 with probability ?. The service completion in both the transmitters follows Poisson processes with the parameters ?1, ?2 and ?3 for the first, second and third 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 three nodes and feedback for first two nodes is shown in figure **??**.1 be the probability that there are n1 packets in the first buffer, n2 packets in the second buffer and n3 packets in the third buffer. The difference-differential equations for the above model are as follows:) ( ) 1 ( ) ( ) 1 ( ) 1 ( ) ( ) 1 ( ) 1 ( ) ( ) ( ) ( )) 1 ( ) 1 (( ) (1 , ,**3 3 1 , 1 , 2 2 , 1 , 1 1 1 ,**+ + + + ? + ? + ? = ? ? µ ? µ ? µ ? µ ? µ ? µ ?) ( ) 1 ( ) ( ) 1 ( ) 1 ( ) ( ) 1 ( ) ( ) ( ) ( )) 1 (( ) (1 , , 0 3 3 1 , 1 ,**2 2 , 1**+ ? + ? + + ? + + ? + + + ? + ? = ? ? µ ? µ ? µ ? µ ? µ ?) ( ) 1 ( ) ( ) 1 ( ) ( ) ( ) ( )) 1 (( ) (1 , 0 , 3 3 1 , 1 , 2 , 0 , 1 , 0 , 3 3 1 1 , 0 , 3 1 3 1 3 1 3 1 3 1 t P n t P t P t t P n n t t P n n n n n n n n n n + ? ? + + ? + + + ? + ? = ? ? µ ? µ ? µ ? µ ?) ( ) ( ) 1 ( ) 1 ( ) ( ) ( ) ( )) 1 ( ) 1 (( ) (1 , , 3 0 , 1 , 1 1 1 0 , , 1 0 , , 2 2 1 1 2 1 2 1 2 1 2 1 0 , 2 1 t P t P n t P t t P n n t t P n n n n n n n n n n µ ? µ ? ? µ ? µ ? + ? + + + ? + ? + ? = ? ? ? + ?) ( ) 1 ( ) ( ) 1 ( ) ( ) ( ) (1 , 0 , 0 3 3 1 , 1 , 0 2 , 0 , 0 3 3 , 0 , 0 3 3 3 3 t P n t P t P n t t P n n n n + ? + + ? + + ? = ? ? µ ? µ µ ?) ( ) ( ) 1 ( ) ( )) 1 (( ) (1 , , 0 3 0 , 1 , 1 1 0 , , 0 2 2 0 , , 0 2 2 2 2 t P t P t P n t t P n n n n µ ? µ ? µ ? + ? + ? + ? = ? ? ? (2.1)) ( ) ( ) ( ) ( )) 1 (( ) (1 , 0 , 3 0 , 0 , 1 0 , 0 , 1 1 0 , 0 ,) ( )) ( ) ( ) ( ) ( ) ( )) 1 (( ) ( ) ( ) 1 ( ) ( )) 1 (( ) ( ) 1 ( ) ( ) 1 ( ) ( ) ( ) ( ) ( ) 1 ( ) 1 ( ) ( ) ( ) ( )) 1 ( )) 1 (( ) ( ) 1 ( ) ( ) 1 ( ) ( ) ( ) ( )) 1 (( ) ( ) 1 ( ) ( ) 1 ( ) 1 ( ) ( ) 1 ( ) ( ) ( ) ( )) 1 (( ) ( ) 1 ( ) ( ) 1 ( ) 1 ( ) ( ) 1 ( ) 1 ( ) ( ) ( ) ( )) 1 ( ) 1 (( ) : 3 , 2 , 1 (1 , 0 , 0 3 0 , 0 , 0 1 1 , 0 , 3 1 1 0 , 0 , 1 1 1 0 , 0 , 1 1 1 2 1 , , 0 3 1 2 0 , 1 , 1 1 1 2 0 , , 0 2 2 1 3 1 , 0 , 0 3 3 1 3 1 , 1 , 0 2 1 3 , 0 , 0 3 3 1 2 1 1 , , 3 1 1 2 1 0 , 1 , 1 1 1 1 1 2 1 0 , , 1 1 1 2 1 0 , , 2 2 1 1 2 1 1 1 1 1 3 1 1 , 0 , 3 3 1 1 3 1 1 , 1 , 2 1 1 3 1 , 0 , 1 1 1 3 1 , 0 , 3 3 1 1 1 1 3 2 1 , , 0 3 3 1 1 2 1 33 2 1 3 2 1 3 2 1µ ? µ ? ? µ ? µ ? µ ? µ ? µ ? µ µ ? µ ? µ ? ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? µ ? + ? + ? + ? + ? + ? ? + ? + ? ? + ? + ? ? + + ? + ? ? + + ? ? + ? ? + ? + ? ? + ? ? + ? ? + ? ? ? + ? + ? ? ? + ? ? + ? ? ? + ? ? ? + + ? + ? ? ? + + ? ? + ? + ? ? + ? ? ? + ? ? ? + ? ? + + ? + ? ? ? + + ? ? ? + ? + ? ? ? + ? + ? ? ? + ? ? ? + + ? + ? + ? ? ? ? = ? ? ? = ? ? = ? = ? = ? ? = ? = + ? = ? ? = ? = ? = ? = ? + ? = ? = ? ? = ? = ? = ? = ? = ? = + ? = ? = ? ? = ? = ? ? = ? = ? = ? = + ? = ? = ? + ? = ? = ? ? = ? = ? = ? = ? = ? = + ? = ? = ? = ? + ? = ? = ? = ? + ? = ? = ? = ? ? = ? = ? = ? = ? = ? = (2.2)

After simplifying we get) 1 ( ) ( ) 1 ( ) ( ) 1 ( ) 1 ( ) : , , (3 3 3 2 3 2 2 1 2 1 1 1 3 2 1 s s p s s s p s s s p s P t t s s s P ? ? ? + ? ? ? ? + ? ? ? ? + ? ? = ? ? µ ? µ ? µ ? (2.3)

Solving equation 2.3 by Lagrangian's method, we get the auxiliary equations as,) 1 ( ) 1 ( ))(1 ( ))(1 (1 1 3 3)) 1 (( ) 1 ( ) 1 ( ) 1 (2 3) 1 (2 3) 1 (2 2 2 ? µ µ ? µ ? µ ? µ ? ? ? ? + ? = ? ? ? ? t t e s e s b (2.5 b) (D D D D D D D D) Year 2014)) 1 ( ) 1 ( ))(1 (( ) 1 ( ) 1 ( ) 1 ( )) 1 ( ) 1 (( ) 1 ( ) 1 ( ) 1 (1 2 1 3) 1 (2 1 3 1 2) 1 (1 2) 1 (1 ? µ ? µ ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? + ? = ? ? ? ? ? ? ? t t( ) ( ) ( ) ? ? ? ? + ? ? ? ? ? ? ? ? + ? ? ? = 3 3 2 2 1 1 1) 1 (1) 1 (1 exp µ ? ? µ ? ? µ ? s s s p d (2.5 d)

Where a, b, c and d 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, S3; t). ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? + ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? + ? ? + ? ? ? ? ? ? + ? ? ? ? + ? ? ? ? ? ? ? = ? ? ? ? ? ? ? ? ? ? µ µ µ ? µ ? µ µ ? µ ? µ ? µ ? µ µ ? µ ? µ ? µ µ ? µ ? ? µ ? µ ? ? µ ? ? µ ? µ ? µ ? µ ? µ µ µ ? µ ? µ ? µ ? µ)) 1 ( )( ) 1 (( ) 1 ( )) 1 ( ) 1 (( )) 1 ( ) 1 ( )( ) 1 (( ) 1 ( ) 1 ( ) 1 (1 1 1) 1 ( ) 1 (1 1) 1 (1 1) 1 (1 exp) : , , (1 3 3 2 2 3 1 2) 1 (1 2 3 1) 1 (2 3) 1 (2 3 3 3 3) 1 ( ) 1 (1 2 2) 1 (2 2) 1 (1 1 3 2 1 3 2 1 2 3 3 1 2 2 1 t t

1 Performance Measures of the Network Model

In this section, we derive and analyze the performance measures of the network under transient conditions. Expand P(S1, S2, S3; t) of equation of 2.6 and collect the constant terms. From this, we get the probability that the network is empty as ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? + ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? + ? ? + ? ? ? ? ? ? + ? ? ? + ? ? ? ? ? ? ? = ? ? ? ? ? ? ? ? ? ? µ µ µ ? µ ? µ µ ? µ ? µ ? µ ? µ µ ? µ ? µ ? µ µ ? µ ? ? µ ? µ ? ? µ ? ? µ ? µ ? µ ? µ ? µ µ µ ? µ ? µ ? µ ? µ)) 1 ( )( ) 1 (( ) 1 ( )) 1 ( ) 1 (( )) 1 ( ) 1 ( )( ) 1 (( ) 1 ( ) 1 ( ) 1 (1 1 1) 1 ( ) 1 (1 1) 1 (1 1) 1 (1 exp) (1 3 3 2 2 3 1 2) 1 (1 2 3 1) 1 (2) 1 (2 3 3) 1 ( ) 1 (1 2) 1 (2) 1 (1 000 3 2 1 2 3 3 1 2 2 1 t t( ) ( ) ( ) ? ? ? ? ? ? ? ? ? = ? ? t e S P) 1 (1 1 1 1 1 1 1 exp t) ; S (? µ ? µ ? (3.2)

Probability that the first buffer is empty as (S1=0)( ) ( ) ? ? ? ? ? ? ? ? ? ? = ? t e t P) 1 (1 .. 0 1 1) 1 (1 exp) (? µ ? µ ? (3.3)

Taking S1, S3=1 in equation 2.6 we get probability generating function of the number of packets in the second buffer is( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? ? = ? ? ? t t t e e s e s t s P) 1 ( ) 1 (1 2 2) 1 (2 2 2 1 2 2) 1 ( ) 1 (1 1) 1 (1 exp) : (? µ ? µ ? µ ? µ ? µ ? ? µ ? (3.4)

Probability that the second buffer is empty as (S2=0)( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? ? = ? ? ? t t t e e t e P) 1 ( ) 1 (1 2) 1 (2 . 0 . 1 2 2) 1 ( ) 1 (1 1) 1 (1 exp ? µ ? µ ? µ ? µ ? µ ? ? µ ? (3.5)

Taking s1=1 and s2=1 we get we get probability generating function of the no of packets in the third buffer ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? ? ? + ? ? ? ? + ? ? ? ? ? = ? ? ? ? ? µ µ µ ? µ ? µ µ ? µ ? µ ? µ ? µ µ ? µ ? µ ? µ µ ? µ ? µ ? µ ? µ ? µ µ µ)) 1 ( )( ) 1 (( ) 1 ( )) 1 ( ) 1 (( )) 1 ( ) 1 ( )( ) 1 (( ) 1 ( ) 1 ( ) 1 (1 1 1 exp) : (1 3 3 2 2 3 1 2) 1 (1 2 3 1) 1 (**2 3**Year 2014 E ( ) ( ) ( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? + ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? + ? ? ? ? ? ? = ? ? ? ? ? µ µ µ ? µ ? µ µ ? µ ? µ ? µ ? µ µ ? µ ? µ ? µ µ ? µ ? µ ? µ ? µ ? µ µ µ)) 1 ( )( ) 1 (( ) 1 ( )) 1 ( ) 1 (( )) 1 ( ) 1 ( )( ) 1 (( ) 1 ( ) 1 ( ) 1 (1 1 1 exp 1 3 3 2 2 3 1 2) 1 (1 2 3 1) 1 (2) 1 (2 3 3 0 ..( ) ( ) t e s t s p t L) 1 (1 1 1 1 1) 1 (1) : 1 ( ) (? µ ? µ ? ? ? ? = ? ? = (3.8) Utilization of the first transmitter is ( ) ( ) ? ? ? ? ? ? ? ? ? ? = ? = ? t e t P t U) 1 (1 .. 0 1 1 1) 1 (1 exp 1) (1) (? µ ? µ ? (3.9)

Variance of the Number of packets in the first buffer is ( ) **??**)t e t V) 1 (1 1 1 1) 1 (1) (? µ ? µ ? ? ? ? = (3.10) Throughput of the first transmitter is ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? + = ? = ? t e t P Th) 1 (1 1 .. 0 1 1 1 1) 1 (1 exp 1)) (1 (? µ ? µ ? µ µ (3.11)

Average waiting time in the first Buffer is)) (1 ( ) ( ) (.. 0 1 1 1 t P t L t W ? = µ (3.12)

Mean number of packets in the second buffer is( ) ( ) ( ) ( ) ( ) t t t e e e s t s p t L) 1 ( ) 1 (1 2) 1 (2 2 2 2 1 2 2) 1 ( ) 1 (1 1) 1 (1) : ( ) (? µ ? µ ? µ ? µ ? µ ? ? µ ? ? ? ? ? ? ? ? ? + ? ? = ? ? = (3.13) Utilization of the second transmitter is ( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? = ? = ? ? ? t t t e e e t P t U) 1 ( ) 1 (1 2) 1 (2 . 0 . 2 1 2 2) 1 ( ) 1 (1 1) 1 (1 exp 1) (1) (? µ ? µ ? µ ? µ ? µ ? ? µ ? (3.14)

Variance of the number of packets in the second buffer is( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? + ? ? = ? ? ? t t t e e e t V) 1 ( ) 1 (1 2) 1 (2 2 1 2 2) 1 ( ) 1 (1 1) 1 (1) (? µ ? µ ? µ ? µ ? µ ? ? µ ? (3.15) Throughput of the second transmitter is ( ) ( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? + ? ? + = ? = ? ? ? t t t e e e t P t Th) 1 ( ) 1 (1 2) 1 (2 2 0 . 2 2 1 2 2) 1 ( ) 1 (1 1) 1 (1 exp 1) (1) (? µ ? µ ? µ ? µ ? µ ? ? µ ? µ µ (3.16)

Average waiting time in the second buffer is ( ). 0 . 2 2 2 1) ( ) (P t L t W ? = µ (3.17)

The mean number of packets in the Third buffer is Variance of the number of packets in the Third buffer is ( ) ( ) ( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? + ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? ? + ? = ? ? = ? ? ? ? ? µ µ µ ? µ ? µ µ ? µ ? µ ? µ ? µ µ ? µ ? µ ? µ µ ? µ ? µ ? µ ? µ ? µ µ µ)) 1 ( )( ) 1 (( ) 1 ( )) 1 ( ) 1 (( )) 1 ( ) 1 ( )( ) 1 (( ) 1 ( ) 1 (1 1 1) : ( ) (1 3 3 2 2 3 1 2) 1 (1 2 3 1) 1 (2) 1 (2 3 3 3 3 3( ) ( ) ( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? + ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? ? ? + ? ? ? = ? = ? ? ? ? ? µ µ µ ? µ ? µ µ ? µ ? µ ? µ ? µ µ ? µ ? µ ? µ µ ? µ ? µ ? µ ? µ ? µ µ µ)) 1 ( )( ) 1 (( ) 1 ( )) 1 ( ) 1 (( )) 1 ( ) 1 ( )( ) 1 (( ) 1 ( ) 1 ( ) 1 (1 1 1 exp 1 1) (1 3 3 2 2 3 1 2) 1 (1 2 3 1) 1 (2) 1 (2 3 3 0 .. 3( ) ( ) ( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? + ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? + ? ? ? ? ? = ? ? ? ? ? ? µ µ µ ? µ ? µ µ ? µ ? µ ? µ ? µ µ ? µ ? µ ? µ µ ? µ ? µ ? µ ? µ ? µ µ µ)) 1 ( )( ) 1 (( ) 1 ( )) 1 ( ) 1 (( )) 1 ( ) 1 ( )( ) 1 (( ) 1 ( ) 1 (1 1 1 1 3 3 2 2 3 1 2) 1 (1 2 3 1) 1 (2) 1 (2 3 3Year 2014 ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ? ? ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? ? ? + ? ? ? ? ? ? ? ? ? ? ? + ? ? ? ? + ? ? ? ? + = ? = ? ? ? ? ? µ µ µ ? µ ? µ µ ? µ ? µ ? µ ? µ µ ? µ ? µ ? µ µ ? µ ? µ µ ? µ ? µ ? µ µ µ)) 1 ( )( ) 1 (( ) 1 ( )) 1 ( ) 1 (( )) 1 ( ) 1 ( )( ) 1 (( ) 1 ( ) 1 (1 1 1 exp 1 1) (1 3 3 2 2 3 1 2) 1 (1 2**3**0 .. 3 3 3 1) ( ) (P t L t W ? = µ (3.22)

Mean number of packets in the entire network at time t is ( )) ( ) ( ) (3 2 1 t t t L L L t L + + = (3.23)

Variability of the number of packets in the network is ( )) ( ) ( ) (3 2 1 t t t V V V t V + + = (3.24)

IV.

2 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 (?) varies from 2x104 packets/sec to 7x104 packets/sec, probability parameters (?, ?) varies from 0.1 to 0.9, the transmission rate for first transmitter (µ1) varies from 5x104 packets/sec to 9x104 packets/sec, transmission rate for second transmitter (µ2) varies from 15x104 packets/sec to 19x104 packets/sec and transmission rate for third transmitter (µ3) varies from 25x104 packets/sec to 29x104 packets/sec. Dynamic Bandwidth Allocation strategy is considered for both the three transmitters. So, the transmission rate of each packet depends on the number of packets in the buffer connected to corresponding transmitter.

The equations 3.9, 3.11, 3.14, 3.16, 3.19 and 3.21 are used for computing the utilization of the transmitters and throughput of the transmitters for different values of parameters t, ?, ?, ?, µ1, µ2, µ3 and the results are presented in the Table **??**.1. The Graphs in figure **??**.1 shows the relationship between utilization of the transmitters and throughput of the transmitters. From the table 4.1 it is observed that, when the time (t) and ? increases, the utilization of the transmitters is increases for the fixed value of other parameters ?, ?, µ1, µ2. As the first transmitter probability parameter ? increases from 0.1 to 0.9, the utilization of first transmitter increases and utilization of the second and third transmitter decreases, this is due to the number of packets arriving at the second and third transmitter are decreasing as number of packets going back to the first transmitter and second transmitter in feedback are increasing. As the second transmitter probability parameter ? increases from 0.1 to 0.9, the utilization of first transmitter remains constant and utilization of the second transmitter increases and the utilization of the third transmitter decreases. As the transmission rate of the first transmitter (µ1) increases from 5 to 9, the utilization of the first transmitter decreases and the utilization of the second transmitter and third transmitter increases by keeping the other parameters as constant. As the transmission rate of the second transmitter (µ2) increases from 15 to 19, the utilization of the first transmitter is constant and the utilization of the second transmitter decreases, the utilization of the third transmitter increases by keeping the other parameters as constant. As the transmission rate of the third transmitter (µ3) increases from 25 to 29 the utilization of the first and second transmitters is constant and the utilization of the third transmitter decreases by keeping the other parameters as constant.

It is also observed from the table 4.1 that, as the time (t) increases, the throughput of first, second and third transmitters is increases for the fixed values of other parameters. When the parameter ? increases from 3x104 packets/sec to 7x104 packets/sec, the throughput of three transmitters is increases. As the probability parameter ? value increases from 0.1 to 0.9, the throughput of the first transmitter increases and the throughput of the second and third transmitters decreases. As the probability parameter ? value increases from 0.1 to 0.9, the throughput of the first transmitter remains constant and the throughput of the second transmitter is increases and the throughput of 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 three buffers and in the network are increasing when other parameters are kept constant. When the ? changes from 3x104 packets/second to 7x104 packets/second the mean number of packets in the first, second, third buffers and in the network increases. As the probability parameter ? varies from 0.1 to 0.9, the mean number packets in the first buffer increases and in the second, third buffer decreases due to feedback for the first and second buffer. When the second probability parameter ? 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, decreases in the third buffer due to feedback from the second transmitter. When the transmission rate of the first transmitter (µ1) varies from 5x104 packets/second to 9x104 packets/second, the mean number of packets in the first buffer decreases, in the second and third buffer increases. When the transmission rate of the second transmitter (µ2) varies from 15x104 packets/second to 19x104 packets/second, the mean number of packets in the first buffer remains constant Year 2014 E and decreases in the second buffer and increases in the third buffer. When the transmission rate of the third transmitter (µ3) varies from 25x104 packets/second to 29x104 the mean number of packets in the first and second buffer remains constant and decreases in the third buffer.

From the table 4.2, it is also observed that with time (t) and ?, the mean delay in the three buffers increases for fixed values of other parameters. As the parameter ? varies the mean delay in the first buffer increases and decreases in the second, third buffer due to feedback for the first and second buffer. As the parameter ? varies the mean delay in the first buffer remains constant and increases in the second buffer and decreases in third buffer. As the transmission rate of the first transmitter (µ1) varies, the mean delay of the first buffer decreases, in the second, Third buffer slightly increases. When the transmission rate of the second transmitter (µ2) varies, the mean delay of the first and third buffer remains constant and decreases for the second buffer. When the transmission rate of the third transmitter (µ3) varies, the mean delay of the first and second buffer remains constant and decreases for the third 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.

3 Sensitivity Analysis

Sensitivity analysis of the proposed network model with respect to the changes in the parameters t, ?, ? and ? on the mean number of packets, utilization of the transmitters, mean delay and throughput of the three transmitters is presented in this section. The values considered for the sensitivity analysis are, t = 0.5 sec, ? = 2x104 packets/sec, µ1 = 5x104 packets/second, µ2 = 15x104 packets/second, µ3 = 25x104 packets/second, ? = 0.1 and ? = 0.1. The mean number of packets, utilization of the transmitters, mean delay and throughput of the transmitters are computed with variation of -15%, -10%, -5%, 0%, +5%, +10%, +15% on the model and are presented in the table 5.1. The performance measures are highly affected by the changes in the values of time (t), arrival and probability constants (?, ?).

When the time (t) increases from -15% to +15% the average number of packets in the three buffers increase along with the utilization, throughput of the transmitters and the average delay in buffers. As the arrival parameter (?) increases from -15% to +15% the average number of packets in the three buffers increase along with the utilization, throughput of the transmitters and the average delay in buffers. As the probability parameter ? increases from -15% to +15% the average number of packets in the first buffer increase along with the utilization, throughput of the transmitters and the average delay in buffers. But average number of packets in the second and third buffer decrease along with the utilization, throughput of the transmitter and the average delay in buffer due to feedback for the first and second transmitters. Similarly, when the probability parameter ? increases from -15% to +15% the average number of packets, utilization, throughput and the average delay in first buffer remains constant. But average number of packets in the second buffer increase along with the utilization, throughput of the transmitter, average delay and the average number of packets in the third buffer decrease along with utilization, throughput of the transmitter, average delay.

From the above analysis it is observed that the dynamic bandwidth allocation strategy has an important influence on all performance measures of the network. It is also observed that these performance measures are also sensitive towards the probability parameters (?, ?), which causes feedback of packets to the first and second transmitters. Year 2014 E [1] [2]

[2] Solving first and second terms in equation 2.4, we get

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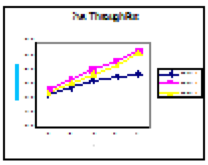
Figure 1: Figure 2 . 1 :



3

Figure 2: 3

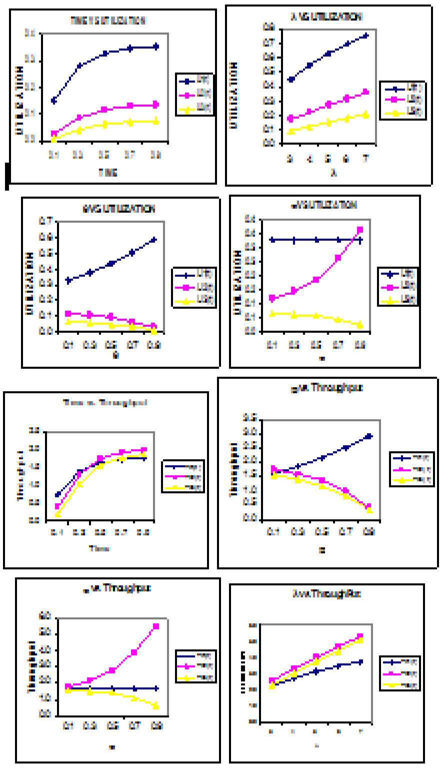


Figure 3:

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and Homogeneous Poisson arrivals

t	?	?	?	?1	?2	?3	U1(t)	U2(t)	U3(t)	Th1(t)	Th2(t)	Th3(t)
0.1	2	0.1	0.1	5	15	25	0.1488	0.0253	0.0075	0.7438	0.3799	0.1878
0.3	2	0.1	0.1	5	15	25	0.2805	0.0877	0.0426	1.4026	1.3161	1.0658
0.5	2	0.1	0.1	5	15	25	0.3281	0.1173	0.0626	1.6403	1.7601	1.5658
0.7	2	0.1	0.1	5	15	25	0.3465	0.1295	0.0711	1.7325	1.9418	1.7771
0.9	2	0.1	0.1	5	15	25	0.3538	0.1344	0.0745	1.7692	2.0153	1.8632
0.5	3	0.1	0.1	5	15	25	0.4492	0.1707	0.0925	2.2460	2.5611	2.3115
0.5	4	0.1	0.1	5	15	25	0.5485	0.2209	0.1213	2.7425	3.3136	3.0334
0.5	5	0.1	0.1	5	15	25	0.6299	0.2680	0.1493	3.1495	4.0206	3.7325
0.5	6	0.1	0.1	5	15	25	0.6966	0.3123	0.1764	3.4831	4.6849	4.4092
0.5	7	0.1	0.1	5	15	25	0.7513	0.3539	0.2026	3.7566	5.3089	5.0644
0.5	2	0.1	0.1	5	15	25	0.3281	0.1173	0.0626	1.6403	1.7601	1.5658
0.5	2	0.3	0.1	5	15	25	0.3763	0.1073	0.0566	1.8816	1.6088	1.4146
0.5	2	0.5	0.1	5	15	25	0.4349	0.0916	0.0476	2.1746	1.3743	1.1905
0.5	2	0.7	0.1	5	15	25	0.5052	0.0671	0.0342	2.5258	1.0063	0.8550
0.5	2	0.9	0.1	5	15	25	0.5872	0.0279	0.0139	2.9360	0.4191	0.3472
0.5	2	0.1	0.1	5	15	25	0.3281	0.1173	0.0626	1.6403	1.7601	1.5658
0.5	2	0.1	0.3	5	15	25	0.3281	0.1445	0.0606	1.6403	2.1678	1.5158
0.5	2	0.1	0.5	5	15	25	0.3281	0.1860	0.0567	1.6403	2.7902	1.4164
0.5	2	0.1	0.7	5	15	25	0.3281	0.2620	0.0424	1.6403	3.9304	1.0606
0.5	2	0.1	0.9	5	15	25	0.3281	0.3680	0.0245	1.6403	5.5200	0.6133
0.5	2	0.1	0.1	5	15	25	0.3281	0.1173	0.0626	1.6403	1.7601	1.5658
0.5	2	0.1	0.1	6	15	25	0.2921	0.1234	0.0664	1.7527	1.8505	1.6600

Figure 4: Table 4 . 1 :

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t	?	?	?	?1	?2	?3	L1(t)	L2(t)	L3(t)	W1(t)	W2

Figure 5: Table 4 . 2 :

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Parameter	Performance Measure	-15	-10	-5	% change in Parameter 0 5		10	15
	L1(t)	0.3788	0.3858	0.3920	0.3976	0.4026	0.4070	0.4110
	L2(t)	0.1156	0.1190	0.1221	0.1248	0.1273	0.1295	0.1315
	L3(t)	0.0587	0.0609	0.0629	0.0647	0.0663	0.0677	0.0690
	U1(t)	0.3153	0.3201	0.3243	0.3281	0.3314	0.3344	0.3370
	U2(t)	0.1091	0.1122	0.1149	0.1173	0.1195	0.1215	0.1232
t=0.5	U3(t)	0.0570	0.0591	0.0609 1.6216	0.0626	0.0641	0.0655	0.0667
	Th1(t)	1.5766	1.6004		1.6403	1.6571	1.6719	1.6851
	Th2(t)	1.6370	1.6827	1.7236	1.7601	1.7927	1.8218	1.8479
	Th3(t)	1.4244	1.4767	1.5236	1.5658	1.6035	1.6373	1.6676
	W1(t)	0.2403	0.2411	0.2418	0.2424	0.2430	0.2435	0.2439
	W2(t)	0.0706	0.0707	0.0708	0.0709	0.0710	0.0711	0.0711
	W3(t)	0.0412	0.0412	0.0413	0.0413	0.0413	0.0414	0.0414
	L1(t)	0.3380	0.3578	0.3777	0.3976	0.4175	0.4374	0.4572
	L2(t)	0.1061	0.1123	0.1186	0.1248	0.1311	0.1373	0.1435
	L3(t)	0.0550	0.0582	0.0614	0.0647	0.0679	0.0711	0.0744
	U1(t)	0.2868	0.3008	0.3146	0.3281	0.3413	0.3543	0.3670
	U2(t)	0.1007	0.1063	0.1118	0.1173	0.1228	0.1283	0.1337
?=2	U3(t)	0.0535	0.0565	0.0596 1.5729	0.0626	0.0657	0.0687	0.0717
	Th1(t)	1.4339	1.5041		1.6403	1.7065	1.7713	1.8349
	Th2(t)	1.5099	1.5938	1.6772	1.7601	1.8424	1.9243	2.0056
	Th3(t)	1.3373	1.4137	1.4899	1.5658	1.6414	1.7168	1.7920
	W1(t)	0.2357	0.2379	0.2401	0.2424	0.2446	0.2469	0.2492
	W2(t)	0.0703	0.0705	0.0707	0.0709	0.0711	0.0713	0.0716
	W3(t)	0.0411	0.0412	0.0412	0.0413	0.0414	0.0414	0.0415
	L1(t)	0.3928	0.3944	0.3960	0.3976	0.3992	0.4009	0.4025
	L2(t)	0.1255	0.1253	0.1250	0.1248	0.1246	0.1244	0.1241
	L3(t)	0.0651	0.0649	0.0648	0.0647	0.0645	0.0644	0.0643
	U1(t)	0.3248	0.3259	0.3270	0.3281	0.3292	0.3303	0.3314
	U2(t)	0.1179	0.1177	0.1175	0.1173	0.1171	0.1169	0.1167
?=0.1	U3(t)	0.0630	0.0629	0.0628 1.6349	0.0626	0.0625	0.0624	0.0623
	Th1(t)	1.6241	1.6295		1.6403	1.6458	1.6513	1.6568
	Th2(t)	1.7690	1.7661	1.7631	1.7601	1.7570	1.7540	1.7508
	Th3(t)	1.5749	1.5719	1.5688	1.5658	1.5626	1.5595	1.5563
	W1(t)	0.2418	0.2420	0.2422	0.2424	0.2426	0.2428	0.2429
	W2(t)	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709
	W3(t)	0.0413	0.0413	0.0413	0.0413	0.0413	0.0413	0.0413
	L1(t)	0.3976	0.3976	0.3976	0.3976	0.3976	0.3976	0.3976
	L2(t)	0.1229	0.1236	0.1242	0.1248	0.1254	0.1261	0.1267
	L3(t)	0.0648	0.0648	0.0647	0.0647	0.0646	0.0646	0.0646
	U1(t)	0.3281	0.3281	0.3281	0.3281	0.3281	0.3281	0.3281
	U2(t)	0.1157	0.1162	0.1168	0.1173	0.1179	0.1185	0.1190
?=0.1	U3(t)	0.0627	0.0627	0.0627 1.6403	0.0626	0.0626	0.0626	0.0625
	Th1(t)	1.6403	1.6403		1.6403	1.6403	1.6403	1.6403
	Th2(t)	1.7353	1.7435	1.7517	1.7601	1.7685	1.7770	1.7855
	Th3(t)	1.5684	1.5676	1.5667	1.5658	1.5648	1.5639	1.5630
	W1(t)	0.2424	0.2424	0.2424	0.2424	0.2424	0.2424	0.2424
	W2(t)	0.0708	0.0709	0.0709	0.0709	0.0709	0.0710	0.0710
	W3(t)	0.0413	0.0413	0.0413	0.0413	0.0413	0.0413	0.0413

Figure 6: Table 5 . 1 :

.1 VI.

.2 Conclusion

This paper introduces a tandem communication network model with three transmitters with dynamic bandwidth allocation and feedback for both transmitters. Arrival of packets at the two buffers follows homogeneous Poisson arrivals and dynamic bandwidth allocation at the transmitters. The performance is measured by approximating the arrival process with the transmission process with Poisson process. The sensitivity of the network with respect to input parameters is studied through numerical illustrations. The dynamic bandwidth allocation is adapted by immediate adjustment of packet service time by utilizing idle bandwidth in the transmitter. It is observed that the feedback probability parameters (?,?) have significant influence on the overall performance of the network. A numerical study reveals that this communication network model is capable of predicting the performance measures more close to the reality. It is interesting to note that this Communication network model includes some of the earlier Communication network model given by P.S.Varma and K.Srinivasa Rao. Basing on the performance measures the model is extended for nonhomogeneous Poisson arrivals.

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