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Performance Evaluation of Wireless Ad Hoc Networks For Three Zones Under Non-Homogeneous Conditions

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Abstract :*Ad hoc networking allows portable devices to establish a communication path without having any central infrastructure. The lack of centralized infrastructure and the mobility of a devices, gives rise to various kinds of problems such as related to routing. A key assumption that nodes within the zone can communicate directly and remote nodes communicate through access point. In this paper we designed and developed a three zones (multi hop) wireless ad hoc network model having dynamic bandwidth allocation with arrival of packets follow non-homogeneous process. The wireless ad hoc network performance measures like mean number of packets in the buffer, throughput utilization and mean delay in packet transmission and derived explicitly.*

Keywords: Wireless ad hoc networks, performance evaluation, dynamic bandwidth allocation

1. INTRODUCTION

The demand for data/voice transmission wireless ad hoc networks growing rapidly in many different fields. To satisfy this rapidly growing demand by many users, various kinds of effective Wireless ad hoc networks have been developed for this purpose. With the development of sophisticated technological innovations in recent years, a wide variety of Wireless ad hoc networks are designed and analyzed with effective bandwidth allocation techniques. In general a realistic and high speed transmission of a data or voice over wireless transmission lines is a major issue of the Wireless systems. It is generally known that the Wireless ad hoc networks gives better performance over traditions networking and yields relatively short network delay.

The statistical multiplexing in Wireless system has a tremendous influence in utilizing channel capacities efficiently. Many of the wireless ad hoc networks which support the Voice, Data and teleprocessing applications are often mixed with statistical techniques and dynamic engineering skills. Due to the unpredicted nature of demands at wireless transmission lines, congestion occurs in Wireless systems. Generally the analysis in a Wireless system is mainly concerned with the problems of allocation and distribution of data/voice packetization, statistical multiplexing, flow control, bit-dropping, link capacity assignment, delays and routing, etc., for efficient utilization of the resources

For efficient utilization of resources, it is needed to analyze the statistically multiplexing of data/voice transmission through congestion control strategies. Usually bit dropping method is employed for congestion control. The idea of bit dropping is to discard certain portion of the traffic, such as least significant bits in order to reduce the transmission time, while maintaining satisfactory quality of service as perceived by the end user, whenever there is congestion in buffers. Bit dropping method can be classified as input bit dropping (IBD) and output bit dropping (OBD) respectively (Kin K.Leung (1997)). In IBD bits may be dropped when the packets are placed in the queue waiting for transmission. In contrast bits are possibly discarding in OBD only from a packet being transmitted over the channel. This implies fluctuations in voice quality due to dynamically varying bit rate during a cell transmission (Karanam, V.R., Sriram, K. and Bowker, D.O. (1988)). To maintain the voice quality another approach is to consider dynamical bandwidth allocation in the transmitter through utilizing the vacant bandwidth available in the router for the cells which are dropped from the packet under transmission. For evaluating the performance of transmitter under following conditions: (1) at a fixed load when instantaneous fluctuations occur and (2) under variable load when variations occur due to bit dropping or dynamic allocation of bandwidth.

Samarth H Shah et al(2003) proposed an admission control and dynamic bandwidth management scheme which provides fair scheduling. Ying Qiu and peter Marbach (2003) proposed an iterative price and rate adaption algorithm. This algorithm converges to a socially optimal bandwidth allocation. Iftekhar Hussain et al (2015) proposed a QoS aware dynamic bandwidth allocation sheme to mitigate congestion problem in gateway based multi hop WiFi based long distance networks and thereby enhance QoS guarantees for real time traffic, Amulya Sakhamuru, Varun Manchikalaudi (2015) presented fair share algorithm in which bandwidth is fairly distributed in order to avoid the packet losses in terms of data transfer in the channel dynamic allocation. Efficiency affected by some factors like throughput, packet transmission and latency. Due to fair distribution of bandwidth in the network, efficient transfer of packets can be achieved. Vivita Sherin B and Sugadev M (2016) presented a novel algorithm for the optimization of the dynamic channel allocation for a CBR(Cluster based routing) called Mobile cluster based relay reconfiguration (MCRR) where the cluster head is chosen considering the energy of the all nodes in the cluster. This approach is used for increasing the performance by optimization in terms of throughput, energy consumption, packet loss and bandwidth for mobility mobile nodes.

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In the review of literature very little work is reporting regarding dynamic bandwidth allocation in Wireless ad hoc networks and no one is reported under homogeneous and non homogeneous conditions. Hence in this thesis we design and develop dynamic bandwidth allocation models for wireless ad hoc networks under non-homogenous conditions.

It is generally difficult to perform laboratory experiments that capture dynamic bandwidth allocation (i.e. changing the bandwidth just before transmitting the packet) effect on packetized voice transmission under a wide variety of traffic conditions. In addition to these complexities in empirical analysis usually the transmitters are connected in tandem with at least two nodes. Therefore to study the performance evaluation of dynamic bandwidth allocation through load dependent strategy, we develop markovian model (using queueing analogy). The Wireless systems are typically modeled as networks of interconnected nodes/queues by viewing the messages as customers, wireless ad hoc networkbuffer as waiting line and all activities in necessary transmission of the messages as services. This representation is most natural with respect to actual operation of such systems. This sort of synchronization has an advantage of conceptual simplicity and great generality. This leads a wireless network to view as a tandem queueing system or serial queueing network. Several authors have studied the Wireless ad hoc network as a tandem network. They have considered the independent assumption among the service and arrival processes (Seraphin B.Calo,(1981)). Also very little work has been reported in literature regarding Transient Analysis of Wireless ad hoc Networks which are very useful for accurate predictions of the performance measures.

In this paper we designed and developed a model for evaluation of the performance of a wireless ad hoc network with three access points connected in tandem and each access point acts as a coordinator/ transmitter for that region.

We are considered a three zone multi hop wireless ad hoc network for transmission of packets from source to destination. For evaluating wireless ad hoc networks in commercial and business application, these models are utilized. Several researchers study performance evaluation of Wireless ad hoc network under various methods. Due to the difficulty of analyzing wireless ad hoc network models exactly, many studies on approximation techniques. The approximation techniques are largely complex and do not scale well. Some of these techniques are proposed without formal proofs. So in this paper, we developed and analyzed a wireless ad hoc network model for three zones for wireless ad hoc network systems in which the packets arrive to a buffer connected to the first node in zone 1 and after transmission to the first node the packet may routed to buffer 2 of node 2 in zone 2 with certain probability and after transmission to the second node the packet may routed to node 3 in zone 3. We also considered that Zone 1, Zone 2 and Zone 3 are connected in series to the serve the packet transmission from source to destination. The transient behaviour of this Wireless ad hoc network is analyzed by deriving the difference-diffential equations of the model. The Wireless ad hoc network performance is evaluated by obtaining explicitly expressions for the joint probability generating function of buffer size distributions, the probability of emptiness of buffers, the throughput of transmitters, the mean delays, the average content of the buffer etc,.

2. Wireless ad hoc networks for three zones under NON-homogeneous conditions:

In this section, a Wireless Ad hoc Networks model having three nodes in tandem is studied. The arrivals to the buffer connected at node one are assumed to follow a non-homogeneous Poisson process with mean arrival rate as a function of time t . It is of the form $\lambda(t) = \lambda + \alpha t$. The transmission process from node one to node two follows a Poisson process with parameter μ_1. After getting transmitted from node one the packets are forwarded to the second buffer for transmission. After getting transmitted from second node it is forwarded to the third buffer for transmission. The transmission processes of node two and three also follows Poisson process with parameters μ_2 and μ_3 respectively. The transmission rate of each packet is adjusted just before transmission depending on the content of the buffer connected to the transmitter. The packets are transmitted through the transmitters by the first in first out discipline. The schematic diagram representing the wireless ad hoc network is shown in Figure 2.1

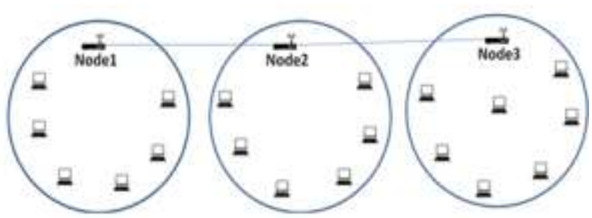

Figure 2.1 : Schematic diagram of the Wireless ad hoc Network Model.

With this structure the postulates of the model are:

1. The occurrences of the events in non-overlapping intervals of time are statistically independent.
2. The probability that there is an arrival of one packet during a small interval of time h is $[\lambda(t)\, h + o(h)]$.
3. The probability that there is one packet transmission through first transmitter when there are n_1 packets in the first buffer during a small interval of time h is $[n_1\, \mu_1\, h + o(h)]$
4. The probability that there is one packet transmission through second transmitter when there are n_2 packets in the second buffer during a small interval of time h is $[n_2\, \mu_2\, h + o(h)]$
5. The probability that there is one packet transmission through third transmitter when there are n_3 packets in the third buffer during a small interval of time h is $[n_3\, \mu_3\, h + o(h)]$
6. The probability that other than the above events during a small interval of time h is $[o(h)]$
7. The probability that there is no arrival to the first buffer and no transmission in first, second and third nodes during a small interval of time h when there are n_1 packets in the first buffer and n_2 packets in the second buffer, n_3 packets in the third buffer is $[1 - \lambda(t)\, h - n_1\, \mu_1\, h - n_2\, \mu_2\, h - n_3\, \mu_3 h + o(h)]$

Let $P_{n_1,n_2,n_3}(t)$ denote the probability that there are n_1 packets in the first buffer and n_2 packets in the second buffer and n_3 packets in the third buffer at time t

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Then difference-differential equations of the network are

$$\frac{\partial P_{n_1,n_2,n_3}(t)}{\partial t} = -\left(\lambda(t)+n_1\mu_1+n_2\mu_2+n_3\mu_3\right)P_{n_1,n_2,n_3}(t)$$
$$+\lambda(t)P_{n_1-1,n_2,n_3}(t)+(n_1+1)\mu_1 P_{n_1+1,n_2-1,n_3}(t)$$
$$+(n_2+1)\mu_2 P_{n_1,n_2+1,n_3-1}(t)$$
$$+(n_3+1)\mu_3 P_{n_1,n_2,n_3+1}(t),\ n_1>0,\ n_2>0,\ n_3>0$$

$$\frac{\partial P_{0,n_2,n_3}(t)}{\partial t} = -\left(\lambda(t)+n_2\mu_2+n_3\mu_3\right)P_{0,n_2,n_3}(t)$$
$$+\mu_1 P_{1,n_2-1,n_3}(t)+(n_2+1)\mu_2 P_{0,n_2+1,n_3-1}(t)$$
$$+(n_3+1)\mu_3 P_{0,n_2,n_3+1}(t),\ n_2>0, n_3>0$$

$$\frac{\partial P_{n_1,0,n_3}(t)}{\partial t} = -\left(\lambda(t)+n_1\mu_1+n_3\mu_3\right)P_{n_1,0,n_3}(t)$$
$$+\lambda(t)P_{n_1-1,0,n_3}(t)+\mu_2 P_{n_1,1,n_3-1}(t)+(n_3+1)\mu_3 P_{n_1,0,n_3+1}(t)$$
$$n_1>0, n_3>0$$

$$\frac{\partial P_{n_1,n_2,0}(t)}{\partial t} = -\left(\lambda(t)+n_1\mu_1+n_2\mu_2\right)P_{n_1,n_2,0}(t)$$
$$+\lambda(t)P_{n_1-1,n_2,0}(t)+(n_1+1)\mu_1 P_{n_1+1,n_2-1,0}(t)+\mu_3 P_{n_1,n_2,1}(t)$$
$$n_1>0,\ n_2>0$$

$$\frac{\partial P_{0,0,n_3}(t)}{\partial t} = -\left(\lambda(t)+n_3\mu_3\right)P_{0,0,n_3}(t)+\mu_2 P_{0,1,n_3-1}(t)$$
$$+(n_3+1)\mu_3 P_{0,0,n_3+1}(t),\ n_3>0$$

$$\frac{\partial P_{n_1,0,0}(t)}{\partial t} = -\left(\lambda(t)+n_1\mu_1\right)P_{n_1,0,0}(t)+\lambda(t)P_{n_1-1,0,0}(t)$$
$$+\mu_3 P_{n_1,0,1}(t),\ n_1>0$$

$$\frac{\partial P_{0,n_2,0}(t)}{\partial t} = -\left(\lambda(t)+n_2\mu_2\right)P_{0,n_2,0}(t)+\mu_1 P_{1,n_2-1,0}(t)$$
$$+\mu_3 P_{0,n_2,1}(t),\ n_2>0$$

$$\frac{\partial P_{0,0,0}(t)}{\partial t} = -\lambda(t)P_{0,0,0}(t)+\mu_3 P_{0,0,1}(t)$$

(2.1)

Let $P(s_1,s_2,s_3;t)=\sum_{n_1=0}^{\infty}\sum_{n_2=0}^{\infty}\sum_{n_3=0}^{\infty}P_{n_1,n_2,n_3}(t)s_1^{n_1}s_2^{n_2}s_3^{n_3}$ be the joint probability generating function of $P_{n_1,n_2,n_3}(t)$.

Multiplying the equation (2.1) with $s_1^{n_1}, s_2^{n_2}, s_3^{n_3}$ and summing over all n_1, n_2 and n_3 we get

$$\frac{dP(s_1,s_2,s_3;t)}{dt}=-\lambda(t)P(s_1,s_2,s_3;t)+\lambda(t)s_1P(s_1,s_2,s_3;t)$$
$$-\mu_1 s_1\frac{\partial P(s_1,s_2,s_3;t)}{\partial s_1}+\mu_1 s_2\frac{\partial P(s_1,s_2,s_3;t)}{\partial s_1}$$
$$-\mu_2 s_2\frac{\partial P(s_1,s_2,s_3;t)}{\partial s_2}+\mu_2 s_3\frac{\partial P(s_1,s_2,s_3;t)}{\partial s_2}$$
$$-\mu_3 s_3\frac{\partial P(s_1,s_2,s_3;t)}{\partial s_3}+\mu_3\frac{\partial P(s_1,s_2,s_3;t)}{\partial s_3}$$

(2.2)

After simplifying, we get

$$\frac{\partial P(s_1,s_2,s_3;t)}{\partial t}=\mu_1(s_2-s_1)\frac{\partial P(s_1,s_2,s_3;t)}{\partial s_1}$$
$$+\mu_2(s_3-s_2)\frac{\partial P(s_1,s_2,s_3;t)}{\partial s_2}+\mu_3(1-s_3)\frac{\partial P(s_1,s_2,s_3;t)}{\partial s_3}$$
$$+\lambda(t)P(s_1,s_2,s_3;t)(s_1-1)$$

(2.3)

Solving the equation (2.3) by Lagrangian's method, the auxiliary equations are

$$\frac{dt}{1}=\frac{ds_1}{\mu_1(s_1-s_2)}=\frac{ds_2}{\mu_2(s_2-s_3)}=\frac{ds_3}{\mu_3(s_3-1)}$$
$$=\frac{dP}{\lambda(t)P(s_1,s_2,s_3;t)(s_1-1)}$$

(2.4)

To solve the equations in (2.4) the functional form of $\lambda(t)$ is required. Let the mean arrival rate of packets is $\lambda(t) = \lambda + \alpha t$, where $\lambda > 0$, $\alpha > 0$ are constants.

Solving the first and fourth terms in equation (2.4), we get

$$a=(s_3-1)e^{-\mu_3 t}$$

(2.5)

Solving the first and third terms in equation (2.4), we get

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$$b = (s_2 - 1)e^{-\mu_2 t} + \frac{\mu_2}{\mu_3 - \mu_2}(s_3 - 1)e^{-\mu_2 t}$$

(2.6)

Solving the first and second terms in equation (6.2.4), we get

$$c = (s_1 - 1)e^{-\mu_1 t} + \frac{\mu_1}{\mu_2 - \mu_1}(s_2 - 1)e^{-\mu_1 t} + \frac{\mu_1\mu_2}{(\mu_3 - \mu_1)(\mu_2 - \mu_1)}(s_3 - 1)e^{-\mu_1 t}$$

(2.7)

Solving the first and fifth terms in equation (2.4), we get

$$d = P(s_1, s_2, s_3; t)\exp\left\{-\left[\frac{(s_1 - 1)}{\mu_1}\left(\lambda + \alpha t - \frac{\alpha}{\mu_1}\right) + \frac{(s_2 - 1)}{\mu_2}\left(\lambda + \alpha t - \frac{\alpha(\mu_1 + \mu_2)}{\mu_1\mu_2}\right) + \frac{(s_3 - 1)}{\mu_3}\left(\lambda + \alpha t - \frac{\alpha(\mu_1\mu_2 + \mu_2\mu_3 + \mu_1\mu_3)}{\mu_1\mu_2\mu_3}\right)\right]\right\}$$

(2.8)

where, a, b, c and d are arbitrary constants.

Using the initial conditions $P_{000}(0) = 1, \quad P_{000}(t) = 0 \quad \forall\, t > 0$. The general solution of (2.5) gives the probability generating function of the number of packets in the first, second and third buffers at time t, as

$$\begin{aligned}
P(s_1, s_2, s_3; t) = \exp\Bigg\{ & \frac{(s_1 - 1)}{\mu_1}\left(1 - e^{-\mu_1 t}\right)\left(\lambda - \frac{\alpha}{\mu_1}\right) + \frac{(s_1 - 1)\alpha t}{\mu_1} \\
& + \frac{(s_2 - 1)}{\mu_2}\left(1 - e^{-\mu_2 t}\right)\left(\lambda - \alpha\left(\frac{1}{\mu_2} + \frac{1}{\mu_1}\right)\right) + \frac{(s_2 - 1)\alpha t}{\mu_2} \\
& + \frac{(s_2 - 1)}{\mu_2 - \mu_1}\left(e^{-\mu_2 t} - e^{-\mu_1 t}\right)\left(\lambda - \frac{\alpha}{\mu_1}\right) \\
& + \frac{(s_3 - 1)}{\mu_3}\left(1 - e^{-\mu_3 t}\right)\left(\lambda - \alpha\left(\frac{1}{\mu_3} + \frac{1}{\mu_2} + \frac{1}{\mu_1}\right)\right) \\
& + \frac{(s_3 - 1)\alpha t}{\mu_3} + \frac{(s_3 - 1)}{\mu_3 - \mu_2}\left(e^{-\mu_3 t} - e^{-\mu_2 t}\right)\left(\lambda - \alpha\left(\frac{1}{\mu_2} + \frac{1}{\mu_1}\right)\right) \\
& + (s_3 - 1)\mu_2\left(\frac{e^{-\mu_3 t}}{(\mu_2 - \mu_3)(\mu_3 - \mu_1)} + \frac{e^{-\mu_2 t}}{(\mu_3 - \mu_2)(\mu_2 - \mu_1)} + \frac{e^{-\mu_1 t}}{(\mu_1 - \mu_3)(\mu_2 - \mu_1)}\right) \\
& \left(\lambda - \frac{\alpha}{\mu_1}\right)\Bigg\}
\end{aligned}$$

for $\lambda < \min\{\mu_1, \mu_2, \mu_3\}$ (2.9)

3. PERFORMANCE MEASURES OF THE NETWORK:

In this section, we derive and analyze the performance measures of the wireless ad hoc network under transient conditions. Expanding $P(s_1,s_2,s_3;t)$ given in equation (2.9) and collecting the constant terms, we get the probability that the network is empty as

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$$P_{000}(t)=\exp\left\{-\left[\frac{1}{\mu_1}\left(1-e^{-\mu_1 t}\right)\left(\lambda-\frac{\alpha}{\mu_1}\right)\right.\right.$$
$$+\frac{\alpha t}{\mu_1}+\frac{1}{\mu_2}\left(1-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)$$
$$+\frac{\alpha t}{\mu_2}+\frac{1}{\mu_2-\mu_1}\left(e^{-\mu_2 t}-e^{-\mu_1 t}\right)\left(\lambda-\frac{\alpha}{\mu_1}\right)$$
$$+\frac{1}{\mu_3}\left(1-e^{-\mu_3 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_3}+\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)+\frac{\alpha t}{\mu_3}$$
$$+\frac{1}{(\mu_3-\mu_2)}\left(e^{-\mu_3 t}-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)$$
$$+\mu_2\left(\frac{e^{-\mu_3 t}}{(\mu_2-\mu_3)(\mu_3-\mu_1)}+\frac{e^{-\mu_2 t}}{(\mu_3-\mu_2)(\mu_2-\mu_1)}+\frac{e^{-\mu_1 t}}{(\mu_1-\mu_3)(\mu_2-\mu_1)}\right)$$
$$\left.\left.\left(\lambda-\frac{\alpha}{\mu_1}\right)\right]\right\} \tag{3.1}$$

Taking $s_2 = 1$, $s_3 = 1$ in equation (2.9), we get the probability generating function of the number of packets in the first buffer as

$$P(s_1,t)=\exp\left\{\frac{(s_1-1)}{\mu_1}\left(\lambda-\frac{\alpha}{\mu_1}\right)\left(1-e^{-\mu_1 t}\right)+\frac{(s_1-1)}{\mu_1}\alpha t\right\}$$

,for $\lambda<\mu_1$. (3.2)

Expanding P(s_1,t) and collecting the constant terms, we get the probability that the first buffer is empty as

$$P_{0..}(t)=\exp\left\{-\left[\frac{1}{\mu_1}\left(\lambda-\frac{\alpha}{\mu_1}\right)\left(1-e^{-\mu_1 t}\right)+\frac{1}{\mu_1}\alpha t\right]\right\} \tag{3.3}$$

Similarly taking $s_1 = 1$, $s_2 = 1$ in equation (2.9),we get the probability generating function of the number of packets in the second buffer as

$$P(s_2,t)=\exp\left\{\left[\frac{(s_2-1)}{\mu_2}\left(1-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)+\frac{(s_2-1)}{\mu_2}\alpha t+\frac{(s_2-1)}{\mu_2-\mu_1}\left(e^{-\mu_2 t}-e^{-\mu_1 t}\right)\left(\lambda-\frac{\alpha}{\mu_1}\right)\right]\right\}$$

for $\lambda < \min\{\mu_1, \mu_2\}$ (3.4)

Expanding P(s_2,t) and collecting the constant terms, we get the probability that the second buffer is empty as

$$P_{.0.}(t)=\exp\left\{-\left[\frac{1}{\mu_2}\left(1-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)+\frac{1}{\mu_2}\alpha t+\frac{1}{\mu_2-\mu_1}\left(e^{-\mu_2 t}-e^{-\mu_1 t}\right)\left(\lambda-\frac{\alpha}{\mu_1}\right)\right]\right\}$$

(3.5)

Similarly taking $s_1 = 1$, $s_2 = 1$ in equation (2.9),we get the probability generating function of the number of packets in the third buffer as

$$P(s_3,t)=\exp\left\{\frac{(s_3-1)}{\mu_3}\left(1-e^{-\mu_3 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_3}+\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)\right.$$
$$+\frac{(s_3-1)\alpha t}{\mu_3}+\frac{(s_3-1)}{\mu_3-\mu_2}\left(e^{-\mu_3 t}-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)$$
$$\left.+(s_3-1)\mu_2\left(\frac{e^{-\mu_3 t}}{(\mu_2-\mu_3)(\mu_3-\mu_1)}+\frac{e^{-\mu_2 t}}{(\mu_3-\mu_2)(\mu_2-\mu_1)}+\frac{e^{-\mu_1 t}}{(\mu_1-\mu_3)(\mu_2-\mu_1)}\right)\left(\lambda-\frac{\alpha}{\mu_1}\right)\right\}$$

for $\lambda<\min\{\mu_1,\mu_2,\mu_3\}$ (3.6)

Expanding P(s_3,t) and collecting the constant terms, we get the probability that the third buffer is empty as

$$P_{..0}(t)=\exp\left\{-\left[\frac{1}{\mu_3}\left(1-e^{-\mu_3 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_3}+\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)\right.\right.$$
$$+\frac{\alpha t}{\mu_3}+\frac{1}{\mu_3-\mu_2}\left(e^{-\mu_3 t}-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)$$
$$+\mu_2\left(\begin{array}{l}\frac{e^{-\mu_3 t}}{(\mu_2-\mu_3)(\mu_3-\mu_1)}+\frac{e^{-\mu_2 t}}{(\mu_3-\mu_2)(\mu_2-\mu_1)}\\+\frac{e^{-\mu_1 t}}{(\mu_1-\mu_3)(\mu_2-\mu_1)}\end{array}\right)$$
$$\left.\left.\left(\lambda-\frac{\alpha}{\mu_1}\right)\right]\right\}$$

(3.7)

The mean number of packets in the first buffer is

$$L_1(t)=\frac{\partial P(s_1,t)}{\partial s_1}\Big|_{s_1=1}$$
$$=\frac{1}{\mu_1}\left(\lambda-\frac{\alpha}{\mu_1}\right)\left(1-e^{-\mu_1 t}\right)+\frac{1}{\mu_1}\alpha t$$

(3.8)

The utilization of the first transmitter is

$$U_1(t)=1-P_{0..}(t)$$
$$=1-\exp\left\{-\left[\begin{array}{l}\frac{1}{\mu_1}\left(\lambda-\frac{\alpha}{\mu_1}\right)\left(1-e^{-\mu_1 t}\right)\\+\frac{1}{\mu_1}\alpha t\end{array}\right]\right\}$$

(3.9)

The mean number of the packets in second buffer is

$$L_2(t)=\frac{\partial P(s_2,t)}{\partial s_2}\Big|_{s_2=1}$$
$$L_2(t)=\frac{1}{\mu_2}\left(1-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)+\frac{1}{\mu_2}\alpha t$$
$$+\frac{1}{\mu_2-\mu_1}\left(e^{-\mu_2 t}-e^{-\mu_1 t}\right)\left(\lambda-\frac{\alpha}{\mu_1}\right)$$

(3.10)

The utilization of the second transmitter is

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

(3.11)

The mean number of the packets in third buffer is

$$L_3(t)=\frac{\partial P(s_3,t)}{\partial s_3}\Big|_{s_3=1}$$
$$=\left[\frac{1}{\mu_3}\left(1-e^{-\mu_3 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_3}+\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)\right.$$
$$+\frac{\alpha t}{\mu_3}+\frac{1}{\mu_3-\mu_2}\left(e^{-\mu_3 t}-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)$$
$$+\mu_2\left(\begin{array}{l}\frac{e^{-\mu_3 t}}{(\mu_2-\mu_3)(\mu_3-\mu_1)}+\frac{e^{-\mu_2 t}}{(\mu_3-\mu_2)(\mu_2-\mu_1)}\\+\frac{e^{-\mu_1 t}}{(\mu_1-\mu_3)(\mu_2-\mu_1)}\end{array}\right)$$
$$\left.\left(\lambda-\frac{\alpha}{\mu_1}\right)\right]$$

(3.12)

The utilization of the third transmitter is

$$U_3(t)=1-P_{..0}(t)$$
$$=1-\exp\left\{-\left[\frac{1}{\mu_3}\left(1-e^{-\mu_3 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_3}+\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)+\frac{\alpha t}{\mu_3}\right.\right.$$
$$+\frac{1}{\mu_3-\mu_2}\left(e^{-\mu_3 t}-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)$$
$$\left.\left.+\mu_2\left(\begin{array}{l}\frac{e^{-\mu_3 t}}{(\mu_2-\mu_3)(\mu_3-\mu_1)}+\frac{e^{-\mu_2 t}}{(\mu_3-\mu_2)(\mu_2-\mu_1)}\\+\frac{e^{-\mu_1 t}}{(\mu_1-\mu_3)(\mu_2-\mu_1)}\end{array}\right)\left(\lambda-\frac{\alpha}{\mu_1}\right)\right]\right\}$$

(3.13)

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The throughput of the first transmitter is

$$\mu_1\left(1-P_{0..}(t)\right)=\mu_1\left[1+\exp\left\{\begin{array}{l}\frac{1}{\mu_1}\left(\lambda-\frac{\alpha}{\mu_1}\right)\left(1-e^{-\mu_1 t}\right)\\+\frac{1}{\mu_1}\alpha t\end{array}\right\}\right] \quad (3.14)$$

The mean delay in the first buffer is

$$W_1(t)=\frac{L_1(t)}{\mu_1\left(1-P_{0..}(t)\right)}=\frac{\frac{1}{\mu_1}\left(\lambda-\frac{\alpha}{\mu_1}\right)\left(1-e^{-\mu_1 t}\right)+\frac{1}{\mu_1}\alpha t}{\mu_1\left[1+\exp\left\{\frac{1}{\mu_1}\left(\lambda-\frac{\alpha}{\mu_1}\right)\left(1-e^{-\mu_1 t}\right)+\frac{1}{\mu_1}\alpha t\right\}\right]} \quad (3.15)$$

The throughput of the second transmitter is

$$\mu_2\left(1-P_{.0.}(t)\right)=\mu_2\left[1+\exp\left\{\left[\begin{array}{l}\frac{1}{\mu_2}\left(1-e^{-\mu_2 t}\right)\\\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)\\+\frac{1}{\mu_2}\alpha t+\frac{1}{\mu_2-\mu_1}\\\left(e^{-\mu_2 t}-e^{-\mu_1 t}\right)\\\left(\lambda-\frac{\alpha}{\mu_1}\right)\end{array}\right]\right\}\right] \quad (3.16)$$

The mean delay in the second buffer is

$$W_2(t)=\frac{L_2(t)}{\mu_2(1-P_{.0.}(t)}=\frac{\begin{array}{l}\frac{1}{\mu_2}\left(1-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)\\+\frac{1}{\mu_2}\alpha t+\frac{1}{\mu_2-\mu_1}\left(e^{-\mu_2 t}-e^{-\mu_1 t}\right)\\\left(\lambda-\frac{\alpha}{\mu_1}\right)\end{array}}{\mu_2\left[1+\exp\left[\begin{array}{l}\frac{1}{\mu_2}\left(1-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)\\+\frac{1}{\mu_2}\alpha t+\frac{1}{\mu_2-\mu_1}\left(e^{-\mu_2 t}-e^{-\mu_1 t}\right)\\\left(\lambda-\frac{\alpha}{\mu_1}\right)\end{array}\right]\right]} \quad (3.17)$$

The throughput of the third transmitter is

$$\begin{aligned}\mu_3(1-P_{..0}(t))=\mu_3\Bigg[1+\exp\Bigg[&\frac{1}{\mu_3}\left(1-e^{-\mu_3 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_3}+\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)\\&+\frac{\alpha t}{\mu_3}+\frac{1}{\mu_3-\mu_2}\left(e^{-\mu_3 t}-e^{-\mu_2 t}\right)\left(\lambda-\alpha\left(\frac{1}{\mu_2}+\frac{1}{\mu_1}\right)\right)\\&+\mu_2\left(\begin{array}{l}\frac{e^{-\mu_3 t}}{(\mu_2-\mu_3)(\mu_3-\mu_1)}+\frac{e^{-\mu_2 t}}{(\mu_3-\mu_2)(\mu_2-\mu_1)}\\+\frac{e^{-\mu_1 t}}{(\mu_1-\mu_3)(\mu_2-\mu_1)}\end{array}\right)\left(\lambda-\frac{\alpha}{\mu_1}\right)\Bigg]\Bigg]\end{aligned} \quad (3.18)$$

The mean delay in the third buffer is

$$W_3(t)=\left[\frac{L_3(t)}{\mu_3\left(1-P_{..0}(t)\right)}\right] \quad (3.19)$$

4. PERFORMANCE EVALUATION OF THE NETWORK

In this section, the performance of the wireless ad hoc network is discussed through numerical illustration. Different values of the parameters are considered for bandwidth allocation and arrival of packets. After interacting with the technical staff at internet providing station, it is considered that the packet arrival parameter (λ) varies from

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$2x10^4$ packets/sec to $7x10^4$ packets/sec, and (α) varies from -0.5 to 1.5 with an average packet size of 53 bytes. After transmitting from node one, the forward transmission rate (μ_1) varies from $5x10^4$ packets/sec to $9x10^4$ packets/sec. The rate of transmission from node two (μ_2) varies from $15x10^4$ packets/sec to $19x10^4$ packets/sec. The rate of transmission from node three (μ_3) varies from $25x10^4$ packets/sec to $29x10^4$ packets/sec. In all the nodes, the 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.

Using equations (3.1), (3.3), (3.5), (3.7) and (3.9), (3.11), (3.13) are the probabilities of the network emptiness, buffers emptiness and utilization of three nodes are computed for different values of the parameters t, λ, α, μ_1, μ_2, μ_3 and are presented in table 4.1. The relationship between parameters and probability of emptiness, utilization are shown in Figure 4.1.

From table 4.1 it is observed that the probabilities of emptiness of the wireless ad hoc network and the three buffers are highly sensitive with respect to changes in time. As time (t) varies from 0.1 seconds to 5 seconds, the probability of the emptiness in the network reduces and the probabilities of emptiness of three buffers are decreases when other parameters are fixed at (2,1,5,15,25) for (λ, α, μ_1, μ_2, μ_3). The decrease in the first buffer is more rapid when compared to that of other buffers.

The influence of arrival parameters on the system emptiness is also studied. As the parameter (λ) varies from $3x10^4$ packets/sec to $7x10^4$ packets/sec, the probability of emptiness of the network decreases and the probabilities of emptiness of three buffers decreases when other parameters are fixed at values (0.5,1,5,15,25) for (t, α, μ_1, μ_2, μ_3). This decrease is more significant in first buffer and moderate in the second and third buffers.

When the parameter (α) varies from -0.5 to 1.5, the probability of emptiness of the network decreases when the other parameters remain fixed. The same phenomenon is observed for the three buffers. The decrease is more rapid in the first buffer and moderate in second and third buffers.

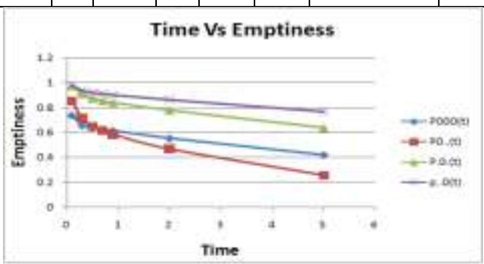
When the transmission rate (μ_1) of node one varies from $5x10^4$ packets/sec to $9x10^4$ packets/sec, the probability of emptiness of the network increases when other parameters remain fixed. Similarly the transmission rate (μ_2) of node two varies from $15x10^4$ packets/sec to $19x10^4$ packets/sec, the probability of emptiness of the network increases when other parameters remain fixed. Similarly the transmission rate (μ_3) of node three varies from $25x10^4$ packets/sec to $29x10^4$ packets/sec, the probability of emptiness of the network decreases when other parameters remain fixed.

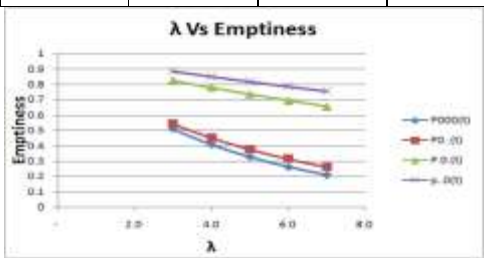
As the time (t) and arrival parameter (λ) increases, the utilization of transmitters are increasing for fixed values of the other parameters. It is also observed that as the parameter (α) increases, the utilization of transmitters at all nodes are increasing for fixed values of the other parameters. As the transmission rate (μ_1) increases, the utilization of the first node decreases and utilization of second and third nodes are increases when the other parameters remain fixed. Similarly, as the transmission rate (μ_2) increases the utilization of the first node is constant, the utilization of the second node decreases and utilization of the third node increases when other parameters remain fixed.

Table 4.1: Values of Emptiness probabilities and Utilization of the Wireless ad hoc Network with Non Homogeneous Process arrivals and Dynamic Bandwidth Allocation

t	λ	α	μ	μ_2	μ_3	$P_{000}(t)$	$P_{0..}(t)$	$P_{.0.}(t)$	$P_{..0}(t)$	U_1 (t)	U_2 (t)	$U_3(t)$
0.1	2	1	5	15	25	0.737302	0.850740	0.972946	0.981548	0.14926	0.027054	0.018452
0.3	2	1	5	15	25	0.656101	0.712003	0.908366	0.939204	0.287997	0.091634	0.060796
0.5	2	1	5	15	25	0.637260	0.650217	0.874460	0.921674	0.349783	0.125540	0.078326
0.7	2	1	5	15	25	0.623887	0.613160	0.854885	0.910767	0.386840	0.145115	0.089233
0.9	2	1	5	15	25	0.611817	0.585083	0.840670	0.902217	0.414917	0.159330	0.097783
2.0	2	1	5	15	25	0.551846	0.467674	0.779673	0.862664	0.532326	0.220327	0.137336
5.0	2	1	5	15	25	0.417075	0.256661	0.638337	0.765112	0.743339	0.361663	0.234888
0.5	**3**	1	5	15	25	0.509119	0.541164	0.824791	0.885583	0.458836	0.175209	0.114417
0.5	**4**	1	5	15	25	0.406745	0.450402	0.777943	0.850906	0.549598	0.222057	0.149094
0.5	**5**	1	5	15	25	0.324957	0.374862	0.733756	0.817587	0.625138	0.266244	0.182413

0.5	**6**	1	5	15	25	0.259615	0.311991	0.692079	0.785573	0.688009	0.307921	0.214427
0.5	**7**	1	5	15	25	0.207411	0.259665	0.652769	0.754812	0.740335	0.347231	0.245188
0.5	2	**-0.5**	5	15	25	0.638780	0.714963	0.897309	0.932448	0.285037	0.102691	0.067552
0.5	2	**0**	5	15	25	0.638273	0.692695	0.889627	0.928843	0.307305	0.110373	0.071157
0.5	2	**0.5**	5	15	25	0.637766	0.671120	0.882011	0.925251	0.328880	0.117989	0.074749
0.5	2	**1**	5	15	25	0.637260	0.650217	0.874460	0.921674	0.349783	0.125540	0.078326
0.5	2	**1.5**	5	15	25	0.636754	0.629965	0.866973	0.918110	0.370035	0.133027	0.081890
0.5	2	1	**5**	15	25	0.637260	0.650217	0.874460	0.921674	0.349783	0.125540	0.078326
0.5	2	1	**6**	15	25	0.679123	0.688200	0.868475	0.918794	0.311800	0.131525	0.081206
0.5	2	1	**7**	15	25	0.713695	0.719842	0.864373	0.916789	0.280158	0.135627	0.083211
0.5	2	1	**8**	15	25	0.742324	0.746334	0.861514	0.915355	0.253666	0.138486	0.084645
0.5	2	1	**9**	15	25	0.766183	0.768665	0.859483	0.914306	0.231335	0.140517	0.085694
0.5	2	1	5	**15**	25	0.637260	0.650217	0.87446	0.921674	0.349783	0.12554	0.078326
0.5	2	1	5	**16**	25	0.641499	0.650217	0.881236	0.921346	0.349783	0.118764	0.078654
0.5	2	1	5	**17**	25	0.645249	0.650217	0.887337	0.921065	0.349783	0.112663	0.078935
0.5	2	1	5	**18**	25	0.648586	0.650217	0.892855	0.920822	0.349783	0.107145	0.079178
0.5	2	1	5	**19**	25	0.651576	0.650217	0.897869	0.920609	0.349783	0.102131	0.079391
0.5	2	1	5	15	**25**	0.637260	0.650217	0.87446	0.921674	0.349783	0.12554	0.078326
0.5	2	1	5	15	**26**	0.635483	0.650217	0.87446	0.924462	0.349783	0.12554	0.075538
0.5	2	1	5	15	**27**	0.633834	0.650217	0.87446	0.92706	0.349783	0.12554	0.07294
0.5	2	1	5	15	**28**	0.632300	0.650217	0.87446	0.929486	0.349783	0.12554	0.070514
0.5	2	1	5	15	**29**	0.630869	0.650217	0.87446	0.931757	0.349783	0.12554	0.068243





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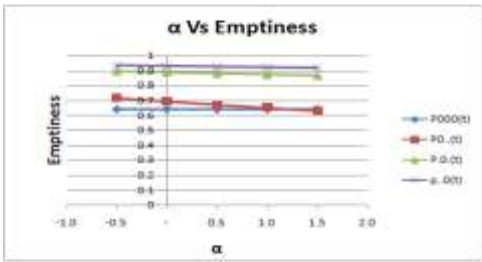

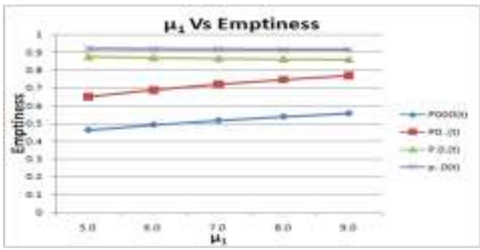

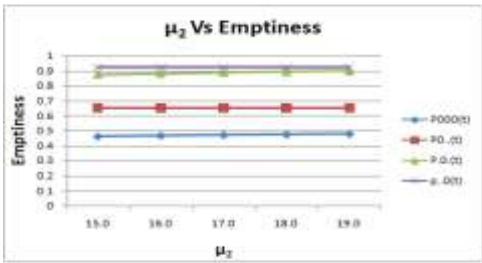

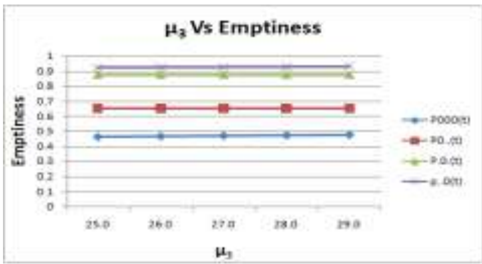

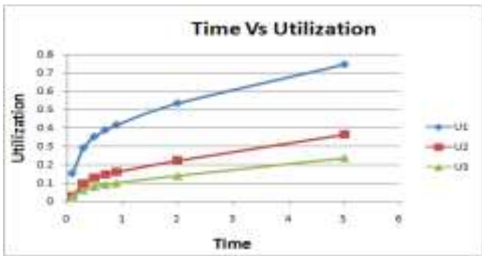

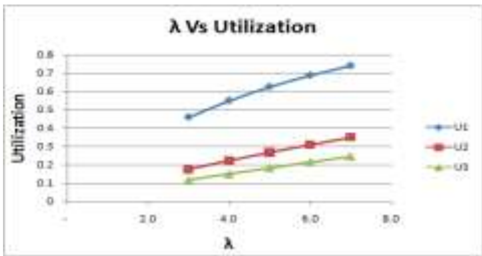

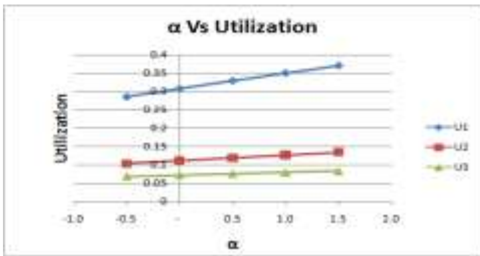

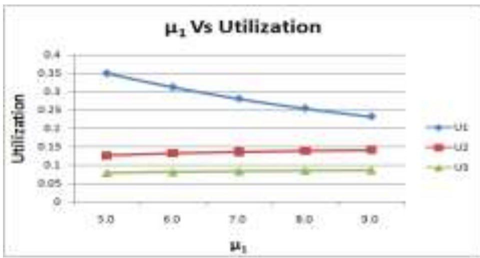

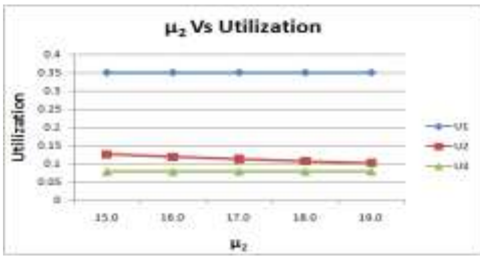

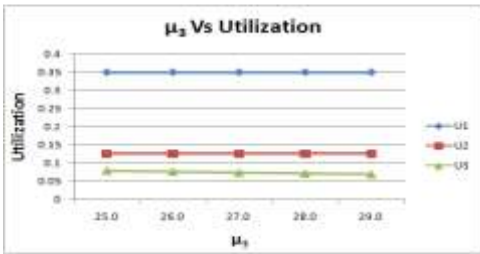

Figure 4.1 : The relationship between Network emptiness, Utilization and various other parameters

Similarly, as the transmission rate (μ_3) increases the utilization of the first and second nodes are constant and the utilization of the third node decreases when other parameters remain fixed.

From equations (3.8),(3.10),(3.12) and (3.15),(3.17),(3.19), the mean number of packets in the buffers and in the network, mean delays in transmission of three transmitters are computed for different values of t, λ, α, μ_1, μ_2, μ_3 and presented in table 4.2. The relationship between the parameters and the performance measure are shown in the figure 4.2.

It is observed that when time t = 0.1 seconds, the number of packets in the first buffer is 1616 packets, after 0.3 seconds it rapidly increases to 3396 packets. After 0.7 seconds, it reaches to 4891 packets and thereafter there is a steady increase in the content of the first buffer for fixed values of other parameters (2, 1, 5, 15, 25) for (λ , α, μ_1, μ_2, μ_3). It is observed that as time (t) varies from 0.1 second to 5 seconds, the average content of the second and third buffers and in the network is increasing when other parameters are fixed.

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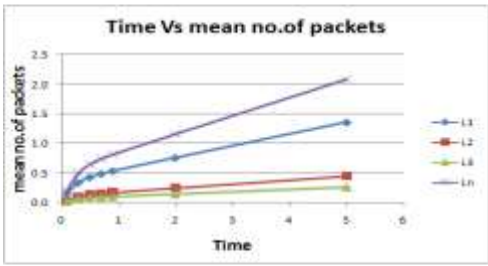
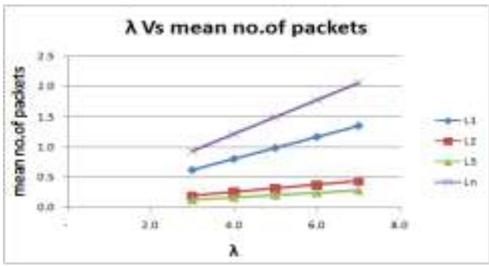
When the parameter (λ) varies from $3x10^4$ packets/sec to $7x10^4$ packets/sec, the average content of packets in the first, second and third buffers and in the network are increasing when other parameters remain fixed.

Table 4.2: Values of mean number of packets and mean delay of the Wireless ad hoc Network with non homogeneous Poisson arrivals and dynamic bandwidth allocation.

t	$\lambda^\$$	α	$\mu_1^\$$	$\mu_2^\$$	$\mu_3^\$$	$L_1(t)$	$L_2(t)$	$L_3(t)$	$W_1(t)$	$W_2(t)$	$W_3(t)$	$L_n(t)$
0.1	2	1	5	15	25	0.16165	0.02743	0.01862	0.21660	0.06759	0.04037	0.20770
0.3	2	1	5	15	25	0.33967	0.09611	0.06272	0.23589	0.06992	0.04127	0.49850
0.5	2	1	5	15	25	0.43045	0.13415	0.08156	0.24612	0.07124	0.04165	0.64616
0.7	2	1	5	15	25	0.48913	0.15679	0.09347	0.25288	0.07203	0.04190	0.73939
0.9	2	1	5	15	25	0.53600	0.17356	0.10290	0.25837	0.07262	0.04209	0.81246
2.0	2	1	5	15	25	0.75998	0.24888	0.14773	0.28553	0.07531	0.04303	1.15659
5.0	2	1	5	15	25	1.36000	0.44889	0.26773	0.36592	0.08275	0.04559	2.07662
0.5	**3**	1	5	15	25	0.61403	0.19263	0.12151	0.26765	0.07329	0.04248	0.92817
0.5	**4**	1	5	15	25	0.79762	0.25110	0.16145	0.29025	0.07539	0.04332	1.21017
0.5	**5**	1	5	15	25	0.98120	0.30958	0.20140	0.31391	0.07752	0.04416	1.49218
0.5	**6**	1	5	15	25	1.16478	0.36806	0.24134	0.33859	0.07969	0.04502	1.77418
0.5	**7**	1	5	15	25	1.34836	0.42653	0.28129	0.36426	0.08189	0.04589	2.05618
0.5	2	**-0.5**	5	15	25	0.33552	0.10836	0.06994	0.23543	0.07034	0.04142	0.51382
0.5	2	**0**	5	15	25	0.36717	0.11695	0.07382	0.23896	0.07064	0.04149	0.55794
0.5	2	**0.5**	5	15	25	0.39881	0.12555	0.07769	0.24252	0.07094	0.04157	0.60205
0.5	2	**1**	5	15	25	0.43045	0.13415	0.08156	0.24612	0.07124	0.04165	0.64616
0.5	2	**1.5**	5	15	25	0.46209	0.14275	0.08544	0.24976	0.07154	0.04173	0.69028
0.5	2	1	**5**	15	25	0.43045	0.13415	0.08156	0.24612	0.07124	0.04165	0.64616
0.5	2	1	**6**	15	25	0.37368	0.14102	0.08469	0.19974	0.07148	0.04172	0.59939
0.5	2	1	**7**	15	25	0.32872	0.14575	0.08688	0.16762	0.07164	0.04176	0.56135
0.5	2	1	**8**	15	25	0.29258	0.14906	0.08844	0.14418	0.07176	0.04179	0.53009
0.5	2	1	**9**	15	25	0.26310	0.15142	0.08959	0.12637	0.07184	0.04182	0.50412
0.5	2	1	5	**15**	25	0.43045	0.13415	0.08156	0.24612	0.07124	0.04165	0.64616
0.5	2	1	5	**16**	25	0.43045	0.12643	0.08192	0.24612	0.06653	0.04166	0.63880
0.5	2	1	5	**17**	25	0.43045	0.11953	0.08222	0.24612	0.06241	0.04167	0.63220
0.5	2	1	5	**18**	25	0.43045	0.11333	0.08249	0.24612	0.05876	0.04167	0.62627
0.5	2	1	5	**19**	25	0.43045	0.10773	0.08272	0.24612	0.05552	0.04168	0.62090
0.5	2	1	5	15	**25**	0.43045	0.13415	0.08156	0.24612	0.07124	0.04165	0.64616
0.5	2	1	5	15	**26**	0.43045	0.13415	0.07854	0.24612	0.07124	0.03999	0.64314
0.5	2	1	5	15	**27**	0.43045	0.13415	0.07574	0.24612	0.07124	0.03846	0.64034
0.5	2	1	5	15	**28**	0.43045	0.13415	0.07312	0.24612	0.07124	0.03704	0.63772
0.5	2	1	5	15	**29**	0.43045	0.13415	0.07068	0.24612	0.07124	0.03572	0.63528





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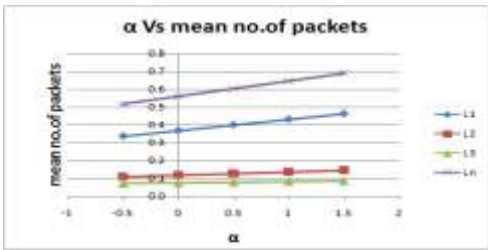

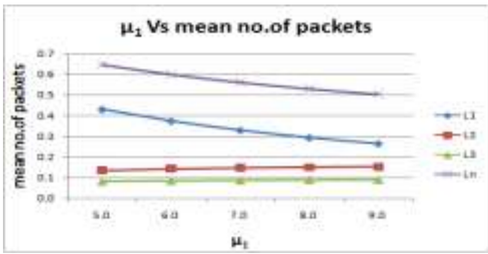

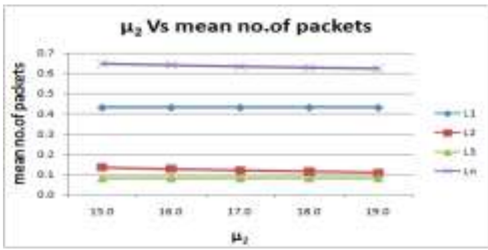

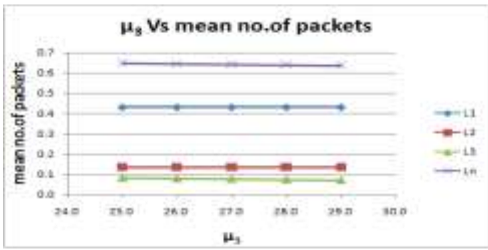

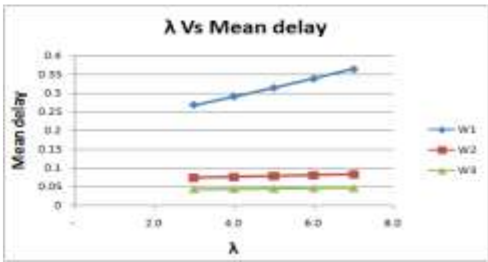

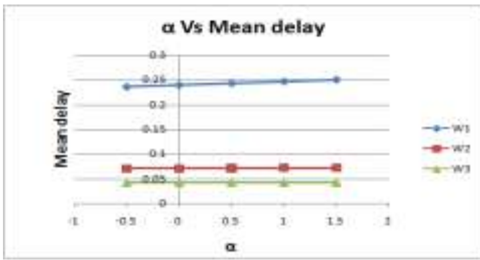

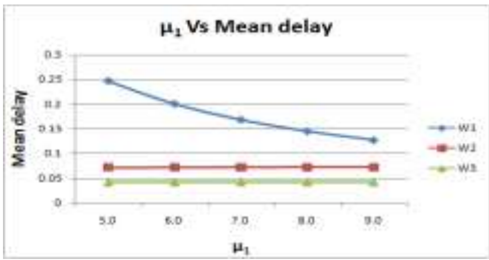

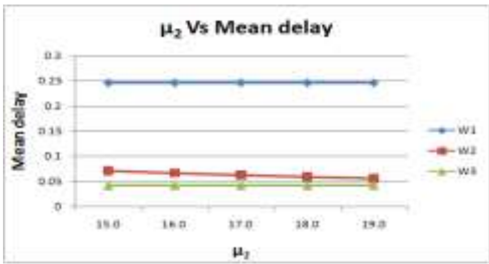

Figure 4.2 : The relationship between mean no. of packets, mean delay and various parameters

When the parameter (α) varies from -0.5 to 1.5, the average content of packets in the first, second and third buffers and in the network are increasing when other parameters remain fixed.

When the transmission rate (μ_1) varies from $5x10^4$ packets/sec to $9x10^4$ packets/sec, the average content of the first buffer and in the network are decreasing from and the mean number of packets in the second and third buffers are increasing when other parameters remain fixed.

When the transmission rate (μ_2) varies from $15x10^4$ packets/sec to $19x10^4$ packets/sec, the average content of the first buffer remains at 4304 packets and the average content of second buffer and in the network are decreasing and in the third buffer the content is increases when other parameters remain fixed.

Similarly the transmission rate (μ_3) varies from $25x10^4$ packets/sec to $29x10^4$ packets/sec, the average content of the first and second buffers remain constant at 4304 packets and 1331 packets respectively and the average content of the

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third buffer and in the network are decreasing when other parameters remain fixed.

It is observed that as the time (t) and the parameter (λ) are increasing, the mean delay in buffers is increases for fixed values of the other parameters. It is also observed that as the parameter (α) varies the mean delay in all buffers are increasing for fixed values of other parameters. As the transmission rate (μ_1) increases, the mean delay in the first buffer decreases and the mean delay in the second and third buffers are increasing when the other parameters remain fixed. Similarly, the transmission rate (μ_2) increases the mean delay in the first buffer remains constant and the mean delay in the second buffer decreases and the mean delay in the third buffer increases when other parameter remains fixed. Similarly, the transmission rate (μ_3) increases the mean delay in the first and second buffers remain constant and the mean delay in the third buffer decreases when other parameter remains fixed.

From the equations (3.14), (3.16), and (3.18) the variance of the number of packets in each buffer and throughput of each node are computed for different values of t, λ ,α, $\mu_{1,}$ $\mu_{2,}$ μ_3 and presented in table 4.3. The relationship between the parameters and the performance measures are shown in figure 4.3.

It is observed that as time t increases, the throughput of first, second and third nodes are increasing for fixed values of the other parameters.

Table 4.3: Effect of various parameters on Throughput and Variance of the Wireless ad hoc Network Model (CNM)

t	λ	α	μ_1	μ_2	μ_3	$Thp_1(t)$	$Thp_2(t)$	$Thp_3(t)$	$V_1(t)$	$V_2(t)$	$V_3(t)$
0.1	2	1	5	15	25	0.74630	0.40580	0.46129	0.16165	0.02743	0.01862
0.3	2	1	5	15	25	1.43998	1.37451	1.51991	0.33967	0.09611	0.06272
0.5	2	1	5	15	25	1.74892	1.88311	1.95816	0.43045	0.13415	0.08156
0.7	2	1	5	15	25	1.93420	2.17673	2.23082	0.48913	0.15679	0.09347
0.9	2	1	5	15	25	2.07458	2.38995	2.44457	0.53600	0.17356	0.10290
2.0	2	1	5	15	25	2.66163	3.30491	3.43340	0.75998	0.24888	0.14773
5.0	2	1	5	15	25	3.71670	5.42494	5.87221	1.36000	0.44889	0.26773
0.5	**3**	1	5	15	25	2.29418	2.62814	2.86041	0.61403	0.19263	0.12151
0.5	**4**	1	5	15	25	2.74799	3.33086	3.72734	0.79762	0.25110	0.16145
0.5	**5**	1	5	15	25	3.12569	3.99366	4.56032	0.98120	0.30958	0.20140
0.5	**6**	1	5	15	25	3.44005	4.61882	5.36069	1.16478	0.36806	0.24134
0.5	**7**	1	5	15	25	3.70168	5.20847	6.12971	1.34836	0.42653	0.28129
0.5	2	**-0.5**	5	15	25	1.42518	1.54037	1.68880	0.33552	0.10836	0.06994
0.5	2	**0**	5	15	25	1.53653	1.65560	1.77893	0.36717	0.11695	0.07382
0.5	2	**0.5**	5	15	25	1.64440	1.76984	1.86872	0.39881	0.12555	0.07769
0.5	2	**1**	5	15	25	1.74892	1.88311	1.95816	0.43045	0.13415	0.08156
0.5	2	**1.5**	5	15	25	1.85018	1.99540	2.04725	0.46209	0.14275	0.08544
0.5	2	1	**5**	15	25	1.74892	1.88311	1.95816	0.43045	0.13415	0.08156
0.5	2	1	**6**	15	25	1.87080	1.97288	2.03016	0.37368	0.14102	0.08469
0.5	2	1	**7**	15	25	1.96110	2.03440	2.08028	0.32872	0.14575	0.08688
0.5	2	1	**8**	15	25	2.02933	2.07730	2.11612	0.29258	0.14906	0.08844
0.5	2	1	**9**	15	25	2.08202	2.10776	2.14236	0.26310	0.15142	0.08959
0.5	2	1	5	**15**	25	1.74892	1.88311	1.95816	0.43045	0.13415	0.08156
0.5	2	1	5	**16**	25	1.74892	1.90023	1.96635	0.43045	0.12643	0.08192
0.5	2	1	5	**17**	25	1.74892	1.91528	1.97337	0.43045	0.11953	0.08222
0.5	2	1	5	**18**	25	1.74892	1.92861	1.97945	0.43045	0.11333	0.08249
0.5	2	1	5	**19**	25	1.74892	1.94050	1.98477	0.43045	0.10773	0.08272
0.5	2	1	5	15	**25**	1.74892	1.88311	1.95816	0.43045	0.13415	0.08156
0.5	2	1	5	15	**26**	1.74892	1.88311	1.96398	0.43045	0.13415	0.07854
0.5	2	1	5	15	**27**	1.74892	1.88311	1.96938	0.43045	0.13415	0.07574
0.5	2	1	5	15	**28**	1.74892	1.88311	1.97438	0.43045	0.13415	0.07312
0.5	2	1	5	15	**29**	1.74892	1.88311	1.97904	0.43045	0.13415	0.07068

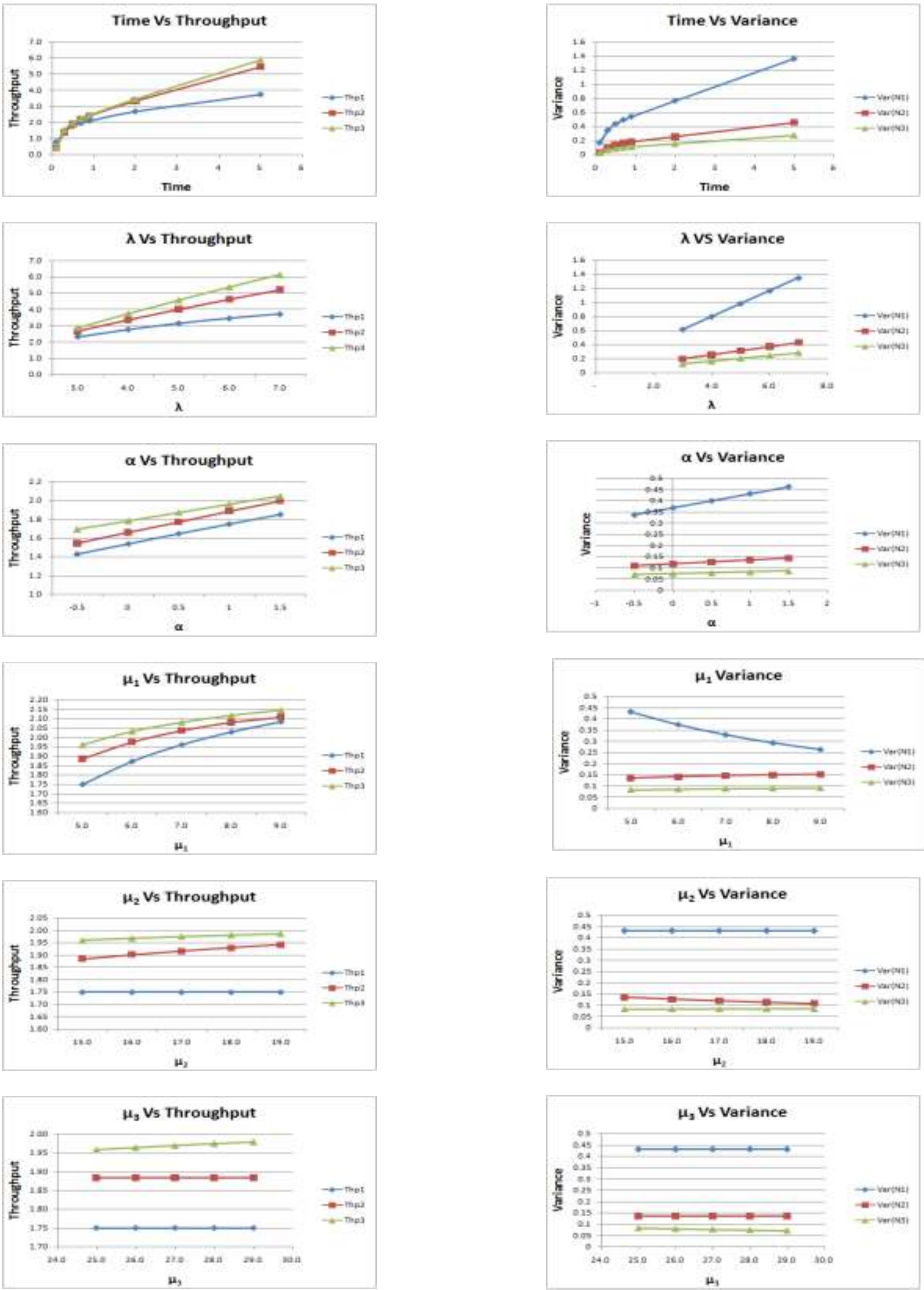

Figure 4.3 : The relationship between Throughput, variance and various parameters

As the parameter (λ) varies from $3x10^4$ packets/sec to $7x10^4$ packets/sec, the throughput of the first node, second node and third node are increasing when other parameters remain fixed. When the parameter (α) varies from -0.5 to 1.5, the throughput of the first node, second node and third node are increasing when other parameters remain fixed.

When the transmission rate (μ_1) varies from $5x10^4$ packets/sec to $9x10^4$ packets/sec and the throughput of the first, second and the third node are increasing when other parameters remain fixed.

Similarly as the transmission rate (μ_2) varies from $15x10^4$ packets/sec to $19x10^4$ packets/sec, the throughput of the first node remains constant at 17489 packets, the second node and the third node are increasing when other parameters remain fixed.

As the transmission rate (μ_3) varies from $25x10^4$ packets/sec to $29x10^4$ packets/sec, the throughput of the first and second nodes remain same at 17489 packets and 18831 packets respectively and for the third node, it increases when 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 becomes small. The co-efficient 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. It helps us to control the smooth flow of packets in buffers.

By increasing/decreasing the input parameter this system performance measures like probability of emptiness of the buffers, throughput of the nodes, the mean delay in transmission and congestion of the buffers can be increased/decreased as per the monitoring and maintaining strategy of the system. The analysis of this numerical illustration will also provide the optimal levels at which the performance measures can be maintained by regulating the input parameters. This managerial implication will help the service providers to utilize the idle bandwidth effectively.

From this analysis 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-homogeneous Poisson arrivals and evaluate the performance of the network under transient conditions. It is also observed that the 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 (service).

5. CONCLUSION:

In this paper a novel and new wireless ad hoc network model developed and analyzed the wireless ad hoc systems more effectively and efficiently. The work presented in this paper focus on the improvement of allocation of bandwidth dynamically using load dependent strategy. This shows that dynamic allocation of bandwidth can reduce mean delay and mean service time. The developed network performs faster than the traditional network without load dependence.

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