A Stochastic Model for Mobile Ad hoc Network

Farah Jamal Ansari
Computer Section, University Polytechnic,
F/O Engineering & Technology, JMI, Delhi.

ABSTRACT

This paper proposed a stochastic model M/M/1/K/K for MANET with finite number of packets and finite number of nodes. In this context, we emphasize on characterizing the average waiting time at the node, queueing delay, node utilization and maximum achievable per node throughput so as to analyse some of the performance measures in order to improve the Quality of Service (QoS) of MANET. The paper establishes a markovian queueing network model for MANET and presents results that have been carried out via MATLAB.

Keywords: Mobile Adhoc Network (MANET), FCFS, AWT, queue length distribution, throughput.

1. **Introduction**

To set up a quick communication is no longer a dream in case of to get and to exchange the desired information. As we see, a rapid popularization of MANET can be seen everywhere to exchange the information which fulfill the purpose of setting up the network on a very fast pace and on ad hoc basis. Its intrinsic capabilities of selfadministration and self automation, simple maintenance, better flexibility, independence of infrastructure and considerable costs advantages enable MANET to become the preferable and reliable network for personal pervasive communication [1]. The importance of MANET is being increasingly recognized by both the research and industry community. MANET are becoming the network of choice everywhere, not only because of flexibility and freedom they offer but also robustness of network and to set up quick communication network. During the last decade, advances in both hardware and software techniques have resulted in mobile hosts and wireless networking common and miscellaneous.

Queueing model deals with to specify some assumptions regarding the probabilistic nature of the arrivals and services processes in the network. The foremost general assumption concerning arrivals to build is that they follow a Poisson process [2][3]. The name came into existence from the fact that the number of arrivals at a server in any specified time interval has a Poisson distribution.

P(t) is the total arrivals at a node in the network during the time interval of length t and follows a Poisson distribution, then

$$\text{Probability}\ \{\mathrm{P(t) = n}\} = e^{-\lambda t}(\lambda . t)^n/\mathrm{n!}$$

where λ is termed as the arrivals rate of the packets on the node in the network.

Poisson process is the time interval between two arrivals, referred to as the inter-arrival time, follows an exponential distribution [4]. Therefore, for a Poisson process with arrival rate λ, if n is the inter-arrival time, then

$$\text{Probability}\ \{\mathrm{n \leq t}\} = 1 - e^{-\lambda t}$$ where, 1/λ is the average time in the network between arrivals.

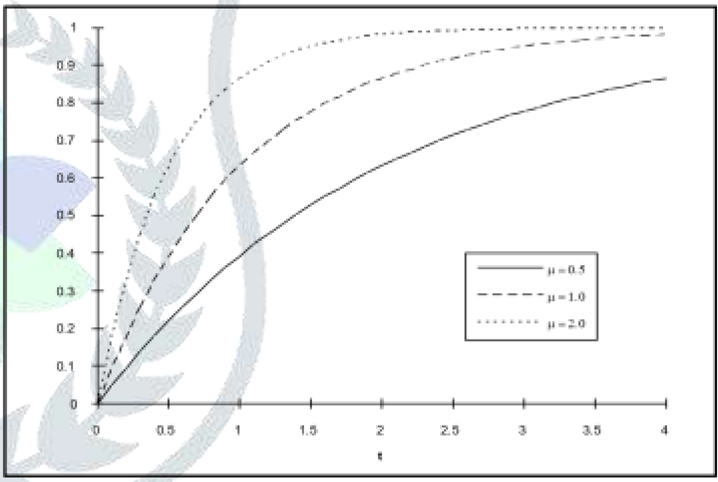

Figure 1. Exponential Service Functions for □ = 0.5, 1.0, 2

We assume that the service time of a packet is independent of the service time of all other packets and follows an exponential distribution as shown in figure 1.

2. **Model Description**

This is also known as a finite population model of population size K where packets arrive according to a Poisson distribution, λ per unit time and the service duration follows an exponential distribution (with service time 1/μ) [5][6]. So, actual arrival rate (λ_{eff}) is given by

$$\lambda_{eff} = \begin{cases} (\mathrm{k-n})\lambda & 0 \leq n \leq K \\ 0 & n > K \end{cases} \qquad (1)$$

with their service rate

$\mu_n = \mu$ for $n > 1$ (2) where,

λ_{eff} Actual arrival rate at a node μ_n Actual service rate at a node

n Number of packets in the node

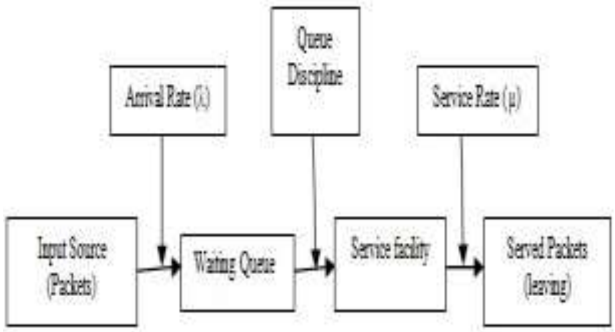

Figure 2 Components of a basic queuing system

The queueing system as shown in figure 2 is considered to be *stable* as long as λ < μ. In any case if arrivals occur faster than the service finished, the queue grows unlimitedly long-lasting, and therefore, the network does not have a stationary distribution [7][8]. This distribution is said a limiting distribution for big values of *t*. No more than K packets reside in the queue at any point of time. Various performance measures and parameters are computed explicitly for the M/M/1/K/K queue by determining closed form expression. We tend to write ρ = λ/μ for the use of buffer and need ρ < 1 for the stable queue. ρ represents the typical proportion of time that the server is occupied.

Therefore,

$$K\lambda P_0 = \mu P_1 \quad (3)$$

$$P_n = P_0\, \rho^n \frac{!K}{!(K-n)} \quad (4)$$

Thus for the distribution, we have

$$P_n = P_0\, \rho^n \frac{!K}{!(K-n)} \qquad 0 \leq n \leq k \quad (5)$$

Hence the probability that the system is empty given by

$$P_0 = \frac{1}{\sum_{n=0}^{k}\left[\frac{!K}{!(K-n)}\rho^n\right]} \quad (6)$$

3. **Performance measurements of the model M/M/1/K/K**

Queuing models are bound to predict the performance measurement in MANETs in order to enhance the Quality of Service (QoS) which is most crucial and unsettled issue.

The following measurements can be obtained as follows.

3.1 Mean number of packets in the node

$$L = E(n) = \sum_{n=0}^{k}(n.P_n) = \frac{\rho}{1-\rho} - \frac{(K+1)\,\rho^{K+1}}{1-\rho^{K+1}} \quad (7)$$

where P_n is the probability that there are n packets in the queue.

3.2 Average waiting time in the node

According to little's law [9] the sojourn time in the system is given by:

$$w = \frac{\lambda}{\lambda_{eff}}$$

hence,

$$W = \frac{\frac{\rho}{1-\rho} - \frac{(K+1)\,\rho^{K+1}}{1-\rho^{K+1}}}{(K-n)\lambda} \quad (8)$$

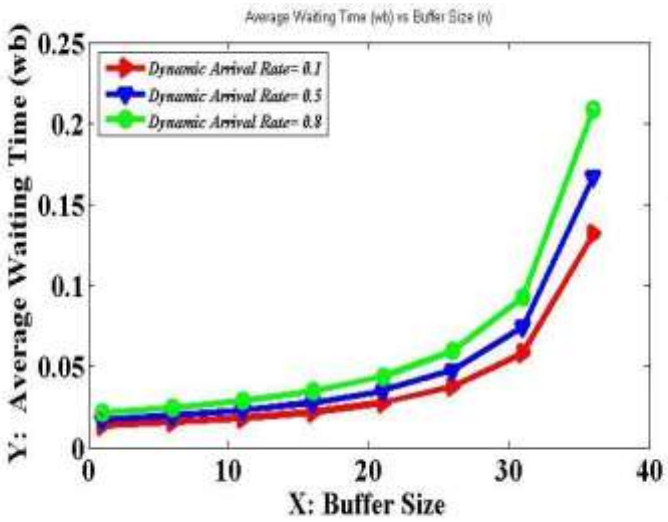

Figure 1: Graph between average waiting time and Buffer Size

3.4 Queueing delay (Q.D) in the queue

Queueing delay is the time a packet waits in the queue at a node for transmission in the network. It is given by

$$\text{Queueing delay (Q.D)} = \frac{\text{Queueing length (Lq)}}{\text{Average arrival rate}(\lambda eff)}$$

$$Q.D = \frac{L}{(K-n)\lambda} - \frac{1}{\mu} \quad (9)$$

3.6 Packet Drop Probability (PDP)

PDP is also known as blocking probability represented by P(drop) at a time when the queue is considered full and limited buffer size K. Therefore, an arriving packet is dropped with a probability P(drop), given by

$$P_k = P(\text{drop}) = P_0\, \rho^n \frac{!K}{!K-n} \qquad 0 \leq k \quad (10)$$

$$P_K = 1 \; for \; n > K$$

3.7 Throughput (λ_t) of the node

By elementary calculations we have

$$\lambda_t = \mu(1 - P_0) \quad (11)$$

$$\lambda_t = \mu\left(1 - \frac{1}{\sum_{n=0}^{k}\left[\frac{!K}{!(K-n)}\rho^n\right]}\right) \quad (12)$$

Queueing Delay (sec)	Response Time (sec)	Hop Count	Queueing Delay (sec)
0.0927 x 10^-3	0.0142	1	0.56 x 10^-2
0.0997 x 10^-3	0.0149	2	0.70 x 10^-2
0.1067 x 10^-3	0.0157	3	0.86 x 10^-2
0.1117 x 10^-3	0.0165	4	0.98 x 10^-2
0.1207 x 10^-3	0.0172	6	1.12 x 10^-2
0.1298 x 10^-3	0.0179	7	1.29 x 10^-2
0.1348 x 10^-3	0.0187	9	1.44 x 10^-2

Table 1: Response Time w.r.t Queueing delay & Queueing delay w.r.t Hop Count

4. **Outcomes**

From the numerical analysis, results are obtained using MATLAB. Figure 1 presents the result of average waiting time for the buffer size with varying arrival rate in the network. The graph shows a positive relationship between them where increment in the arrival rate is associated with the increment in the average waiting time in the network.

We formulated an analytical queueing network model M/M/1/K/K for MANET to find the queuing delay and average response time as a performance parameters. It is observed that with the increasing values of arrival rate, the queueing delay increases. Also, increasing value of nodes leads to enhancement in the queueing delay. With the increment in the hop count values, response time of a packet is also bound to enlarge. This all showing positive relationships in our outcomes.

5. **Conclusion**

We have developed a M/M/1/K/K queueing network model for MANET to evaluate some of the performance parameters. Formulas are derived analytically and graphs are made using MATLAB which represent positive relationship between them. For the future purpose, extensive simulation and more insight need to be performed for comprehensive performance analysis.

References

[1] Chip E. et. al., "Self-Organizing, Self Healing Wireless Networks", IEEE ICPWC 2000, pp. 355-361, Cambridge, MA, 2000.

[2] G. Bolch, S. Greiner, Hermann D. Meer, Kishore S. Trivedi, Queueing Networks and Markov Chains: Modeling and Performance Evaluation with Computer Science Applications. John Wiley & Sons, NY, 1998.

[3] Arnold O. Allen, Probability, Statistics, and Queueing Theory with Computer Science Applications, Academic Press, 1978.

[4] Y. Yeh, "Handbook of Healthcare Delivery Systems", Taylor & Francis Group, CRC Press, 2011.

[5] D. Gross and C. M. Harris, Fundamental of Queueing Theory, 3rd Ed., John Wiley and Sons Inc., NY, 1998.

[6] U. Narayan Bhat, Simple Markovin Queueing Systems, An Introduction to Queueing Theory, springer, 2008.

[7] Andreas Willig, A Short to Queueing Theory, Telecommunication Networks Group, Berlin, July 21, 1999.

[8] Aliakbar Montazer Haghighi, Dimitar P. Mishev, Difference and Differential Equations with Applications in Queueing Theory, Wiley, 424 pages, June 2013.

[9] Donald Gross, John F. Shortle, James M. Thompson, Carl M. Harris, Fundamentals of Queueing Theory, John Wiley & Sons, 23-Sep-2011.

AUTHOR PROFILES

Ms. Farah Jamal Ansari is currently working as an Assistant Professor in University Polytechnic, Jamia Millia Islamia, New Delhi with a long experience of teaching. She received her B.Tech and M.Tech from Jamia Millia Islamia and pursuing a Ph.D. from IIT Delhi, INDIA. Her areas of interest are Machine Learning, NLP, wireless network She is specialized in JAVA, Python, Android, and PHP programming. She has published many research papers. She has many achievements in her hand.