A Novel Queueing Network Model for MANETs to enhance QoS

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

Abstract

Despite the long history of ad hoc networking, there are still quite a number of problems that are open. Particularly among ad hoc networks designed for the military, scalability is one of the most important open problems. Scalability in ad hoc networks can be broadly defined as whether the network is able to provide an acceptable level of service to packets even.in the presence of a large number of nodes in the network. In this context, this paper establishes a markovian queueing model for multiple mobile nodes so as to determine the average waiting time and network utilization of the network.

Keywords: Mobile Ad hoc Network (MANET), Queueing theoretic approach, Performance Analysis, Average Waiting Time.

1. Introduction

During the last decade, advances in hardware equipment, software development techniques and other high-performance networking devices have resulted in development of robust self-automated Adhoc Networks. Moreover, traditional home appliances, e.g. digital cameras, cooking ovens, washing machines, refrigerators, vacuum cleaners, and thermostats, with computing and communicating powers attached, extend the field to a fully pervasive computing environment. In moving forward towards fulfilling the successful addressing of open technical and economic issues will play a critical role in achieving the eventual success and potential use of MANET [1].

To serve the best purpose of ad hoc network, queueing models can ensure the performance with respect to the execution and designing of upcoming MANET technologies [2]. Queueing models encourage to achieve reasonable performance targets and provide a clear and understandable roadmap to several communication researchers by indicating whether or not a performance target is physically attainable or not, what may be the advancement in performance in order to have a better Quality of Service (QoS) that is still possible to make by means of efforts under the existed developed technologies [3].

It has some pinpoint assumptions regarding the probabilistic environment of the entering and service activities within the network, the quantity and nature of nodes, additionally queueing discipline [4]. Components of a basic queuing system shown in figure 1.

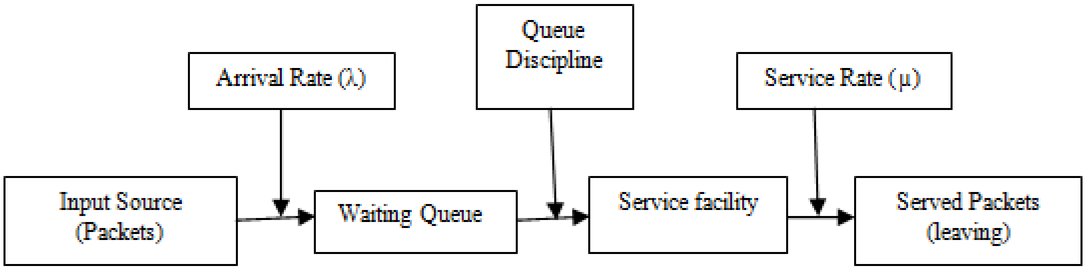

Fig. 1 Components of a basic queuing system

In addition, since they are extremely fast to run, they offer an easier way to perform *"what-if"* analyses, discover tradeoffs and identify engaging solutions rather than simply estimating performance in the network [5-8]. Let us say, P(t) is the total arrivals at a node in the network during the time interval of length t, if n is the inter-arrival time and P(t) follow a Poisson distribution, then

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

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

The paper is structured as follows. In Section 2, model description is introduced briefly. In Section 3, proposed mathematical model is evaluated in detail to calculate the performance parameters. In Section 4, performance measurements of the model are determined. Results are presented in Section 5.

2. Queueing network model description

The model assumes multiple queues (c) with finite buffer of size K where packets arrive according to a Poisson distribution with mean rate λ per unit time and the service duration follows an exponential distribution with service rate μ. This model considers the population of size K and service discipline at node is taken First-Come–First-Serves (FCFS) basis. All the packets wait in the queue of the node till their service is finished completely in order to depart from the MANET [9-10].

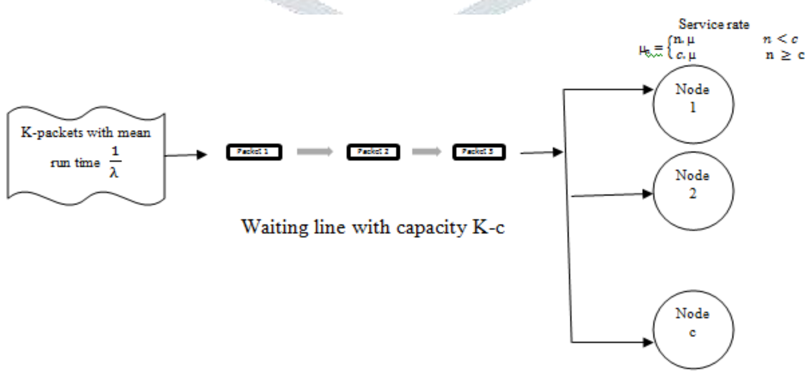

Fig. 2 M/M/c/K/K Queueing Network Model

The actual arrival rate of finite population model with multiple node can be given by

$$\lambda_n = \begin{cases} (k-n)\lambda & 0 \le n \le K \\ 0 & n > K \end{cases} \qquad (1)$$

having their service rate

$$\mu_n = \begin{cases} n.\mu & n < c \\ c.\mu & n \geq c \end{cases} \quad (2)$$

where, λ_n Actual arrival rate at a node

μ_n Actual service rate at a node

n Number of packets in the node

$1/\lambda$ Average time in the network between arrivals.

3. Performance measures of the Queueing model (M/M/c/K/K in MANET

Various performance measures and parameters are computed explicitly for the M/M/c/K/K queue by determining closed form expression. We tend to write $\rho = \lambda/c\mu$ for the use of buffer and need $\rho < 1$ for the stable queue. ρ represents the typical proportion of time that the node is occupied.

Therefore,

$$P_n = P_0 \frac{\lambda 0.\lambda 1.--------\lambda n-1}{\mu_1.\mu_2.----------\mu_n} \quad (3)$$

Where P_n and P_0 is the steady state probabilities of having n packets and zero packet in the system.

$$P_n = P_0 \frac{K(K-1)\;--------(K-n+1)\lambda^n}{!n\;\mu^n} \quad (4)$$

for $n \geq c$

$$P_n = \left(\frac{!K}{!K-n\;!C\;C^{n-c}}\right) P_0\, \rho^n \quad (5)$$

Using normalizing condition

$$\sum_{n=0}^{c} p_n + \sum_{n=c+1}^{k} p_n = 1 \quad (6)$$

$$P_0 = \frac{1}{\sum_{n=0}^{c}\left(\frac{K}{n}\right)\rho^n + \sum_{n=c+1}^{k}\frac{!K}{!K-n\;!C\;C^{n-c}})\;\rho^n} \quad (7)$$

4. Simulation Result

4.1 Model Output: Performance Metrics

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.

4.1 Mean number of packets in the node

$$L = E(n) = [\sum_{n=0}^{c} n.\left(\frac{K}{n}\right)\rho^n + \sum_{n=c+1}^{k}\frac{!K}{!K-n\;!C\;C^{n-c}})\;\rho^n\,]. P_0 \quad (8)$$

where P_n is the probability that there are n packets in the queue. Simply, expression can be written as

$$E(n) = [\,k\sum_{n=0}^{c}(\rho^n) + \sum_{n=c+1}^{k}\frac{!K}{!K-n\;!C\;C^{n-c}})\;\rho^n\,]. P_0 \quad (9)$$

4.2 Average waiting Time at the node

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

$$W = L/\lambda_n \qquad (10)$$

$$W = \begin{cases} \frac{L}{(k-n)\lambda} & 0 \le n \le K-1 \\ infinity & n \ge K \end{cases} \qquad (11)$$

4.3 Mean number of packets in the queue

$$L_q = L - \lambda_n / c\mu = = L - (k\text{-}n)\lambda / c\mu \qquad (12)$$

$$E\,(D_q) = \frac{L}{(K-n)\lambda} - \frac{1}{c\mu} \qquad (13)$$

4.4 Node utilization (NU)

Node Utilization is commonly specified as a percentage of capacity of the node in manet to hold the packets. NU can also be described as the ratio of current packets on node to the maximum packets that the node can hold which can be written as

$$\rho = \lambda_n / c\mu = (k - n)\lambda / c\mu \qquad (14)$$

From Erlang B formula,

$$B = \frac{\frac{A^N}{!N}}{\sum \frac{A^t}{!t}} \qquad (15)$$

Where:

B=Erlang B loss probability
N=Number of trunks in full availability group
A=Traffic offered to group in Erlangs

The summation is undertaken from i = 0 to N

Therefore, the relationship between utilization of the node in the network with response time is shown in figure 3. It is showing a positive relationship.

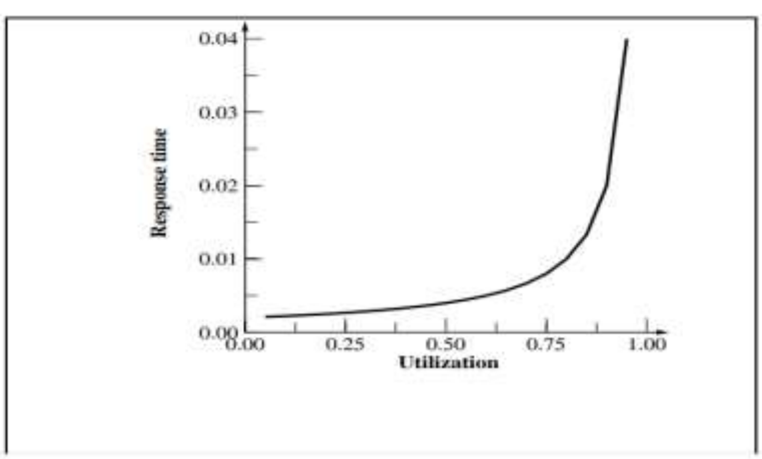

Fig. 3: Graph between Utilization and Response Time of the Node

The utilization of a node in the network represents the fraction of time a node is engaged in providing service. It is considered dimensionless and should be less than one in order for a serve to cope with the service demand and for the network to be stable. Hence, the greater the variability in the response time (e.g. length-of-stay), the longer the delays at any given utilization level in the network.

The relationship between the maximum length of the queue and load is shown in the figure 4 which again showing a positive relationship. As the capacity of queue to hold the packets is increasing, the load value is also increasing.

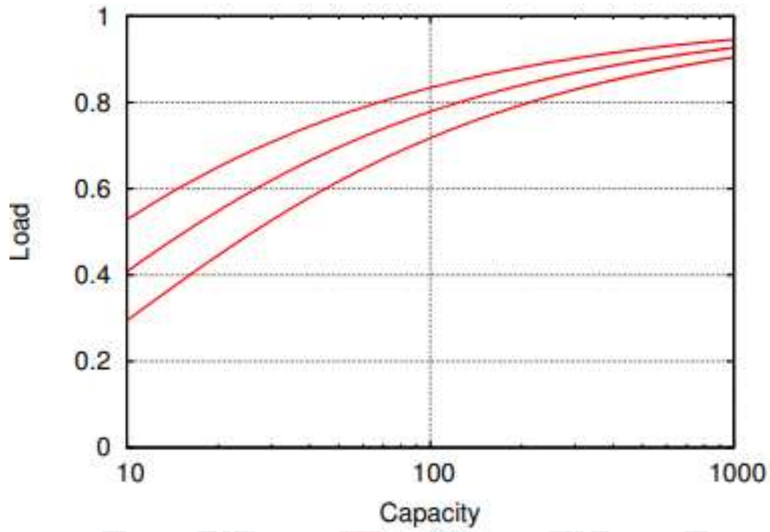

Fig. 4: Graph between Utilization and Response Time of the Node

5 Conclusion

Future investigations should be conducted to determine the applicability of this methodology for the determination of other optimal conditions in finite queueing networks. For instance, this method could be applied to optimize throughput in finite general, multi node queueing networks or queueing networks with loops. Thus, the method could be used to model systems that lead to a reverse stream of products. Moreover, future research should be conducted to evaluate the algorithms in real-life situations.

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