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A Modified M/M/c/K+Flush/K Analytical Model for improving Delay Aware QoS of MANET

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Abstract: This research paper is intended to develop a finite queueingmodel M/M/c/K+Flush/Kwhich can help it in designing and implementation in order to obtain an efficient, low cost, and high-speed MANET.In this context, weemphasize on characterizing the average waiting time at the node, queueing delay,node utilization andmaximum achievable throughput per nodeso as to analyze some of the performance measures in order to enhance the QoS of MANET.The paper establishes a Markovian queueing model for MANET andpresents results that have been carried out via MATLAB. Impact of parameters such as the speed, the arrival rate and service rate on a mobile node in a given area using Poisson distribution is investigated.

Keywords: MANET, Markovian queueing model, Node utilization, Quality of Service (QoS).

I. INTRODUCTION

The appearance offast popularization of Mobile Adhoc Network (MANET) can be noticedeverywhere to exchange the information which fulfill the purpose of setting up the network on a very fast pace [1-5]. Therefore, to set up a quick communication is no longer a dream in case to get and exchange the desired information. Its intrinsic capabilities of self-administration and self automation, simple maintenance, better flexibility, independence ofinfrastructure andconsiderable costs advantages enables MANET to becomethe preferable and reliablenetwork for pervasive communication [6]. That's why the significance of MANET is increasingly acknowledged by the researchers 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 [7-8].

Extensive research work is being carried out to find attainable solutions to the sophisticated problems encountered in MANET to develop it more and more efficient, robustand economical[9].Statistical models serve as essentialguiding principle for the development, optimization andexecution of upcoming MANET technologies. Statistical models encourageachieving reasonable performance targets and providing a clear and understandable roadmap to researchers by examining whether or not a performance target is physically attainable. This may lead to the advancementin performance in order to have a better QoSpossibly by means of efforts under the existeddeveloped technologies [10-12].

Queueing approach is aconsiderable statistical depiction of queueing system [13]. A queueing model for the MANET is simply delineate as packet reachingat a node, waititschanceto get serviced if not immediate, afterhaving waited it is serviced by the nodeand then packet leaves the network. It hasfew important assumptions about the probabilistic setting of the entering and servicingactions, the quantity of nodes, their naturein the network and queueing discipline. There may be numerouspossibledifferences in the queueing models, howeverfew models are more generally casted-off [14-17]. Forthe purpose of developing efficient MANET, queueing models may obtainthe new derivations and formulasforthe approximationof performance measures in the MANET. This can assist inanupgrading a servicing model or can design better the current one [18-19].

Queueing approaches aresuitable in anticipating and determining theperformance of the mobile network. Unlike simulation methodologies, they need basic information and lead to comparatively easy derivations for predicting many performance outcomes such as delay, average waiting time and probability of waiting in the network etc. Queueing approaches are essential to evaluate the QoS in network [20-21]. In addition, not only fast to run, but also present easiermeans to perform *"what-if"* analyses, discover tradeoffs and identifyengaging solutions rather than simply estimating performance in the network [22].

Considering, probability at any time t, let us say, P(t) is the sum ofincoming packets at a node in the network during the time t, if n is considered the inter-arrival time and P(t) follow a Poisson distribution, then

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

where λ is the incoming rate of the packets [23].

We have proposed an analytical modelto prove that our proposed approach outperforms other approaches mentioned in paper. The paper is prepared with the following sections. Section II gives a brief idea to the existing research on various queueing models for MANETs. Section III provides an explicit description of the proposed queueing model. In Section IV, proposed mathematical model is evaluated in detail, to calculate the performance parameters and performance measurements of the model are determined. Outcomes are shown in Section V and the paper is summarized by conclusions in Section VI.

II. RELATED WORK

Queueing model in MANET have been studied by numerous researchers. Some of these researches are discussed here.In [24], the authorsstudied the queuing model (G/G/1) for delay measureusing diffusion approximation method. The authors estimated the mean E-2-E delay for multi-hop network. The previous approaches were mainly focused on theoretical work and most of the papers assumed that these networkscontain infinite buffer capacity. Though, node in a real time network contains a restricted buffer, which further tend us to predict the packet drop probability. In [25], a cross-layer approach is proposed for refining the delay of real-time traffics. It was performed bylessening the packets that came after their schedule deadline. This paper was also focused on the theoretical effort.

Inpaper [26], the average throughput per node in the network reducedto $1/\sqrt{n}$ or $\frac{1}{\sqrt{\mathrm{nlgn}}}$, say n is sum of nodes.This was to mean, that the whole network capacity bound to enhance nearly $\sqrt{n}$. Moreover, in [27] it is shown that mobility can improve the capacity. However, delay is not guaranteed in their approach. Hence, delay increased due to more possiblenumber of hops or queueing in order to increase the throughput. Authors have analyzeda fixed population loss and delay [28] considering the assumptions of interarrival time and service times, manageableincoming rates. In paper [29], a M/M/c/∞ inter-reliant model with controllable incoming rateswasanalyzed. Further, an interdependent model M/M/1/K with manageableincoming rates has been analyzed in [30].

In [31], paper discussed G/G/1 analytical techniqueto evaluate the performance of networkconsidering discreet time. A new model was projected with the help of probability generating function. In this paper, packet delay was determined considering unsaturated traffic and probability distribution function.In [32], for single hop scenarios, markov chain model was presented to get a mathematical expression for delay, along with first moment of the service time.In this paper, a M/G/1 model wasimplemented. The paper furthers improved the queueing method for a single hop network to mapped with a multi-hop wireless network. The authors presented theterminologies for the probabilities of collision and lossrateowing to the hidden node problem. Though, in multi-hop situations, they solely discussed the rough throughput of node and did not consider the delay.

In [33], authors took the work forward introduced in paper [34] to estimate the delay analysis. The authors modeled the multi-hop wireless networkan M/G/1 queue under unsaturated traffic condition. Service time distribution function was determined for each node under hidden and exposed terminal problem. Further, with the assistance of the service time distribution, delay for single hop network was estimated.

III. PROPOSED M/M/c/K+Flush/K QUEUEING MODEL

The model described in this paper comprises two sections, firstly, queue with flushing technique and second, queue without flushing technique. This givesadescription to the network behaviour under the impact of flushing technique (Fig. 1).In this paper, the model assumes multiple queues (c) with finite buffer of size K. Each packet reaches at the MANET's node following Poisson distribution with incoming rate λ per unit time and the service time, which is an exponential distribution,μ with flushing in overloaded queue. This model is considered a population of size K and service discipline at node is served on the basis of First-Come–First-Serves (FCFS).

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

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

having their service rate (μ_n) expressed as,

$$\mu_n = \begin{cases} \mathrm{n}.\mu & n < c \\ c.\mu & \mathrm{n} \ge c \end{cases} \tag{2}$$

where, λ_n Actual incoming rate at the node
μ_n The service rate at a node
n Number of packets
$1/\lambda$ Mean time between two consecutive arrivals.

Flushing of packets take place when buffer of the node is already occupied and has no space left toacquire the packet further. The flushing of packets occure in the proposed model depend on the number of packets in the queue relative to a threshold. This flushing queue simulates the behaviour of a ring buffer. At the same time as we know, node in the MANET is prone to failures and at the time it occurs, all the packets are flushed out of the node.

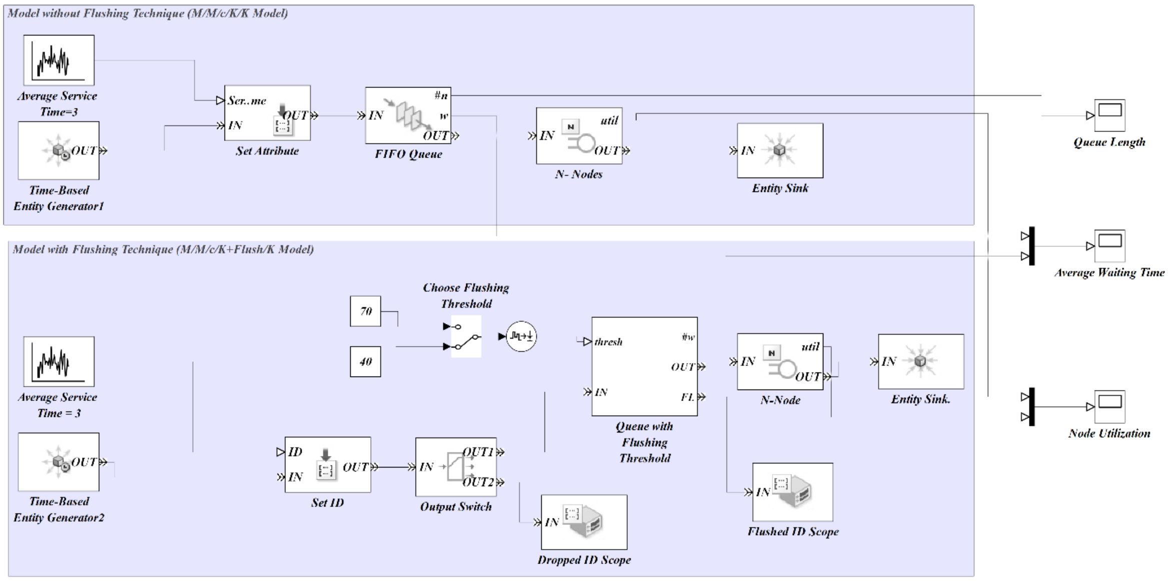

Fig. 1. M/M/c/K+Flush/K Queueing Network Model: Simulink

3.1 Queue with Flushing Technique

In this technique, the queue of the node with flushing threshold containsonly one input port labelled thresh that shows the threshold for flushing the packets from the node. Inthis flushing technique, a FCFS Queue block contains packets, whereas the Control Space Usage subunit (as shown in figure 1)relates the queue length of node to the threshold. If the queue length surpasses the threshold, the Enabled Gate block allow thesufficient packets to leave from the queue until the queue length no longer exceeds the threshold. This technique get aheaduntil the Enabled Gate block's OUT port is not kept blocked.

1.2 Queue without Flushing Technique

In this technique, generally, queue without flushing threshold subsystem needsa signal input port.There is no need of labelling to threshas it was used by earlier one technique forshowing the flushing of the packets in the queue. Consequently, queue can grip the number of packets equal to the maximum population size (K) which may caused the packets loss. The packets still arriving at the queue regardless of the queue is full.

IV. Performance Metrics forM/M/c/K+Flush/K

Severalclosed form expressionsfor the performanceparameters of M/M/c/*K*+*Flush*/K model are determined. The traffic intensity on the node $\rho = \lambda/c\mu$, $\rho < 1$ for the stable queue. Here, ρ indicates the typical proportion of time.
Therefore,

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

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

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

for $n \geq c$

$$P_n = P_0 \frac{\lambda 0.\lambda 1.--------\lambda(n-1)}{(\mu_1.\mu_2.---\mu_c).(\mu_{c+1}---\mu_n)} (5)$$

$$P_n = P_0 \frac{K(K-1)--------(K-n+1)\lambda^n}{!C\;C^{n-c}.\mu^n} (6)$$

$$P_n = \left(\frac{!K}{!K-n!C\;C^{n-c}}\right)P_0\rho^n (7)$$

Using normalizing condition

$$\sum_{n=0}^{c} p_n + \sum_{n=c+1}^{k} p_n = 1 (8)$$

$$P_0 = \frac{1}{\sum_{n=0}^{c}(\frac{K}{n})\rho^n + \sum_{n=c+1}^{k}\frac{!K}{!K-n!C\;C^{n-c}})\rho^n} \qquad (9)$$

$$L = \sum_{n=0}^{c} n.p_n + \sum_{n=c+1}^{k} n.p_n (10)$$

Where, L denotes the queue's length at the node.
L_q denotes the waiting queue's length and given by,

$$L_q = \sum_{n=c+1}^{k} (n - c) p_n$$
(11)

Performance Metrics
Queuing approachesgenerally estimate the performance measurement to increase the Quality of Service (QoS) which isconsidered a biggerchallengein network[35-38].Some crucial parametersaredetermined as follows.
4.1 Average number of packets in the node

$$L = E(n) = [\sum_{n=0}^{c} n.(\frac{K}{n})\rho^n + \sum_{n=c+1}^{k} \frac{!K}{!K-n\ !C\ C^{n-c}})\rho^n].P_0 \qquad (12)$$

Here, P_n represents the probability holding n packets in the queue. Simply, expression can be written as

$$E(n) = [k \sum_{n=0}^{c} (\rho^n) + \sum_{n=c+1}^{k} \frac{!K}{!K-n\ !C\ C^{n-c}})\rho^n].P_0 (13)$$

1.3 *Average waiting Time at the node*
According to little's law [39], the sojourn instance at the node is given by:
W= L/ λ_n(14)

$$W = \begin{cases} \frac{L}{(k-n)\lambda} 0 \le n \le K-1 \\ infinity n \ge K \end{cases} (15)$$

1.4 *Average number of packets in the queue*
$L_q = L - \lambda_n / c\mu = = L - (k\text{-}n)\lambda / c\mu$ (16)
1.5 *Queueing delay in the queue*
Expected queueing delay is defined as a packet waiting in the queue till it get serviced. It is given by,

$$\text{Expected Queueing delay } (E(D_q)) = \frac{\text{Queue length (Lq)}}{\text{Average arrival rate } (\lambda eff)}$$

$$E(D_q) = \frac{L}{(K-n)\lambda} - \frac{1}{c\mu} (17)$$

1.6 *Node utilization*

$$\rho = \lambda_n / c\mu = (k-n)\lambda / c\mu (18)$$

1.7 *Throughput (λ_t) of the node*
By elementary calculations, we have

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

As it is know that, $\mu_n = \begin{cases} n.\mu n < c \\ c.\mu n \ge c \end{cases}$
Therefore,

$$\lambda_t = \begin{cases} n.\mu(1 - P_0) n < c \\ c.\mu(1 - P_0) \quad n \ge c \end{cases} (19)$$

***1.8* Packet Drop Probability (PDP) at a node**
Packet Drop Probability (PDP) is also identified as blocking probability of the node represented when the queue is found full and restricted buffer capacity of K. This probability of rejection (P_k) of anincoming packet at any node in MANET isgiven by,

$$P_k = P(drop) = P_0 \frac{\rho^K}{c! c^{K-c}} (20)$$

Since this queue is of finite capacity, ρis greater than 1.

V. SIMULATION RESULTS AND OBSERVATION

The performance of proposed M/M/c/K+Flush/K queueing model is evaluated using MATLAB. Table 1 presents the values of parameters used in the analysis and simulations. Analytical outcomes are given away by simulations which shows better consequences. In fig. 2, comparison are made between traditional and proposed M/M/c/ K+Flush/K queueing model for buffer capacity of the node.

Table 1: Simulation Parameters

Parameter	Value
Distribution of Arrival Rate	Poisson
Distribution Service Rate	Exponential
Simulation Time	300 sec
Queue Limit	100 packets
Traffic Generator	CBR

Threshold Upper	70
Threshold Lower	40
Packet Size	512 byte
Number of Nodes	12

For performance evaluations of the model, we considered QoS that includes delay management, queue length and utilization of the node. It is considered a set of service necessaries to be seen when sending a packet flow from source to destination. Therefore, our performance assessmentsaremade on the three performance metrics concerning QoS requirements. The FIFO queue is considered to have a buffer of finite length. Upper and lower flushing threshold values are set to 70 and 40 respectively. Initially number of nodes are taken 12 for the simulation.Simulation result in Figure 2 shows the average number of packets in the queue at any given time. Mean number of packets are kept same for both the techniques (with flushing and without flushing). It is analysed from the simulation that length of queue at node of this models does not exceed the average length of the queue at any time.

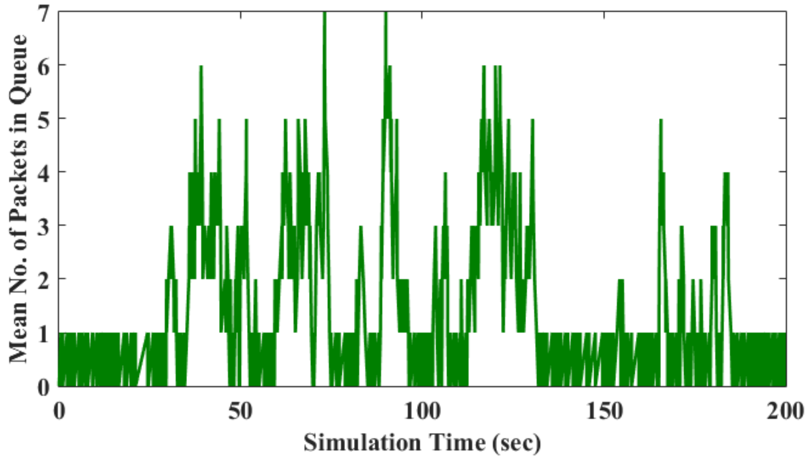

Fig. 2.Quantity of packets for proposed M/M/c/K+Flush/K model

Having the same number of packets in queue, queueing delay and node utilization are compared for both the techniques through simulations. Through simulation consequence, figure 3 presents the comparison between the proposed M/M/c/K+Flush/K model and conventional M/M/c/K/K in terms of queueing delay. It can be observed clearly that each packet has to wait comparatively lesser for the projected modelM/M/c/K+Flush/K. Initially for a small period, the value of queueing delay remains same but in conventional model, at a point of time it upsurgesrapidly and keeps on changingbased on the volume of the queue. The peak value of queueing delay for earlier model is more than 0.7 msec but for M/M/c/K+Flush/K model its 0.35, almost half the delay practiced by traditional l model. This evidently demonstrate that our proposed model outperforms the traditional one.

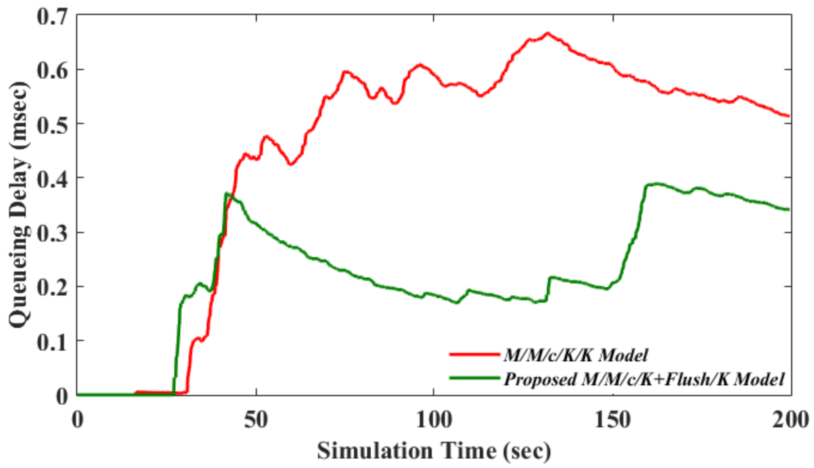

Fig. 3. Queueing Delay: Proposed M/M/c/K+Flush/K vs conventional M/M/c/K/K

Simulation outcome in Fig. 4illustrate the comparison betweenM/M/c/K+Flush/K model and the conventional M/M/c/K/Kw.r.tnode utilization, which generallyaffected by the arrival rate and service pattern of the packets, queue content. Hence, as the queue content is increased, node utilization also bound to increase and vice-versa, which shows a positive relationship. It can be seen from the figure 4, that ourproposed model outperforms the conventional queueing model in terms of node utilization.

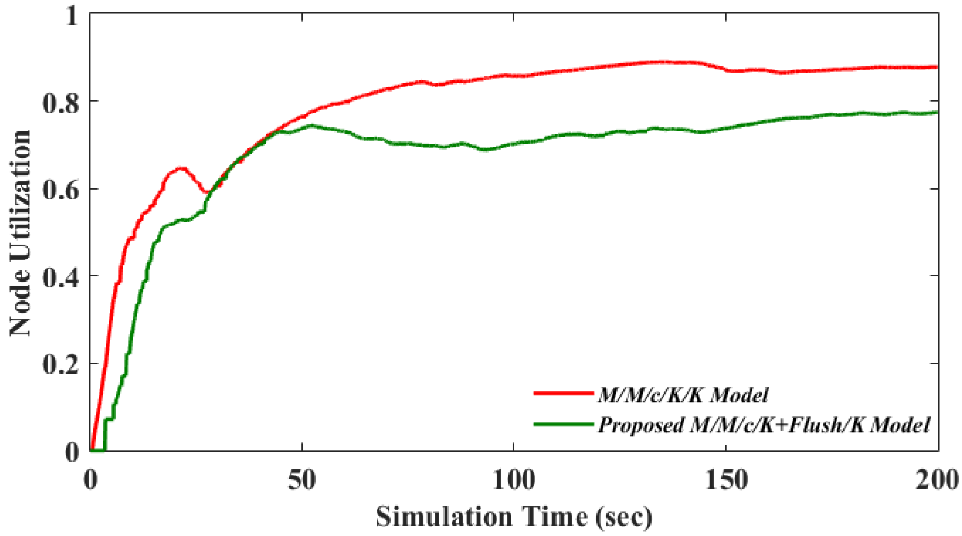

Fig. 4. Node utilization: Proposed M/M/c/K+Flush/K vs conventional M/M/c/K/K

VI. CONCLUSION

The paper proposed a queuing approachforincreasing theperformance of MANETso as toimprove QoS. We have established the closed form expressions for steady state probabilities with fewkey performance parameters like queueing delay, node throughput,average waiting time, node utilization,queue length and packet drop probability are determined. Further, these analytical outcomes are verified using using MATLAB software. Simulationoutcomeproves that the presented proposed model (M/M/c/K+Flush/K) outperforms the traditional queueing model (M/M/c/K/K). In figure 3 and figure 4, we have found that results of queueing delay and node utilization are far better than the conventional model.

Conflicts of Interest

The authors declare no conflict of interest.

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