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PERFORMANCE COMPARISON OF PRIORITY SCHEMES WITH PRIORITY JUMPS IN WIRELESS NETWORKS

Geetanjali Sharma* and G. N. Purohit

Centre for Mathematical Sciences, Banasthali University-304022, Rajasthan, India

E-mail: geetanjali.bu@gmail.com, gn_purohitjaipur@yahoo.co.in

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ABSTRACT

Network traffic can often be divided into multiple classes of traffic, each having a different QOS (Quality of Service) standard. For delay-sensitive traffic, it is important that mean delay and delay jitter are not too large, while for delay-insensitive traffic, the loss ratio is the restrictive quantity. To support and differentiate several classes of traffic in a network, priority schemes are used. In the priority scheduling discipline for instance, priority is always given to the delay sensitive traffic, i.e. high priority traffic is always scheduled for service before the delay-insensitive (low-priority) traffic. We consider three models and analyze a jumping scheme in which a random call of the low priority queue can jump to the high priority queue (to incorporate "impatient" calls). Some performance measures such as blocking probability of new calls and dropping probability of handoff calls is obtained.

***Keywords**: New calls, handoff calls, jumping mechanism, queueing, performance analysis, Cellular Network.*

1. INTRODUCTION:

Priority scheduling does indeed provide low delays for the high priority traffic, but if a large portion of the network traffic consists of high priority traffic, the performance for the low-priority traffic can be severally degraded. Specifically, priority-scheduling scheme can cause excessive delays for the low priority traffic, especially if the network is highly loaded (which is a major problem if this type of traffic is not entirely delay-insensitive, but has also some delay requirement). This problem is also known as the starvation problem. In order to find a solution for this constraint, several dynamic priority schemes have been proposed in the literature. These schemes are mostly obtained by alternately serving high-priority traffic and low priority traffic, depending on a certain threshold, or by allowing priority jumps. In a priority-scheduling scheme, new calls and handoff calls arrive in separate queues, i.e., the high and low priority queue respectively. In order to deal with possibly excessive delays however, handoff calls in the low priority queue can in the course of time jump to the high priority queue. Then these calls are treated in the high priority queue as if they were new calls. We have considered three models; in model I we are taking two separate queues and giving separate service. In model II, one call of low priority queue can jump randomly to the high priority queue. In model III, three handoff calls of low priority queue can jump randomly to the high priority queue.

The paper is organized as follows: In section 2, we describe the related work. Section 3 presents three models. In section 4, we describe the numerical results. Some conclusions are formulated in section 5.

2. RELATED WORK:

A general model (i.e., a G/G/c/c queuing system) for teletraffic analysis in future wireless networks is presented in [1], and then evaluate the traffic distribution as well as the blocking probability using the maximum entropy principles. In [2], the Modified First in First out (MFIFO) and the Ratioed Channel Assignment scheme (RCAS) are proposed to improve the call completion rates. The theoretical analysis and simulation results both show that proposed scheme is better than the NPS (Nonprioritized Scheme) and the FIFO scheme, in respect to the call incompletion probability. A concept of clustered multihop cellular network (cMCN) with the introduction of dedicated information ports (DIPs) to support multihop transmission is proposed in [3], DIPs are deployed wireless ports functioning as central controllers in virtual microcells for multihop users then conclude that cMCN with the proposed FCA scheme can reduce the call blocking probability significantly as compared to singlehop cellular networks (SCNs). An analysis and simulation model is proposed in [4] to study three Automatic Link Transfer (ALT)-initial access channel assignment schemes: the non prioritized scheme (NPS), the First in First out (FIFO) scheme, and the Measured Based Priority Scheme (MBPS) and observed that the FIFO scheme significantly reduces the forced termination probability, slightly increases blocking

***Corresponding author: Geetanjali Sharma*,*E-mail: geetanjali.bu@gmail.com**

probability of an originating calls and yield slightly better (smaller) non completion probability of an originating call compared to NPS. A new self-adaptive jumping scheme: the HOL-JIA^2 (Head-Of-Line Jump-If-Arrival^2) scheme is introduced in [5] and extensively compared the performance of the various priority schemes with priority jumps. Special attention is given to the new HOL-JIA^2 scheme and also shown that subtle difference between jumping schemes can yield considerable differences between their performances. A queuing system with a modified HOL priority scheduling discipline, with two priority classes is analysed in [6]. They derived the joint generating function of the contents in the high and low priority queue and concluded that m-HOL priority scheduling disciplines decreases the delay of the high priority packets in comparison with a FIFO scheduling discipline. A general power allocation problem is formulated in [7] for a multi-node wireless network with time varying channels and adaptive transmission rates. The network capacity region was established with a dynamic routing and power control (DRPC) algorithm and shown to stabilize the network whenever the arrival rate matrix is within the capacity region. Fast recursive expressions for some loss formulas to avoid possible overflow and underflow during computation of the loss formulas are derived in [8]. Then developed algorithms to determine the optimal number of guard channels with a fixed-point iteration scheme to determine the handoff arrival rate into a cell. In [9], a queuing system with HOL priority scheduling is analysed and adopted a generating functions approach, which led to closed-form expressions of performance measures, such as mean and variance of the system contents and cell delay, and the correlation coefficient of the system contents of both types of calls, that are easy to evaluate. The blocking probability behavior of connection-oriented traffic is studied in [10]. They investigated dynamic channel assignment algorithms for multihop wireless networks with exact and approximate blocking probability formulas for a line network that yielded useful insights into the effect of transmission radius on call blocking.

3. MODEL DESCRIPTION:

We consider a multiserver queuing system with two priority queues of infinite capacity. Further we have considered jumping. The system is characterized by three processes: the arrival process, the service process and the jumping process. We first describe the arrival process: two types of traffic arrive in the system, namely calls of class 1 and calls of class 2, which arrive in the first and the second queue respectively. Calls in queue 1 have a higher priority than those in queue 2 (we will call queue1, the high priority queue and queue 2, the low priority queue). New calls arrive in high priority queue only and handoff calls arrive in low priority queue only. The service process is determined by the number of servers and we are considered a multiserver system. New arriving calls can enter into service on their arrival till all servers are busy otherwise they form a high-priority queue. If at any time high priority queue is empty and some servers are idle, then clients (handoff calls) from low priority queue can enter into service and as many clients are provided service as many servers are idle. The service discipline of low priority queue is FIFO.

The system also includes jumping of a low priority queue into high priority queue: In case of emergency, a client (handoff call) from low priority queue jumps into the high priority queue with certain probability and it takes its position in the front of higher priority queue; however, it is served with its own service rate. This is included to reduce the starving of low priority queue.

3.1 Model I:

The Markovian M/M/m model is assumed, where m is the total number of channels allocated to the reference cell. Both the originating calls and handoff calls are treated equally by m channels in the cell, the calls are served on their arrival if free channels are available and both kinds of requests are blocked if all the m channels are busy. The 2D Markov chain for this model of the cell is shown in Fig. 1. All mobile stations (MSs) are assumed to be uniformly distributed through out the cell; the average arrival rate of originating calls (new calls) is denoted by λ_0 and the average arrival rate of handoff calls is denoted by λ_H; the average service termination rates of originating calls and handoff calls are denoted by μ_0 and μ_H respectively.

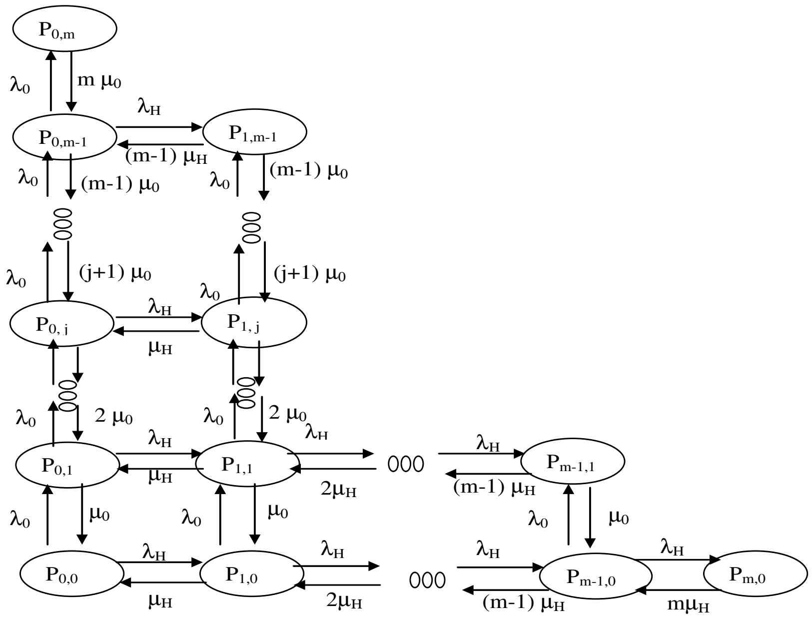

Fig.1 State Transition Rate Diagram

All the elements in a column represent new calls, whereas all the elements in a row represent handoff calls.

$$\lambda_0 P_{x,0} = \mu_0 P_{x,1}$$

$$(\lambda_0 + \mu_0) P_{x,1} = 2\mu_0 P_{x,2} + \lambda_0 P_{x,0}$$

$$\vdots$$

$$\vdots$$

$$(\lambda_0 + y\mu_0) P_{x,y} = \lambda_0 P_{x,y-1} + (y+1)\mu_0 P_{x,y+1}, \qquad \text{where } 0 \le x + y \le m$$

Solving these equations by generating function method, then we obtain:

$$P_{x,1} = \frac{\lambda_0}{\mu_0} P_{x,0}$$

$$P_{x,2} = \frac{1}{2!}\left(\frac{\lambda_0}{\mu_0}\right)^2 P_{x,0}$$

$$\vdots$$

$$\vdots$$

$$P_{x,y} = \frac{1}{y!}\left(\frac{\lambda_0}{\mu_0}\right)^y P_{x,0} \qquad 0 \le x + y \le m$$

$$P_{x,y} = \frac{a_0{}^y}{y!} P_{x,0} \qquad 0 \le x + y \le m \tag{1}$$

where $a_0 = \dfrac{\lambda_0}{\mu_0}$ is the offered traffic load of the new calls.

As stated earlier, the elements in a row are corresponding to handoff calls and their stationary probability states are given by the following equations

$$\lambda_H P_{0,y} = \mu_H P_{1,y}$$
$$(\lambda_H + \mu_H) P_{1,y} = 2\mu_H P_{2,y} + \lambda_H P_{0,y}$$
$$\vdots$$
$$\vdots$$
$$(\lambda_H + x\mu_H) P_{x,y} = \lambda_H P_{x-1,y} + (x+1)\mu_H P_{x+1,y}$$

Solving these equations by generating function method, then we obtain

$$P_{1,y} = \frac{\lambda_H}{\mu_H} P_{0,0}$$
$$P_{2,y} = \frac{1}{2!}\left(\frac{\lambda_H}{\mu_H}\right)^2 P_{0,0}$$
$$\vdots$$
$$\vdots$$
$$P_{x,y} = \frac{1}{x!}\left(\frac{\lambda_H}{\mu_H}\right)^x P_{0,y}$$

$$P_{x,y} = \frac{a_H^{\ x}}{x!} P_{0,y}, \qquad 0 \le x + y \le m \tag{2}$$

where $a_H = \dfrac{\lambda_H}{\mu_H}$ is the offered traffic load of the handoff calls.

Putting y=0 in equation (2), we obtain

$$P_{x,0} = \frac{a_H^{\ x}}{x!} P_{0,0}$$

Substituting this value in equation (1), we obtain

$$P_{x,y} = \frac{a_H^{\ x}}{x!} \frac{a_0^{\ y}}{y!} P_{0,0}, \qquad 0 \le x + y \le m$$

where $P_{0,0}$ is obtained from the normalization condition i.e., the sum of all the stationary probability states $P_{x,y}$ is unity.

$$P_{0,0} = \left[\sum_{y=0}^{m} \sum_{x=0}^{m-y} \frac{a_H^{\ x}}{x!} \frac{a_0^{\ y}}{y!}\right]^{-1}$$

Thus here the blocking probability of new calls is same as the dropping probability of handoff calls and are given by

$$P_b = P_D = \sum_{x=0}^{m} P_{m-x,\,x} = \sum_{x=0}^{m} \frac{a_H^{\ m-x}}{(m-x)!} \frac{a_0^{\ x}}{x!} P_{0,0}$$

3.2 Model II:

In this model, we introduce jumping of a client (handoff call) of a low priority queue into high priority queue in case of emergency. This is done in order to enhance priority scheduling in case of excessive delays for some handoff calls, while keeping the delay for new call traffic small. In this model, only one random client of the low priority queue can jump to the high priority queue (to incorporate ‘impatient’ calls).

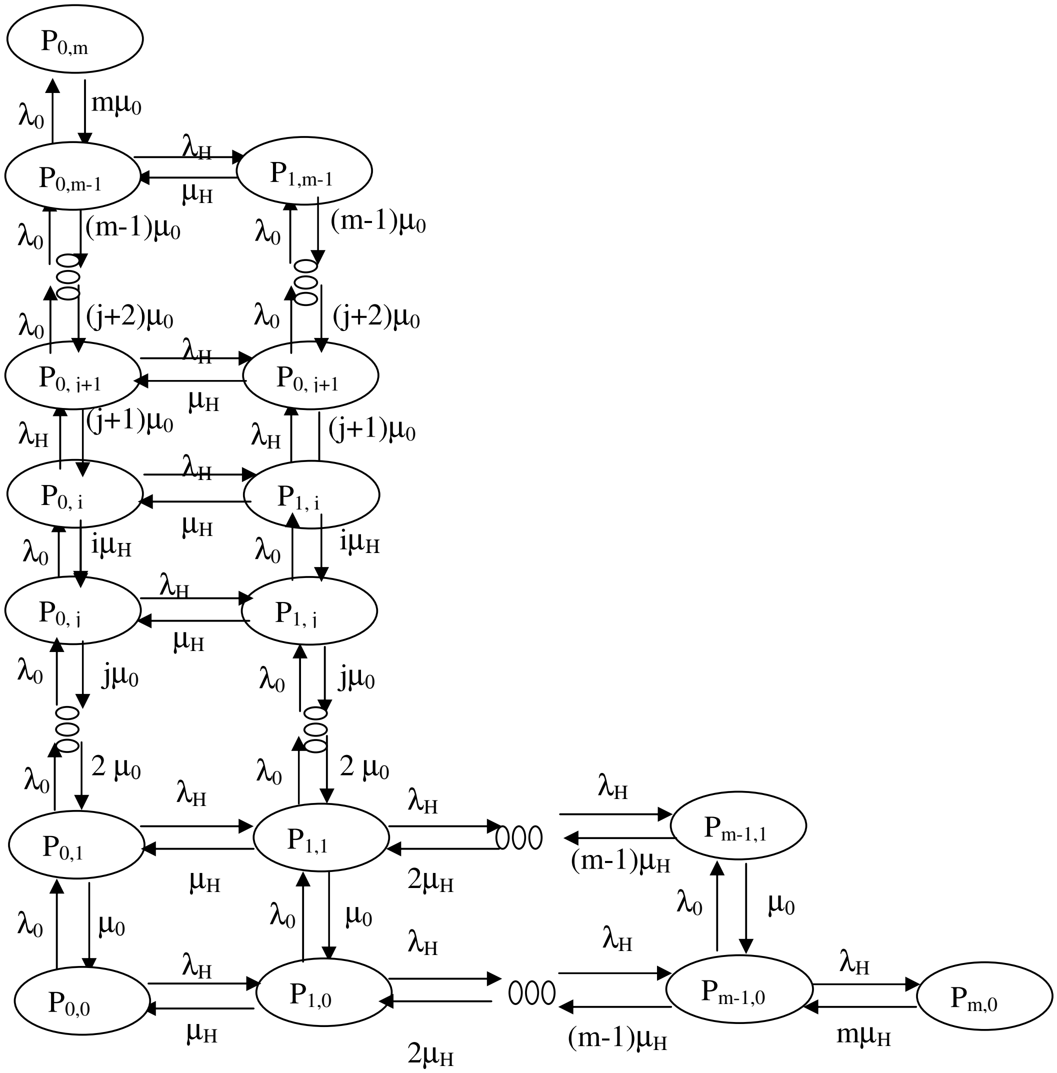

Fig. 2 State Transition Rate Diagram

All the elements in a column represent new calls and their stationary probability states are given by the following equations.

$$\lambda_0 P_{x,0} = \mu_0 P_{x,1}$$
$$(\lambda_0 + \mu_0)P_{x,1} = \lambda_0 P_{x,0} + 2\mu_0 P_{x,2}$$
$$(\lambda_0 + (j-1)\mu_0)P_{x,j-1} = \lambda_0 P_{x,j-2} + j\mu_0 P_{x,j}$$
$$(\lambda_0 + j\mu_0)P_{x,j} = \lambda_0 P_{x,j-1} + i\mu_H P_{x,i}$$
$$(\lambda_H + i\mu_H)P_{x,i} = \lambda_0 P_{x,j} + (j+1)\mu_0 P_{x,j+1}$$
$$(\lambda_0 + (j+1)\mu_0)P_{x,j+1} = \lambda_H P_{x,i} + (j+2)\mu_0 P_{x,j+2}$$
$$\vdots$$
$$(\lambda_0 + (m-1)\mu_0)P_{x,m-1} = \lambda_0 P_{x,m-2} + m\mu_0 P_{x,m}$$

Solving these equations by generating function method, we obtain:

$$P_{x,1} = \frac{\lambda_0}{\mu_0} P_{x,0}$$

$$P_{x,2} = \frac{1}{2!}\left(\frac{\lambda_0}{\mu_0}\right)^2 P_{x,0}$$

$$\vdots$$

$$P_{x,j} = \frac{1}{j!}\left(\frac{\lambda_0}{\mu_0}\right)^j P_{x,0}$$

$$P_{x,i} = \frac{\lambda_0}{i\mu_H}\frac{1}{j!}\left(\frac{\lambda_0}{\mu_0}\right)^j P_{x,0}$$

$$P_{x,j+1} = \frac{\lambda_H}{i\mu_H}\frac{1}{(j+1)!}\left(\frac{\lambda_0}{\mu_0}\right)^{j+1} P_{x,0}$$

$$P_{x,j+2} = \frac{\lambda_H}{i\mu_H}\frac{1}{(j+2)!}\left(\frac{\lambda_0}{\mu_0}\right)^{j+2} P_{x,0}$$

$$\vdots$$

$$P_{x,m} = \frac{\lambda_H}{i\mu_H}\frac{1}{m!}\left(\frac{\lambda_0}{\mu_0}\right)^m P_{x,0}$$

So $P_{x,y} = \frac{1}{y!} {a_0}^y \frac{\lambda_H}{i\mu_H} P_{x,0}$ (3)

where $a_0 = \frac{\lambda_0}{\mu_0}$

All the elements in a row represent handoff calls and their stationary probability states are given by the following equations.

$$P_{x,y} = \frac{{a_H}^x}{x!} P_{0,y} \qquad \text{where} \quad 0 \le x + y \le m \tag{4}$$

Putting y=0 in this equation

$$P_{x,0} = \frac{{a_H}^x}{x!} P_{0,0}$$

Substituting this value in equation (3), we obtain

$$P_{x,y} = \frac{{a_0}^y}{y!}\frac{\lambda_H}{i\mu_H}\frac{{a_H}^x}{x!} P_{0,0} \tag{5}$$

Normalization condition is given by

$$P_{0,0} = \left[\sum_{y=0}^{m}\sum_{x=0}^{m-y}\frac{{a_0}^y}{y!}\frac{\lambda_H}{i\mu_H}\frac{{a_H}^x}{x!}\right]^{-1}$$

Blocking probability of new calls

$$P_b = \sum_{y=0}^{m-1} P_{y,m-y} = \sum_{y=0}^{m-1}\frac{{a_0}^{m-y}}{(m-y)!}\frac{\lambda_H}{i\mu_H}\frac{{a_H}^y}{y!} P_{0,0}$$

Dropping probability of handoff calls

$$P_D = \sum_{x=0}^{m-1} P_{m-x,x} = \sum_{x=0}^{m-1}\frac{\lambda_H}{i\mu_H}\frac{{a_H}^{m-x}}{(m-x)!}\frac{{a_0}^x}{x!} P_{0,0}$$

3.3 Model III:

In this model, also we included jumping mechanism from low priority queue and up to three random clients of the low priority queue can jump into the high priority queue (to incorporate 'impatient' calls). The 2D Markov chain for this model is shown in Fig. 2.

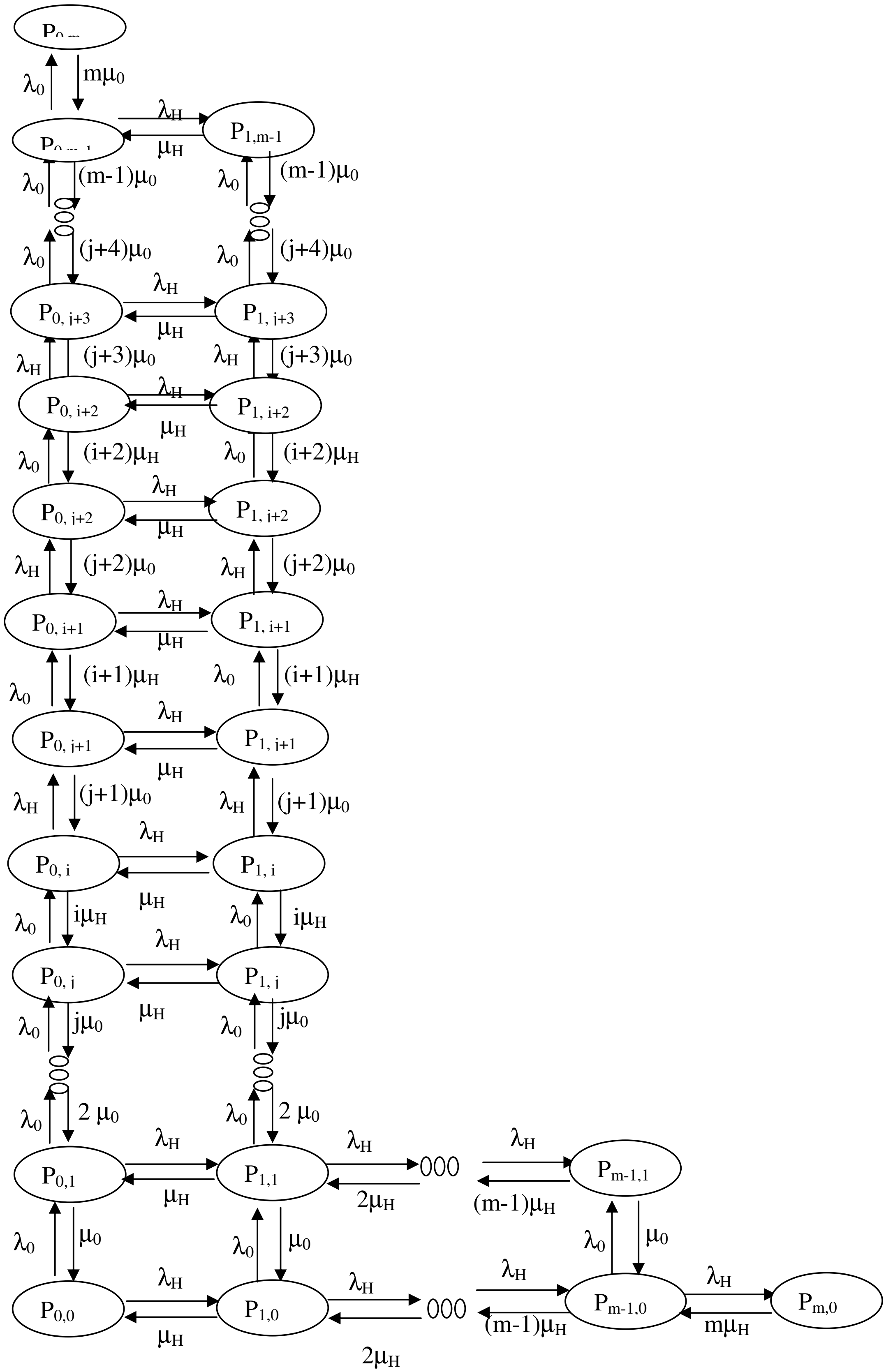

Fig.3 State Transition Rate Diagram

All the elements in a column represent new calls and their stationary probability states are given by the following equations

$$\lambda_0 P_{x,0} = \mu_0 P_{x,1}$$
$$(\lambda_0 + \mu_0) P_{x,1} = \lambda_0 P_{x,0} + 2\mu_0 P_{x,2}$$
$$\vdots$$
$$(\lambda_0 + (j-1)\mu_0) P_{x,j-1} = \lambda_0 P_{x,j-2} + j\mu_0 P_{x,j}$$
$$(\lambda_0 + j\mu_0) P_{x,j} = \lambda_0 P_{x,j-1} + i\mu_H P_{x,i}$$
$$(\lambda_H + i\mu_H) P_{x,i} = \lambda_H P_{x,j} + (j+1)\mu_0 P_{x,j+1}$$
$$(\lambda_0 + (j+1)\mu_0) P_{x,j+1} = \lambda_0 P_{x,i} + (i+1)\mu_H P_{x,i+1}$$

$$(\lambda_H + (i+1)\mu_H) P_{x,i+1} = \lambda_H P_{x,j+1} + (j+2)\mu_0 P_{x,j+2}$$
$$(\lambda_0 + (j+2)\mu_0) P_{x,j+2} = \lambda_0 P_{x,i+1} + (i+2)\mu_H P_{x,i+2}$$
$$(\lambda_H + (i+2)\mu_H) P_{x,i+2} = \lambda_H P_{x,j+2} + (j+3)\mu_0 P_{x,j+3}$$
$$(\lambda_0 + (j+3)\mu_0) P_{x,j+3} = \lambda_H P_{x,i+2} + (j+4)\mu_0 P_{x,j+4}$$
$$\vdots$$
$$(\lambda_0 + (m-1)\mu_0) P_{x,m-1} = \lambda_0 P_{x,m-2} + m\mu_0 P_{x,m}$$

Solving these equations by generating function method, we obtain

$$P_{x,1} = \frac{\lambda_0}{\mu_0} P_{x,0}$$
$$P_{x,2} = \frac{1}{2!}\left(\frac{\lambda_0}{\mu_0}\right)^2 P_{x,0}$$
$$\vdots$$
$$P_{x,j} = \frac{1}{j!}\left(\frac{\lambda_0}{\mu_0}\right)^j P_{x,0}$$
$$P_{x,i} = \frac{\lambda_0}{i\mu_H}\frac{1}{j!}\left(\frac{\lambda_0}{\mu_0}\right)^j P_{x,0}$$
$$P_{x,j+1} = \frac{1}{(j+1)!}\left(\frac{\lambda_0}{\mu_0}\right)^{j+1} \frac{\lambda_H}{i\mu_H} P_{x,0}$$
$$P_{x,i+1} = \frac{1}{(j+1)!}\left(\frac{\lambda_0}{\mu_0}\right)^{j+1} \frac{\lambda_0}{(i+1)\mu_H}\left(\frac{\lambda_H}{i\mu_H}\right) P_{x,0}$$
$$P_{x,j+2} = \frac{1}{(j+2)!}\left(\frac{\lambda_0}{\mu_0}\right)^{j+2} \frac{1}{i(i+1)}\left(\frac{\lambda_H}{\mu_H}\right)^2 P_{x,0}$$
$$P_{x,i+2} = \frac{1}{(j+2)!}\left(\frac{\lambda_0}{\mu_0}\right)^{j+2} \frac{\lambda_0}{(i+2)\mu_H}\frac{1}{i(i+1)}\left(\frac{\lambda_H}{\mu_H}\right)^2 P_{x,0}$$
$$P_{x,j+3} = \frac{1}{(j+3)!}\left(\frac{\lambda_0}{\mu_0}\right)^{j+3} \frac{1}{i(i+1)(i+2)}\left(\frac{\lambda_H}{\mu_H}\right)^3 P_{x,0}$$

$$P_{x,j+4} = \frac{1}{(j+4)!}\left(\frac{\lambda_0}{\mu_0}\right)^{j+4} \frac{1}{i(i+1)(i+2)}\left(\frac{\lambda_H}{\mu_H}\right)^3 P_{x,0}$$

$$\vdots$$

$$P_{x,m} = \frac{1}{m!}\left(\frac{\lambda_0}{\mu_0}\right)^{m} \frac{1}{i(i+1)(i+2)}\left(\frac{\lambda_H}{\mu_H}\right)^3 P_{x,0}$$

So, $$P_{x,y} = \frac{a_0{}^y}{y!}\frac{1}{i(i+1)(i+2)}\left(\frac{\lambda_H}{\mu_H}\right)^3 P_{x,0}, \qquad 0 \le x+y \le m \tag{6}$$

All the elements in a row represent handoff calls and their stationary probability states are given by the following equations.

$$P_{x,y} = \frac{a_H{}^x}{x!}P_{0,y}, \tag{7}$$

Putting y=0 in this equation, we obtain

$$P_{x,0} = \frac{a_H{}^x}{x!}P_{0,0}$$

Substituting this equation in (6), we obtain

$$P_{x,y} = \frac{a_0{}^y}{y!}\frac{1}{i(i+1)(i+2)}\left(\frac{\lambda_H}{\mu_H}\right)^3 \frac{a_H{}^x}{x!}P_{0,0}, \tag{8}$$

where $P_{0,0}$ is obtained from the normalization condition that the sum of all the stationary probability states $P_{x,y}$ is unity. i.e.

$$P_{0,0} = \left[\sum_{y=0}^{m}\sum_{x=0}^{m-y}\frac{a_0{}^y}{y!}\frac{a_H{}^x}{x!}\frac{1}{i(i+1)(i+2)}\left(\frac{\lambda_H}{\mu_H}\right)^3\right]^{-1}$$

The blocking probability of new calls are given by

$$P_b = \sum_{y=0}^{m-1} P_{y,m-y} = \sum_{y=0}^{m-1}\frac{a_0{}^{m-y}}{(m-y)!}\frac{1}{i(i+1)((i+2)}\left(\frac{\lambda_H}{\mu_H}\right)^3\frac{a_H{}^y}{y!}P_{0,0}$$

The dropping probability of handoff calls are given by

$$P_D = \sum_{x=0}^{m-1} P_{m-x,x} = \sum_{x=0}^{m-1}\frac{a_0{}^{x}}{x!}\frac{1}{i(i+1)(i+2)}\left(\frac{\lambda_H}{\mu_H}\right)^3\frac{a_H{}^{m-x}}{(m-x)!}P_{0,0}$$

4. **Numerical Results**: In order to verify the validity of the models described in previous section we performed numerical evaluation and computed the blocking probabilities of new calls and dropping probabilities of handoff calls. For this purpose, in present study we have taken m=15 channels in the cell. The chosen values of parameters are λ_0=0.3, λ_H=0.5, μ_0=0.07, μ_H=0.03. The obtained performance measures, for these parameters, are shown graphically in Figs. 4 and 5. Further the results are also given in tabular form in Table I and II.

Table I: Arrival of new calls (λ_0) versus blocking probability of new calls (P_b)

Arrival rate of new calls	Model I	Model II	Model III
λ_0	P_b	P_b	P_b

Table II: Arrival rate of new calls (λ_0) versus dropping probability of handoff calls (P_D)

Arrival rate of new calls	Model I	Model II	Model III
λ_0	P_D	P_D	P_D

0.1	0.448722	3.40E-09	0
0.2	0.674004	0	0
0.3	0.769722	0	0
0.4	0.822158	0	0
0.5	0.855188	0	0
0.6	0.877887	0	0
0.7	0.89444	0	0
0.8	0.907045	0	0
0.9	0.916962	0	0
1	0.924969	0	0

0.1	0.448722	0.349006	8.70E-06
0.2	0.674004	0.262113	6.50E-06
0.3	0.769722	0.199557	4.90E-06
0.4	0.822158	0.159864	4.00E-06
0.5	0.855188	0.133029	3.30E-06
0.6	0.877887	0.1138	2.80E-06
0.7	0.89444	0.099382	2.50E-06
0.8	0.907045	0.088185	2.20E-06
0.9	0.916962	0.079244	1.90E-06
1	0.924969	0.071942	1.80E-06

The new call blocking probabilities against arrival rate of new calls is given in Fig. 4. It can be seen that, the blocking probability of model I is higher than other two models, which is obvious since we are using jumping mechanism in model II and III.

Figure 5 shows the effect of arrival rate of new calls on dropping probability of handoff call (P_D) for all three models. The dropping probability of model III is much lesser than other two models, which is due to using jumping mechanism of handoff calls in model II and III.

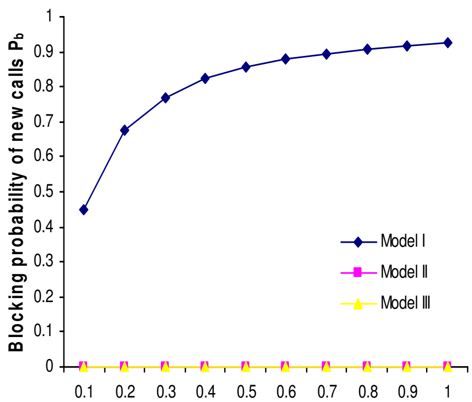

Fig. 4 Arrival rate of new calls λ_0

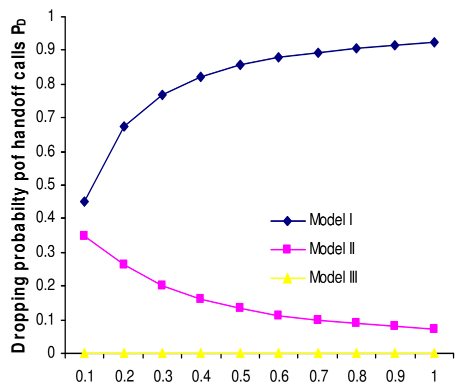

Fig. 5 Arrival rate of new calls λ_0

5. CONCLUSION:

Three traffic models for cellular networks have been proposed. In model I, there are two separate queues and take the service separately. We are using jumping mechanism in Models II and III. In Model II, only one random call of the low priority queue can jump to the high priority queue. In model III, up to three random calls can jump to high priority queue. The ultimate goal is to find a jumping scheme that performs well for every traffic scenario. The comparison of P_b and P_D for three models is done numerically. We infer from the results, that the model III gives better results in terms of lesser blocking probability and dropping probability. In conclusion Model III gives better Quality of Service (QOS) for handoff calls for high traffic conditions.

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