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DYNAMIC CALL TRANSMISSION PRIORITY DISCIPLINE WITH PRIORITY JUMPS

Geetanjali Sharma* and G. N. Purohit

Center for Mathematical Sciences, Banasthali University-304022

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

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ABSTRACT

In this paper, we propose and analyze a dynamic call transmission priority discipline, head-of-the line with priority jumps (HOL-PJ). The fundamental principle of HOL-PJ is to give transmission priority to the call having the largest queueing delay in excess of its delay requirement. In this priority scheduling scheme, calls are classified in a number of priority classes (based on their delay constraints). As long as calls of the highest priority class are present in the queueing system, this type of traffic is served. Calls of lower priority can only be transmitted when no higher priority traffic is present in the system. In order to deal with possibly excessive delays however, data calls in the low priority queue can in the course of time jump to the high priority queue at the r-th position from the head of the priority queue, r being a non-negative integer.

Keywords: *Cellular Network, jumping mechanism, new calls, data calls, priority queues, performance analysis.*

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1. INTRODUCTION:

In recent years, much interest has developed for incorporating multimedia applications in IP networks. Different types of traffic need different QOS standards. For real-time applications, it is important that mean delay and delay jitter are bounded, while for non real-time applications, the Loss Ratio (LR) is the restrictive quantity. In general, one can distinguish two priority strategies, which will be referred to as Time Priority and Space priority. Time priority schemes attempt to guarantee acceptable delay boundaries to delay-sensitive traffic (such as voice/video). This is achieved by giving it non-preemptive priority over non delay-sensitive traffic, and /or by sharing access to the server among the various traffic classes in such a way so that each can meet its own specify delay requirements. On the other hand, Space Priority schemes attempt to minimize the packet loss of loss sensitive traffic (such as data). Various types of Space Priority (or cell discarding) strategies for ATM (such as Push-Out Buffer (POB), Partial Buffer Sharing (PBS)) have been presented in [8].

The server (transmission link) always chooses the call for service (transmission) at the head of the highest priority nonempty queue. Unlike HOL (Head-of-the-Line), however, the priorities of the calls increase as their queueing delays increase relative to their delay requirements. This is avoided by the call priority jumping (PJ) mechanism. The basic principle of the PJ mechanism is summarized as following:

A limit is imposed on the maximum queueing delay for the calls at each priority queue. The value of the limit at a priority queue is set as the difference between the delay requirement for the corresponding priority class and that for the next higher priority class. As soon as the calls delay at the current queue exceeds the limit, the call jumps to the tail of the next higher priority queue. This call is treated in the next higher priority queue as if it were a newly arriving call to that queue. Calls from all classes except the highest priority class continue this jumping process until they are served or join the highest priority queue. The priority jumping mechanism guarantees that at any time, the calls are queued (from the head of the lowest priority queue to the tail of the highest priority queue) according to the largeness of their queuing delays in excess of their respective delay requirements.

A new queueing model is proposed in [1] for integrated high speed data networks in which three types of traffic e.g. voice, data, video are considered and employed priority queueing discipline to analyze mean delay of the system, high priority is given to highly sensitive data and low priority is given to normal data. Then they concluded that the high sensitive data (i.e. video or multimedia data) has minimum delays comparative to other categories of the data. The authors in [2] defined a two-level bandwidth allocation and admission control strategy and showed that the capacity to follow variations in traffic parameters by means of a fast and simple adaptation mechanism. A fixed point iteration scheme is developed in [3] in order to determine the handoff arrival rate into a cell and also developed optimization problems to determine the optimal number of guard channels and the optimal number of total channels. Then they derived fast recursive formulae for the blocking probability of new calls and dropping probability of handoff calls. A priority scheme with priority jumps (in the remainder called a jumping scheme), was first introduced in [4], the priority

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

level of calls can be adapted in the course of time. Concretely, calls of the low priority queue can in the course of time jump to the (tail of the) high priority queue. Introducing jumping mechanisms in priority schemes tries to enhance priority scheduling by avoiding excessive delays for type-2 packets, while keeping the delay for type-1 traffic small. The authors in [5] proposed a bandwidth management framework for ATM-based B-ISDN and concluded that based on the proposed bandwidth management framework, all ATM service classes can be served with reasonable QOS guarantees, the CAC (Connection Admission Control) procedures can be easily implemented, and potential rate-based ABR (Available Bit Rate) congestion control can be easily incorporated. The authors in [6] introduced a new self adaptive jumping scheme and compared the performance of the various priority schemes with priority jumps. Furthermore they compared the three jumping schemes that do not have a jumping parameter and examined their impact on the mean packet delays of both types of traffic i.e. type 1 and type 2 traffics. The queuing model of a single cell of wireless network with guard channels taking into account handover effect was investigated in [7]. They also developed a new effective method based on the principles of phase merging of stochastic systems for calculation of loss probability of both new and handover calls as well as average number of busy channels. The authors in [9] proposed a new CAC (Call Admission Control) policy for voice calls by taking into account handoff calls in cellular networks. Then they investigated upto what degree it has an impact on the traffic performance of the network. A traffic model for cellular communication networks with arbitrary cell connection and arbitrary probabilistic movement of mobiles between the cells is presented in [10], they also gave a recursive approach for finding the probabilities of destiny of an arbitrary call generated in the network.

In this paper, we consider two models. Model I is the general markovian M/M/m model. A jumping mechanism is considered in model II. In this model there are two queues, one for data calls and another for new calls which are termed as the low priority queue and high priority queue, respectively. In order to deal with possibly excessive delays; a data call from low priority queue can jump in course of time to a high priority queue. The blocking probabilities of new calls, dropping probabilities of data calls and the probability of jumped data call are calculated for varying assumed values of arrival rate of new calls, arrival rate of data calls and service rates. The rest of this paper is organized as follows. In Section 2, we describe both the models. The numerical results are analyzed in Section 3. Section 4 concludes the paper.

2. MODEL DESCRIPTION

We consider a multiserver queueing system with two priority queues of infinite capacity. Also we have considered priority scheduling scheme. In a priority scheduling scheme with priority jumps, new calls and data calls arrive in separate queues, i.e., the high and low priority queue respectively. In order to deal with possibly excessive delays however, data calls in the low priority queue can in the course of time jump to the high priority queue. With the assumption that both types of traffic arrive in separate queues, calls of the low priority queue are thus only transmitted when the high priority queue is empty. Customer can jump at the r-th position into the high priority queue. r may be 0,1,2,3,4.

The arrival processes of both classes are assumed to be Poissonian with rate λ_n for new calls and λ_d for handoff calls, j=1,2,…….,n and service time are exponentially distributed with mean $\frac{1}{\mu_n}$ for new calls and $\frac{1}{\mu_d}$ for data calls.

2.1 Model I

The markovian M/M/m model is assumed. Here m and n are the total no. of channels allocated to the reference cell. Both the new calls and handoff calls are treated equally by m and n channels respectively 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 and n channels are busy. The two dimensional Markov chain for this model of the cell is shown in Fig. 1.

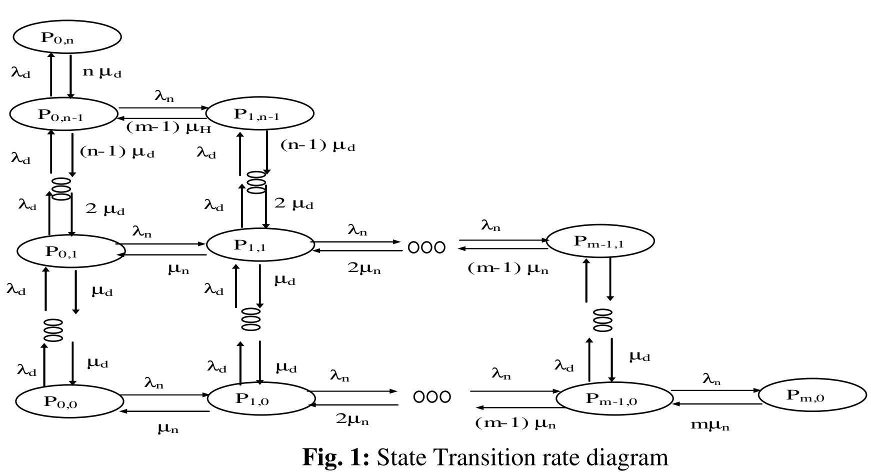

Fig. 1: State Transition rate diagram

All the elements in a column represent data calls, whereas all the elements in a row represent new calls. By using the state transition diagram, we get the steady state probability as

$$0 = -\lambda_d P_{x,0} + \mu_d P_{x,1}$$

$$P_{x,1} = \frac{\lambda_d}{\mu_d} P_{x,0}$$

$$0 = -(\lambda_d + \mu_d)P_{x,1} + \lambda_d P_{x,0} + 2\mu_d P_{x,2}$$

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

$$\vdots$$

$$\vdots$$

$$P_{x,n} = \frac{1}{n!}\left(\frac{\lambda_d}{\mu_d}\right)^n P_{x,0}$$

$$\text{So, } P_{x,y} = \frac{1}{y!}\left(\frac{\lambda_d}{\mu_d}\right)^y P_{x,0} \tag{1}$$

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

$$0 = -\lambda_n P_{0,y} + \mu_n P_{1,y}$$

$$P_{1,y} = \frac{\lambda_n}{\mu_n} P_{0,y}$$

$$0 = -(\lambda_n + \mu_n)P_{1,y} + \lambda_n P_{0,y} + 2\mu_n P_{2,y}$$

$$P_{2,y} = \frac{1}{2!}\left(\frac{\lambda_n}{\mu_n}\right)^2 P_{0,y}$$

$$0 = -\{\lambda_n + (m-1)\mu_n\}P_{m-1,y} + \lambda_n P_{m-2,y} + m\mu_n P_{m,y}$$

$$P_{m,y} = \frac{1}{m!}\left(\frac{\lambda_n}{\mu_n}\right)^m P_{0,y}$$

$$\text{So, } P_{x,y} = \frac{1}{x!}\left(\frac{\lambda_n}{\mu_n}\right)^x P_{0,y} \tag{2}$$

Putting y=0 in equation (2)

$$P_{x,0} = \frac{1}{x!}\left(\frac{\lambda_n}{\mu_n}\right)^x P_{0,0}$$

From eqn. (1)

$$P_{x,y} = \frac{1}{x!}\left(\frac{\lambda_n}{\mu_n}\right)^x \frac{1}{y!}\left(\frac{\lambda_d}{\mu_d}\right)^y P_{0,0} \tag{3}$$

We know that the normalization condition is that the sum of all the stationary probability states $P_{x,y}$ is unity. i.e.

$$\sum_{y=0}^{n}\sum_{x=0}^{m-y} P_{x,y} = 1$$

$$P_{0,0} = \left[\sum_{y=0}^{n}\sum_{x=0}^{m-y} \frac{1}{x!}\left(\frac{\lambda_n}{\mu_n}\right)^x \frac{1}{y!}\left(\frac{\lambda_d}{\mu_d}\right)^y\right]^{-1}$$

The blocking probability of new calls is given by

$$P_B = \sum_{y=0}^{n} P_{m-y,y} = \frac{1}{(m-y)!}\left(\frac{\lambda_n}{\mu_n}\right)^{m-y} \frac{1}{y!}\left(\frac{\lambda_d}{\mu_d}\right)^{y} P_{0,0}$$

The dropping probability of data calls is given by

$$P_D = \sum_{x=0}^{m} P_{x,n-x} = \frac{1}{x!}\left(\frac{\lambda_n}{\mu_n}\right)^{x} \frac{1}{(n-x)!}\left(\frac{\lambda_d}{\mu_d}\right)^{n-x} P_{0,0}$$

2.2 Model II

In this model, we introduce a jumping mechanism in which a data call of a low priority queue can jump into high priority queue in case of emergency. This is done in order to enhance priority scheduling in case of excessive delays for some data calls, while keeping the delay for new call traffic small. In this model, only one client at the head of the low priority queue can jump at the r-th position of the high priority queue. The two dimensional Markov chain for this model is shown in Fig. 2

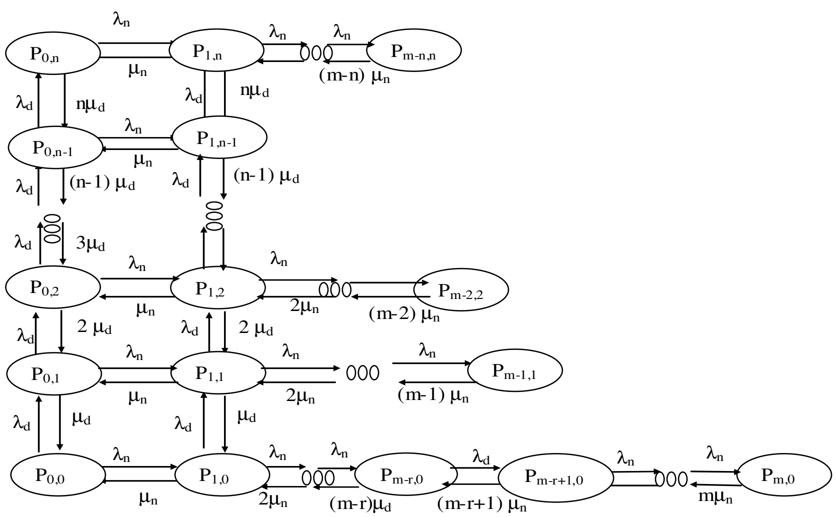

Fig. 2: State Transition rate diagram

All the elements in a column represent data calls, whereas all the elements in a row represent new calls. By using the state transition diagram, we get the steady state probability as

$$0 = -\lambda_d P_{x,0} + \mu_d P_{x,1}$$

$$P_{x,1} = \frac{\lambda_d}{\mu_d} P_{x,0}$$

$$0 = -(\lambda_d + \mu_d)P_{x,1} + \lambda_d P_{x,0} + 2\mu_d P_{x,2}$$

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

$\vdots$

$\vdots$

$$0 = -(\lambda_d + (n-1)\mu_d)P_{x,n-1} + \lambda_d P_{x,n-2} + n\mu_d P_{x,n}$$

$$P_{x,n} = \frac{1}{n!}\left(\frac{\lambda_d}{\mu_d}\right)^n P_{x,0}$$

So, $P_{x,y} = \frac{1}{y!}\left(\frac{\lambda_d}{\mu_d}\right)^y P_{x,0}$ (4)

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

$$0 = -\lambda_n P_{0,y} + \mu_n P_{1,y}$$

$$P_{1,y} = \frac{\lambda_n}{\mu_n} P_{0,y}$$

$$0 = -(\lambda_n + \mu_n)P_{1,y} + 2\mu_n P_{2,y} + \lambda_n P_{0,y}$$

$$P_{2,y} = \frac{1}{2!}\left(\frac{\lambda_n}{\mu_n}\right)^2 P_{0,y}$$

$$\vdots$$

$$\vdots$$

$$0 = -(\lambda_n + (m - r - 1)\mu_n)P_{m-r-1,y} + \lambda_n P_{m-r-2,y} + (m - r)\mu_d P_{m-r,y}$$

$$P_{m-r,y} = \frac{\lambda_n}{\mu_d}\frac{1}{(m-r)!}\left(\frac{\lambda_n}{\mu_n}\right)^{m-r-1} P_{0,y}$$

$$0 = -\{\lambda_d + (m - r)\mu_d\}P_{m-r,y} + \lambda_n P_{m-r-1,y} + (m - r + 1)\mu_n P_{m-r+1,y}$$

$$P_{m-r+1,y} = \frac{1}{(m-r+1)!}\left(\frac{\lambda_d}{\mu_d}\right)\left(\frac{\lambda_n}{\mu_n}\right)^{m-r} P_{0,y}$$

$$\vdots$$

$$\vdots$$

$$0 = -(\lambda_n + (m-1)\mu_n)P_{m-1,y} + \lambda_n P_{m-2,y} + m\mu_n P_{m,y}$$

$$P_{m,y} = \frac{\lambda_d}{\mu_d}\frac{1}{m!}\left(\frac{\lambda_n}{\mu_n}\right)^{m-1} P_{0,y}$$

So $$P_{x,y} = \frac{\lambda_d}{\mu_d}\frac{1}{x!}\left(\frac{\lambda_n}{\mu_n}\right)^{x-1} P_{0,y} \qquad (5)$$

putting $y = 0$ in eqn. (5), we obtain

$$P_{x,0} = \frac{\lambda_d}{\mu_d}\frac{1}{x!}\left(\frac{\lambda_n}{\mu_n}\right)^{x-1} P_{0,0}$$

Substituting this eqn. in (4), we obtain

$$P_{x,y} = \frac{1}{y!}\left(\frac{\lambda_d}{\mu_d}\right)^y \frac{\lambda_d}{\mu_d}\frac{1}{x!}\left(\frac{\lambda_n}{\mu_n}\right)^{x-1} P_{0,0}$$

We know that the normalization condition is that the sum of all the stationary probability states $P_{x,y}$ is unity. i.e.

$$\sum_{y=0}^{n}\sum_{x=0}^{m-y} P_{x,y} = 1$$

Where $P_{0,0}$ is given by

$$P_{0,0} = \left[\sum_{y=0}^{n}\sum_{x=0}^{m-y}\frac{1}{y!}\left(\frac{\lambda_d}{\mu_d}\right)^y \frac{\lambda_d}{\mu_d}\frac{1}{x!}\left(\frac{\lambda_n}{\mu_n}\right)^{x-1}\right]^{-1}$$

The blocking probability of new calls is given by

$$P_B = \sum_{y=0}^{n} P_{m-y,y} = \sum_{y=0}^{n} \frac{1}{y!}\left(\frac{\lambda_d}{\mu_d}\right)^{y} \frac{\lambda_d}{\mu_d} \frac{1}{(m-y)!}\left(\frac{\lambda_n}{\mu_n}\right)^{m-y-1} P_{0,0}$$

The dropping probability of data calls is given by

$$P_D = \sum_{x=0}^{m} P_{x,n-x} = \sum_{x=0}^{m} \frac{1}{(n-x)!}\left(\frac{\lambda_d}{\mu_d}\right)^{n-x} \frac{\lambda_d}{\mu_d} \frac{1}{x!}\left(\frac{\lambda_n}{\mu_n}\right)^{x-1} P_{0,0}$$

3. NUMERICAL RESULTS:

The obtained results are numerically analyzed in order to provide the comparison between different indices. The various performance indices namely blocking probability of new calls, dropping probability of data calls are tabulated. For numerical evaluation of the indices we have taken m=n=15 channels in the cell. The chosen values of parameters are λ_n =0.5, λ_d=0.43, μ_n =0.084, μ_d =0.03. It is observed that by increasing the arrival rate of new calls, the blocking probabilities for both models tends to zero. For examining the effect of arrival rate of new calls (λ_n) on the metric P_D (dropping probability of data calls) are calculated and shown in Table I. It is observed that, when arrival rate of the new calls (λ_n) is 0.1-0.3 the dropping probability of handoff calls tends to zero. Further the dropping probabilities increase with the increase of λ_n. Under this mechanism the dropping probability (P_D) is less compared to the ordinary model that is when there are two separate queues for handoff calls and new calls. The probability of the jumping of a data call at the head of the low priority queue to the r^{th} position from the head in high priority queue $P_{m-r,0}$ is calculated for r=0,1,2,3,4 and are given in Table-II

Table I Arrival rate of new calls versus dropping probability

λ_n	Model I	Model II
0.4	9.294E-07	0.00000016
0.5	2.62703E-05	0.00000357
0.6	0.000402507	0.00004577
0.7	0.004041699	0.00039617
0.8	0.029787309	0.00256902
0.9	0.173342972	0.01336296
1	0.83724923	0.05841274

Table II Probability of jumped data call at the rth position

r	$P_{m-r,0}$
0	3.42E-26
1	4.30E-26
2	5.06E-26
3	5.53E-26
4	5.57E-26

4. CONCLUSION:

The future success of the next generation communication systems depends on its ability to efficiently accommodate integrated traffic and services to provide a variety of applications having different quality of service requirements. To support integrated traffic, a prespecified grade of service can be achieved by incorporating the priority scheduling scheme. In this paper, two traffic models for cellular networks have been proposed. In model I, there are two separate queues and will take the service separately. A jumping mechanism is used in model II, in which only one call at the head of low priority queue can jump into the high priority queue at the r-th position from the head of the queue, where r being a non-negative integer. The new call blocking probabilities and dropping probabilities of data calls for both models are calculated. The probability of the jumping of a handoff call from the low priority queue to the r-th position from the Head-of-the-Queue is also calculated. We infer from the results, that the P_B for both models tends to zero by increasing of arrival rate of new calls i.e. there is much lesser blocking probabilities. The dropping probabilities are less compared for model-II to the ordinary model, when there are two separate queues for handoff calls and new calls.

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