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Performance analysis of queueing strategies for multiple priority calls in multiservice personal communications services

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Abstract

Supporting multiple priority calls, we propose the queueing strategies which efficiently manage the queue to reduce the blocking probability with multiclass calls in multiservice personal communications services (MPCS). The two queueing schemes are proposed and are shown the analytic model with $(n + 1)$ class calls. Numerical results demonstrate that the two proposed schemes show the improved performance compared to the previous scheme with two types of traffic in terms of the blocking probability. The proposed schemes are flexibly adaptable to MPCS. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Queueing strategies; Multiple priority calls; Multiservice personal communications service

1. Introduction

Technological advances and rapid development of handheld wireless terminals have facilitated the rapid growth of wireless communications and mobile computing. Taking ergonomic and economic factors into account and considering the new trend in the telecommunications industry to provide ubiquitous information access, the population of many users will continue to grow at a tremendous rate. Another important developing phenomenon is the shift of many applications to multimedia platforms in order to present information more effectively.

The tremendous growth of the wireless/mobile user population, coupled with the bandwidth requirements of multimedia applications, requires an efficient use of the scarce radio spectrum allocated to wireless/mobile communications.

It has been anticipated that demands for multiple types of service from low-bandwidth applications such as voice to high-bandwidth applications such as data, image, and video will grow for future mobile personal communications. For delivering the desired levels of quality of service (QoS) in multiservice personal communications services (MPCS) to multiple type of mobile users, an improved channel allocation mechanism is required. It is to obtain a high admitted traffic and to reduce blocking probability while guaranteeing the protection of calls in restricted channels. The channel allocation scheme has been introduced such as fixed channel allocation (FCA), dynamic channel allocation (DCA), hybrid channel allocation (HCA), distribute channel allocation (DCA), borrowing channel allocation (BCA), and adaptive channel allocation (ACA) [16,17]. For reducing blocking probability of call, those schemes make use of queueing in personal communications services (PCS).

We classify calls in PCS as voice call and data call: new voice call, new data call, hand-off voice call, and hand-off data call. Intuitively, when channels are busy, the blocking probability of the hand-off data call can be reduced by waiting only the hand-off data call in the queue. The blocking probability of voice call can be also reduced by giving priority to voice call in the queue environment [1,3,4,7,10–13].

Another priority control method is the measured based priority scheme (MBPS). It is the scheme in which the hand-off call requests which can not be served are queued and served according to a signal power level based strategy [14]. MBPS always shows the better performance than FIFO scheme does.

However, the previous schemes consider only two class calls and have limits in reducing the blocking probability of multiple priority calls by allocating channels efficiently in MPCS. An efficient queueing management with priority methods for multiclass calls can reduce the blocking probability of calls in restricted channels in a cell.

In this paper, we consider the queueing strategies for multiple priority calls in MPCS and propose the two

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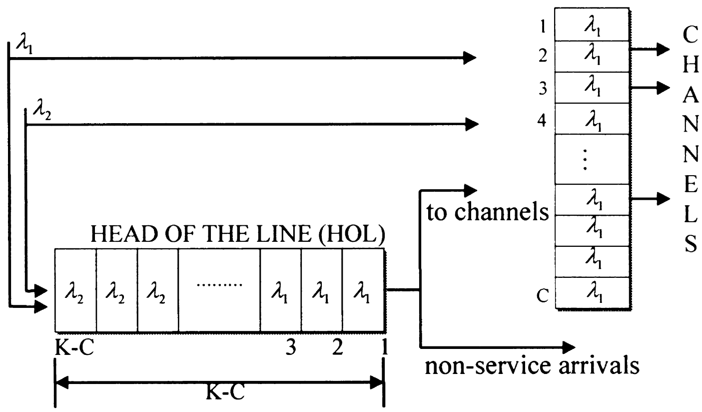

Fig. 1. The previous queueing scheme with two types of traffic.

queueing schemes. As main performance measures, the blocking probability and the mean waiting time of multi-class calls are considered.

The organization of the paper is as follows. Section 2 describes the previous queueing scheme with two types of traffic. Section 3 describes the two proposed queueing schemes of $(n+1)$ class calls, which show the blocking probability and the mean waiting time of priority calls as main performance measures. In Section 4, the analytic results of two schemes are verified by performing the simulation and compared to the previous scheme with two types of traffic (voice calls and data calls). Additionally, we compare the two proposed schemes of each other with four class calls. Finally, we conclude this paper in Section 5.

2. The previous queueing scheme

The previous scheme considers only two types of traffic (voice calls and data packets), which is supported by a set of C channels plus a buffer of size K-C [12,13]. The arrival rates are λ_1 and λ_2, respectively and the channel holding time in a cell (the time in which a call or a packet occupies a channel while its terminal is cell) follows exponential distributions for both types of traffic with means $1/\mu_1$ and $1/\mu_2$, respectively. Any type of arrival has access to any facility but voice call can preempt the service of data packet which return to the queue next to the last voice call arrival. Thus, this scheme has a system with preemptive priority in the C channels and Head-of-the-Line (HOL) priority in the queue, where voice has a priority over data packet. A call in such a system is blocked only if there are already K calls in the system while a data packet is blocked if the system is full. Moreover, any type of traffic must leave the queue after a finite time because the vehicle has to leave the cell.

In this scheme, it is assumed that the time T_Q per voice call or data packet is allowed (the dwelling time in queue), which follows an exponential distribution with mean $1/\mu_Q$dependent mainly on the system structure, i.e. the cell length and the vehicle speed. The previous queueing scheme is depicted in Fig. 1 and the state diagrams are given in two-dimensional case.

Since voice call has a preemptive priority over data packet in the service facility and HOL priority control in the queue, the probabilities $P_{i,0}$ for $i = 0, 1, 2, \ldots, K$ are given by the M/M/C/K formulae modified for the purpose of covering the mobility in queue, i.e.

$$P_{i,0} = P_{0,0}\frac{\rho^i}{i!} \qquad i \le C$$

$$P_{i,0} = P_{0,0}\frac{\rho^C}{C!}\left[\frac{\lambda_2^{i-C}}{\prod_{n=1}^{i-C}(C\mu + n\mu_Q)}\right] \qquad C < i \le K \tag{1}$$

where $\rho = \lambda_1/\mu_1$

Moreover, it can use the normalizing condition below.

$$\sum_i^K \sum_j^K P_{i,j} = 1 \qquad i = 0, 1, \ldots, K \;\; j = 0, 1, \ldots, k \tag{2}$$

The systems (1) and (2) are now sufficient for the evaluation of the state probabilities $P_{i,j}$. Evaluating those probabilities, the main performance parameters are defined to be:

1. The blocking probabilities (P_{bi}, voice calls ($i = 1$) and data packets ($i = 2$)) are given by

$$P_{b1} = \sum_{i=C}^K P_{i,j}P_{Q1} \qquad \text{and} \qquad P_{b2} = \sum_{i=0}^K \sum_{j=C-i+1}^{K-i} P_{i,j}P_{Q2} \tag{3}$$

where P_{Qi} is the probability of leaving the cell.

2. The average time W_i in the queue is given by

$$E(N_1) = \lambda_1\left(\frac{1}{W_1}\right) \qquad \text{and} \qquad E(N_2) = \lambda_2\left(\frac{1}{W_2}\right) \tag{4}$$

where *E(N*$_i$*)* is the mean number of call in the queue.