THRESHOLD-BASED BANDWIDTH ALLOCATION SCHEME FOR MULTISERVICE WIRELESS NETWORKS

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ABSTRACT

Priority Queuing with Buffer Management (PQBM) has been recently proposed in the literature. The protocol is acclaimed to be a very attractive candidate in current (2.5G and 3G) and next (4G) multiservice wireless networks. However, it suffers bandwidth monopolization by higher priority data packets. This paper proposes a new scheme namely Improved Priority Queuing with Buffer Management (IPQBM) with a view to redistributing service provision to the data classes optimally. In particular, the scheduling discipline of PQBM is modified so as to correct the monopoly problem. IPQBM is compared with PQBM vis-à-vis throughput and mean delay of data packets. Numerical results reveal that IPQBM offers improved throughput for lower priority data packets by ensuring that higher priority data class does not have a monopoly of bandwidth resources.

KEYWORDS: Priority Queuing, Buffer Management, Protocol, Bandwidth, multi-service wireless networks.

INTRODUCTION

Emerging wireless technologies such as 3G and 4G will increase the cell capacity of wirelesscellular networks to several Mbps (Varshney and Jain, 2001). With this expansion of wireless bandwidth, the nextgenerations of mobile cellular networks are expected to support diverse applications such asvoice, data and multimedia with varying quality of service (QoS) and bandwidth requirements(Hui and Yeung, 2003). Wireless links bandwidth is limited and is generally much smaller than that of wired access links. Consequently, for integrated voice/data mobile networks it is necessary to develop mechanisms that can guarantee effective bandwidth management while satisfying the QoS requirements of bothtraffic classes. One of the challenges in a multiservice system is that the radio resources should be properly distributed among multiple traffic classes so that the QoS requirements of each class can be satisfied while the resources are utilized as efficiently as possible (Leong et al, 2006)

The mechanisms that are being used for effective service provisioning in the design of multiservice systems include Call Admission Control (CAC), Buffer Management (BM) and Scheduling. CAC restricts the access to the network based on resource availability in order to prevent network congestion and service degradation for already supported users. BM ensures that all service queues are guaranteed a minimum amount of memory, yet available memory can be shared between service queues when necessary. Scheduling is the strategy that determines which queue is given the opportunity totransmit data packets that are already stored in the buffer. Several works that employ these mechanisms exist in the literature.

Carvalho et al (2008) proposed two models namely FIFO with Buffer Management (FIFOBM) and Priority Queuing with Buffer Management (PQBM). In this work, we seek to modify PQBM such that the bandwidth monopolization tendency of the higher priority data packets can be avoided. To achieve this, we introduce another threshold (in addition to the one in the existing scheme) in the lower priority buffer in such a way that if its occupancy is equal to or greater than this threshold, the available radio resources will be shared by both data packet service classes. Herein the model is called Improved PQBM (IPQBM)

The paper is organized as follows: section 2 presents the system model while themarkovian model of IPQBM is described in section 3. The performance analysis of IPQBM is contained in section 4. Comparison study, results analysis and discussionare done in section 5 while the paper is finally concluded in section 6.

SYSTEM MODEL

The system under study inherits most of the properties and dynamics of the system for which

PQBM was designed. In fact the dynamics of the voice service class remains the same. The difference is only in the data service class.

The system model as described by Carvalho et al (2008) is as follows:

A typical cellular mobile network with cells providing wireless access for mobile users throughout the Base Station (BS) is assumed. A total of N radio channels are available in each cell. Two service classes access the network: voice and data. Both new and handoff calls constitute voice traffic. Voice calls and data packets arrive in the system according to two Poisson processes, with parameters λ_v and λ_d respectively. As voice service is composed by new calls and handoffs, their arrival rates are given as $\lambda_{n,v}$ and $\lambda_{h,v}$ respectively. Thus, $\lambda_v = \lambda_{h,v} + \lambda_{n,v}$.

Arrival of packets takes place in the following way: $\lambda_d = \lambda_{h,d} + \lambda_{l,d}$; where $\lambda_{h,d}$ and $\lambda_{l,d}$ are higher priority data packets arrival rate and lower priority data packets arrival rate respectively. The service times of voice calls and data packets follow exponential distributions with parameters μ_v and μ_d respectively. It is also assumed that data packets will be transmitted using all available radio resources. For the sake of simplicity, it is assumed that the wireless channel is error-free.

A threshold divides the lower priority buffer into two areas: one used to accommodate only lower priority data packets and another shared between both data packet service classes. Thus when the higher priority buffer is full, higher priority data packets may be accommodated into lower priority buffer as long as there is available space into the shared area.A guard channel CAC is used to differentiate handoff voice calls from new voice calls. These guard channels are also shared with data packets in order to increase the utilization of the radio channels. A priority for handoff voice traffic ensures that its performance is not affected.

In addition to the above basic model, the system also has additional threshold Kdt in the lower priority buffer in such a way that if its occupancy is equal to or greater than this threshold, the available radio resources will be shared by both data packet service classes.

IPQBM

The system has two buffers: one for higher priority data packets and another for lower priority data packets with sizes Bh and Bl, respectively. The system also has additional threshold Kdt in the lower priority buffer in such a way that if its occupancy is equal to or greater than this threshold, the available radio resources will be shared by both data packet service classes. A multidimensional Continuous Time Markov model of this scheme is developed whose state is defined as $\Omega = \{(v, h, l) / 0 \le v \le N, 0 \le h \le Bh, 0 \le l \le Bl\}$, where v is the number of voice calls (new and handoff); h is the number of higher priority data packets into the higher priority buffer; and l is the number of lower priority data into the lower priority buffer.

Table 1 shows the state transitions of IPQBM model. Changes in the state variable h are motivated by an arrival or a departure of a higher priority data packet. Likewise for l, but if higher priority buffer is full, all higher priority data packets may be accommodated into the lower priority buffer as long as there is available space in the shared area (Bl – Kd). A higher priority data packet will be transmitted with rate $\min(N\text{-}v, h)\mu_d$ if there are free radio resources. Whenever l is greater than or equal to Kdt and there are free radio resources, both lower priority data packet and higher priority data packet will be transmitted with rates $\min(\frac{N-v}{2}, l)\ \mu_d$ and $\min(\frac{N-v}{2}, h)\ \mu_d$ respectively

Table 1

IPQBM, transitions from state $\Omega = (v, h, l)$

Successor state	Condition	Rate	Event
(v + 1, h,l)	$v < Kv$	λ_v	Arrival of voice call (new and handoff)
(v+1, h, l)	$Kv \le v < N$	$\lambda_{h,v}$	Arrival of handoff voice call
(v, h+1, l)	$h < Bh$	$\lambda_{h,d}$	Arrival of higher priority data packet
(v, h, l+1)	$l < Bl$	$\lambda_{l,d}$	Arrival of lower priority data packet
(v,h, l+1)	$h = Bh \wedge l < Bl - Kd$	$\lambda_{h,d}$	Arrival of higher priority data packet into lower priority buffer
(v-1, h,l)	$v > 0$	$v\mu_v$	Departure of voice call
(v,h-1,l)	$\min(N-v,h)>0 \wedge h>0 \wedge l<Kdt$	$\min(N-v,h)\mu d$	Departure of higher priority data packet only
(v, h-1, l-1)	$\min(N-v,l)>0 \wedge l>0 \wedge \min(N-v,h)>0 \wedge h>0 \wedge l \ge Kdt$	$\min(\frac{N-v}{2}, l)\ \mu_d$ $\min(\frac{N-v}{2}, h)\ \mu_d$	Departure of both lower priority data packet and higher priority data packet .
(v, h, l-1)	$\min(N-v, l)>0 \wedge h=0 \wedge l>0$	$\min(N-v, l)\mu d$	Departure of lower priority data packet only

PERFORMANCE ANALYSIS OF IPQBM

When analyzing the performance of a computing or telecommunication system, a number of performance measures may be of importance. Measures that are often used to describe the performance of a system include blocking probability, throughput, utilization, mean delay, transit delay, delay variation, error rate, response time, etc.

Here, we concentrate on only two performance indices namely throughput and mean delay. Let $\pi(v, h, l)$ be the steady-state probability of the IPQBM continuous time Markov chain.

The throughput of higher priority data packets can be expressed as:

$$X_{hd} = X_{hd1} + X_{hd2} \qquad (1)$$

Where;

$$X_{hd1} = \sum_{v=0}^{N-1} \sum_{\min(N-v,h)>0} \sum_{h>0} \min(N-v,h)\, \mu_d \pi(v,h,l)$$

$\forall l < Kdt$ (2)

$$X_{hd2} = \sum_{v=0}^{N-1} \sum_{\min\left(\frac{N-v}{2},h\right)>0} \sum_{h>0} \min\left(\frac{N-v}{2},h\right) \mu_d \pi(v,h,l)$$

$\forall l \geq Kdt$ (3)

Similarly the throughput of the lower priority data packets is given as

$$X_{ld} = \sum_{v=0}^{N-1} \sum_{\min\left(\frac{N-v}{2},l\right)>0} \sum_{l\geq Kdt} \min\left(\frac{N-v}{2},l\right) \mu_d \pi(v,h,l) + \sum_{v=0}^{N-1} \sum_{\min(N-v,\; l)>0} \sum_{l>0} \min(N-v,l)\, \mu_d \pi(v,0,l)$$

(4)

Employing Little's law, the mean delay of higher and lower priority data packets may be respectively expressed as :

$$W_{hd}^{IPQBM} = \frac{\sum_{h=1}^{Bh} h}{\sum_{v=0}^{N-1}\sum_{\min(N-v,h)>0}\sum_{h>0}\min(N-v,h)\mu_d + \sum_{v=0}^{N-1}\sum_{\min(\frac{N-v}{2},h)>0}\sum_{h}}$$

(5)

The first term of the denominator of equation (5) is subject to $l < Kdt$ while the second term is subject to $l \geq Kdt$and

$$W_{ld}^{IPQBM} = \frac{\sum_{v=0}^{N}\sum_{h=0}^{Bh}\sum_{l=1}^{Bl} l\pi(v,h,l)}{\sum_{v=0}^{N-1}\sum_{\min(\frac{N-v}{2},l)>0}\sum_{l\geq Kdt}\min(\frac{N-v}{2},l)\mu_d\pi(v,h,l) + \sum_{v=0}^{N-1}\sum_{\min(N-v,}\sum_{l>0}\min(N-v,l)\mu_d\pi(v,0,l)}$$

(6)

COMPARISON WITH PQBM

In order to examine the effectiveness of IPQBM, we perform numerical analysis of IPQBM and PQBM vis-à-vis mean delay suffered higher priority packets under the two schemes.The mean delay of higher priority packets in PQBM as derived by Carvalho et al (2008) can be expressed as follows:

$$W_{hd}^{PQBM} = \frac{\sum_{h=1}^{Bh} h}{\sum_{v=0}^{N-1}\sum_{\min(N-v,h)>0}\sum_{h>0}\min(N-v,h)\mu_d}$$

(7)

The tables and graphs below show the results obtained when equations (5) and (7) were used to compute the mean delay suffered by specific number higher priority packets in PQBM and IPQBM when Kdt is fixed.

Table 2: Mean Delay of Higher Priority Data packets; Bh = 10, N = 6, μ = 0.02

Number of Higher Priority Packets (h)	Mean Delay(W_{hd})	
	QBM	IPQBM
1	458.33	500.00
2	161.76	183.33
3	85.94	107.84
4	55.00	76.39
5	39.29	59.14
6	30.22	48.25
7	24.55	40.74
8	20.68	35.26
9	17.86	31.07
10	15.71	27.78

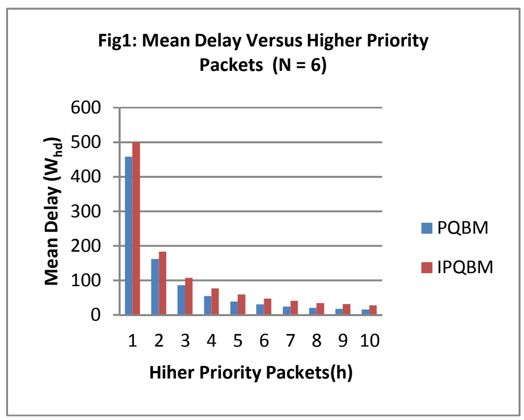


Table 3: Mean Delay of Higher Priority Data packets; Bh = 20, N = 8, μ = 0.02

Number of Higher Priority Packets (h)	Mean Delay (W_{hd})	
	PQBM	IPQBM
2	456.52	500.00
5	105.00	142.86
8	51.47	82.35
11	33.65	57.85
14	25.00	44.59
17	19.89	36.27
20	16.51	30.57

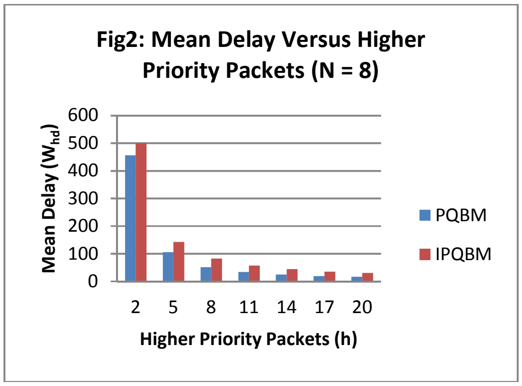
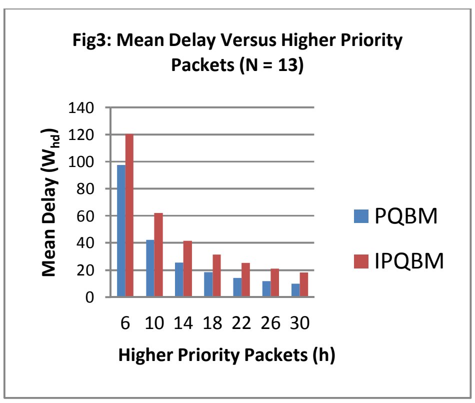


Table 4: Mean Delay of Higher Priority Data packets; Bh = 30, N = 13, μ = 0.02.

Number of Higher Priority Packets (h)	Mean Delay (W_{hd})	
	PQBM	IPQBM
6	97.69	120.47
10	42.27	62.00
14	25.55	41.74
18	18.25	31.46
22	14.19	25.24
26	11.61	21.08
30	9.83	18.09



CONCLUSION

The scheduling discipline of PQBM is modified to evolve IPQBM. From tables 2 – 4 and figures 1 – 3 above, it is clear that the mean delay perceived by higher priority packets in IPQBM is higher than that perceived in PQBM. The implication of this is that IPQBM offers better throughput for lower priority packets. As such there cannot be monopoly of bandwidth resources by higher priority packets in IPQBM. However, if the number of channels (N) increases, the effectiveness of IPBQM in checking the monopoly of higher priority packets will reduce. Overall, IPQBM ensures fairness in the use of radio resources by both higher and lower priority packets and is therefore of better performance than PQBM.

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