Adaptive Threshold Based Channel Allocation Scheme for Multimedia Network

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Summary
This paper presents an adaptive threshold channel allocation scheme for new and handoff calls in wireless multimedia network. We divide the channels of each cell into two parts; one for handoff call and the other for new call. To give handoff call higher priority over new calls, the handoff call is allowed to preempt the new call when it finds no channel available on its arrival. The interrupted new call goes to the buffer until channel is available at the new call reserve channels. The call in the buffer is served using ticket scheduling. The system is supported with an analytical model, and the numerical analysis to estimate the blocking probabilities of both new call and handoff call. The scheme is also simulated using extensive runs and the numerical results confirm the optimality of the scheme when queuing of new calls is allowed.
Key words:
Multimedia network, handoff call, quality of service (QoS), new call, buffer, channel.

1. Introduction

With the proliferation of wireless devices such as mobile phones, the demand for wireless communications has grown exponentially over the last decade and is expected even more in the future. More and more multimedia traffic are being transmitted via wireless media, and such applications require diverse QoS. Due to the intrinsic scarcity of wireless channel, it is challenging to provide diverse QoS while achieving high bandwidth utilization [1]. When a mobile user tries to communicate with another user or a base station, it must first obtain a channel from one of the base stations that hears it. An allocated channel is released under two scenarios: the user completes the call or the mobile user moves to another cell before the call is completed. If a channel is available, it is granted to the user otherwise the new call is blocked. The procedure of moving from one cell to another while a call is in progress is called handoff. While performing handoff, the mobile unit requires that the base station in the cell that it moves into will allocate it a channel. If no channel is available in the new cell, the handoff call is blocked [15] Poorly designed handoff schemes tend to generate very heavy signalling traffic, and hereby, a dramatic decrease in QoS. Therefore, minimizing the handoff-dropping probability is usually considered in the wireless system design. On the other hand, the goal of a network service provider is to maximize the revenue by improving network resource utilization, which is usually associated with minimizing the new-call-blocking probability Hence the need for buffering pre-empted new calls while keeping the handoff dropping below a certain threshold [7].

In recent years, there has been increasing research interest in channel allocation technique in wireless multimedia networks. The simplest way of giving priority to handoff calls is to reserve a fixed (static) number of channels for them, which is called "Guard channel" scheme [9]. In [5], a system with queues only for voice handoff calls are studied. In [4], queues are allowed only for the new voice calls. Both the new calls and handoff calls are allowed to be queued in [20,23]. However, all these researches are based on voice calls only and multiple traffic have not been considered. In [13], a special two-dimensional model for cellular mobile systems with preemptive priority to real-time service calls was proposed. However, no distinction is made between originating and handoff requests. In order to prevent ongoing calls from potential dropping, Lin et al. [8] gave priority to hand-off calls over new calls, such that the forced-termination probability is improved without seriously degrading the blocking probability of new calls. Ming-Hsing and Mostafa [21] proposed a predictive scheme for handoff prioritization in cellular networks based on mobile positioning. Yuguang and Yi [22] developed a new call admission control schemes and performance analysis in wireless mobile networks. Naghshineh et al. [11] proposed a distributed call admission control scheme by estimating the possible number of hand-off calls from adjacent cells. Various reservation-based admission control schemes (or so called Guard Channels) have also been proposed to reduce the probability of terminating ongoing or hand-off calls [6], [16]. Some optimal solutions subject to different constraints have also been proposed in [14], [10]. Slightly different from the reservation based call admission control (CAC), once the system load exceeds a predefined threshold, we restrict the traffic of newly initiated calls so as not to drop hand-off calls. However, static reservation

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is not efficient for varying traffic conditions found in wireless networks. Lately, several distributed call-admission-control schemes have been proposed to dynamically calculate the required bandwidth in order to maintain a low cell-overload probability [12], [17]. However, the statistical models used in calculation were not realistic. Moreover, these schemes were designed based on traditional mobile networks with only voice traffic. Thus, they cannot effectively handle a variety of connection bandwidths, traffic loads, and user's mobility [7]. Also

In this paper, we propose an adaptive threshold channel allocation for new and handoff calls in wireless multimedia networks. The main features of the proposed system are highlighted as follows.

9 It is based on a service model consisting of two types of traffic (i.e new call and handoff call).

9 The available channel in each cell is divided into two parts; one for handoff call and the other for new call.

9 It employs the use of adaptive threshold for channel allocation, based on input traffic rate, to guarantee the QoS for the different traffic types.

9 It gives higher priority to handoff calls in order to reduce their dropping probability and allow preempted new calls to be stored in the buffer due to unavailability of channel.

9 It exploits the dynamic nature (feature) of multimedia traffic applications to further improve the efficiency of resource utilization.

The rest of the paper is organized as follows. Section 2 describes our proposed channel allocation policy. The mathematical (analytical) analysis for the proposed system is presented in section 3 and simulation results are provided in section 4. Finally, concluding remark is given in section 5.

2. System Description and Assumptions

We consider a cellular network in which a mobile communicates with others via a base station while residing in the cell of that base station. When a mobile leaves a cell, it could be either successfully handed off, or dropped in case of shortage of channels in the new cell. Since dropping hand-off calls is usually less desirable and less tolerable than blocking newly initiated calls, hand-off calls are given priority over new calls. This is how the scheme works: A single cell is considered where the total channel C is partition into two; new call channel (NH) with capacity Nn and handoff call channel (HC) with capacity Nh. Channel threshold for each traffic is adjusted dynamically based on the input traffic rate. The available buffer has a finite capacity Q and is to queue preempted new calls only.

Handoff call arrivals first check whether there are channels available in HC. If there are, the calls are served. If HC is full, it checks if there are channels available in NH. If there is free channel, the call is served. But if there is no free channel in either HC or NH, but there are new calls in NH and the buffer is not full, the handoff call will be served by preempting new call and store the preempted call in the buffer. (The preempted new call waits for free channel based on FIFO scheduling). However, if there is no free channel in both HC and NH, handoff call is blocked. New calls are allowed only when the number of occupied channel has not reached its maximum capacity Nn. Restricting new incoming calls into the system once its load exceeds a certain threshold is because handoff calls forced termination is always annoying. Obviously, this threshold is a design parameter, and one of the objectives in this paper is to reduce the blocking probability of handoff call and at the same time maintain the QoS of new calls. Therefore, once the total required channels exceed the cell capacity (or the total available channels in that cell), only then handoff calls will be lost. Under this basic control model, handoff calls get higher priority, while new call receives lower service. The reason is that force termination of handoff call is annoying to users while the buffer for the new call allows operators to have revenue generation too (see figures 1 and 2).

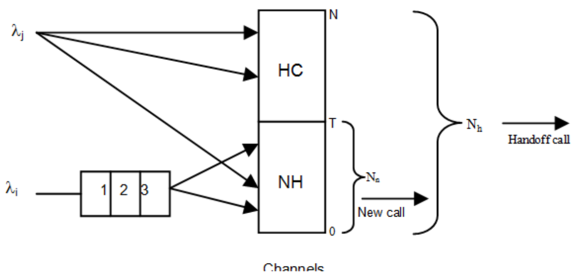

Fig. 1 Proposed system model

3. The Analytical Model

The system considers a multimedia network where each cell consists of a total of N channels and a buffer capable of buffering a number of Q new call requests. Call arrivals are assumed to be generated according to Poisson distribution with rates λ_n and λ_h for new calls and handoff calls respectively.

Thus the total arrival rate is $\lambda = \lambda_n + \lambda_h$. Service requirements for both streams are identical and exponentially distributed. The assumption of exponentially distributed holding times has been justified by [17]. Call holding times of new and handoff calls are exponentially distributed with the average call duration time $1/\mu_{hr}$ and $1/\mu_{nr}$. Also, the cell residence time for new and handoff call is exponentially distributed with mean $1/\mu_{vh}$ and $1/\mu_{dh}$ respectively. Channel occupancy times for new and handoff calls are exponentially distributed with mean $1/\mu_h$ and $1/\mu_n$ respectively.

The system is modeled using a three dimensional Markov chain. Let $P_{i,j,k}$ be the steady state probability that there are i new calls, j handoff calls and k data calls in the buffer. According to [18,19], a steady state balance equations can be written for each state as follows:

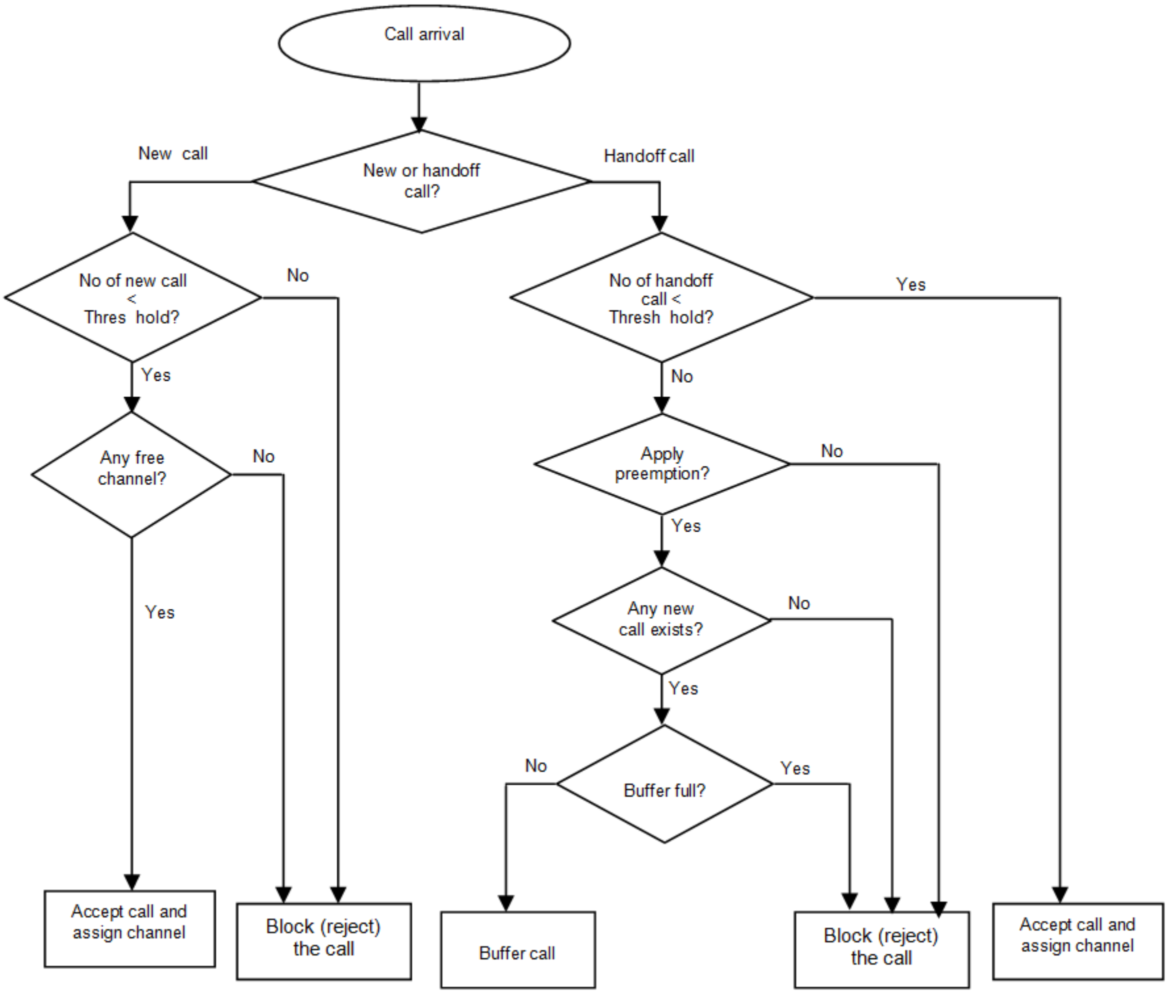

Fig. 2 Flowchart of the proposed scheme

If i+j = 0 (initial state), then

$$(\lambda_n + \lambda_h)P_{0,0,0} = \mu_v P_{1,0,0} + \mu_n P_{0,1,0} \quad (1)$$

If 0< i+j < K (some arrivals of new and handoff call), then

$$(\lambda_h + \lambda_n + i\mu_h + j\mu_n)P_{i,j,k} = (i+1)\mu_h P_{i+1,j,0} + (j+1)\mu_n P_{i,j+1,0} + \lambda_h P_{i-1,j,0} + \lambda_n P_{i,j-1,0} \quad (2)$$

If i+j = K and Q=0 (arrival of both calls at threshold), then

$$(\lambda_h + \lambda_n + i\mu_h + j\mu_n)P_{i,j,0} = (i+1)\mu_h P_{i+1,j-1,1} + (j+1)\mu_n P_{i,j+1,0} + (i+1)\mu_h P_{i+1,j,0} + j\mu_n P_{i,j,1} + \lambda_h P_{i-1,j,0} + \lambda_n P_{i,j-1,0} \quad (3)$$

If i+j = K and Q>0 (arrival of both calls at threshold with some new call in buffer), then

$(\lambda_h + \lambda_n + i\mu_h + j\mu_n)P_{i,j,k} = (i+1)\mu_h P_{i+1,j-1,k+1} + (j+1)\mu_n P_{i,j+1,k} + (i+1)\mu_h P_{i+1,j,k} + j\mu_n P_{i,j,k+1} + \lambda_n P_{i,j-1,k}$ (4)

If K< i+j < N (arrival more than threshold, only handoff is served), then
$(\lambda_h + \lambda_n + i\mu_h + j\mu_n)P_{i,j,k} = (i+1)\mu_h P_{i+1,j,k} + (j+1)\mu_n P_{i,j+1,k} + \lambda_h P_{i-1,j,k} + \lambda_n P_{i,j,k-1}$ (5)

if i+j = N (arrival equal total channel capacity), then
$(\lambda_n + i\mu_h + j\mu_n)P_{i,j,k} = \lambda_n P_{i-1,j,k} + \lambda_n P_{i,j,k-1}$ (6)

However, after obtaining steady state equations for each state, using normalization for the linear equation, according to [20], we have

$$\sum_{i+j\geq 0}^{N}\sum_{k\geq 0}^{Q} P_{i\,i\,k} = 1 \quad (7)$$

Therefore, the steady state probabilities for handoff call P_h, new call P_n, and average queue length L are stated below:

$$P_h = \sum_{i+j\geq T}^{N}\sum_{k\geq 0}^{Q} P_{i\,i\,k} \quad (8)$$

$$P_n = \sum_{i+j\geq T}^{N}\sum_{k\geq 0}^{Q} P_{i,j,k} \quad (9)$$

$$L = \sum_{i+j=L}^{N}\sum_{k=Q} kP_{i\,i\,k} \quad (10)$$

4. Simulation Results and Discussion

We construct a simulation model to evaluate the performance of the proposed scheme. The result of the simulation is presented below.
Figure 3 shows the blocking probability experienced by handoff calls under different threshold values. It can be seen that the higher the threshold value, the lower the blocking probability because more channels would be available for use by handoff calls. It shows that the blocking probability of handoff calls decreases, at different buffer sizes, with increased threshold values.

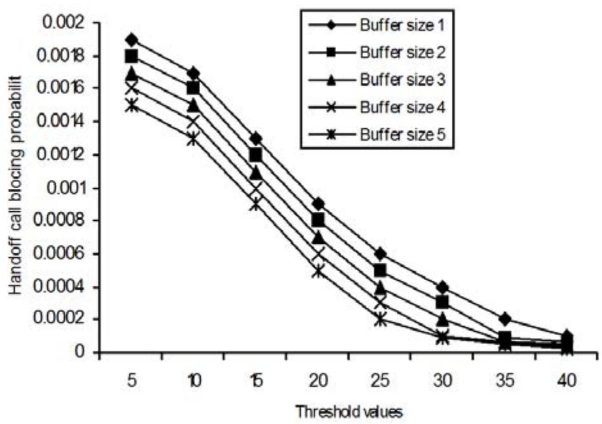

Fig. 3 Handoff probability versus threshold values

From figure 4, it is seen that the blocking probability of new calls under different threshold values increases. The higher the threshold value, the higher the number of new calls that would be buffered and served later. On the other hand, the blocking probability is low when the buffer size is 5. This is an indication that the scheme still maintains new call quality of service to some extent. As a result, a number of channels would be available for use by new calls. Another observation is that both new call and handoff call are very sensitive to change in threshold values. However, the sensitivity is much higher for new calls.

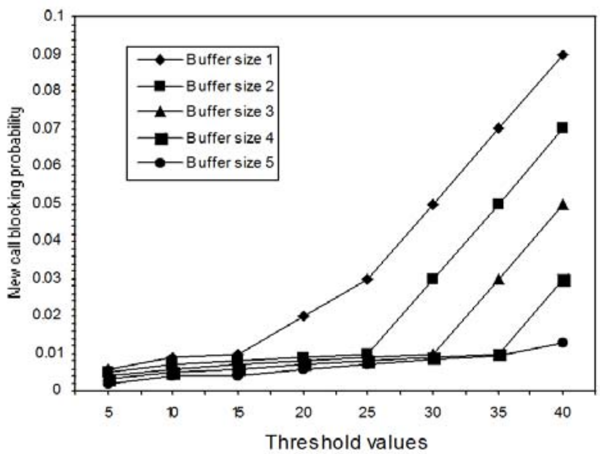

Fig. 4 New blocking probability versus threshold values

In figure 5, the average delay of new calls in the buffer before being served is very high when the buffer size is high whereas it is low when the size of the buffer is minimal. This is because the more the number of calls in the buffer the more the delay. However, the delay is low when buffer size is very small because the number of calls to treat is very small.

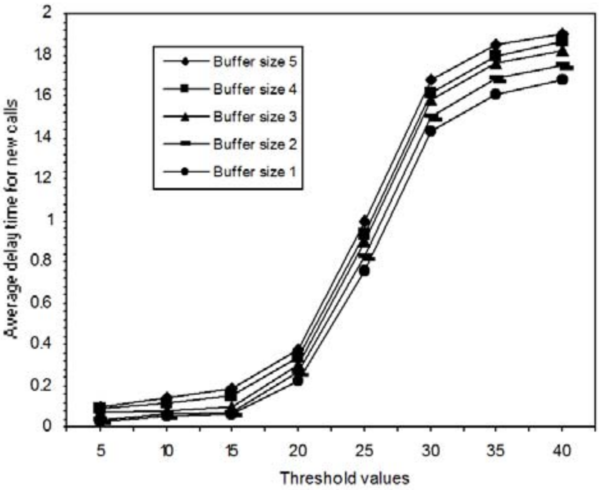

Fig. 5 Average delay time versus threshold values

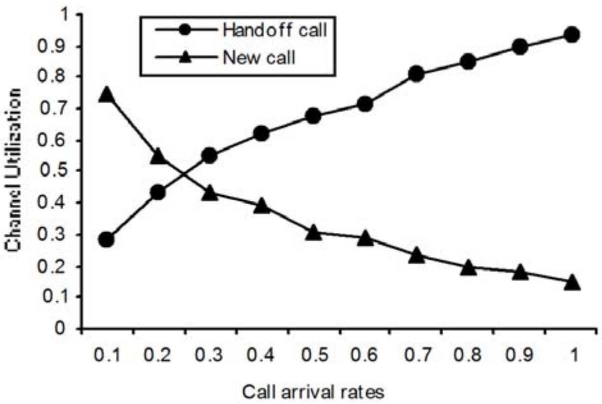

Fig. 6 Channel Utilization

From figure 6, it is seen that the channel utilization is higher for handoff calls. On the other hand, it is very low for new calls. This shows the possibility of arriving handoff calls to preempt new calls in cases where there is no available channel on the arrival of handoff call. As a result, the number of handoff arrival is more, and consequently, the number of reserved channels for new calls at any given time will be small. Since the scheme is incorporated with a buffer, instead of blocking the preempted new calls, they are queued up in the buffer until channel is made available. This is the reason for channel utilization being high and low for handoff and new calls respectively.

5. Conclusion

In this paper, we have proposed an adaptive channel allocation policy for wireless multimedia networks with two different traffic types: new call and handoff calls. The scheme is based on using the traffic arrivals to determine dynamically the threshold for the two calls and introducing a buffer for queuing preempted new calls. The preempted new calls in the buffer are served using FIFO scheduling. Handoff call is given higher priority because it has been shown that forced termination of handoff call is annoying. Through analysis and simulations, it was demonstrated that the proposed scheme meet the quality of service desired and achieve reasonably high network utilization.

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