# Prioritized Call Admission Control Scheme for Multimedia Wireless Networks

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*Abstract* – **In this paper, we propose a new Call Admission Control (CAC) and resource reservation scheme for cellular-based multimedia wireless networks. The well-known CAC guard channel policy [3] is modified to be applicable for different traffic classes with diverse QoS requirements. The proposed scheme is modeled as M/M/C/C queueing system and the performance measures, call blocking probability and call dropping probability are computed. The performance of our scheme is compared to the Complete Sharing (CS) policy. Simulation results show that our scheme surpasses the CS policy in terms of call blocking probability, call dropping probability and bandwidth utilization.**

*Index terms* – **Wireless cellular networks, Call admission control, Bandwidth reservation, Quality of service, Real-time multimedia traffic.**

## I. INTRODUCTION

Wireless communication technologies are witnessing rapid growth, lately. The third generation wireless communication system, UMTS, can support multimedia services (audio phone, video on demand, video conference, Web service, etc.) with diverse Quality of Service (QoS) requirements at a target transmission rate of up to 2 Mbps for static mobile users and 384 kbps for high mobility users. The multimedia services make a great demand for bandwidth on the wireless networks. Because bandwidth is a scarce resource in wireless networking, it is necessary to allocate it carefully to utilize the system bandwidth efficiently amongst competing connections with different QoS requirements.

### *A. Background and Related Work*

In order to allow higher transmission capacity and thus to achieve better performance, the total area covered by a wireless network is divided into small sized cells (i.e., microcells or picocells [1]). However, unlike wired networks, mobile users in wireless networks change their connectivity via handoff when they move from one cell to another. Thus, the use of pico or micro -sized cells will increase the handoff rate, and thus, leads to higher handoff dropping rate that makes QoS guarantees to the multimedia services difficult. Multimedia services impose stringent QoS demands on the wireless networks.

The key problem in the design of a cellular-based multimedia wireless system is to balance the two opposing objectives of the service provider and mobile

The crafting of these schemes is generally approached by focusing on a subset of the design issues, while users. The former wants to achieve high system utilization so that more users can be accommodated by the system and more revenue can thus be obtained while the later wants to receive better QoS. In wireless cellular networks, user's QoS requirements can be quantitatively expressed in terms of probabilistic connection-level QoS parameters such as Call Blocking Probability (CBP) and Call Dropping Probability (CDP) [2]. A new call is initiated when a user requests a new connection, while a handoff call occurs when an active user moves from one cell to another neighboring cell. Thus, the CBP is the probability of a new arriving call being rejected while the CDP is the probability that an accepted call is terminated before the completion of its service, i.e., the probability that a handoff attempt fails [2].

Therefore, one of the most important connection-level QoS issues is how to reduce and control CDP due to the lack of available bandwidth so that mobile users can continue their ongoing connections. Reserving enough bandwidth for handoff mobile users can reduce CDP in wireless cellular networks. However, it may lead to high blocking rate of new connections and low bandwidth utilization. Reduction of CDP and CBP are contradictory. Therefore, new and efficient bandwidth reservation schemes must be developed in the multimedia wireless networks. We must make a tradeoff between the bandwidth utilization and bandwidth reservation such that the CDP and the CBP can be reduced, while efficiently maintaining high bandwidth utilization. Hence, striking a proper balance between bandwidth utilization and user's QoS satisfaction is the focus of this paper.

Efficient Call Admission Control (CAC) and Bandwidth Reservation (BR) schemes are necessary to maintain the desired QoS. CAC schemes enable the system to provide QoS for arriving calls (new and handoff) as well as existing calls. BR scheme, such as guard channel (GC) [3], is used to reserve the resources for certain high priority calls. On the other hand, network is required to take advantage of resource sharing among traffic in order to achieve better bandwidth utilization. Obtaining a right balance between the two opposing criteria is a big challenge.

Several CAC and BR schemes have been discussed in the literature [4-9] to develop and design conventional wireless cellular networks which provide QoS guarantees and use system resources efficiently. ignoring others. Handoff calls have been the main design factor in maintaining and evaluating the performance of a wireless cellular network. Some models such as those mentioned in [4], [7-9] use GC policy [3] for handoff calls to reduce dropping probability. In the GC, percentage of the base station's capacity is exclusively reserved for handoff calls. If the percentage is high, adequate capacity will most likely be available to maintain the QoS needs of handoff calls. This, therefore, will result in decreasing the CDP. Clearly, however, lowering the CDP will, in general, mean increasing the probability of new calls being blocked. While minimizing the CDP is very desirable from the user's point of view, this often comes at the expense of the bandwidth utilization, which is very undesirable from the service provider's point of view. In the limit, one can achieve 0% CDP at a 100% CBP. This demonstrates the importance of providing a balance between the user's connection-level QoS satisfaction and system utilization. The aforementioned models assume that all connection requests are identical. This assumption, however, is not valid if multimedia services are to be supported by wireless cellular networks. Since multimedia connections may differ in the amount of bandwidth they need to meet their QoS requirements. Therefore, we believe that sensible CAC and BR schemes should take both supporting of multimedia services and reducing connection probabilities (blocking and dropping) into account. Designing and analyzing such a scheme is the focus of this paper.

### *B. Contributions*

This work addresses the issue of how to provide seamless handoffs to mobile users, under the constraints of limited resources and high frequency of handoff, in a multimedia wireless network. We adopt the concept of the guard channel (GC) scheme, which gives preferential treatment to the high priority calls, including handoff calls, by reserving a fixed number of channels exclusively for them. However, such scheme decreases the handoff dropping rate at the cost of increasing the blocking rate for other users due to poor bandwidth utilization. To deal with this challenge, in this paper, we propose and analyze a generalized and enhanced version of the GC scheme which we call Multimedia Guard Channel (MGC). The GC policy is modified to be applicable for different traffic classes with different QoS requirements. MGC consists of a bandwidth reservation module combined with a CAC algorithm. The main objective of our work is to be able to achieve better QoS provisioning, in terms of CBP and CDP, for mobile users while achieving efficient utilization of the available limited spectrum. The scheme can be modeled as a Markov birth-death M/M/C/C queuing discipline model. The Markovian model captures the call admission decision and, thus, we provide a mathematical derivation for the call blocking probability and the call dropping probability for each distinct class.

### *C. Organization of the paper*

The rest of this paper is organized as follows. The system model is described in Section II. The Multimedia Guard Channel (MGC) scheme with its main components is presented in Section III. The analytical model and derivations of connection-level QoS metrics are provided in Section IV. Simulation results and performance comparisons are reported in Section V. Finally, conclusions drawn from the paper and future work are discussed in Section VI.

## II. SYSTEM MODEL

We consider a multimedia wireless/mobile network with a cellular infrastructure, comprising a wired backbone and a number of base stations (BSs). The geographical area controlled by a BS is called a cell. A mobile, while staying in a cell, communicates with another party, which may be a node connected to the wired network or another mobile, through the BS in the same cell. When a mobile move into an adjacent cell in the middle of communication session, a handoff will enable the mobile to maintain connectivity to its communication partner, i.e., the mobile will start to communicate through the new BS, hopefully without noticing any difference.

In this paper, we are concerned with CAC and bandwidth management in each cell. Therefore, we decompose the cellular network into individual sub-systems, each corresponding to a single cell. The correlation between these sub-systems, results from handoff connections between the corresponding cells, which is re-introduced as an input to each sub-model. Under this assumption, each cell can be modeled and analyzed individually. A same model is used for all cells in the network, but the model parameters may be different, reflecting the mobility and traffic conditions in individual cells, as well as the channel assignment policy employed by the network. Therefore, we can model the system at single-cell level.

We assume the system uses Fixed Channel Allocation (FCA), which means each cell has a fixed amount of capacity. No matter which multiple access technology (FDMA, TDMA, or CDMA) is used, we could interpret system capacity in terms of effective or equivalent bandwidth [10]. Hereafter, whenever we refer to the bandwidth of a connection, we mean the number of basic bandwidth units (BBUs) that is adequate for guaranteeing desired QoS for this connection with certain traffic characteristics.

Consider a cell that has a total capacity of $C$ BBUs. Two types of connections share the bandwidth of the cell: *new* connections and *handoff* connections. In this work, we consider only real-time services. Typically, class-1 traffic includes voice service while class-2 traffic is comprised of video service. Thus, traffic arriving at the cell is partitioned into two separate classes based on bandwidth requirements. Each class-i connection requires bandwidth $c_i$ BBU (i = 1, 2). The classes are indexed in an increasing order according to their bandwidth requirements, such that: $c_1 \leq c_2$. The block diagram representation of the wireless cell is shown in Figure 1.

## III. MULTIMEDIA GUARD CHANNEL SCHEME

The proposed scheme combines a bandwidth reservation module and a Connection Admission Control (CAC) algorithm. The bandwidth reservation scheme is employed to assign the amount of reserved bandwidth. Whereas, the CAC algorithm is employed to control whether the connections can be served or not. In this section, we first describe the details of the proposed bandwidth reservation scheme. Then we present the proposed CAC algorithm.

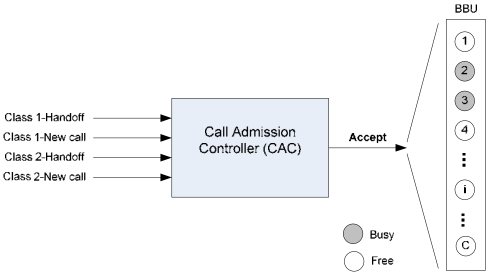

Figure 1: System model

### A. Bandwidth Reservation Scheme

Any bandwidth reservation scheme in general provides QoS guarantees and lower Call Dropping Probability (CDP) by reserving a fixed amount of bandwidth exclusively for handoffs, thus giving them priority over new connections. However, it heavily decreases the Bandwidth Utilization (BU) and leads to high Call Blocking Probability (CBP) for new calls.

In this paper, we propose a much more reasonable and realistic bandwidth reservation scheme that reduces CDP, CBP, and improves BU simultaneously. As aforementioned we consider two types of traffic, new calls and handoff calls, which are each further separated into two classes. Thus, we have the following four traffic categories: class-1 handoff, class-2 handoff, class-1 new call, and class-2 new call. In order to provide better balance between CDP and CBP, and thus improve the BU of the system (a cell), we assign a priority order as follows: class-1 handoff (highest priority), class-1 new call, class-2 handoff, and class-2 new call (lowest priority). The main concept of our bandwidth reservation scheme is based on reserving different amount of bandwidth for each category. A series of bandwidth thresholds determines the maximum amount of bandwidth that connections in each category can use. Four bandwidth thresholds, $t_1$, $t_2$, $t_3$, and $t_4$ ($t_1 \leq t_2 \leq t_3 \leq t_4$) are used as illustrated in Figure 2. The bandwidth allocation in a cell, as illustrated in Figure 2, contains two portions: the used portion and the reserved and shared available portion. The used bandwidth represents the portion of the cell bandwidth that is currently used by ongoing connections (new calls or handoff calls). The reserved and shared available bandwidth portion contains the bandwidth that is reserved for future calls and can be shared with all type of incoming calls. In our bandwidth reservation scheme we have $t_1$, $t_2$, $t_3$, and $t_4$ that represent the bandwidth thresholds that are assigned for class-1 handoff, class-1 new call, class-2 handoff call, and class-2 new call, respectively. Note that as the threshold index increases the reserved bandwidth of the corresponding category decreases, and therefore, the priority level decreases. For example, according to our priority assignment class-1 handoff has the highest priority which means more bandwidth should be reserved for future incoming class-1 handoff connections. This can be achieved by selecting the smallest threshold value, $t_1$.

### B. Call Admission Control (CAC) Algorithm

The algorithm uses the threshold values that are assigned in the bandwidth reservation scheme as described above to make the decision whether to admit or reject an incoming connection request. For each arriving call request (new or handoff), the algorithm calculates the available bandwidth according to the priority level of the arriving call request as follows.

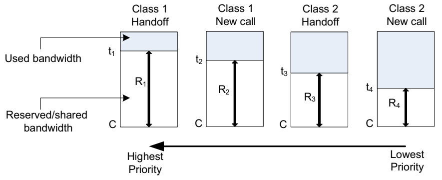

Figure 2: Bandwidth reservation scheme

For i = 1, 2, let $m_i$ denote the number of class-i new calls, and let $n_i$ denote the number of class-i handoff calls that are present in the system at the time of the call request. Also, let $C_{nc_i}$ denote the total occupied bandwidth by class-i new calls, and let $C_{h_i}$ denote the total occupied bandwidth by class-i handoff calls. Note that, $C_{nc_i} = m_i c_i$ and $C_{h_i} = n_i c_i$. The total occupied bandwidth in the cell, $C_{OB}$, is then given by

$$C_{OB} = \sum_{i=1}^{2}(C_{nc_i} + C_{h_i})$$

Let $R_i = C - t_i$, for i = 1, 2, 3, 4. Given the threshold values, $t_1$, $t_2$, $t_3$, and $t_4$, a class-1 handoff call is accepted if $c_1 + C_{OB} \leq R_1$, a class-1 new call is accepted if $c_1 + C_{OB} \leq R_2$, a class-2 handoff call is accepted if $c_2 + C_{OB} \leq R_3$, and a class-2 new call is accepted if $c_2 + C_{OB} \leq R_4$. Figure 3 shows the CAC decision rule.

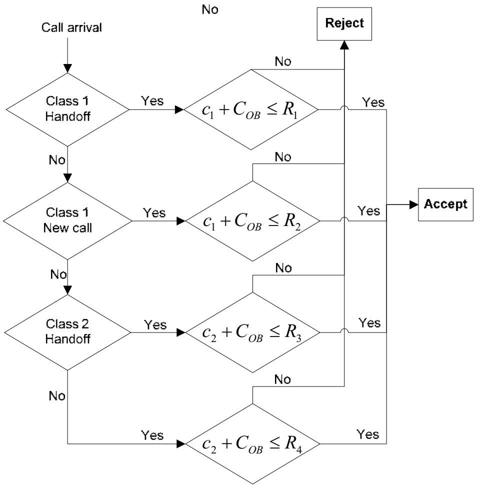

Figure 3: Call admission control flowchart

## IV. ANALYTICAL MODEL

In this section, we show that our proposed Multimedia Guard Channel (MGC) scheme can be modeled as a M/M/C/C queuing system. Indeed, the major contribution of this paper is the analytical model. From the steady state probability distribution of the M/M/C/C, performance measures of interest, CBP and CDP, can be computed.

### A. Assumptions

In our system model, a real-time traffic is never buffered. Thus, an arriving connection (new or handoff) that finds all bandwidth is occupied is blocked or dropped. As for traffic characterization, we assume a simple model from a cell's perspective. For i = 1, 2, new call arrivals and handoff call arrivals of class-i connections are assumed to follow a Poisson process with rates $\lambda_{nc_i}$ and $\lambda_{hi}$, respectively. The call holding time (CHT) of a class-i call is assumed to follow an exponential distribution with mean $1/\mu_i$. For simplicity, we assume that $\mu_1 = \mu_2 = \mu$. For mobility characterization, the cell residence time (CRT), i.e., the amount of time that a mobile user stays in a cell before handoff, is assumed to follow an exponential distribution with mean $1/h$ [11]. CRT is independent of the service class. Hence, connections in any class follow the same CRT distribution. Note that the parameter $h$ represents the call handoff rate.

The channel occupancy time is the minimum of the CHT and the CRT. As the minimum of two exponentially distributed random variables is also exponentially distributed, the channel occupancy time for new calls and handoff calls for class-i traffic is therefore assumed to be exponentially distributed with means $1/\mu_{nc_i}$ and $1/\mu_{hi}$, respectively, where $\mu_{nc_i} = \mu_{h_i} = \mu + h$.

### B. Analysis and Derivations

Based on the above assumptions, the system (a cell) follows an M/M/C/C queuing discipline leading to the simple birth and death Markov chain with threshold states $R_j$, for j = 1, 2, 3, 4, as illustrated in Figure 4.

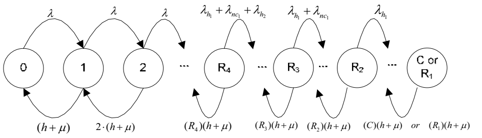

Figure 4: Markov transition diagram for the multimedia guard channel scheme

A state of the model representing the considered cell is determined by $x$, the non-negative integer number of occupied bandwidth (in basic bandwidth unit) by ongoing new calls and handoff calls of class-i traffic, for i = 1, 2. As a consequence, the state space of the cell can be defined as: $\Omega = \{x | 0 \le x \le C\}$. We can derive the steady-state probability distribution $P_j$ for $j$ bandwidth units to be occupied as follows:

$$\lambda P_0 = (h+\mu)P_1$$

$$\lambda P_0 + 2\cdot(h+\mu)P_2 = \lambda P_1 + (h+\mu)P_1$$

$$\ldots$$

$$\lambda P_{R_4-1} + (R_4+1)(h+\mu)P_{R_4+1} = (\lambda_{h_1} + \lambda_{nc_1} + \lambda_{h_2})P_{R_4} + (R_4)(h+\mu)P_{R_4}$$

$$\ldots$$

$$(\lambda_{h_1} + \lambda_{nc_1} + \lambda_{h_2})P_{R_3-1} + (R_3+1)(h+\mu)P_{R_3+1} = (\lambda_{h_1} + \lambda_{nc_1})P_{R_3} + (R_3)(h+\mu)P_{R_3}$$

$$\ldots$$

$$(\lambda_{h_1} + \lambda_{nc_1})P_{R_2-1} + (R_2+1)(h+\mu)P_{R_2+1} = \lambda_{h_1}P_{R_2} + (R_2)(h+\mu)P_{R_3}$$

$$\ldots$$

$$\lambda_{h_1}P_{R_2-1} + (R_2+1)(h+\mu)P_{R_2+1} = \lambda_{h_1}P_{R_2} + (R_2)(h+\mu)P_{R_3}$$

$$\ldots$$

$$\lambda_{h_1}P_{C-1} = C(h+\mu)P_1$$

where $\lambda = \lambda_{h_1} + \lambda_{nc_1} + \lambda_{h_2} + \lambda_{nc_1}$. The above equation can be summarized as follows:

$$P_j = \begin{cases} \frac{1}{j!}\cdot\left(\frac{\lambda}{h+\mu}\right)^j \cdot P_0 & if\, 0 \le j \le R_4 \\ \frac{(\lambda_{h_1} + \lambda_{nc_1} + \lambda_{h_2})^{j-R_4}}{j!}\cdot\left(\frac{\lambda}{h+\mu}\right)^j \cdot P_0 & if R_4 \le j \le R_3 \\ \frac{(\lambda_{h_1} + \lambda_{nc_1})^{j-R_3}\cdot(\lambda_{h_1} + \lambda_{nc_1} + \lambda_{h_2})^{R_3-R_4}}{j!}\cdot\left(\frac{\lambda}{h+\mu}\right)^j \cdot P_0 & if R_1 \le j \le R_2 \\ \frac{(\lambda_{h_1})^{j-R_2}\cdot(\lambda_{h_1} + \lambda_{nc_1})^{R_2-R_3}\cdot(\lambda_{h_1} + \lambda_{nc_1} + \lambda_{h_2})^{R_3-R_4}}{j!}\cdot\left(\frac{\lambda}{h+\mu}\right)^j \cdot P_0 & if R_1 \le j \le C \end{cases}$$

where

$$P_0 = \begin{pmatrix} \sum_{j=0}^{R_4}\frac{1}{j!}\cdot\left(\frac{\lambda}{h+\mu}\right)^j + \sum_{j=R_4+1}^{R_3}\frac{(\lambda_{h_1} + \lambda_{nc_1} + \lambda_{h_2})^{j-R_4}}{j!}\cdot\left(\frac{\lambda}{h+\mu}\right)^j + \\ \sum_{j=R_3+1}^{R_2}\frac{(\lambda_{h_1} + \lambda_{nc_1})^{j-R_3}\cdot(\lambda_{h_1} + \lambda_{nc_1} + \lambda_{h_2})^{R_3-R_4}}{j!}\cdot\left(\frac{\lambda}{h+\mu}\right)^j + \\ \sum_{j=R_2+1}^{C}\frac{(\lambda_{h_1})^{j-R_2}\cdot(\lambda_{h_1} + \lambda_{nc_1})^{R_2-R_3}\cdot(\lambda_{h_1} + \lambda_{nc_1} + \lambda_{h_2})^{R_3-R_4}}{j!}\cdot\left(\frac{\lambda}{h+\mu}\right)^j \end{pmatrix}^{-1}$$

Given the steady state distribution above, the connection blocking/dropping probability for each priority class can be expressed as shown in Table 1. Note that connection blocking/dropping probability of class-i, $P_{B_i} / P_{D_i}$, can be interpreted as the probability of the system in the states where $R_i$ or more bandwidth units are occupied.

Table 1: Blocking/Dropping Probabilities

| Category | Blocking/Dropping Probability |
|---|---|
| Class-1 handoff | $P_{D_1} = \sum_{j=R_1}^{C} P_j$ |
| Class-1 new call | $P_{B_1} = \sum_{j=R_2}^{C} P_j$ |
| Class-2 handoff | $P_{D_2} = \sum_{j=R_3}^{C} P_j$ |
| Class-2 new call | $P_{B_2} = \sum_{j=R_4}^{C} P_j$ |

## V. SIMULATION RESULTS

Numerical and simulation analyzes are given in this section to show how the proposed CAC algorithm can reduce CDP, CBP, and improve BU. In order to evaluate the performance of our proposed scheme, we built a simulation model for the wireless cellular environment. The assumptions for our simulation study are as follows:

- The cellular network studied assumes a standard 7-cell configuration with identical mobility and traffic conditions. The diameter of each cell is 1 km (i.e., micro cellular environment). The base station resides at the center of each cell.
- The total capacity of each cell is $C$ (BBU). Two types of real-time traffic are considered, voice and video. Voice bandwidth requirement is $c_1$ BBU and video bandwidth requirement is $c_2$ BBUs, where $c_1 \le c_2$.
- For the traffic characteristics, we assume that the call arrival process for new calls of both classes is a Poisson

process with rate $\lambda = \lambda_{nc_1} = \lambda_{nc_2}$ (calls/sec/cell). The Call Holding Time (CHT) is assumed to follow an exponential distribution with mean *1/μ* and it is selected when the call is first admitted into the network. Note that $\mu = \mu_1 = \mu_2$.

- We assumed that the handoff call arrival rate of class-i is assumed to be proportional to the new call arrival rate of class-i by $\lambda_{h_i} = \frac{h}{\mu_i}\lambda_{nc_i}$ for i = 1, 2. The range of offered load (call arrival rate) varies from 0 to 6.0.
- For the mobility model, we consider three parameters, the initial position of a mobile, its direction and its speed. A newly generated call can appear anywhere in the cell with an equal probability. When a new call is initiated, a mobile is assigned a random initial position derived from a uniform probability distribution function over the cell area. As for handoff calls, the initial position is determined when the handoff event is scheduled as described below. A mobile is assigned a random direction upon entering a cell. The distribution of the direction reflects the correlation between the different cells. Different mobility scenarios can be modeled by proper selection of the distribution. For example, in order to model the morning rush hour mobility pattern, the distribution is selected to be biased to the direction leading to the downtown area. While for the evening rush hour, the distribution is biased towards the direction that leads to the suburbs. A constant randomly selected speed is assigned to a mobile when it enters a cell either at call initiation or after handoff. The speed is obtained from a uniform probability distribution function ranging between $V_{min}$ and $V_{max}$. From the three parameters described above, along with the radius of the cell *R*, and the network topology, the simulation tool calculates the mobile's residence time in the cell. It also determines the cell to which the mobile will handoff to if a handoff is taking place, as well as the initial position of the mobile in the next cell.

In [11], an analytical model is developed for the above system, and it was found that the average residence time for a new call, $t_{nc}$, is given by: $t_{nc} = 8RE[1/V]/3\pi$, while the average residence time of a handoff call, $t_h$, is given by: $t_h = \pi R/2E[V]$, where *R* in the radius of the cell and *V* is the average speed of a mobile in the cell. Therefore, the handoff rate of new calls, $h_{nc}$ equals 1/ $t_{nc}$ and the handoff rate of handoff calls, *h*, equals $1/t_h$. The simulation model is very flexible and allows us to test the system under different scenarios. Here, we limit our experimental tests to the simulation parameters values that are shown in Table 2 where $T_{sim}$ is the simulation time. However, we believe that the higher the bandwidth capacity and simulation time are, the more efficiency our scheme can achieve.

Performance measures obtained through simulation are Call Blocking Probability (CBP) of new calls, Call Dropping Probability (CDP) of handoff calls, and Bandwidth Utilization (BU). These performance measures are plotted as a function of the offered load (call arrival rate). For comparison purposes, we simulated the Complete Sharing (CS) policy (i.e., $t_1 = t_2 = t_3 = t_4 = C$) as well, whereby an arrival call of class-i is admitted whenever a cell has enough available bandwidth to accommodate the call. Figures 5-7 show the performance comparison of our scheme (MGC) with the CS policy in terms of CBP, CDP and BU.

In order to validate our analytical model, we compare its results with the simulated MGC system. Figures 5-6 compare the analytical and simulation results. The comparison illustrates that the difference between the two models are negligible, thereby validating the ability of the analytical model to accurately capture the behavior of the system. The simulation results obtained in all experiments have a 95% confidence level with 5% confidence intervals.

Table 2: Simulation parameters

| Parameter | Value | Unit |
|---|---|---|
| **Total bandwidth, *C*** | 100 | BBU |
| **Class 1, $c_1$** | 4 | BBU |
| **Class 2, $c_2$** | 7 | BBU |
| { $t_1$, $t_2$, $t_3$, $t_4$} | {25, 40, 70, 100} | BBU |
| **Cell diameter, R** | 1 | km |
| **Call arrival rate** | λ | call/sec/cell |
| **$\mu^{-1}$** | 500 | sec |
| **$h^{-1}$** | 200 | sec |
| **$V_{min}$** | 10 | km/hr |
| **$V_{max}$** | 60 | km/hr |
| **$T_{sim}$** | 10000 | sec |

Figure 5 shows the CBP of both traffic services. When the call arrival rate is low (below 2), the performance of both schemes is identical. This is because both schemes have enough bandwidth to accept the arrival calls (new and handoff). However, as the call arrival rate increases, the amount of an unused bandwidth decreases. Thus, the CBP for both schemes increases. We remark that the CBP in the case of MGC scheme is lower than that of CS scheme due to bandwidth reservation. We also notice that class-2 calls suffer from a higher blocking probability than class-1 calls. This is because class-2 has lower priority than class-1 in accessing the system bandwidth and has higher bandwidth requirement.

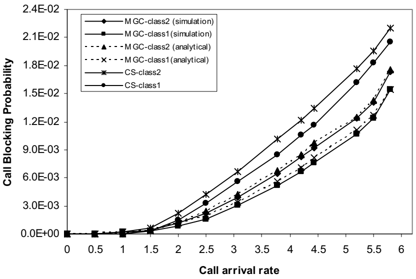

Figure 5: Comparison results for connection blocking probability

For similar simulation parameters, we show the performance of the MGC scheme and the CS scheme in terms of CDP in Figure 6. As one can see, by increasing the call arrival rate, the performance of both schemes becomes comparable at low rates. However, at high rates, the MGC provides a lower CDP and shows a 16% improvement in the CDP over CS scheme. This substantial improvement in CDP is expected because of the bandwidth reservation and the stringent call admission algorithm that gives more priority to handoff calls which results in a lower CDP. Furthermore, the results in Figure 6 show that the CDP for both schemes increases as the class index increases. This is due to the assigned priority levels between the handoff connections. Therefore, the prioritization among different classes is achieved.

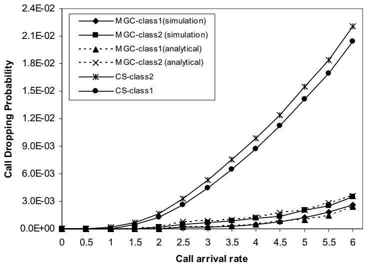

Figure 6: Comparison results for connection dropping probability

Figure 7 shows BUs of the schemes under consideration. From this figure, it can be observed how effectively the bandwidth is used. For low values of call arrival rate ($\lambda$), the bandwidth utilization is linearly increases and virtually the same for both schemes, until $\lambda$ reaches a value of 2.5. However, as $\lambda$ increases beyond 2.5, we observe that the bandwidth utilization for MGC scheme is higher than in CS scheme. The MGC scheme shows higher BU values since it considers QoS guarantees and reserves bandwidth for incoming calls (new and handoff). Furthermore, MGC scheme provides a better balance between CBP and CDP for all traffic services which is translated into low blocking and dropping calls and, thus, high bandwidth utilization.

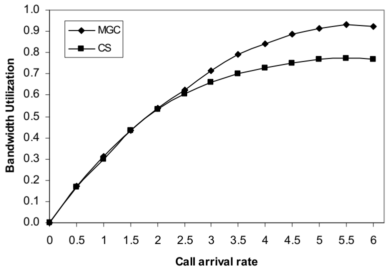

Figure 7: Comparison results for bandwidth utilization

## VI. CONCLUSIONS AND FUTURE WORK

Call Admission Control (CAC) and bandwidth reservation are key resource management methods in ensuring the quality of service in wireless cellular networks. The traditional resource reservation, guard channel (GC) scheme and its numerous variants are designed for a single type of traffic. Its goal is to reduce the Call Dropping Probability (CDP) of handoff calls. However, new calls have not been able to take advantage of the GC scheme and thus Call Blocking Probability (CBP) has not been improved as much. In addition, the GC scheme is not valid if multimedia services are to be supported. In this paper, we propose and analyze a threshold-based CAC scheme which we call Multimedia Guard Channel (MGC). The MGC is a generalized and enhanced version of the GC scheme where the GC scheme is modified to be applicable for different traffic classes with different QoS requirements in wireless cellular networks. Our specific objective in designing the MGC scheme is reducing the blocking and dropping probabilities, while efficiently maintaining bandwidth utilization. The scheme is modeled as a Markov birth-death M/M/C/C queuing discipline model. The Markovian model captures the call admission decision and, thus, we provide a mathematical derivation for the CBP and the CDP for each distinct class. The performance of our scheme is compared with that of the Complete Sharing (CS) scheme. Simulation results show that our scheme presents an improvement and reduced values for the connection-level QoS parameters: CDP and CBP than the CS scheme. The requirements of the mobile users are hence satisfied. Moreover, the results ensure efficient and better utilization of bandwidth by implementing our scheme than the CS scheme. This latter facet is highly desirable by service providers. Our future work includes extending the model in this paper to develop an adaptive threshold-based CAC scheme, which dynamically computes and changes the threshold values based on the traffic and mobility parameters.

## REFERENCES

[1] J. Padgett, C. Gunther and T. Hattori, “Overview of Wireless Personal Communications”, *IEEE Communications Magazine*, vol. 33, no. 1, January 1995, pp. 28-41.

[2] S. S. Rappaport, “The Multiple-Call Hand-off Problem in High-Capacity Cellular Communications Systems”, *IEEE Transactions on Vehicular Technology*, Vol. 40, No. 3, August 1991, pp. 546-557.

[3] D. Hong and S. S. Rappaport, “Traffic Model and Performance Analysis for Cellular Mobile Radio Telephone Systems with Prioritized and Non-prioritized Handoffs Procedures”, *IEEE Transactions on Vehicular Technology*, Vol. 35, No. 3, Aug. 1986, pp. 77-92.

[4] C.H. Yoon and C.K. Un, “Performance of personal portable radio telephone systems with and without guard channels”, *IEEE Journal on Selected Areas in Communications*, Vol. 11, No. 6, Aug. 1993, pp. 911 – 917.

[5] A. Lombardo, G. Morabito, S. Palazzo, G. Schembra, “An adaptive threshold-based call admission strategy for wireless networks”, *IEEE International Conference on Personal Wireless Communication*, 1999, pp. 423 – 427.

[6] Xue-Ping Wang, Jian-Li Zheng, Wei Zeng, Gen-Du Zhang, “A probability-based adaptive algorithm for call admission control in wireless network”, *International Conference on Computer Networks and Mobile Computing*, 2003, pp. 197 – 204.

[7] Hung-Huan Liu, “Guard channel sharing strategies in integrated voice/data mobile networks”, *International Conference on Advanced Information Networking and Applications*, 2004. pp. 79 – 82.

[8] J.L. Vazquez-Avila, F.A. Cruz-Porez, L. Ortigoza-Guerrero, “Performance comparison of fractional guard channel policies in mobile cellular networks”, *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, 2004, pp. 1476 – 1480.

[9] Nasser, N.; Hassanein, H. “Optimal multi-class guard channel admission policy under hard handoff constraints”, *ACS/IEEE International Conference on Computer Systems and Applications*, 2005, pp. 53-59.

[10] G. Kesidis, j. Walrand and C. Chang, “Effective Bandwidths for Multiclass Markov Fluides and other ATM Sources”, *IEEE Transactions on Networking*, Vol. 1, No. 4, Aug. 1993, pp. 424-428.

[11] K. Yeung and S. Nanda, “Channel Management in Microcell/macrocell Cellular Radio Systems”, *IEEE Transactions on Vehicular Technology*, Vol. 45, Nov. 1996, pp. 601-612.