Interference-based Guard Margin Call Admission Control for CDMA Multimedia Wireless Systems

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ABSTRACT

A call admission control (CAC) scheme and a resource reservation estimation (RRE) method suitable for the wide-band code division multiple access (W-CDMA) systems are proposed in this work. The proposed CAC scheme gives preferential treatment to high priority calls, such as handoff calls, by pre-reserving a certain amount of channel margin against the interference effect. It is called the interference guard margin (IGM) scheme. The amount of guard margin is determined by the measurement performed by the RRE module in base stations. Each RRE module dynamically adjusts the level of guard margin by referencing traffic conditions in neighboring cells based upon users' requests. A comprehensive service model is adopted to accommodate the scenario of multiple services supported in the W-CDMA system. The service model of consideration includes not only mobile terminal's service rate (source rate) but also different levels of priorities, mobility and rate adaptivity characteristics. Simulations are conducted with OPNET[1] to study the performance of the proposed scheme in term of the objective function under different traffic conditions.

Keywords: W-CDMA, resource reservation, guard margin, OPNET

1. INTRODUCTION

The second generation (2G) wireless systems, such as GSM and IS-95, have enabled the voice traffic to go wireless, but their capabilities to handle other services, such as data, images and video, are still very limited. With the increasing need for multimedia services and the stimulus of the development of International Mobile Telephony 2000(IMT-2000),[2] industry and academia are actively working to design suitable methods for providing multimedia services over wireless. The third generation (3G) wireless systems target at broadband wireless multimedia communications. In standard forums, the wide-band CDMA (W-CDMA) technology has emerged as the main air interface for 3G wireless systems, which promises to provide a transmission rate up to 2Mbps, enabling multimedia services as those provided by broadband wired networks.

To meet the large bandwidth requirement of multimedia traffic, it is important to utilize the system resource efficiently and provide preferential treatment according to mobile user's traffic profile when the system is congested. The Radio Resource Management (RRM) module in the cellular network system is responsible for the utilization of air interface resources. RRM is needed to offer efficient system utilization and guarantee a certain QoS level to different users according to their traffic profiles. The call admission control (CAC) mechanism is one of the most important components of RRM affecting the resource management efficiency and QoS guarantees provided to users. The radio resource reservation estimation (RRE) mechanism helps CAC to decide how much resource is needed to be reserved in order to provide QoS guarantees to mobile users. The RRE module residing in each base station dynamically estimates the amount of resource to be reserved by referencing traffic conditions in neighboring cells periodically or upon the call request arrival depending on the design of the system.

In 2G TDMA/FDMA wireless systems, network accessibility, which is controlled by the radio resource management (RRM) module, is typically designed based on the number of available channel elements. Due to the limited system resources (in terms of the number of channels), preferential treatment should be given to provide high priority calls to support them with higher QoS guarantees when the system is congested. It is widely agreed that dropping an ongoing call during handoff is less tolerable than blocking a new call. Therefore, one way to provide preferential treatment is to pre-reserve a certain number of channels for the use of high priority calls such as handoff calls. This is referred as the guard channel (GC) scheme.[3] Various GC schemes have been widely studied as discussed in Section 2.[3–5,?,16,17]

However, such an approach is not applicable in the 3G wide-band code division multiple access (W-CDMA) system, where the system capacity is not hard- but soft-constrained. In other words, system capacity is limited by the maximum tolerable interference in the system. A new call request is admitted if it does not introduce excessive interference into the system. J. Knutsson *etal.*[6] investigate the CAC for downlink. Many researches debate that the link capacity of CDMA system is limited by the reverse link.[7] Due to the asymmetric traffic condition in the reverse (from the mobile terminal to the base-station) and the forward link (from the base-station to the mobile terminal) directions, the CAC scheme should admit a call only when the signal-to-interference Ratio (SIR) requirements E_b/N_0 of the user are satisfied in both directions.

Resource management is critical issues in the 3G wireless systems. It received a wide attention and active study in this field.

Liu and Zarki[8] proposed an SIR-based call admission control (CAC) scheme for the reverse-link in DS-CDMA system to improve the system performance under heavy traffic conditions. Liu and Zarki's scheme assumes that the base station receives the same signal power from each of its mobile users. Under this assumption, their scheme calculates residue capacity of the cell and their proposed CAC algorithm can be functioned based on the variation of signal to noise ratio (SIR) value. However, such assumption is not valid in a practical system due to the use of power control mechanism (PCM). PCM adjusts the signal power level for each mobile user according to the link condition to the base station. Consequently, the use of PCM keeps the SIR to its target value the same level during the whole operation.[9] On the other hand, our scheme assumes the SIR target value can be maintained by the use of power control and calculate the total interference level by employing the load curve introduced by Shapira[10] and Holma.[11] The use of load curve also make it possible to consider different interference increase introduced by heterogeneous traffic with various service rates.

Recently, Shin *et al.*[7] proposed an interference-based channel assignment scheme for DS-CDMA Cellular Systems. However, it has the following limitations: (1)Shin's scheme is based on the IS-95 specification, in which each user requests only one kind of service rate. (2) Their proposed CAC algorithm is based on fixed resource reservation, where a fixed number of channels is reserved to give the preferential treatment to high priority handoff calls. The amount of reserved resources are dynamically changed in our scheme by referencing the traffic condition in the neighboring cells. It is done by using resource reservation estimation (RRE) module proposed in Section 3.3. Other schemes include Ching Yao Huang and R. D. Yates[12] proposed a transmitted power based call admission control (TPCAC) scheme. This scheme try to protect ongoing calls and a received power based call admission control scheme that rejects new call requests when the total received power at a base station exceeds a certain threshold. Other schemes are mentioned in N. Dimitriou and R. Tafazolli.[13] They discuss a broad aspects of the CAC such as QoS requirement, power limitation and self-similar nature of certain traffic.

The features of our proposed dynamic resource management are summarized below:

- Supports multiple service rate which is suitable for 3G system such as wideband-CDMA (W-CDMA).
- Supports rate adaptive characteristics for multiple services with flexible QoS guarantees.
- Our scheme employs resource reservation estimation process to adjust the level of reserved resources dynamically by referencing the traffic condition in the neighboring cells.
- Bridges two concepts, guard channel (GC) and load curve (LC) to provide the preferential treatment for high priority calls.
- Traffic mobility is considered in system model to achieve better resource estimation results.

The remaining parts of this paper are organized as follows. In Section 2, we review the background of related work in priority handoff for conventional TDMA/FDMA systems and the load estimation scheme for CDMA system. In Section 3, the interference guard margin (IGM) scheme to provide preferential treatment to mobile users for W-CDMA systems is proposed. It includes the CAC scheme and the associated dynamic RRE method. Several QoS metrics are measured in terms of the cost function, the handoff dropping probability and the new call blocking probability. Section 4 shows some simulation results conducted with OPtimized Network Engineering Tool (OPNET) by using a comprehensive service model. Finally, concluding remarks and future work are presented in Section 5.

2. RELATED WORK

2.1. Preferential Treatment in Conventional 2G Systems

Due to the resource constraint, a wireless system cannot always meet the different QoS requirement of every mobile user. Consequently, the system needs rules to decide who will receive the services according to some predefined cost function. Prioritizing determines the relative importance of call events, and should be used in a process to make access decisions for traffics with multiple services when the system is congested. Such a process is especially important to effective system planning. Usually, handoff calls are assigned a higher priority over new calls because it is less tolerable to drop an ongoing call than to block a new call. How to seamlessly transfer resources between cells during handoff is an intensively studied topic. Sophisticated resource reservation and call admission schemes should be integrated with the handoff mechanism to provide more flexibility to all mobile users and better QoS guarantees for premium users.

Many different admission control strategies have been discussed in the literature for 2G wireless systems to provide priorities to priority call and handoff requests without significantly jeopardizing new connection requests. These strategies fall into two categories: Handoff Queue (HQ)[14] and Guard Channel (GC)[3] schemes.

The use of guard channel (GC) in FDMA/TMDA system is a good scheme to provide preferential treatment to different priority calls. The basic GC scheme[3] can be extended to deal with multimedia traffics with different priorities,[4] in which multiple thresholds are used. The traffic scenario with only two priority classes, i.e. new calls and handoff calls, is regarded as a special case in which many parameters in the traffic profile are aggregated. The QoS metrics for the performance is often measured by an objective function J in terms of the weighted sum of the rejection probability for each class within each service attribute.

The GC scheme described above is static because it is not adaptive to the quick variation of the traffic pattern. Recently, dynamic GC schemes have been discussed in the literature to improve the system efficiency while providing the QoS guarantees to priority calls. These dynamic schemes adaptively reserve resources needed for priority calls and, therefore, accept more lower priority calls as compared to a fixed GC scheme. Naghshineh and Schwartz[5] proposed an analytical model to estimate resource requirements for handoff calls. In their model, all connection requests have an identical traffic profile under stationary conditions. Ramanathan *et al.*[15] proposed a dynamic resource allocation scheme based on the estimation of the maximum resource requirement needed for handoff calls. Acampora and Naghshineh[16] applied a linear weighting scheme as part of their admission control algorithm. The linear weighting scheme uses the average number of ongoing calls in all cells within the region of awareness to determine the admission policy. Sutivong and Peha[17] adopted a hybrid scheme based on the weighted sum of ongoing calls in the originating cell and in other cells to determine the admission scheme. Dynamic GC schemes are generally very complicated. Since their performance cannot be easily analyzed with analytical models, they are often verified via computer simulation.

2.2. Capacity and Load Estimation in W-CDMA Systems

The measurement of the resource capacity in a spread spectrum system is very different from conventional TDMA/FDMA systems. In conventional TDMA and FDMA systems such as IS-54 (TDMA adopted in North American) and GSM (hybrid TDMA/FDMA adopted in Europe), the number of traffic channels is fixed. It is determined by the number of time slots in the TDMA system or by the number of non-overlapping frequencies in the FDMA system.[18] In such systems, traffic channels are allocated to users as long as there are available channels. Otherwise, the call is blocked.

The spread spectrum system, such as W-CDMA, does not have a fixed number of channels. Instead, the capacity of a CDMA system is limited by the total interference the system can tolerate. Such a system is referred to as the interference-limit system. Each additional active mobile user will increase the overall level of interference. In other words, call blocking occurs when the overall interference level reaches a certain level above the background noise.[19] Normally, the interference level increases rapidly when the system load reaches a certain level. Users with different traffic profiles and attributes such as the service rate, the signal-to-Interference ratio (SIR) requirement, media activity, etc. introduce different amount of interference to the system. These factors are especially important in 3G wireless networks that support multimedia services.

The system capacity depends on system parameters as well as the amount of the interference increment that each active mobile user brings in. Viterbi,[19] Holma[11] and Liu and Zarki[8] studied the effect of interference increase for traffics with the following attributes:

- Service rate R: it is the data rate or the bandwidth of the source in bps.

- Processing gain G_p: it is defined as the ratio of the chip rate W of a W-CDMA system to its source rate R, i.e. $G_p = W/R$.
- Target signal-to-interference ratio (SIR) ϵ: in order to achieve certain QoS in terms of the frame error rate (FER) or the bit error rate (BER), the SIR value is set to a target value and governed by power control. Here, we assume perfect power control so that target SIR can be maintained.
- Media activity level ν: it is defined as the ratio of the busy period to the total connection period and lies in the range between 0 and 1. The overall interference in the system increases with increase in the media activity level.
- Other cell to own cell interference ratio f: it is an aggregate value obtained from the field experiment (normally $f = 0.55$).

Let ϵ_i denote target SIR for user i, which can also be expressed as $(E_b/N_0)_i$. Then, we have[19]

$$\epsilon_i \equiv (E_b/N_0)_i = \frac{W}{\nu_i R_i} \cdot \frac{S_i}{I_{total} - S_i}, \tag{1}$$

where E_b is the energy per user bit and N_0 the noise spectral density, S_i is the received power at the base station from user i, ν_i is the activity level of user i, and I_{total} is the total received power at the base station, which is limited by an upper-bound for a system. When I_{total} is higher than the upper-bound, the system is unstable and the overall interference increases dramatically. By replacing W/R_i with $G_{p,i}$ in (1), we can express the received power S_i for user i at the base station as

$$S_i = (\frac{1}{1 + \frac{G_{p,i}}{\epsilon_i \cdot \nu_i}}) \cdot I_{total} = \triangle\rho_i \cdot I_{total} \tag{2}$$

where $\triangle\rho_i$ is known as load factor increment,[11] i.e. $\triangle\rho_i = (1 + \frac{G_{p,i}}{\epsilon_i \cdot \nu_i})^{-1}$. The total load factor of such an interference system is the sum of load factor increments brought by N active mobile users, i.e. $\rho = \sum_{i=1}^{N} \triangle\rho_i$. Shapira and Padovani[10] and Holma *et al.*[11,**?**] estimated the interference increase by taking into account the load curve as shown in Fig.1. The ratio of I_{total} to the background noise P_N, is called noise-rise and denoted by η, where η is normally set to 0.1..[19] The noise-rise, η, in Fig. 1 can be written as

$$\eta = \frac{I_{total}}{P_N} = \frac{\sum_{i=1}^{N} S_i + P_N}{P_N} = \frac{1}{1-\rho} \tag{3}$$

By taking the partial derivative of I_{total} with respective to ρ, we have

$$\frac{\partial I_{total}}{\partial \rho} = \frac{\partial (P_N/(1-\rho))}{\partial \rho}. \tag{4}$$

Thus, we can get the interference increment due to user i as

$$\triangle I_i = \frac{\triangle\rho_i}{1-\rho} \cdot I_{total}. \tag{5}$$

The load curve serves as a good tool for interference increment estimation in our proposed model.

3. PROPOSED SCHEME

In this section, we will develop a dynamic call admission control scheme based on two concepts. First, a certain amount of interference-based guard margin (IGM) is pre-reserved for the use of high priority calls. The amount of IGM is dynamically adjusted by the resource reservation estimation module. This work is presented in Section 3.2. Second, the load curve is used to estimate the load increase as well as the interference increase.

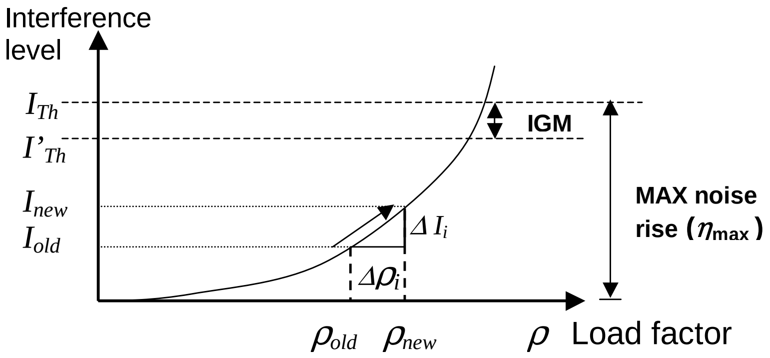


Figure 1. The load curve and the load estimation increase for active user's activities.

3.1. Service Model and Traffic Profile

For wireless multimedia services, the attributes in the service model characterize the traffic. The service model under our consideration is described below.

- The rate adaptivity denoted by $\mathbf{r}$ describes whether a connection is flexible in its service rate. If a connection is rate adaptive, it can be serviced in a degraded mode when congested. This connection thus has a high probability to receive services in full or degraded rates. Adjusting the service rate will result in different processing gain G_p.
- The maximum and the minimum service rates denoted by $\mathbf{R_{max}}$ and $\mathbf{R_{min}}$, respectively, describe the target bandwidth consumption of the traffic.
- Higher priority $\mathbf{\Pi}$ is assigned to services that are willing to pay more. They are likely to receive better QoS guarantees in terms of lower blocking or dropping probability and a better quality mode. Similarly, the system will gain higher rewards if it serves more higher priority calls.
- The mobility $\mathbf{M}$ describes the movement of a mobile terminal. High- and low-mobility traffic types are included in our service model. Different mobility traffic will have a different weighting factor to the estimated bandwidth to be reserved. This is discussed in our proposed resource reservation estimator in Section 3.3.

In a mobile communication system with N active mobile users, the ith ($i < N$) user's traffic profile can be represented as

$$\text{Traffic Profile of user } i = \{\mathbf{r}, (\mathbf{R_{max,i}}, \mathbf{R_{min,i}}), \mathbf{\Pi_i}, \mathbf{M_i}\} \tag{6}$$

We also consider other parameters such as the target SIR value ϵ, the media activity ν and the other cell to own cell interference ratio f.

3.2. Preferential Treatment with Interference Guard Margin (IGM)

The concept of a guard margin is illustrated in Fig. 1. For a new call to be admitted, the total interference level should not exceed the upper bound of the interference with threshold I_{th} that the system can tolerate. In addition to the constraint of I_{th}, a lower priority call should comply with the augmented constraint I'_{th}. The margin between I_{th} and I'_{th} is exactly the guard margin, which provides the preferential treatment to high priority calls by limiting the access to the low priority calls.

3.3. Dynamic Resource Reservation Estimation

When a mobile terminal (MT) moves toward cell boundaries, the neighboring base stations (BS) receive stronger signal from it. Each of the BS in the neighboring cell will send messages to the main traffic switching office (MTSO) to register itself as a handoff candidate for MT. The handoff candidate registration (HCR) table is used in MTSO to maintain the registration record and to inform the MT about where to handoff when its signal fades. This table also provides very useful information to estimate future handoff calls for a given cell. Before admitting a new or handoff call, j, in a cell, our proposed dynamic resource reservation estimation scheme estimates the interference guard margin IGM based on a weighted sum of estimated minimum interference-increments according to the traffic profile for each neighboring active calls.

The value of IGM can be represented as

$$\begin{aligned} IGM &= \alpha \cdot \sum_{i \in S} \omega_i \cdot \triangle I_{min,i} \qquad (7) \\ &= \alpha \cdot \sum_{i \in S} \omega_i \cdot \left(\frac{\triangle \rho_i}{1-\rho} \cdot I_{total}\right) \\ &= \alpha \cdot \sum_{i \in S} \omega_i \cdot \left(\frac{\frac{1}{1+\frac{W/R_{min,i}}{(\epsilon_i)\cdot\nu_i}}}{1-\rho}\right) \cdot I_{total} \end{aligned}$$

In Eq. 7, α is a empirical factor which capture the facts of either some calls in set $S(j)$ are terminated before they can arrive or calls in current cell left and release the resource. The results for IGM using $\alpha = 1$ and $\alpha = 0.7$ are compared in simulation results. Next, in the same equation, the weighting factor, ω_i, for each call is a function of the mobility of user i, $\mathbf{M_i}$, and the distance from user i to base station, d_i. The value of the weighting factor, ω_i, is proportional to the ratio of mobility to distance for user i, i.e., $\omega_i \propto (M_i/d_i)$. We reserve the resources partially according to this weighting.

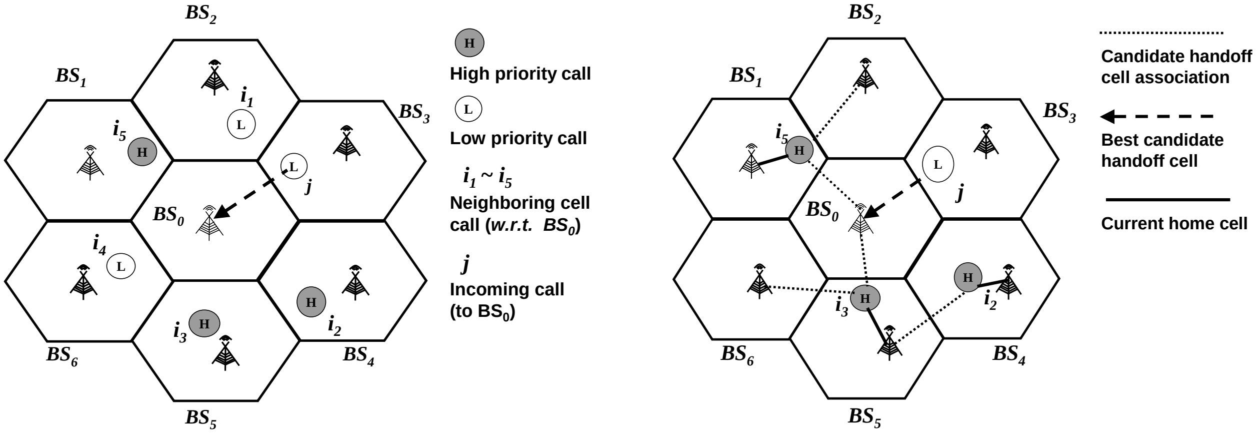
Let us first define a set $S(j)$ for call j that has to be considered for the estimation of resource reservation as defined in Eq. 7. $S(j)$ consists of all neighboring active calls that satisfy two criteria: (1) The handoff candidate cell of call i in the HCR table is the same as the target cell of call j. (2) The priority of call i is higher than that of incoming call j. Note that there is one more hidden assumption, i.e. the current cell of neighboring call i is not equal to the target cell of incoming call j. We define the following operations for call i (similar for call j):

$\Pi(i)$: Priority of call i (8)
$\Lambda(i)$: The handoff candidate cell of call i (9)
$\Lambda^*(i)$: The target cell of call i (10)
(the cell with maximum SNR among the handoff candidate cells)

Thus, set $S(j)$ can be represented as that in Eq. 11:

$$S(j) = \{i|\Pi(i) > \Pi(j), \Lambda^*(j) \in \Lambda(i)\}. \qquad (11)$$

Fig. 2 illustrate the operation of (a) $\Pi(i) > \Pi(j)$ and (b) $\Lambda^*(j) \in \Lambda(i)$ in set $S(j)$ respectively. In Fig. 2(a), we first notice an incoming call j who request a handoff from base station BS_3 toward its target cell BS_0. From Fig. 2 (a), we can notice that the operation of $\Pi(i) > \Pi(j)$ will find out neighboring calls ($w.r.t\ BS_0$) whose priority is higher than that of call j. Consequestly, we get $\{i|\Pi(i) > \Pi(j)\} = \{i_2, i_3, i_5\}$. Then we go on to perform the screening process of second rule. In Fig. 2 (b)For incoming call j, the target cell BS_0 is chosen as best candidate cell from j's handoff candidate registration (HCR) table. Therefore, we denote cell BS_0 as $\Lambda(j)^*$. One this figure, we see several dotted lines associated to each call. The dotted line represents the cells on the HCR table for each call i. i_5 has $\{BS_0, BS_2\}$ on its HCR table, i_3 has $\{BS_0, BS_6\}$ on its HCR table and i_2 has $\{BS_4, BS_5\}$ on its HCR table. Therefore, only call i_5 and i_3 satisfy the test of $\Lambda^*(j) \in \Lambda(i)$. Intersect the result of (a) and (b) we get $S(j) = \{i_3, i_5\}$.



(a) (b)

Figure 2. Set $S(j)$ in Resource reservation estimation: (a) $\Pi(i) > \Pi(j)$ and (b)$\Lambda(j)^* \in \Lambda(i)$.

3.4. Proposed call admission control (CAC) algorithm

Three types of mobility, i.e. high, moderate and low mobilities, are considered in our simulation. We assign 1, 2 and 4 units of speed for moderate and high mobility traffics, respectively. The proposed CAC algorithm implies that a high speed MT is more likely to handoff into the current cell even though it is farther away with respect to a BS in comparison with a low speed MT.

The proposed CAC algorithm for the new and handoff call request can be expressed as in Fig. 3. Fig. 4 represents proposed CAC in the format of flow diagram.

Note that, for the handoff call, we replace IGM_{new} by $IGM_{handoff}$ in the above algorithm, where IGM_{new} and $IGM_{handoff}$ are the estimated bandwidths required to be reserved for new and handoff calls, respectively. The flow diagram of call admission control is illustrated in Fig. 4.

3.5. System and Service Model Parameters

Simulations were conducted by using the OPtimized Network Engineering Tool (OPNET),^{1} which is a discrete event simulator. We implemented a service model and the CAC algorithm, and compared the traffic under different scenarios. Our goal is to investigate the QoS performance in terms of the objective function J as defined in (**??**). The performance of the non-priority scheme, the fixed guard margin scheme as well as the dynamic IGM scheme with the associated resource reservation estimation module were compared.

In our simulation, we used a network topology with 7 cells, which covers a region in a non-overlapped fashion. Each cell has its own base station. The maximum interference level I_{th} is normally set to ten times of background noise, i.e. $\eta = 0.1$. There are 420 mobile terminals with three types of mobility (140 mobiles for each of the low, the moderate and the high speed traffic classes). A central control node MTSO is connected with each base station via a wired link. There are a number of mobile users with their own traffic profiles in each cell, which can move across two or more cells according to their predetermined trajectories. Along its trajectory, a mobile user can originate connection requests randomly at its call generation rate. We assume a Poisson generation rate of connection requests, i.e. the inter-arrival time between two consecutive requests from a mobile user is exponentially distributed, and the connection duration is exponentially distributed. They are controlled by the following two parameters:

- λ: the mean request arrival rate measured in the number of connections per hour.
- l: the mean duration of each flow in minutes.

```
If Incoming calls are new calls
    If Calls are non-rate adaptive
        If $(I_{current} + \triangle I_i) < (I_{Th} - IGM_{new})$
                Admit call request with rate $R_i$
        Else
                Reject call request
    Else /*Calls are rate adaptive*/
        If $(I_{current} + \triangle I_{max,i}) < (I_{Th} - IGM_{new})$
                Admit call request with rate $R_{max,i}$
        Else If$(I_{current} + \triangle I_{half,i}) < (I_{Th} - IGM_{new})$
                Admit call request with rate $R_{half,i}$
        Else If$(I_{current} + \triangle I_{min,i}) < (I_{Th} - IGM_{new})$
                Admit call request with rate $R_{min,i}$
        Else
                Reject call request
Else /*Incoming calls are handoff calls*/
    If Calls are non-rate adaptive
        If $(I_{current} + \triangle I_i) < (I_{Th} - IGM_{handoff})$
                Admit call request with rate $R_i$
        Else
                Reject call request
    Else /*Calls are rate adaptive*/
        If $(I_{current} + \triangle I_{max,i}) < (I_{Th} - IGM_{handoff})$
                Admit call request with rate $R_{max,i}$
        Else If$(I_{current} + \triangle I_{half,i}) < (I_{Th} - IGM_{handoff})$
                Admit call request with rate $R_{half,i}$
        Else If$(I_{current} + \triangle I_{min,i}) < (I_{Th} - IGM_{handoff})$
                Admit call request with rate $R_{min,i}$
        Else
                Reject call request
```

Figure 3. Proposed call admission control algorithm.

Table 1. W-CDMA system parameters used in the simulation model.[20]

Parameter	*Value*	*Explanation*
W	3.84 Mcps	W-CDMA chip rate
ν	1	Media activity
f	0	Other cell to own cell interference ratio
ε_i	$7\ dB$	Target SIR

The parameter l is assigned the value of 15 minutes for each call connection. Increasing the value of λ results in the increment of the network traffic load. We performed experiments for different traffic densities, i.e. λ from 1 to 5. The parameters in the traffic profile are listed as follows.

- R_{max} and R_{min} denote the maximum and minimum service rates of a connection in Kbps. We simulated the multimedia traffic with the maximum service rate R_{max} set to 19.2 Kbps, 38.4 Kbps and 76.8 Kbps for voice, audio and video transmissions, respectively.
- The rate adaptivity of a connection $r \in \{YES, NO\}$.
- The priority of a connection $\Pi \in \{new, handoff\}$ with an equal probability in all simulations.
- The mobility of a connection $\mathbf{M} \in \{\mathbf{HIGH}, \mathbf{MOD}, \mathbf{LOW}\}$ with an equal probability.

Without loss of generality, simulation parameters used in the W-CDMA system are listed in Table. 1.

3.6. System Utilization Comparison for Rate and Non-rate Adaptive Traffic

The performance comparison in terms of system utilization is illustrated for heavy traffic scenarios in Fig. 5. Note that the system utilization is higher for traffic with the rate-adaptive capability than that without the rate-adaptive capability under heavy traffic loads. This can be explained by the fact that the system can provide calls with a degraded service in terms of lower bandwidth when the system is congested, thus increasing the overall system utilization. The use of weighting factor on IGM , $\alpha = 0.7$, increases the system utilization at risk of blocking more handoff calls.

3.7. Simulation Results for Non-rate Adaptive Traffic

To illustrate the advantage of the use of the dynamic guard margin, we compare the QoS performance of our proposed scheme with that of the non-priority scheme, in terms of the objective function (J). Here we consider traffic with three mobility types with two priority classes (i.e. new and handoff calls) each. The traffic density λ is assigned a value from 1 (light load)to 5 (heavy load) calls/hr/mobile, for a total of 420 mobile users. Calls belonging to each mobility class are equally-probable. The following three schemes are compared:

- Non-priority scheme.
- Fixed IGM 20% scheme.
- Dynamic IGM scheme with $\alpha = 1$.
- Dynamic IGM scheme with $\alpha = 0.7$.

Fig.6(a) shows that our proposed dynamic scheme has the best QoS performance in terms of the objective function, J. Notice that the use of weighting factor, $\alpha = 0.7$, increases the system utilization (as in Fig. 5) at the cost of more fluctuated. Also Fig.6(b) shows that our proposed dynamic scheme significantly reduces the handoff dropping probability without much increase in the new call blocking probability, under light as well as heavy traffic load conditions.

3.8. Simulation Results for Rate Adaptive Traffic

For rate adaptive users, we compare the QoS performance of the three schemes as described above. The performance comparison in terms of objective function (J) is given in Fig. 7(a) while the probabilities of new call blocking P_n and handoff call dropping P_h are in Fig. 7(b). Again, the traffic density λ takes a value from 1 to 5 (calls/hr/mobile) for a total of 420 mobile users. Our proposed dynamic scheme has the best QoS performance in terms of the objective function as well as handoff dropping and new call blocking probabilities, under light as well as heavy traffic loads.

4. CONCLUSION AND FUTURE WORK

A fixed and a dynamic call admission control schemes and their associated resource reservation schemes based on the concept of interference guard margin (IGM) for a spread-spectrum wireless communication system such as W-CDMA were presented. In the dynamic IGM scheme, the resource reservation module is used to dynamically reserve an interference margin for the use of potential high priority calls by referencing the traffic condition and mobile users' traffic profile in neighboring cells. The time-aware weighted sum plays an important role for the resource estimation process. The effect on different mobility can thus be taken into consideration. Under light as well as heavy traffic conditions, our proposed fixed and dynamic IGM schemes outperform the non-priority scheme in the overall objective function J. The cases for different traffic profiles of mobile terminals under various traffic conditions have been considered in the simulation.

We have considered a comprehensive service model, including mobile terminals' service rate, their different levels of priority, rate adaptivity as well as their mobility. Our RR scheme provides an good estimation of the potential higher-priority call arrival and gets better QoS measured in the objective function while providing QoS guarantees to higher-priority calls. In the future, we will take the multi-user detection (MUD) technique and the soft handoff scheme into consideration to achieve better QoS support.

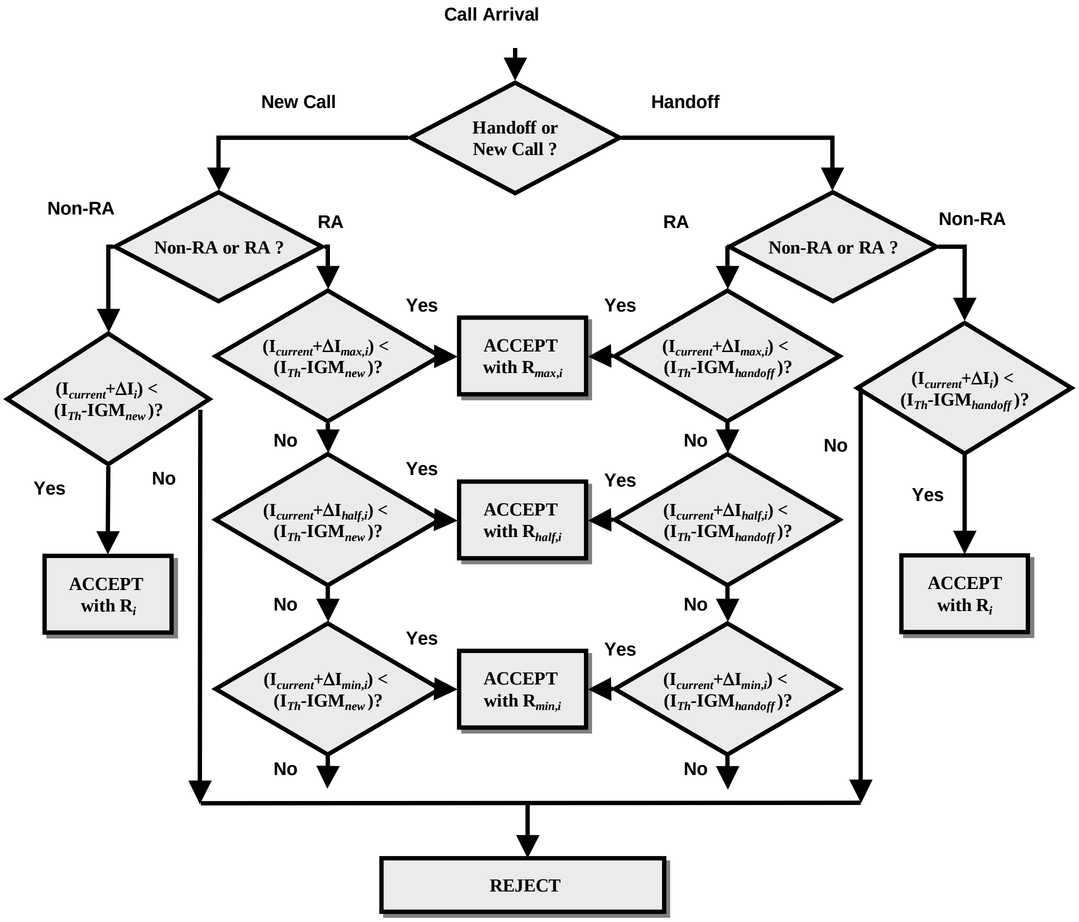


Figure 4. Call admission control flow diagram

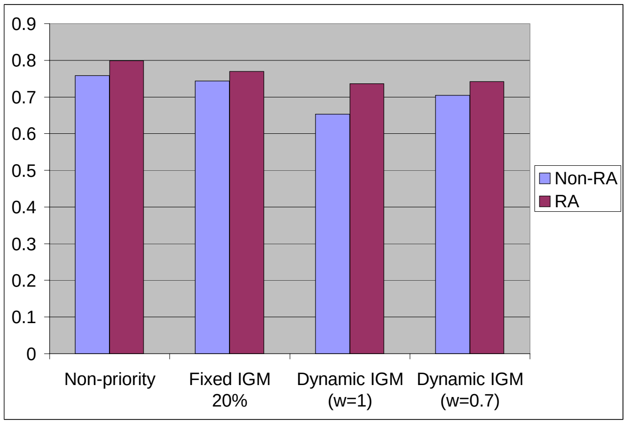
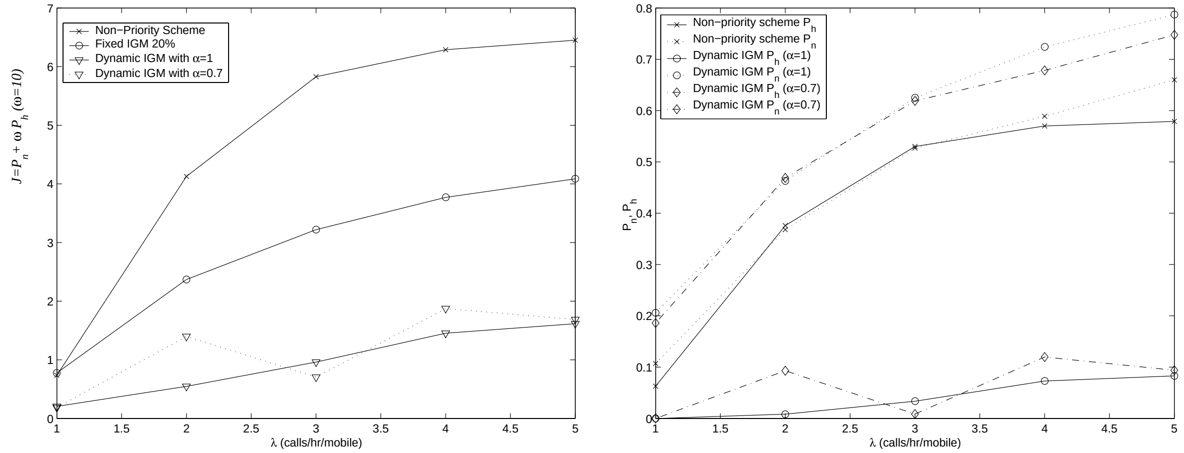
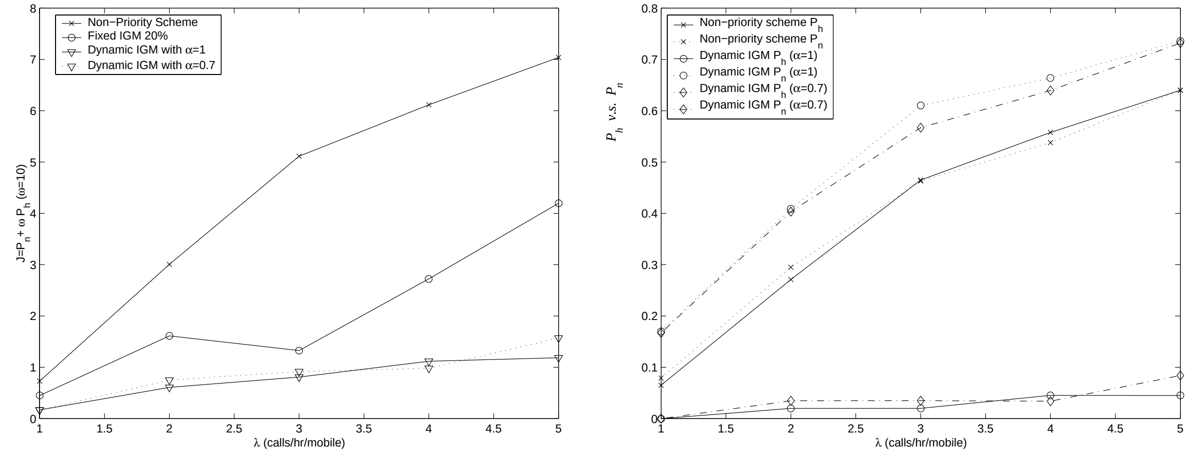


Figure 5. System Utilization for Rate adaptive and Non-rate adaptive scheme



(a) (b)

Figure 6. Performance comparison for non-rate adaptive users with 2-level priority and mobility differentiation for different schemes under different traffic densities: (a) the objective function J for different schemes, and (b) the new call blocking rate P_n and the handoff dropping rate P_h.



(a) (b)

Figure 7. Performance comparison for rate adaptive users with 2-level priority and mobility differentiation for different schemes under different traffic densities: (a) the objective function J for different schemes and (b) the new call blocking rate P_n and the handoff dropping rate P_h.

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