Call Admission Control for Multitier Networks with Integrated Voice and Data Services

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Abstract

Hierarchical Cell Structure (HCS) or multi-tier has become a major trend in the design of 3G systems networks in order to support the high capacity demand required for multimedia traffic in 3G systems. In this type of network an efficient cell assignment scheme is required to improve the Quality of Service (QoS) of the system in terms of dropping probability, blocking probability, and channel utilisation.
In this paper we propose a new channel assignment scheme which exploits the delay insensitive property of the non real-time data service to admit users to the preferred cell layer. We believe the new scheme is anticipated to improve the QoS of the real-time voice users for both blocking probability and channel utilisation parameters.

1. INTRODUCTION

The 3G wireless network integrates different types of multimedia traffic such as voice, data, and compressed images and videos. The implementation of broadband features on the wireless medium is one of the most difficult encountered problems to handle, as a large bandwidth is required to offer such services with QoS similar to these of wired networks. Therefore a major trend in the design of wireless networks is to use Hierarchical (multi-tier) Cellular Structure (HCS). In HCS more than one cell's size type are employed to provide high coverage and capacity. Depending on the traffic density area, wireless cellular systems are partitioned into two cellular categories: small cells of a few hundred meters which is called microcells and larger ones called macrocells covering few kilometres area. Another category could be added to serve indoor users of an area as large as an office which is called picocells. Macrocells provide cost efficient coverage and are used in low density areas. On the other hand microcells are used to achieve high spot traffic in urban areas. There are two principal benefits of a two-tier design. The first is, if a macrocell covers an area, it is not necessary to cover the same area with a microcell. In rural areas with low overall demand and scattered high demand points, this means that fewer resources need to be spent on providing adequate service. Instead of covering the entire service area with microcells, a macrocell can be used in combination with microcells at high demand points. The second being if there are mobile phone's users that are travelling at high speeds, these users can be serviced by the macrocell and thereby reduces the need for handoff of the calls. When a handoff is avoided, the risk of call dropping due to channel shortage in the handoff service area is eliminated.

Trend in cellular networks is to shrink cell size in order to accommodate more mobile users in a given geographical area. This results in more frequent handoffs, and makes connection-level QoS more difficult to achieve. Some important connection-level QoS parameters are the probability of blocking newly-requested connections and the probability of dropping handoffs due to the unavailability of channels in the new cell, and channel utilization. Dropping a call in progress is generally considered to have more negative impact from users' perception than rejecting (blocking) a newly requested call. Therefore, one of the key design goals is to minimize the call dropping probability by giving priority to handoff calls. This, however, usually comes at the expense of high call blocking probability and potentially poor channel utilization by admitting less new calls; therefore there is a trade-off between these two probabilities. Basically, there are two ways to prioritise handoff calls for reducing dropping probability: guard channel and queuing. Many variation or combination of the above two schemes have been proposed [1-3]. Reserving a number of channels exclusively for handoff will improve dropping probability at the expense of higher new call blocking probability. Handoff queuing is an alternative scheme that employs a handoff queue for storing temporarily unacceptable handoff attempts. However dropping would not be totally eliminated due to the limited size of the handoff queue.

In order to achieve high QoS performance in terms of the aforementioned parameters within HCS environment good admission control and channel assignment policies should be utilised. These policies should be able to assign users to the appropriate cell layer such that minimum number of handoff occur and at the same time preserving good channel utilisation. Much works have been done regarding this issue. One method to do this is by classifying users according to their speeds so that fast moving users will be assigned to the macrocell layer while low speed and stationary users will be assigned to the microcell layer. The other method used in this respect is to transfer users between cell tiers in case of no channels available at the preferred tier, this is called *overflow* as shown in Figures 1.

We have proposed a cell assignment management policy for HCS radio systems that aims to reduce dropping probability and at the same time preserving good channel utilisation by exploiting the time delay tolerance characteristic of the non real time users. In our policy, real time user that cannot find free channel at either cell layers can be admitted to the preferred tier by delaying a non real-time user. This paper is organised as follows: In section 2, the cell assignment policies in HCS in the literature are reviewed. In section 3, the new proposed scheme is presented, and the performance of the scheme is evaluated in section 4. Section 5 presents the conclusion.

2. HCS ASSIGNMENT POLICIES

To provide higher capacity in 3G systems, cells in hierarchical networks are being designed with smaller size. However such a trend may result in increased number of handoff requests and the corresponding increase in signalling load. Among the other problems raised in HCS that of how to assign a mobile to microcell or a macrocell has attracted a lot of interest [7-10]. Mainly there are two schemes for assigning calls to cell's layer in HCS these are: the overflow scheme and the speed-sensitive assignment. In the overflow scheme all types of traffic users will be assigned to a default cell layer (normally the lower layer). Calls that cannot find a channel at the default layer will be handed up (overflow) to the higher layer (the overlaying macrocell) as shown in Figure 1. The overflow could move in both directions i.e from microcell level to macrocell level and vice versa.

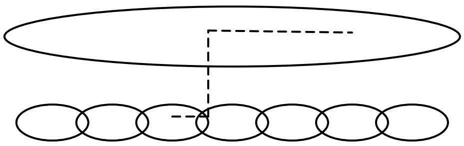

Figure 1. Call overflow

On the other hand, in the speed-sensitive assignment scheme calls are required to be classified according to their speed. Moving fast or slow this decision will be made either by the mobile terminal which is able to evaluate its own speed, or by the base station which measures the dwell time of a mobile and compares it with a threshold [11-12]. If the dwell time of the mobile user lower than the microcell dwell time threshold, this user will be considered fast user and assigned to the macrocell layer otherwise it is considered as slow user and assigned to the microcell layer. The threshold can be adjusted dynamically by either the network or by the mobile terminal.

Only single type of service was considered in the above schemes that is real time voice service. We present our new scheme in the next section, which differs from these schemes by considering the non real-time service as well and exploiting the delay insensitive characteristic of this service to reduce dropping and blocking probability for the real time services.

3. THE PROPOSED SCHEME

A. System description

An FDD-WCDMA [13] system employing two-tier hierarchical cell structure is proposed in this paper. Therefore the resources in this system are the codes which in combination with the frequency band represent the user's channels. We have decided to consider one macrocell cluster overlaying N microcells and we consider a homogeneous cellular network. That means, all cells of the same hierarchical level are assumed statistically identical so that we can focus on one particular cell in each layer. Each macrocell can support C_o users while a microcell can support C_i users. Values of N, C_o and C_i are selected to meet the requirements of our system. Two types of users are defined according to their mobility: slow users such as pedestrian denoted as S, and fast users such as vehicles denoted as F. Classifying new arriving users as fast or slow is performed by the cellular system. We assume that new slow users and new fast users arrive according to Poisson process with mean arrival rate $?_s$ and $?_f$ respectively. The call holding time is defined as the time that a call would last if it could successfully complete without forced termination. The two mobility types have an exponentially distributed call holding time of l/μ_s and l/μ_f respectively. The call sojourn time represent how long a call can be maintained in a cell, it follows an exponential distribution with mean $l/?_{si}$ in the microcells and mean $1/?_{so}$ in the macrocells. For the fast users at the macrocell, sojourn time is also supposed to be exponentially distributed with mean $1/?_{fi}$ and $l/?_{fo}$ at the microcell.

Two classes of services are considered here: real-time voice service and non real-time data service. Data users are assumed to have only slow mobility with a rate of arrival according to Poisson process $?_d$. Data traffic is buffered upon arrival to the microcell layer and they are served in a FIFO queuing discipline to fill their reserved capacity C_D. A data call can occupy an idle channel at the range (C_i-C_D), with pre-emption priority to the voice calls; the pre-empted data call will join the head of the buffer. The difference in the QoS requirements of the two classes will be exploited to favour the real time service when admitting users to the network as it will be shown next.

B. Scheme description

A new call that originated by a user will be assigned to microcell or macrocell depending on its mobility. We assume that knowledge of user mobility criterion is provided at the time of new call request [14]. Hence when a new connection arrives, it first declares its mobility criterion, and its class of service, to inform the network of the user class request. High bit rate data users require high transmission power for reliable QoS performance. Therefore we assume data service is only associated with slow users.

A new call request of slow voice user, denoted as S type, is first served at the microcell level if there is idle channel. In case there is no idle channel available this request will be served by the overlaying macrocell level. Again if there is no channel available at the macrocell level the scheme will try to find data user at the microcell level that could be served at lower rate or even drop that user in order to accommodate for the voice user. The selection of data user for this purpose can be done based on different criteria such as selecting the one with highest transmission power or the one that is at the cell boundary or the one who is been connected for long time, etc. Finally if no such a user can be found the connection is blocked and cleared out. For handoff request the algorithm process in the same manner as for the new request. Slow data users type will arrive to a buffer of length L according to Poisson process. Data calls at the head of the buffer will be served at the microcell until these calls fill the channels reserved for them (C_D), after that they will wait to be served if there is available channel in the range of (C_i-C_D), as shown in Figure 3 otherwise if no idle channel available at this range the connection blocked and cleared out after waiting time t_d.

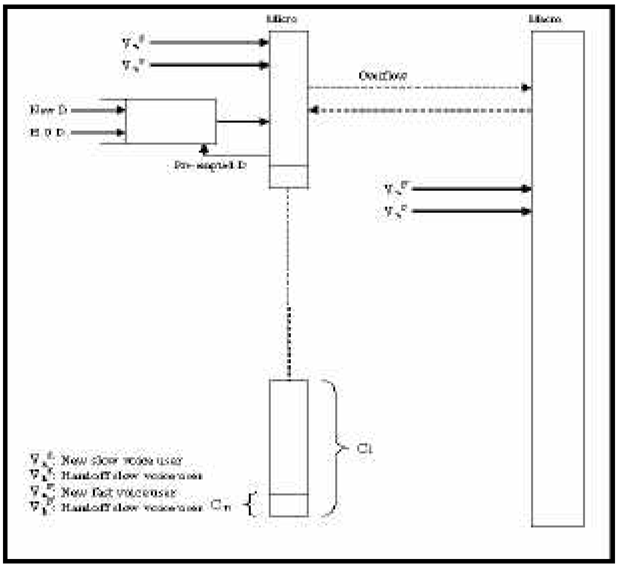

Figure 2. System model

When a fast user denoted as F type, request a call, it will first served at the macrocell level if there is an idle channel. Otherwise the F type user will be assigned to the microcell level. If once more no channel available at the microcell the connection is blocked and cleared out. If an F type user is being served at the microcell level the scheme tries to move it back to the macrocell as it crosses the microcell boundary during handoff. If a channel is still not available at the macrocell level the F type user will continue on the microcell level if there is channel available. Otherwise it will be dropped and cleared out. The scheme works in the same way for the handoff request.

4. PERFORMANCE EVALUATION

Performance evaluation of our policy is carried out in terms of blocking probability for both voice and data compared with two other schemes: the first is the same proposed scheme but with only single type service and the other scheme is the fixed resource allocation. In the fixed resource allocation scheme a fast user is assigned to the macrocell layer and it will be accepted if there is available channel, otherwise the call is blocked. New connection request or handoff request originates by slow moving user will be served at the microcell level. If there are no channels available the request will be either blocked or dropped whichever is applicable. The initial results show an increase in the outage as the data services were introduced this is only normal as that means an increase in the traffic offered to each microcell, however the outage obtained when the pre-emption policy is used is less than that obtained without the policy. Figure 3. shows the results for the system without overflow scheme and no data were used, however the results in Figure 4. shows a decrease in the outage probability when the overflow scheme method was introduced. When data service was introduced, blocking probability was dropped even further as a result of the pre-emption policy used.

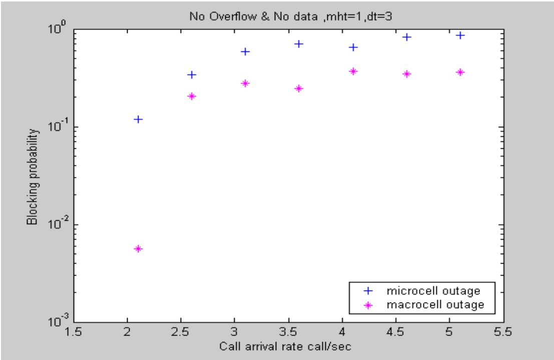

Figure 3. No Overflow & No data

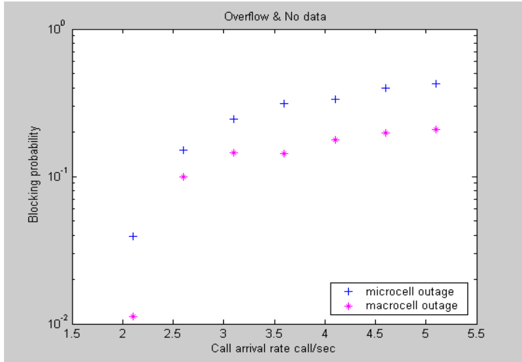

Figure 4. Overflow & No data

5. CONCLUSIONS

The results show that when the overflow method was used a decreased rate of blocking probability was achieved. Furthermore introducing data service has lead to a reduced blocking probability for the voice service. The pre-emption priority scheme which has been used at the microcell level could be extended to the macrocell level. This however required efficient control on the high interference results from high speed data service at the macrocell layer.

Further work will be conducted to extend the scheme to include data service at the macrocell, and the ability of voice users to pre-empt data users at both cell layers.

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