

Access Control Scheme for QoS provisioning in UTRA

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ABSTRACT

An access control strategy in order to guarantee the QoS requirements for the large variety of services supported in UTRA (UMTS Terrestrial Radio Access) is proposed in this paper. The derived admission criterion is based on the prediction of the interference level, considering the impact of the high data rate users on the adjacent cell interference variations. The obtained results show that the best performance of the proposed admission strategy is achieved by using a prioritised resource management technique based on an adaptive bit rate assignment according to the system load.

1. INTRODUCTION

The goal of UMTS (Universal Mobile Telecommunication System) is to support a large variety of services with variable asymmetric data rates and different quality of service (QoS) requirements. Wideband code division multiple access (WCDMA) has been chosen as the technology to be used on the air interface in 3G network [1] defined by the third generation partnership project (3GPP). The capacity of CDMA systems is interference limited and any reduction in interference converts into an increase in capacity. In [2], assuming an uniform density of voice users, the total other cell user interference-to-signal ratio is modelled as a Gaussian random variable. An improved series of bounds is presented in [3] for the other-cell interference in cellular power-controlled CDMA, thus obtaining a relative other-cell interference factor f . The interference budget is not strictly limited in CDMA systems, i. e. the system is characterised by a soft capacity that is mainly determined by the service mix. For this reason these systems have been shown to be well suited to support variable bit rate services, such as speech (activity monitoring). Variable rate transmission enables to reduce the interference for other users due to the fact that a lower bit rate allows a lower transmit power. Moreover, users at high data rates in an integrated system result in large adjacent cell interference variations which drastically degrade the system capacity. This high level of interference is caused mainly by the high data rate users in the vicinity of the cell boundaries. For this reason the provision of high data rates in 3G systems is not a simple issue.

We propose a SIR-based call admission control (CAC) for a mixed UTRA (UMTS Terrestrial Radio Access) system supporting variable bit rate services with different QoS requirements. In recent years, much research has focused on call admission techniques [4],

[5] but our aim is the provision of high data rate access in an integrated 3G network. Besides we study the CAC algorithm for the multimedia UTRA system taking into account several aspects not considered jointly in recent literature, such as: 1) the analysis of radio resource management techniques that improve the CAC efficiency to offer QoS guarantees, 2) the impact of variations in the traffic loading within an integrated system supporting M classes of high data rate users (burst mode packet service) and a voice service (circuit mode), 3) a variable spreading gain for different classes, i. e. different power levels based on the data rates and QoS requirements of the classes.

2. SYSTEM MODEL

We consider a multiservice UTRA system supporting M+1 kinds of services, a voice service (subindex v), and M types of high rate data services. The parameters of the class i are the followings: number of users N_i , bit rate R_i , processing gain G_i , activity factor α_i , bit energy/noise density requirement γ_i , normalised gaussian intercell interference Y_i and transmit power P_i . We assume power control is ideal and the power levels allocated to users belonging to class i and j are [6]:

$$\frac{P_i}{P_j} = \frac{R_i}{R_j} \cdot \frac{\gamma_i}{\gamma_j} \quad (1)$$

We assume an uniform density of voice users and we shape the voice intercell interference as a gaussian variable. We employ a burst traffic model for high data rate users, positioned at reference cell. A burst-mode packet access scheme is used assigning high data rates to mobiles for short burst durations.

We propose a two-phase access control scheme to establish how to assign powers to different classes of traffic so as to maximize capacity. First, the admission control guarantees that QoS requirements can be met for all types of services. Secondly, the congestion control schedules the available resources among all type of users.

The admission strategy accounts for channel loading, interference and soft handoff in making rate assignment and QoS decisions [4]. The pilot strength measurements for soft handoff decisions is extended for access control of high data rate users. The ratio of pilot strength measurements out of the base stations s and t are:

$$\frac{P_s}{P_t} = \left[\frac{r_s}{r_t} \right]^\mu 10^{(\zeta_s - \zeta_t)/10} \quad (2)$$

where r_i is the distance from the mobile to the base station i , ξ models the shadowing effect and μ is the distance attenuation factor [2].

We introduce prioritised management of access requests. Real time voice service is thought to have higher priority than data services. Besides, the data services are classified according to its priority level, so that lower priority data connections can be made to finish in order to permit the transmissions of higher priority data traffic. We propose two scheduling mechanisms, the first one employs the delay and buffer length criterion (the user who has the higher delay and the less buffer length is the first to transmit). The second one is an adaptive control that reduces the bit rate of the service the higher the system load is.

3. ADMISSION CRITERION

In this section we derive the admission criterion for all users to satisfy their QoS requirements in local and neighbour cells. This work is focused on the high data rate provision having multiple kinds of data services. Following this we have:

$$G_i \cdot \frac{P_i}{I_v + I_D - \alpha_i P_i} \geq \gamma_i \quad \forall i = 1..M+1 \quad (3)$$

where I_v is the voice interference and I_d is the interference due to the M types of data users. This is equal to:

$$G_i \cdot \frac{P_i}{N_v \alpha_v P_v + P_v Y_v + \sum_{j=1}^M \sum_{i=1}^{N_j} \alpha_j P_j \partial_j - \alpha_i P_i} \geq \gamma_i \quad \forall i = 1..M+1 \quad (4)$$

where ∂_j is intercell interference factor of data users. This factor is 1 if we refer to the local cell where the data users are (perfect power control), and it is equal to the relation between the powers of pilot signals if we refer to a neighbour cell (see eq. 2).

Using the eq. 1, the admission criterion can be expressed as:

$$(N_v \alpha_v + Y_v) \frac{\gamma_v}{G_v} + \sum_{j=1}^M \frac{\gamma_j}{G_j} \alpha_j \sum_{i=1}^{N_j} \partial_i \leq 1 \quad (5)$$

This expression is not easy to solve analytically. For this reason we employ a rigorous simulation method to evaluate the blocking probability, defined as the probability for a new request to be rejected. We also analyse the quality improvement when using jointly this admission technique and the congestion controls described in section 2.

This admission threshold is simplified in [7] assuming an uniform density of all users (gaussian intercell interference [2]), not evaluating the impact of

high data rate users in cell boundaries. In this case this is:

$$G_i \cdot \frac{P_i}{\sum_{j=1}^{M+1} N_j \alpha_j P_j - \alpha_i P_i + \sum_{j=1}^{M+1} P_j Y_j} \geq \gamma_i \quad (6)$$

$$\forall i = 1..M+1$$

This is:

$$\sum_{j=1}^{M+1} \frac{\gamma_j}{G_j} (N_j \alpha_j + Y_j) \leq 1 \quad (7)$$

In other recent works such as [6], the interference from other cell is characterised by the intercell interference factor, simplifying very much the admission criterion:

$$G_i \cdot \frac{P_i}{\sum_{j=1}^{M+1} N_j \alpha_j P_j (1+f) - \alpha_i P_i} \geq \gamma_i \quad (8)$$

$$\forall i = 1..M+1$$

This is equal to:

$$\sum_{j=1}^{M+1} N_j \alpha_j \frac{\gamma_j}{G_j} \leq \frac{1}{1+f} \quad (9)$$

4. SIMULATION PARAMETERS

The simulation parameters are the followings: 1) Bandwidth of 4.096 Mchips/s [1], 2) Voice service: $G_v=128$, $\gamma_v=7$ dB, $\alpha_v=1$, 3) $M=2$, data service of class 1: $G_1=16$, $\gamma_1=8$ dB, $\alpha_1=0.4$; data service of class 2: $G_2=32$, $\gamma_2=8$ dB, $\alpha_2=0.4$. The priorities of the classes are the following: first the voice service, secondly the class 1 data service and finally the class 2 data service.

We consider three sectored cells and we focus our attention on the out of cell interference contribution from the two dominant neighbouring cells. We carry out nine millions of iterations for each point in these simulations. We use the t-Student distribution and we obtain small confidence intervals for a 95% probability.

5. RESULTS

Fig. 1 shows that the adaptive rate assignment strategy (R) outperforms the control based on delay (D) because it optimises the power assignments according to the system load variations. For example for 20 voice users, the blocking probability for the congestion controls D and R is: 1) 0.11 and 0.017 respectively for 4 data users, 2) 0.26 and 0.1 for 6 data users and 3) 0.33 and 0.19 for 8 data users. These results show that the blocking probability for 6 data users using the adaptive R technique is similar to the one obtained with the D control for 4 data users. This effect is also shown for 6 and 8 data users, the R control for 8 data users outperforms the D scheduler for 6 data users.

Fig. 2 shows that the adaptive algorithm R outperforms the other ones in a system supporting two classes of data users and a voice service, just as we saw in the above system (see fig. 1). The second scheduler

D^* also outperforms the last two ones, because it finishes the class 2 transmissions to satisfy the class 1 QoS requirements.

6. CONCLUSIONS

This paper analyses an access control scheme in order to evaluate the performance of a multiservice UTRA system at both the call level and the burst level. The dynamic SIR based CAC is more efficient when using a prioritised resource management technique based on an adaptive bit rate assignment according to the traffic load variations. Besides the obtained results show that if the lower priority data connections are forced to finish in order to permit the transmissions of higher priority traffics, the system capacity is maximized.

ACKNOWLEDGEMENTS

This work has been partially supported by the Comision Interministerial de Ciencia y Tecnologia CICYT, Proyect n° TIC2000-1120-C03

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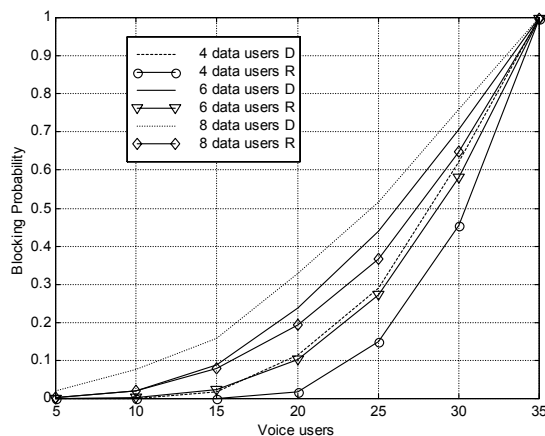


Figure 1: Blocking probability. Voice and class 1 data services. Schedulers: D (delay) and R (adaptive rate).

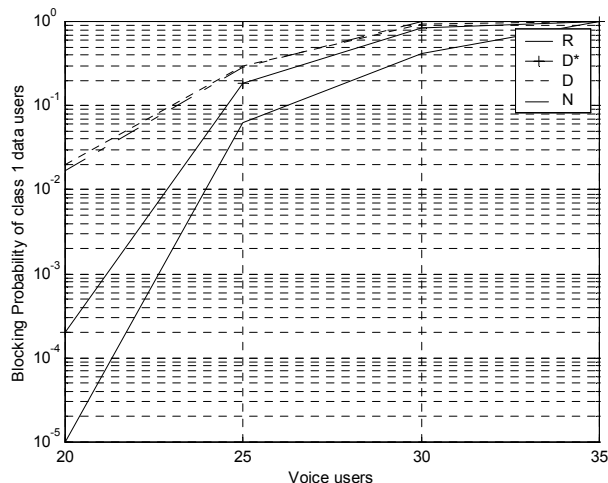


Figure 2: Blocking probability of class 1 data users. Voice, class 1 and class 2 data services. Schedulers: R (adaptive rate), D^* (delay that curtails the data transmission of class 2 to accept new class 1 requests), D (delay) and N (none)