Multimedia Traffic Management for Packetized Uplink Transmission in WCDMA UMTS

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Abstract—This paper analyses the performance of scheduling strategies for packet transmission in the FDD mode of UMTS. Both transmissions of real-time and non-real-time services are assumed in packetized form over dedicated channel. Over that, a centralized demand assignment protocol is implemented. The scheduling strategies are based on the establishment of static priorities between classes of traffic combined with the assignment of dynamic priorities, associated with time stamps, to the individual packets belonging to a connection. Arrangement of transmissions is combined with a distributed power control that allows to maximize the throughput by adjusting the transmitted powers of terminals in order to minimize the interference. Interference level at the base station is always maintained under a threshold level while output powers of mobile station are constrained. Performance in time variant wireless channel conditions is evaluated considering several alternatives for a channel–state dependent scheduling algorithm. The ratio between intercell and intracell interference and the channel condition should be known in order to achieve the minimum transmitted power criterion with accuracy in a multi-cell scenario. This work considers and evaluates the system performance assuming that power control is implemented in a distributed manner. That is, base stations of individual cells manage the power levels and instants of transmission of mobile terminals in base of local measurements of the interference without needing information interchange between different cells. The effect of the errors in the estimation of the ratio is evaluated.

I. INTRODUCTION

Next generation mobile systems, such as WCDMA, must support multimedia communications services as well as conventional voice service. Because many multimedia applications are packet-oriented, optimized third-generation techniques that support variable bit rate and packet capabilities with quality of service requirements will be needed.

A dual mode packet transmission scheme is envisaged within the W-CDMA concept defined in the UMTS terrestrial radio access (UTRA): Common and Dedicated transmission channels. The common channel packet transmission on RACH is typically used for transmission of short infrequent packets, while dedicated channel with closed loop power control is used for large packet transmissions. UTRA specifies packet transmission on Common Packet Channels (CPCH). Transmission on CPCH has two phases of contention: random access phase and contention resolution phase. Although closed power control is allowed on CPCH, a restriction on maximum duration of transmission is needed. The procedure of CPCH access is described in [1]. For large and frequent data packet, transmission on the dedicated channel is considered (DPDCH).

The scope of this study is limited to packet transmission over the dedicated channel. A demand assignment protocol is proposed in order to guarantee service multiplexing with Quality of Service requirements. In the Dedicated Channel mode the data transfer is more reliable due to the closed loop power control and the absence of collisions. Power control is performed thanks to the Dedicated Control Channel (DPCCH) associated with DPDCH. The present study considers DPDCH and DPCCH channels. However, this paper does not consider multi-code transmission in order to increment the transmission rate of individual users. Multirate is performed by varying the spreading factors.

In the context of W-CDMA, both powers of mobiles and transmission rates may be considered as controllable resources. Since users interfere with each other, to achieve transmission rates and delay requirements is closely related to power allocation. Thus, power control is an important technique in WCDMA mobile systems to increase the system capacity and to guarantee the required QoS of a multimedia system. The scheduling scheme implemented at the base station, BS, in coordination with a minimum transmitted power criterion, are responsible for arranging transmission of packets within their specified rate requirements and delay tolerances taking into consideration channel conditions of individual users. The purpose of the minimum power control criterion is to meet the Bit Error Rate (BER) of simultaneously transmitted packets, assigning an optimum level to the transmitted powers for all the users in such a way that interference caused to other cells is minimized and the system efficiency is increased.

This work considers and evaluates the system performance assuming that power control is implemented in a distributed manner. To achieve the minimum transmitted power criterion in a cellular system supposes to know in advance the ratio between intercell and intracell interference. Measurements of interference levels in previous transmissions are used to estimate this parameter. System performance is evaluated in several channel conditions.

The paper is organized as follows. First, we review the access protocol. Next, we explain the fundamentals of minimum transmitted power criterion and the scheduling discipline implemented over dedicated channels. Descriptions of traffic sources and assumptions about the cellular system, channel and mobility models are presented subsequently. Finally, we investigate the performance of the proposed packet scheduling policy under realistic channel conditions and considering services with different QoS requirements.

II. PROTOCOL DESCRIPTION.

Over dedicated channel DPDCH+DPCCH, a centralized demand assignment protocol is implemented in order to guarantee QoS requirements. Every user who has packets waiting for transmission sends a request over the Random Access Channel to setup a dedicated code. This initial Random request includes the type of service and the amount of data to be transmitted. Once the dedicated channel (code) is assigned, user waits the notification from the base station to transmit in each of next frames. At the end of each frame, the base station specifies the set of services allowed to be transmitted simultaneously, together with the transfer format (e.g. the bit rate) to be used for packet transmission. This procedure is carried out in conjunction with power control in such a way that the QoS requirements of all scheduled services are met. If a user has more packets to transmit, the mobile station, MS, sends a new access request on the dedicated channel or piggybacks the information in the last transmitted packet. Useful information of access request is contained at the beginning of the frame to allow the response of the base station at the end of the same frame. This access request is performed with maximum spreading factor (W/r=256) in order to decrease the interference originated over the rest of users. This is the only amount of load that is not controlled by the base station, as it will be deduced in section III, so a minimum capacity is reserved for request in order to agree with minimum transmitted power criterion. In order to increase the data throughput and to decrease the delay, data rates can be increased during periods of low activity. A fixed processing delay of one frame is assumed for all packets. The retransmission strategy used is the selective repeat ARQ scheme with negative acknowledgements.
The scope of this work is limited to transmissions over dedicated channels. Contention on RACH and delay associated to this process are no considered. All the users in the system have an associated code although this does not mean that they have packets to transmit.

III. MINIMUM TRANSMITTED POWER CRITERION

Every user has an individual quality of service requirement that specifies in terms of: maximum transfer delay and delay jitter, guaranteed minimum transmission rate r_i, and maximum bit error rates (BER) or block error rates (BLER) mapped into an equivalent E_b/N_o constraint denoted by γ_i. If we consider a cellular system, the quality $(E_b/N_o)_{i,k}$ for the uplink, associated with a mobile i located in a cell k, is defined as:

$$\left(\frac{E_b}{N_o}\right)_{i,k} = \frac{W}{r_{i,k}} \frac{P_{i,k} h_{i,k}}{I_{\text{int}k} + I_{ext,k} + \eta_o W} \geq \gamma_i \quad i = 1..N \qquad (1)$$

with $I_{ext,k} = \sum_{\forall k' \neq k} \sum_{\forall l} P_{l,k'} h_{l,k}$ and $I_{\text{int},k} = \sum_{\forall i} P_{i,k} h_{i,k}$

where E_b is the bit energy, N_o the total interference density received at the base station, η_o the thermal noise spectral density, $I_{int,k.}$ and $I_{ext,k}$ the intracell and intercell interference, $P_{i,k}$ the transmitted power associated to the mobile i located in cell k, $h_{i,k}$ the path loss between MS i and the BS k, N the number of users in the cell k and W the available bandwidth in the cell (chip rate). The path loss is modeled considering the dependence with distance from MS to BS, the shadowing and the fast fading. The model is described in detail in section VI.

The base station scheduler is responsible for providing both bounded delay and fair sharing of the available wireless resources while the aim of a defined power control criterion is to meet the Bit Error Rate (BER) requirements of simultaneously transmitted packets.

Given a set of requirements, we adopt as optimization criterion to assign an optimum level of the transmitted powers for all the users in such a way that their sum is minimized, guaranteeing that the E_b/N_o requirements of all of the users are met. This criterion minimizes the interference caused to other cells increasing the system efficiency. It was shown that for a bandwidth W and N transmitter users, considering that power output constraints are applied to mobile stations, $0 < P_{i,k} < p_{i,k,\max}$, the power control problem in a cell is feasible if and only if [2]:

$$\sum_{j=1}^{N} \frac{1}{\left(\frac{W}{r_{j,k}\gamma_j} + 1\right)} \leq \frac{1-\eta}{(1+f)} \qquad (2)$$

where $$\eta = \frac{\eta_o W}{min_j \left[p_{j,k,max} h_{j,k} \left(\frac{W}{r_{j,k}\gamma_j} + 1 \right) \right]} \qquad (3)$$

and $$f = \frac{I_{ext,k}}{I_{\text{int},k}}$$

Note that, if there are no transmit power limits, the parameter η in (2) becomes equal to 0.
If condition (2) is satisfied for a set of rates and E_b/N_o values, then the power can be obtained using (4):

$$P_i = \frac{\eta_o W}{\hat{h}_{i,k} \left(\frac{W}{r_{i,k}\gamma_i} + 1 \right) C_{res}} \qquad C_{res} = (1+f) \left(\frac{1}{(1+f)} - \sum_{j=1}^{N} \frac{1}{\frac{W}{r_{j,k}\gamma_j} + 1} \right) \qquad (4)$$

Evidently, the minimum transmitted power criterion is only achieved if the path loss estimation is perfect. Since closed power control is performed on dedicated channels (DPDCH+DPCCH), the path loss estimation is very accurate, so we will assume that $\hat{h}_i$ almost compensate h_i. Imperfections in the power control mechanism are not considered in this work.

Equation (2) is a necessary and sufficient condition to guarantee E_b/N_o and rate requirements. However, note that, when the system load increases, the total power in a given cell becomes very dependent from the factor η. If no limitation is imposed, the total transmitted power in each cell could be very different, thus intercell interference and parameter f increase. As a consequence, the capacity of the system could decrease compensating the initial profit of adjusting parameter η to the minimum needed to limit MS power output. So, in order to limit the maximum total power received at the base station $I_{total,k}$, a minimum value of parameter η equal to 0.1 is considered. This means that thermal noise represents at least the 10% of the maximum total interference level, so we have an interference margin of 10dB.

Estimation of inter-cell/intra-cell ratio is required in order to perform the criterion. Several possibilities could be contemplated in order to obtain an optimal solution. This work evaluates perhaps the most simple, the viability of using as estimation of the ratio in a given frame the ratio measured in the frame before. Note that measurements at the base station allow to distinguish intra-cell interference from the total power received $I_{total,k.}$ On the other hand, to separate inter-cell interference from thermal noise, estimations based on measurements of background noise must be used. So, the measure of ratio f in a given frame implies also estimation. Simulations results showed in this work assume the thermal noise level is known and therefore the measures of ratio f are performed without error collecting at base station the received power from mobiles of the own and adjacent cells.
Estimation taking into account measures in more than one frame is not contemplated for the moment given that changes in charge conditions are shown to be frequent.

In any case, as it can be seen, perfect power control is required in order to satisfy the inequality. If the inequality is not satisfied, then such a power assignment does not exist and the Eb/No requirements of all users can not be met. Power control loops can be designed to adjust the power of a user on an individual basis, based on current conditions for that user. This paper assumes perfect channel estimation and power control.

Now, taking into account the minimum total transmitted power criterion, we can consider two transmission modes for delay tolerant users.

- In the first one, all users admitted in the system are allowed to transmit information, with a rate as higher as that allowed in the system to satisfy minimum power constraint requirements.
- For the second case, in a given time instant, only a limited number of users are allowed to transmit, while the remaining users can not transmit even though they are in contact with the base through a control channel.

Given that only a set of spreading factors (W/r_i) can be used in W-CDMA, only the second option will be analyzed in this paper, because the first option needs infinite granularity in the selection of the spreading factor if the power assignments must be optimized.

On the other hand, W-CDMA defines two types of dedicated physical channels: the dedicated physical data channel (DPDCH), used to carry dedicated data, and dedicated physical control channel (DPCCH), used to transmit control information [pilot bits, transmit-power control (TPC) commands, and optional transport format indicator (TFI)]. The DPCCH is transmitted continuously at a constant symbol rate and spreading factor of 256, with relatively low power and enabling physical maintenance (i.e. closed-loop power control, time synchronization, and up-link channel estimation for coherent demodulation). In the up-link, the DPDCH and DPCCH are transmitted in parallel in phase and quadrature-phase branches, respectively, using different orthogonal codes. Although there is no self-interference among DPDCH and DPCCH, we must consider the effect of the DPCCH channel coming from other users. Thus, the condition must be satisfied in order to allow the transmission of M<N users in a given time-slot is:

$$\sum_{i=1}^{M} \frac{1}{\dfrac{W}{r_{d,i}\gamma_{d,i}(1+m)}+1} + \sum_{j=M+1}^{N} \frac{1}{\dfrac{W}{r_{c,j}\gamma_{c,j}}+1} < \frac{1-\eta}{1+f} \quad (5)$$

with M=1..N and $m = \dfrac{P_{c,i}}{P_{d,i}}$.

wherein r_d, , r_c are the rates, γ_d, γ_c are the E_b/N_o constraints for DPDCH and DPCCH respectively, and m is the amount of overhead introduced by DPCCH.
Starting from here, we will consider 1 as the maximum available capacity in the cell. So, C is the remaining capacity, C_{res} is the residual capacity after assigning all permits in a given frame, η is the reserved capacity needed to guaranty that powers assigned to mobiles stations are lower than power constraints, η_{limit} is the minimum reserved capacity in order to constraint the total interference received at BS, and C_i is the capacity consumed by a mobile station.

$$C_i = \frac{1}{\dfrac{W}{r_{d,i}\gamma_{d,i}(1+m)}+1} \quad \text{or} \quad C_i = \frac{1}{\dfrac{W}{r_{c,i}\gamma_{c,i}}+1} \quad (6)$$

The scheduling algorithm at the base station arranges the user transmissions according with an algorithm related with delay requirements (explained in section IV) and assigns permits to transmit as long as condition (5) is satisfied. So the scheduling algorithm has to consider the channel conditions in addition to delay and rate QoS requirements. Mobile stations that can not meet Eb/No requirements, due to the absence of enough resources, are delayed. Then, unused resources (power and time instant of transmission) are assigned to the rest of mobile stations. When reserved capacity, η_i, required by a mobile station i in order to achieve Eb/No requirement is lower than η_{limit}=0.1, the mobile station is allowed to transmit as long as condition (5) is satisfied. However, if the reserved capacity, η_i, is lower than the remaining capacity but higher than η_{limit}=0.1 in a given instant, we have to make some considerations prior to decide if the mobile station should be allowed to transmit on DPDCH.

1) If the capacity wasted by all users waiting to transmit (assuming their nominal rates) is lower than the remaining capacity C, and the reserved capacity η_i is lower than Cres resulting after considering all mobiles transmitting on DPDCH with $\eta=\eta_{limit}$=0.1, then, the mobile is allowed to transmit and η is updated with the new value. After that, all mobiles that require $\eta_i \leq \eta$ are automatically allowed to transmit in the same frame.

2) If the capacity wasted by all users waiting to transmit exceed the capacity of the system, two alternatives are considered:

2.1) Mobile stations which require $\eta_i>(\eta_{limit}=0.1)$ are delayed. So, mobiles with bad channel conditions are blocked in order to improve global system efficiency allowing the transmission of a higher number of users. Note that given a level of thermal noise, a maximum output transmitted power for MS and a maximum radio to the cell, η_{limit}=0.1 imposes a maximum allowed path loss to the mobiles placed in the limit of the cell.

2.2) Mobile stations that require $\eta_i>(\eta_{limit}=0.1)$ are allowed to transmit if after updating the value of $\eta=\eta_{i,}$ condition (5) can be satisfied. So no limitation in channel conditions is imposed in advance.

Simulation results presented in sections VII evaluate the performance of the two alternatives.
Note that, a priori, every mobile having permit to transmit must reach its Eb/No constraints. Only imperfections in estimation of ratio f could prevent it given that perfect channel estimation is assumed. Note also that power allocation to every mobile has a common parameter, $\eta_o W/C_{res}$, while the value of C_i is known by mobiles and corrections associated with h_i are controlled by the closed loop power control

IV. SCHEDULING DISCIPLINES.

In ETSI WCDMA scheduling is a resource allocation function closely connected to the transport format selection (rate of the dedicated channel, coding used, etc). During communication, MAC scheduler selects the appropriate transport format from an assigned transport format set for each active transport channel depending on the source rate and radio resource limitations. The selection can be done on a 10ms frame basis or slower. Depending on the selected transport format, one or more transport blocks can be transmitted. The main objective of the scheduler is to integrate traffic sources with different transmission rates, priorities, delays and packet loss requirements optimizing the uplink channel utilization. We propose and evaluate a scheduling strategy based on both static and dynamic priorities in order to ensure QoS requirements in terms of rate and minimum delay. Between service classes, static priorities are used. We assume that minimum capacity is guaranteed for non-delay constrained traffic (10%), while the remaining is assigned with preemptive priority to delay constraint traffic.
For all packets belonging to the same class, dynamic priorities based on lifetime of packets (Time Stamp Strategy) are applied. Priorities based on lifetime, are calculated as:

$$vt_k \leftarrow max(d_i-(t-t_a), vt_{k-1}+T) \qquad (7)$$

The lifetime (in frames) of the packet placed on the first places of the queue of the terminal, when it sends a request for transmit, is calculated as $d_i-(t-t_a)$,, where d_i is the delay tolerance of the packet (normalized to the frame duration) and t and t_a are respectively the current frame number and the frame number when the packet was generated. The lifetime of the other packets is calculated according to equation (7), where T is the estimated packet inter-arrival time. The base station has a request table containing terminal requirements and the lifetimes of next packets to be transmitted. The lifetimes are updated and decreased at each frame. The base station has not to be informed about the arrival of each new packet because it can estimate the time of the next packet applying the same scheme. Only in case of a faulty estimation, the wireless terminal has to transmit an explicit capacity request in order to resynchronize the estimation algorithm. The packets to be transmitted are scheduled in increasing order of lifetime. If vt>d, the next packet to be reserved has not been generated yet. Therefore the reservation will be inserted in service queue as soon as vt=d. Packets with delay constraints are retransmitted until they are correctly received, or their deadlines are violated (in this case packets are dropped). As a consequence of the dynamic frame assignment, an error packet can be recovered immediately through a retransmission attempt. In any case, when all users have received its corresponding service, remaining capacity is shared by increasing the rate of users with packets waiting to be transmitted.

We will present the results of simulation experiments that illustrate the performance of the scheduling algorithms in terms of average and maximum delay, throughput and packet loss rate. When service degradations occur, and in order to evaluate how fairly they are distributed among the users that belong to the same traffic class, we assess not only the mean values, but also the distributions of QoS parameters.

V. Traffic Source Models.

The paper considers two kind of traffic sources:

- Real Time Services (Class I). Data services with delay constraints of 300 ms and a Block Error Rate (BLER)<10^{-2}.
- Non-real Time Services (Class II). Data services with non-delay constraints and a Block Error Rate (BLER)<10^{-2}. Two types of services are considered here.

Convolutional coding rate ½ together with a retransmission scheme (ARQ) are used to achieve BLER=10^{-2}.

Although circuit-switched mode transmission has been proposed by ETSI for Class I, packet–switched and activity factor <100% have been considered in this work, in order to support multimedia real time services. Therefore, in our simulations, real-time sessions are based on Packet Calls with a number of packets exponentially distributed with mean 35 packets, while a service of 36kps (transport block of 360bits) is assumed although real transmission rate is 120kbps, so a spreading factor of 32 is used. Average inter-packet arrival time is 10ms while packet call inter arrival time is exponentially distributed with mean 1s.

From the viewpoint of non-real time sessions, the traffic sources are based on the model presented in [3]. Two types of traffic generators are considered: 8Kbps and 32Kbps data rate services. In both cases, sessions consist of a sequence of packet calls during which several packets may be generated. Normal Pareto distribution with mean 480 bytes is considered for the data packet size, while an inter arrival time between packets of 500ms is assumed for the 8Kbps data traffic and 125ms for the 32Kbps data traffic, being 25 the average number of packets within a packet call in both of them. Average time between the last packet of a packet call and the next packet call is 4s. Packets are segmented in PDU contained in transport blocks of 360 bits (real transmission of 120Kbps and packet size of 1200 bits) when 32Kbps is considered and in transport blocks of 168 bits (real transmission of 60Kbps and packet size of 600bits) when 8Kbps is assumed.

Power ratios of –2.69dB and –3.59 dB between DPCCH and PDDCH are considered for transport block size of 168 and 360 bits respectively, as proposed in [4]. Link level results for static propagation conditions are used when only shadowing fading is considered. These conditions give a requirement of Eb/No=2.06dB and Eb/No=1.75dB (considering overhead of DPCCH) to achieve a BLER=10^{-2}, assuming an interleaving of 10ms.

Additionally, when a multi-path-fading environment is evaluated, link level results for multipath test case 3 fading channel, proposed in [4], are used. Eb/No=2.73dB for 168bits and Eb/No=2.3dB for 360bits are required to achieve a BLER=10^{-2} assuming an interleaving of 10ms.

The return channel (downlink DPDCH-PDCCH) is assumed to be error free.

VI. System model

In this section we propose a cellular system model in order to perform intercell interference. The whole service area is divided into hexagonal cells and each cell is served by a Base Station located at the center of the cell. We use a cellular system model with 19 cells as shown in Fig 1. Cell C_0 is taken as the reference cell. In the intercell interference analysis for the seven inner cells C-0 to C-6, only interference from the first-tier of adjacent cells is taken into consideration. Cells C-8 to C-19 are only interfered by the nearest cells.

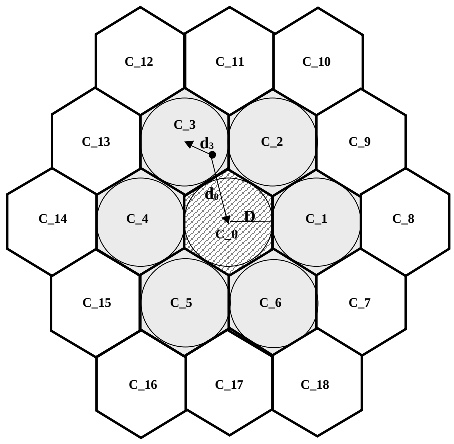

Figure 1

The geometry of each cell is modeled by the radius of the cell (D). Macrocell propagation model proposed in [5] is adopted for path loss. Considering a carrier frequency of 2GHz and a base station antenna height of 15 meter, the formula of path loss becomes:

$$L = 128.1 + 37.6 Log10(d) \quad (dB) \tag{8}$$

where d is BS-MS separation in kilometers.

Log-normally distributed shadowing with standard deviation of $\sigma = 6.25dB$ is added, so the resulting path loss between a given Mobile Station i and the Base Station k, ($h_{i,,k}$) is :

$$10 \log h_{i,k} = L_k + \zeta_k \tag{9}$$

where ζ_k is the dB attenuation due to shadowing. Since analysis of other cell interference involves comparison of propagation losses among two or more base stations, the model must take into consideration the dependence of the propagation losses to two different base station from a mobile station. ζ_k may be expressed as the weighted sum of a component, ξ, in the near field of the user, which is common to all base stations, and a component, ξ_k, which is independent from one base station to another, so:

$$\begin{aligned} &\varsigma_k = a\xi + b\xi_k \quad \text{where } a^2 + b^2 = 1 \\ &\mathrm{Var}(\varsigma_k) = \mathrm{Var}(\xi) = Var(\xi_k) = \sigma^2 \quad a = b = \frac{1}{2} \end{aligned} \tag{10}$$

In order to model shadow fading, we have assumed that channel conditions change every 1s, so Gaussian distributed random variables, ξ, and ξ_k, are generated every 100frames (1s-14 meters with 50Km/h mobility users), and lineal interpolation is applied in order to calculate channel attenuation in the intermediate frames. Interpolation decreases standard deviation of log-normally distributed shadowing although log-normal statistic is maintained. So, in order to achieve a real standard deviation of 6.25dB, random variables with standard deviation of $\sigma = 8dB$ are used.

Additionally, a multi-path time-varying environment according with models proposed in [4] is considered. In this case, all taps have Classical Doppler Spectrum and independent channels are considered from MS to BS.
In any case, 11dB antenna gain in base station and thermal noise power of –103dBm are assumed [5].
On the other hand, mobiles with a maximum output power of 27 dBm are considered according with class 2 defined in [4].

Mobility is limited within the bounds of the circle of radius D. Mobiles move with a speed from 25 to 50Km/h, and they can randomly change its trajectory every 1sec.
Each mobile is power controlled with respect to its home cell site. Although soft handoff has been shown can increase the capacity of the reverse link in CDMA systems, has not been considered here [6]. The purpose of this work is to evaluate the maximum efficiency of the resources management strategy proposed within a cell without considering mobility between cells. Partial results obtained here could be additionally improved in a practical system with soft handoff.

VII. SIMULATION RESULS

In this section we present some results to assess the performance of the proposed radio resource management. We have considered a system with 30 class I mobiles and variable number of class II mobiles in each cell, (all cells, from C-0 to C-19, support the same number of mobiles). In particular, we have considered that 50% of class II mobiles require a service of 8Kbps data rate (class II.1) while the other 50% specify a service of 32Kbps (class II.2). The total number of class II mobiles, with a dedicated code within the system, has been increased from 20 to 64 in order to find the limits of the system capacity. It is necessary to remember that only some of them require to transmit simultaneously. Perfect closed power control is assumed. So, deviations from required Eb/No are only due to the error in the estimation of ratio f between external and internal interference. Capacity required for request has been shown to be smaller than the 2% reserved to them so they do not cause degradations in Eb/No. Several simulations of 2000 sec (200000 frames) have been carried out to average the results.
Two scenarios have been considered, compared and evaluated. In the first one, only shadow fading has been assumed (link level results for static propagation conditions have been used).
In the second one, simulations have been performed with a full channel model that takes into account shadow fading in addition to fast fading channel (link level results for case 3 fading channel have been used).
In both scenarios, we have evaluated the performance of the two alternatives, 2.1 and 2.2, described in section V. The study assume transmission in both DPDCH and DPCCH and considers that mobiles are always associated to the nearest base station. The radius of the cells is D=2Km. This means that a class I or class II.1 mobile, situated in the border of the cell, can only tolerate 10dB of attenuation due to shadow and fast fading if $\eta=\eta_{limit}=0.1$, although worse attenuation conditions could be tolerated if there is enough resources. Simulations with smaller radius (1Km and 1.5Km) and higher tolerance (20dB and 15dB) are made although results have been worse due the increase of ratio f.
Figure 2 and figure 3 show the dropping probability of class I mobiles (scenario 1 and 2) and mean packet delay of class I and class II mobiles (scenario 2). If dropping probability of 1% for class I is assumed as criterion of quality, the number of users supported by the system considering full model channel is 78, whereas, considering only shadow fading the number is 90. In any case, the number of users supported in full channel models is lower, although no significant differences could be observed between alternatives 2.1 and 2.2 within the margin of operation of the system. However, results suggest that the option of imposing a maximum allowed path loss to mobiles could offer best results (see figure 1 and 2) if the services become more tolerant to retard or some mechanism is implemented in order to compensate delayed class I mobiles.

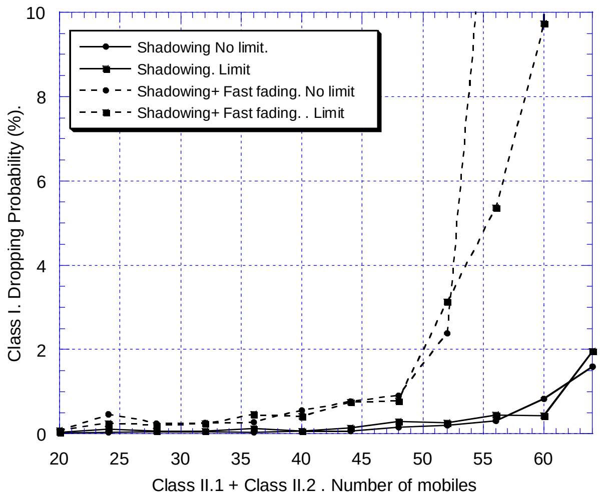

Figure 2

Figure 4 and 5 show probability distribution function of Eb/No considering only shadow fading and considering full channel model, respectively. Figure 4 shows that deviations with respect to the desired Eb/No, despite they are considerable, guarantee that 90% of packet are received with a Eb/No above 1.4dB and 1.8dB (BLER<3.10^{-2}).

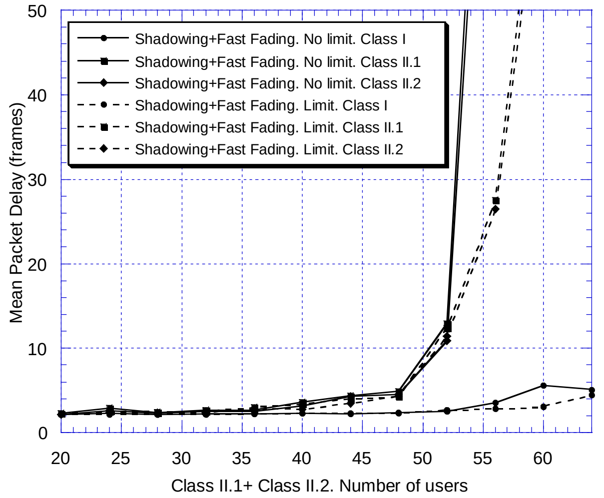

Figure 3

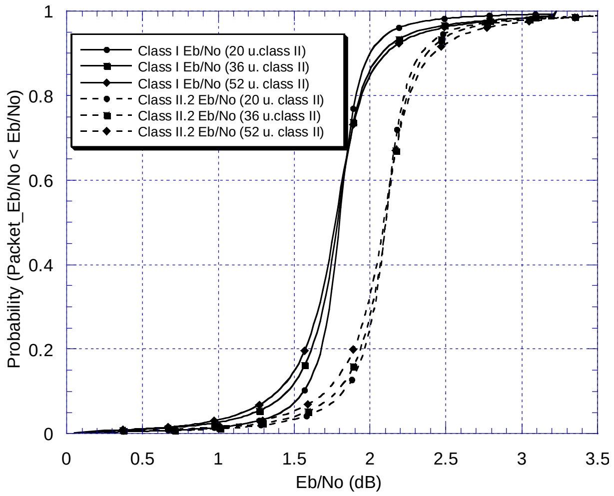

Figure 4

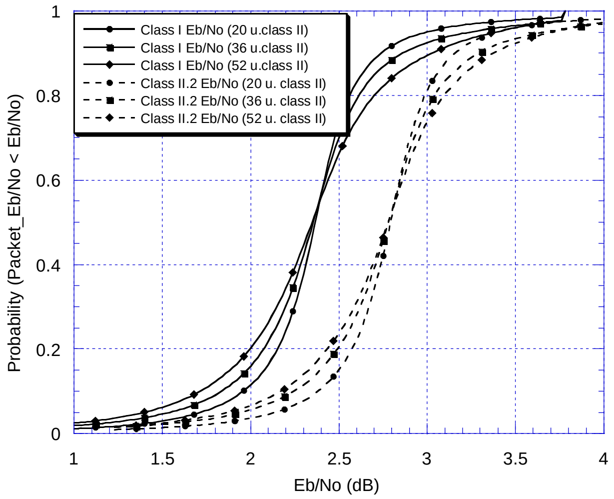

Figure 5

Figure 5 shows higher deviations from the desired Eb/No, although 90% users have guaranteed that BLER<3.5.10^{-2}. A margin in the desired Eb/No could be estimated in order to perform BLER=10^{-2}. Deviations in full channel fading are higher because error in estimation of ratio f is higher, as it can be seen in figure 6. This is because ratio f is also higher, about 0.82 in the margin of interest of full channel model (prob. Dropping<1%) contrary to 0.7 of shadow fading. The absolute value of the estimation error is more important than the relative value. In any case results show that the scheduling mechanism offers differentiated quality of service in a scenario with multimedia traffic, realistic radio channel conditions and mobility.

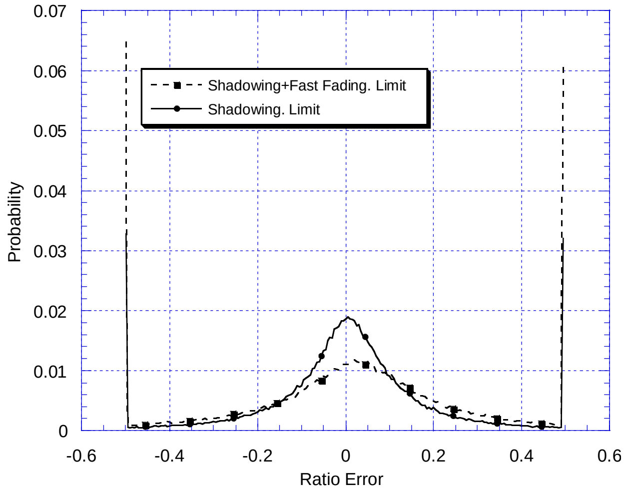

Figure 6

VIII. CONCLUSIONS

We have evaluated the performance of a centralized demand assignment protocol implemented over the UMTS Dedicated Channel. Distributed Power Control is implemented. The scheduling algorithm, based on channel condition and on static priorities and dynamic priorities (related with delay requirements), provide semantic and temporal transparency inside the cell. Level of interference is maintained under a threshold, even in absence of a centralized controller. The study has been performed in various radio channel conditions.

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