An Admission Control Algorithm to Manage High Bit Rate Static Users in W-CDMA

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ABSTRACT

High bit rate multimedia services will play an important role in 3G communication systems like UMTS. The high requirements of these services introduce new challenges in order to achieve an efficient use of the available spectrum by means of effective Admission Control algorithms and other Radio Resource Management (RRM) strategies. On the other hand, the usual static behaviour of high bit rate users claims for the introduction of techniques that can improve performance taking into account the easier predictability in resource consumption. In this framework, this paper presents an admission control strategy to manage high bit rate static users in the downlink direction of W-CDMA. The proposed policy is conceived to predict the future transmitted power by making use of the user's measurements reports. The system performance is evaluated through simulations with a 384 kb/s service and it is also compared with a reference admission control algorithm conceived for mobility scenarios with more uncertainty in the user location. The proposed algorithm exhibits a better performance in terms of admission probability and throughput thus fitting better the achieved capacity in the planned coverage area.

I. INTRODUCTION

Data traffic will play a crucial role in the Universal Mobile Telecommunication System (UMTS) [1], where high bit rates up to 384 kb/s are envisaged for macrocellular environments. The mechanisms to support these kind of services must be significantly different from those common for traditional 2G services (i.e. voice), where all the users have the same characteristics and requirements in terms of bit rate and Quality of Service (QoS).

In order to accept and adopt the new facilities and to be willing to pay for (at least initially) costly terminals and services in UMTS, users should experience significantly different service characteristics. In that sense, high bit rate services will be a key component for the success of 3G technology because they constitute an essential differentiation with respect to previous 2.5G and 2G systems.

In addition to the bit rate, QoS will also be crucial for 3G success from the user point of view. It should be provided by means of a proper utilization of the air interface resources, that at the same time should assure the planned coverage area and offer a high system capacity to maximize operators' revenue. The trade-off between all these opposite requirements is faced by the use of Radio Resource Management (RRM) strategies. RRM strategies at network level include admission control, congestion control, packet scheduling and code management [2][3].

In this context, it becomes prime important to identify the key elements characterising high bit rate services and anticipate the required mechanisms to support these services through the air interface in a suitable and optimised manner. In particular, it can be considered that users receiving high bit rate services, typically with laptops in scenarios like offices, airports, etc., use to be static or at least with a very limited mobility. This fact gives room to propose more sophisticated RRM strategies, which may provide significant performance improvements.

This paper focuses on downlink Admission Control (AC), since downlink is normally the limiting direction in high bit rate services, because of their usual asymmetry. The Admission Control decides whether a new request to set-up or reconfigure a radio bearer can be accepted, in both uplink and downlink directions. Different admission control strategies have been proposed and analyzed in the open literature [4-10]. In [6], a downlink admission control strategy considering real-time and non-real-time services is proposed. Other strategies are based on the classification of users in a cell [7], where a priority-oriented call admission control is presented based on the release of radio resources by lower priority classes to the higher priority classes when necessary. In [8] a strategy is studied that extends the assured forwarding model to support the delivery of quasi constant bit-rate (QCBR) traffic streams on the downlink. The admission control strategy in [9] is based on maximum base station transmit power and service class priority. Nevertheless, and to the author's knowledge, the problem of admission control for high bit rate users in W-CDMA has not been addressed so far in the open literature. In this case, the adoption of an appropriate admission control policy results in a significant improvement of the system behaviour. In particular, this paper proposes an algorithm that benefits from the easier predictability in terms of power consumption of static high bit rate users. It makes use of the measurement reports provided by the terminal during the call set-up process in order to have a proper estimation of the required power. The proposed algorithm is compared with another one that assumes an average power distribution between users.

This paper is organized as follows. Section II presents the two downlink admission control strategies based on power measurements. In turn, Section III provides an overview of the simulation model that is used to assess the system performance and Section IV presents and discusses the results for the different considered conditions. Conclusions are summarized in Section V.

II. DOWNLINK ADMISSION CONTROL

Downlink admission control strategies are usually based on power consumption, since it is the main resource shared between the users connected to the Node-B. As a result, admission control strategies based on power estimation must take into account whether or not the Node-B has enough power to ensure the agreed QoS requirements of both the new user and the already accepted users. The general expression of an admission control based on power estimation that occurs in the i-th frame can be represented by [10]:

$$P_{AV}(i) + \Delta P_T(i) \le P_T^* \qquad (1)$$

where $P_{AV}(i)$ is the averaged Node-B transmitted power in the i-th frame, $\Delta P_T(i)$ is the estimated power increase due to the acceptance of the new user and P_T^* is a certain admission threshold.

It should be mentioned that the algorithm must average the transmitted power measurements in order to obtain a long-term estimate without including the effects of the instantaneous channel and traffic variability. In particular, the algorithm averages the Node-B transmitted power with a slide window that takes into account the power consumption along the last T frames [10]:

$$P_{AV}(i) = \frac{\sum_{j=1}^{T} P_T(i-j)}{T} \qquad (2)$$

where $P_T(i)$ is the instantaneous Node-B transmitted power at the i-th frame.

Note that provided that N users are already accepted in the cell, the total transmitted power can be expressed as:

$$P_T(i) = P_c + \sum_{n=1}^{N} P_{T,n}(i) \qquad (3)$$

where $P_{T,n}(i)$ is the power devoted to the n-th user in the i-th frame, which should suffice to provide the agreed quality level and is adjusted by means of downlink power control. In turn, P_c is the power devoted to the pilot and the common control channels.

Due to power limitations, the total transmitted power should be below the maximum power available at the Node-B P_{max}. Besides, the power devoted to every single connection n should also be limited to $P_{max,n}$ in order to avoid that certain users that can be exceptionally far from the base station consume too much power, so that:

$$P_{T,n}(i) \le P_{\max.n} \qquad (4)$$

By appropriately setting the admission control parameters the appearance of the following two events, that impact operator's revenue and user's satisfaction, can be minimised:

1. Bad rejections, which occur whenever the admission control algorithm rejects a connection request although there was actually enough capacity in the system to allocate it. In this case, capacity is wasted and operator's revenue is not optimized. Bad rejection can be due to e.g. a too low admission threshold or a too pessimistic power increase estimate (ΔP_T is higher than required).

2. Bad admissions, which occur whenever the admission control algorithm accepts a connection request although there was actually not enough capacity in the system to allocate it. In this case, QoS guarantees are not provided and user's satisfaction is degraded. Bad admission can be due to e.g. a too high admission threshold or a too optimistic power increase estimate (ΔP_T is lower than required).

Since high bit rate users are high power demanding users, the term ΔP_T in (1) may be an important fraction of the total available power and therefore the power increase estimation becomes a key and critical issue. In order to gain insight, two possibilities are studied:

Algorithm #1: Power Averaging Based Admission Control (PABAC)

In this case the power increase required by new users is estimated as the average power transmitted by the already accepted users. So, assuming that all the users in a given moment are equal in terms of (E_b/N_o) and bit rate requirements, it can be expressed as [10]:

$$\Delta P_T(i) = \frac{P_{AV}(i) - P_c}{N} \qquad (5)$$

where N is the current number of users already accepted in the cell at frame i. The rationale behind this algorithm relays in the fact that, when mobility is not a priori known, user power consumption may vary along connection lifetime depending on its location and on the location of the rest of users. As a result, an average estimation provides a good trade-off between bad rejections and bad admissions.

Note that for the algorithm operation it is only required to average and update the total transmitted power by the Node-B without including common control channels, as well as to keep track of the number of the already connected users in the cell.

Algorithm # 2: Path Loss Estimation Based Admission Control (PLEBAC)

When considering static users, the power increase ΔP_T can be more accurately estimated by taking into account user measurement reports provided during the call set-up process. As stated in 3GPP specifications [11], these reports include the total path loss with respect to the serving cell and their periodicity can range from 0.25s up to 16s. Notice also that the observation of path loss reports during a period of time could be used to distinguish whether a user is static or not.

The algorithm defines a set of M+1 path loss ranges $\{PL_0, PL_1, ...PL_M\}$ where:

$$PL_k(dB) = PL_0(dB) + k\Delta(dB) \qquad (6)$$

The k-th range (k=1..M-1) includes all the path loss values higher or equal than PL_k and lower than PL_{k+1}. For the special cases k=0 and k=M, they include the values lower than PL_0 and higher than PL_M, respectively. The resolution is given by Δ.

A correspondence is established between each path loss range and a power increase estimation ΔP_T. For the k-th range, this correspondence is obtained from the average with a slide window of T frames of the transmitted power to already accepted users whose reported path loss falls within this range. This averaging process allows to adapt the power estimation to interference and traffic variations. Then, the power demand estimation in the i-th frame for the k-th range is defined as:

$$\Delta P_T(k,i) = \frac{1}{T}\sum_{j=1}^{T}\frac{1}{N_{k,i-j}}\sum_{n=1}^{N_{k,i-j}} P_{T,n}(i-j) \qquad (7)$$

where $N_{k,i-j}$ is the number of accepted users at frame i-j whose last path loss report falls within the k-th range.

Therefore, when admission control is executed at the i-th frame for a user that has reported a path loss in the k-th range PL_k, the algorithm checks (1) with the corresponding estimated power increase $\Delta P_T(k,i)$.

We note that, for static users, $\Delta P_T(k,i)$ provides a good estimate of the power that will be transmitted to the user along the connection lifetime.

III. SYSTEM MODEL

In order to assess the potentials of the proposed power increase estimation algorithms, a set of system level simulations have been carried out. Simulations consider a CBR 384 kb/s service. The propagation models are defined in [12] for macrocellular environment. The characteristics of the radio access bearer are given by a Transmission Time Interval (TTI) of 20 ms, a Transport Block Size (TB) size of 640 bits and a Transport Format allowing to send 12 Transport Blocks per TTI. Taking into account the CRC and turbo-encoding process such transmission requires a spreading factor equal to SF=4. For the PLEBAC admission control algorithm, PL_0=70dB, PL_M=155 dB and a resolution of Δ=5 dB have been considered. The rest of simulation parameters are summarized in Table I.

Table I. Simulation parameters

Parameter	**Value**
Scenario size	9 Km x 9 Km
Chip rate W	3.84 Mcps
Frame duration	10 ms
BS parameters	
Cell radius	2000 m
Cell type	Omnidirectional
Maximum DL power P_{max}	43 dBm
Maximum DL power per user $P_{max,n}$	38 dBm
Maximum admission power P_T^*	40 dBm
Pilot and common control channels power P_c	30 dBm
Thermal noise	-106 dBm
Shadowing deviation	10 dB
Shadowing decorrelation length	20 m
Orthogonality factor	0.4
Measurement period (*T*)	1 s
UE parameters	
Number of users	30
Maximum transmitted power	21 dBm
Minimum transmitted power	-44 dBm
Thermal noise	-100 dBm
Mobile speed	0 km/h
Handover parameters	
Active Set maximum size	1
AS_Rep_Hyst (replacement Hysteresis)	1 dB
Time to trigger HO	0.5 s
Traffic model	
Call duration	120 s
Offered bit rate	384 kb/s (CBR)
Activity factor	1
Call rate	29 calls/h/user
QoS parameters	
Block Error Rate (BLER) target	1 %

The characterization of the physical layer has been made by means of a link level simulator, that feeds the system level simulator with the transport Block Error Rate (BLER) statistics for each average (E_b/N_o). This characterization includes a detailed evaluation of all the processes involved in the physical layer, like the estimation of the channel, antenna diversity, rate 1/3 turbo coding as well as the 1500 Hz closed loop power control. Similarly, these results at link level are used later to execute the outer loop power control (i.e. to compute the required Eb/No, given a BLER requirement).

IV. RESULTS

This section presents some representative results in order to evaluate the performance of the previously described algorithms under different situations with the purpose of identifying the key issues that should be taken into account when developing the admission control algorithm and setting its parameters.

The essential difference between PLEBAC and PABAC behaviour is presented in Figure 1, that shows the ΔP_T value that is applied as a function of the path loss in both algorithms. With an admission based on the averaged power (PABAC), the power increase required by a new user is constant. In contrast, with an admission based on path loss (PLEBAC), the estimated value of the power increase required by the new user adjusts better to the real value, as it increases with path loss.

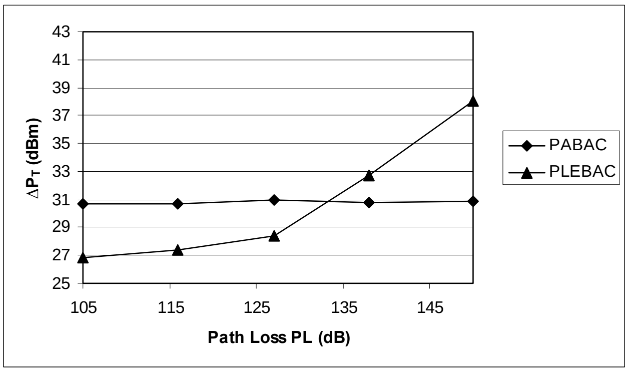

Figure 1. Average power increase required by new users

Figure 2 illustrates the impact of the admission control on the admission probability, represented as a function of the measured path loss. Similarly, Figure 3 represents the measured BLER as a function of the path loss. With PABAC, the admission probability does not depend on the path loss. On the contrary, with PLEBAC admission probability is improved for low path losses (i.e. for users close to the cell) and it is reduced for high path losses (i.e. for users at the cell edge). In any case, notice that in Figure 3 it can be observed that PLEBAC tends to reject those users whose QoS in terms of BLER cannot be guaranteed (i.e. those with high path loss values) while it admits those users whose BLER is guaranteed at the target value of 1%. Thus, PLEBAC reduces both bad admissions (i.e. the users with high path loss whose BLER is not assured) and bad rejections (i.e. the users with low path loss whose BLER could be assured). On the contrary, PABAC is not able to discriminate bad admissions and bad rejections.

Table II presents the overall performance statistics. Notice that the overall admission probability remains more or less the same in both cases. However, the reduction of bad rejections and bad admissions turns into an overall BLER reduction, a lower power consumption and an increase in system throughput. As a result, it can be concluded that PLEBAC strategy is better adapted to user's distribution in the network than PABAC.

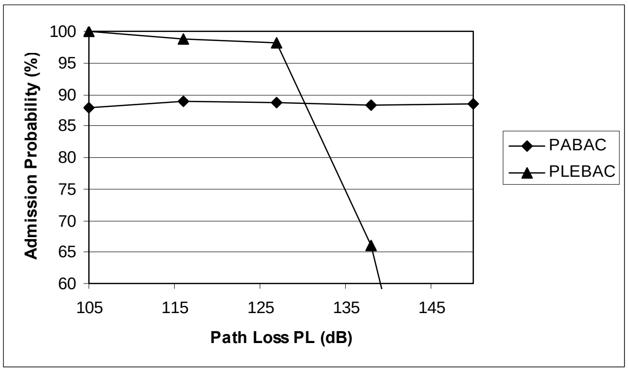

Figure 2. Admission probability

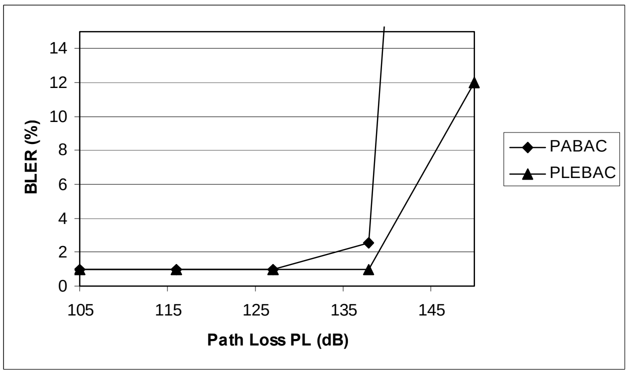

Figure 3. Downlink BLER

Table II. Overall performance measurements

Statistic	**PABAC**	**PLEBAC**
Admission Probability (%)	87.97	87.67
BLER (%)	4.85	1.0
Average DL Transmitted Power per user (dBm)	30.77	28.59
Total throughput (Mb/s)	1.08	1.48

Another interesting statistic is the total throughput as a function of the path loss, presented in Figure 4. Since the admission probability is higher for low path losses with PLEBAC, the total throughput is also higher in this region, thanks to avoiding bad rejections. On the other hand, for high path losses, there is not any significant difference between both admission controls in terms of throughput. Although PABAC provides a higher admission probability, it is not reflected as a higher throughput because of the degradation observed by users far from the base station that shouldn't have been admitted. Moreover, Figure 5 shows the downlink throughput from the user point of view for both algorithms. As it can be seen, users with high path loss levels are those who have a worse throughput, due to a high block error rate. Nevertheless, it can be seen the positive influence of the PLEBAC algorithm achieving significantly higher throughput per user.

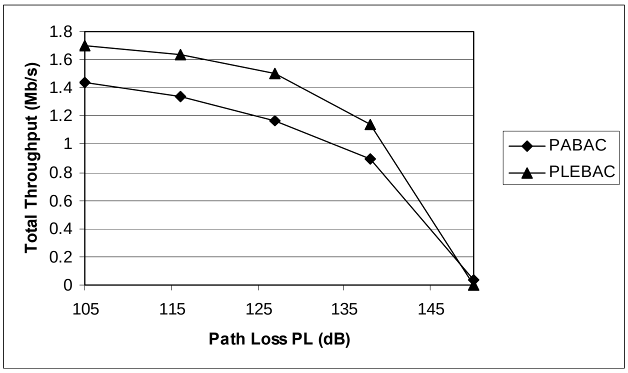

Figure 4. Downlink Total Throughput

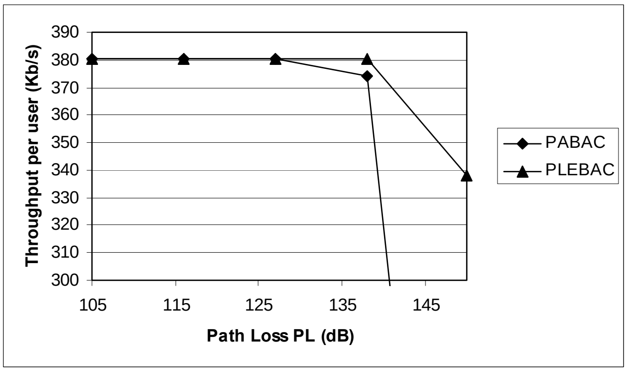

Figure 5. Downlink Throughput per user

V. CONCLUSIONS

This paper has addressed the problem of high bit rate static users, that are expected to be very important in 3G systems. The peculiarities arising from these services have claimed for more advanced RRM solutions. In this sense, an Admission Control strategy based on user's measurements reports on path loss (PLEBAC) in the downlink direction has been proposed and compared with a reference algorithm (PABAC) based on the average power transmitted by the Node-B entity. This proposed algorithm becomes an effective policy to allocate resources to high bit rate static users. Results show that both bad rejections and bad admissions are improved.

ACKNOWLEDGEMENTS

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