PLEBAC: A New Downlink Admission Control for UTRAN-FDD

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Abstract.- This paper deals with the problem of admission control in the downlink of W-CDMA, where high bit rate data services will play an important role in the downlink of W-CDMA. 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 data traffic users claims for the introduction of techniques that can take advantage of the easier predictability in resource consumption thus achieving a better performance. In particular, this paper presents the PLEBAC (Path Loss Estimation Based Admission Control) algorithm, conceived to predict the future required transmitted power based on path loss measurements reported by the terminal. The algorithm is evaluated under different traffic conditions and cell radii and compared with a reference admission control, obtaining a significant performance improvement in terms of throughput especially for high service bit rates and high cell radius.

I. INTRODUCTION

The flexibility in the provision of multiple bit rate services in 3G communication systems will allow users to benefit from services better adjusted to their specific requirements. This is expected to be one of the main features for which users will be willing to pay for, at least initially, costly terminals and services in 3G.

In addition to higher bit rates, QoS (Quality of Service) 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, which 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 [1][2].

In this context, it becomes prime important to identify the key elements characterising the different services and anticipate the required mechanisms to support these services through the air interface in a suitable and optimised manner. In particular, users that receive data traffic 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.

In particular, this paper focuses on downlink Admission Control (AC), since downlink is normally the limiting direction in data traffic 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.

Many AC strategies have been proposed and analyzed in the open literature [4-10]. In [5], 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, like in [6] 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 [7] 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 [8] is based on maximum base station transmit power and service class priority. Nevertheless, and to the author's best knowledge, the exploitation of the usual static nature of data traffic in W-CDMA for admission control purposes has not been addressed so far in the open literature. In this case, the adoption of an advanced admission control policy that takes path loss reports into account results in a significant improvement of the system performance.

Under this framework, this paper proposes an algorithm that benefits from the easier predictability in terms of power consumption of static data users. It makes use of the measurement reports provided by the terminal during the call set-up process in order to have a more accurate estimation of the required power along the connection time. The proposed algorithm is evaluated under different conditions of service bit rate and cell radii and compared against a reference algorithm. Furthermore, the paper also establishes a suitable metric to compare different downlink admission control algorithms based on the difference between the power predicted in the admission control phase and the real transmitted power.

This paper is organized as follows. Section II presents the downlink admission control strategy based on path loss 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 scenarios. Conclusions are summarized in Section V.

II. Admission Control Algorithm Description

Downlink admission control is usually based on power consumption measurements and estimates, since it is the main resource shared among the users connected to the base station [10][11]. The main function of AC is to decide in a specific point of time (i.e. when there is a connection request) if the base station will have enough power to ensure the agreed QoS requirements to both the new user and the already accepted users along the connection time duration. Clearly, the better the estimations on the required transmitted power levels the more accurate the AC decisions will be. Notice that the uncertainty associated to AC decisions may lead to the two following events:

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.
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.

The Path Loss Estimation Based Admission Control algorithm (PLEBAC) proposed in this paper is also based on power consumption. Nevertheless, the novelty is that it takes path loss measurements into account in order to achieve lower bad rejection and bad admission decisions. The PLEBAC algorithm applied at the i-th frame can be formulated as follows:

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

where $P_{AV}(i)$ is the averaged base station 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.

In order to obtain a long-term estimate of the base station transmitted power without including the effects of the instantaneous channel and traffic variability it is necessary to average the transmitted power measurements. In particular, the algorithm averages the base station transmitted power with a slide window that takes into account the power consumption along the last T frames:

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

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

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

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

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 base station 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 too far from the base station consume too much power, so that:

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

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 [12], 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, by observing the variation range on successive reported path losses.

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

$$PL_k(dB) = PL_0(dB) + k\Delta(dB) \quad (5)$$

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 adapting 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:

$$\Delta P_T(k,i) = \frac{1}{T}\sum_{j=1}^{T}\frac{1}{N_{k,i-j}}\sum_{n=1}^{N_{k,i-j}} P_{T,n}(i-j) \qquad (6)$$

where $N_{k,i-j}$ is the number of accepted users at $(i-j)$-th frame 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. As a result, the algorithm can reduce bad rejections due to a too pessimistic power increase estimate (ΔP_T is higher than required) as well as bad admissions due to a too optimistic power increase estimate (ΔP_T is lower than required).

III. System Model

In order to assess the potential of the proposed PLEBAC algorithm, a set of system level simulations have been carried out. Different scenarios have been considered with different cell radii, ranging from 500 m up to 2 Km. The propagation models are defined in [13]. The corresponding transmission rates and spreading factors of the different radio access bearers are 384 kb/s (SF=4), 256 kb/s (SF=8), 128 kb/s (SF=16) and 64 kb/s (SF=32).

With respect to the PLEBAC algorithm parameters, PL_0=70dB, PL_M=155 dB and a resolution of Δ=5 dB have been considered. The rest of the common simulation parameters are summarized in Table I.

Physical layer is characterised 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 algorithm under different situations, allowing to determinate the impact of some scenario parameters such as cell radius, offered bit rate and offered load.

As a reference, all the results have been compared with the so called Power Averaging Based Admission Control (PABAC) [9], which does not exploit the predictability associated to static users and makes an average power increase estimation instead. This comparison allows to asses the gain achieved by the proposed algorithm in different scenario conditions and to envisage the potentials of PLEBAC in front of other common AC solutions. Specifically, PABAC algorithm estimates the power increase required by new users 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:

$$\Delta P_T(i) = \frac{P_{AV}(i) - P_c}{N} \qquad (7)$$

where N is the current number of already accepted users 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.

TABLE I.
SIMULATION PARAMETERS

Parameter	Value
Chip rate W	3.84 Mcps
Frame duration	10 ms
BS parameters	
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	
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
Activity factor	1
Call rate	29 calls/h/user
QoS parameters	
Block Error Rate (BLER) target	1 %

Table II presents the system throughput increase obtained with the PLEBAC algorithm when it is compared with the PABAC algorithm in the scenario with cell radius 2 km. The throughput is defined as the total number of bits that are successfully received per unit of time, taking into account all the users accepted in a base station. Notice that as the bit rate increases, also does the gain. In all cases, it can be seen the positive influence of the PLEBAC algorithm achieving significantly higher throughput thanks to reducing 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).

TABLE II.
THROUGHPUT STATISTICS FOR DIFFERENT BIT RATES (R=2KM)

Bit Rate (kb/s)	**Throughput (PABAC)**	**Throughput (PLEBAC)**	**Gain (%)**
384	0.97 Mb/s	1.32 Mb/s	36.08
256	1.07 Mb/s	1.29 Mb/s	20.56
128	1.16 Mb/s	1.24 Mb/s	6.89
64	1.19 Mb/s	1.24 Mb/s	4.20

An interesting statistic to compare the behaviour of both algorithms is the difference between the power increase estimation ΔP_T that was used in the admission process and the actual transmitted power by a given user along its connection lifetime. The lower this difference, the better the algorithm is adjusted to the real traffic conditions. This statistic is presented in Table III in terms of the average and the standard deviation for the case with radius 2km and 384 kb/s. As it can be observed, by means of the user's path loss reports, the PLEBAC algorithm is able to estimate the power increase devoted to new users with a significantly lower error with respect to the real value. Fig. 1 presents the transmitted power and the power increase estimation for both algorithms as a function of the path loss. Notice that PLEBAC adjusts more accurately the power increase estimation to the real transmitted power, which is higher when the path loss increases.

TABLE III.
DIFFERENCE BETWEEN POWER INCREASE ESTIMATION AND TRANSMITTED POWER

	PABAC	**PLEBAC**
Average (dB)	5.04	1.67
Standard Deviation (dB)	4.43	1.52

When extending the analysis to other scenarios, Fig. 1 illustrates the throughput gain of the PLEBAC admission control with respect to PABAC for different cell radii, when the offered bit rate is 256 kb/s and 384 kb/s. Notice that the gain is bigger for larger cell radii and higher service bit rates. In these cases, the higher power demand of users with larger path loss leads to performance degradation not only for these users but also for other users that are located closer to the base station. As a result, an algorithm like PLEBAC, which takes into account user's path loss, improves the overall performance while at the same time it guarantees the quality of the accepted users. Furthermore, the higher the service bit rate, the higher the contribution of a user to the total system throughput, and consequently, a bad admission or a bad rejection turns into larger throughput reductions. As a result, it can be concluded that the PLEBAC strategy is better adapted to user's distribution in the network.

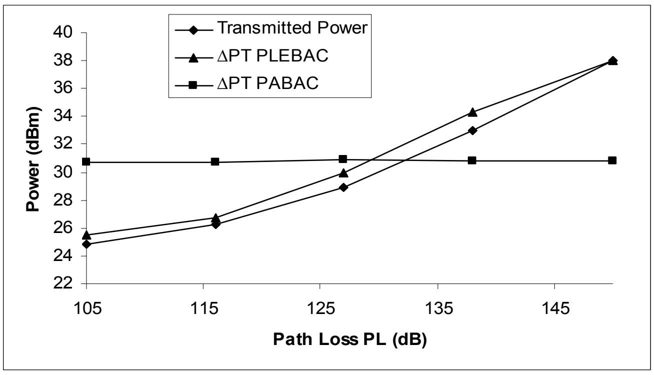

Fig.1. Actual transmitted power and power increase as a function of the path loss

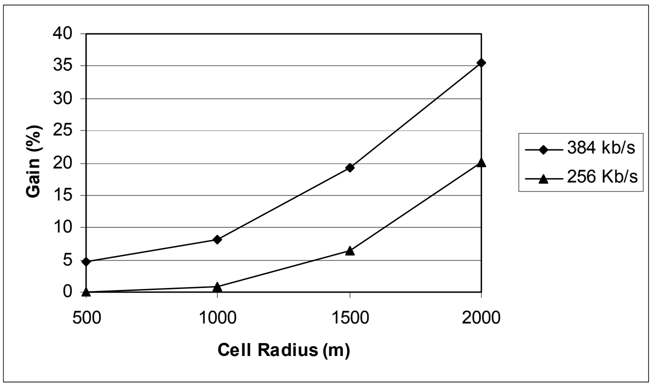

Fig.2. Throughput gain as a function of the cell radius

The impact of the offered load is shown in Fig. 3 and Fig. 4, which represent the throughput gain of PLEBAC with respect to PABAC as a function of the offered cell load for different cell radii and different bit rates, respectively. As it is shown in Fig.3, the highest throughput increase is achieved for the largest cell radii and the benefit is more significant for higher offered loads in the system. The same trend is observed in Fig.4, where it is also shown that the higher improvement of PLEBAC with respect to PABAC is obtained for high bit rate services, that are the most demanding ones.

V. CONCLUSIONS

This paper has addressed the problem of static data users, which are expected to be very important in 3G mobile communications systems. The peculiarities arising from these services have claimed for more advanced RRM solutions. In this sense, a downlink Admission Control strategy based on user's path loss measurements reports (PLEBAC) has been proposed and compared with a reference algorithm (PABAC) based on the average power transmitted by the base station. The proposed algorithm has been evaluated in different scenarios with different cell radius, service bit rate and offered load. Results show that PLEBAC outperforms PABAC in all the cases thanks to a lower error between the power estimation in the admission control phase and the actual transmitted power along the connection lifetime. The throughput gain is very significant especially in those scenarios with large cell radius and high bit rates, where higher power consumption is required and therefore bad admissions and bad rejections in the admission control phase may lead to important degradations for all the accepted users.

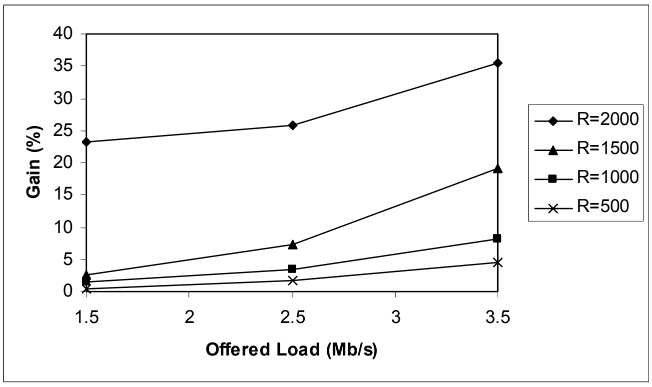

Fig.3. Throughput gain as a function of the offered load for different cell radii R (m) with a service bit rate of 384 kb/s

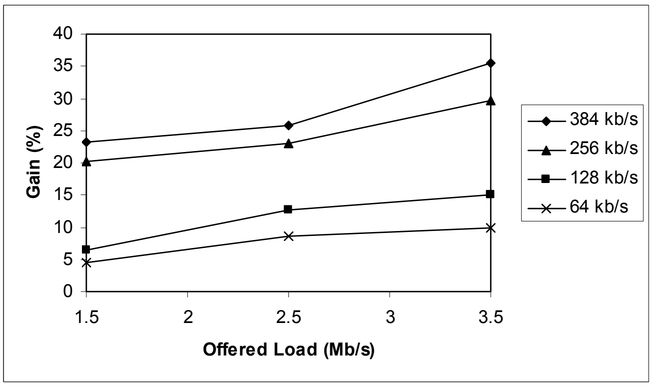

Fig.4. Throughput gain as a function of the offered load for different bit rate with a cell radius of 2000 m

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