An Admission Control Algorithm for WCDMA Considering Mobile Speed and Service Characteristics

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Abstract— **This paper deals with the problem of the downlink admission control for UTRA-FDD systems. In W-CDMA systems, elements such as traffic variability or user mobility cause that the resource requirements for each user in order to guarantee its QoS (Quality of Service) vary along time, making very difficult to estimate whether there will be or not available resources to satisfy the user demands. Admission Control and other RRM (Radio Resource Management) strategies will play an important role in order to achieve an efficient use of the radio interface. In this context, information of certain user characteristics (such as user location or user mobility) would be prime important to obtain a more accurate estimation of the required resources for each user during its connection lifetime. This paper proposes an admission control algorithm which takes into account user mobility and service characteristics in order to obtain better decisions of admission or rejection of connection requests. The obtained results show the improvement of this new admission control proposal in heterogeneous scenarios when low-speed indoor users and medium/high-speed outdoor users have to coexist.**

Keywords: W-CDMA, UTRA-FDD, RRM, Admission Control.

I. INTRODUCTION

3G communications systems will have to support heterogeneous situations where users have different characteristics and different QoS (Quality of Service) requirements. These goals can be achieved by using a more flexible but also more complex radio access scheme called WCDMA (Wideband Code Division Multiple Access) [1]. Due to the peculiarities of W-CDMA, effects such as traffic variability or user mobility cause that the resource requirements for each user to guarantee its QoS changes along time. In this context, RRM (Radio Resource Management) become crucial in order to control these dynamic changes and optimize the available resources in order to assure certain QoS requirements to the connected users [2].

Having knowledge of certain user characteristics (such as user location or user mobility) would be very important in order to obtain a more accurate estimation of the required resources for each user. As an example, indoor users are usually static or at least with a reduced mobility while outdoor users are more likely to have higher mobility. Taking into account this information, more sophisticated Radio Resource Management algorithms can be implemented.

This paper proposes and studies an admission control (AC) that decides whether to accept or reject a connection request depending on the available resources in the network considering mobile speed and service characteristics. It is worth noting that the decision of admission or rejection must be made at the connection request instant of the new user, without knowing exactly the required resources that the user will need during the call. So, future predictions of the network changes would provide more correct decisions about admission or rejection.

Many different admission control strategies can be found in the open literature [3-6]. In [3] and [4] the estimation of user mobility is taken into account in order to design an improved admission control. Other works such as [5] demonstrates how path loss or user location information provides better network performance by facilitating admission of users in handover process. In [6], an advanced admission control for high bit rate static users is proposed. It considers an admission control named PLEBAC (Path Loss Estimation Based Admission Control) which takes advantage of the easy predictability in terms of power requirements of static users, and it is compared to PABAC (Power Averaging Based Admission Control). It was observed that PLEBAC provides better results for the case of static users.

In this context, this paper studies which algorithm (PLEBAC or PABAC) provides better decisions of admission and rejection in dynamic scenarios. Both algorithms have been evaluated under different conditions of user mobility and service bit rate. The difference between the power predicted by PLEBAC or PABAC and the real transmitted power is presented and the impact on base station throughput is provided for both algorithms. On the other hand, and based on the initial results, this paper proposes a Combined PLEBAC/PABAC Based Admission Control (CPBAC) which uses either PLEBAC or PABAC estimation depending on the requesting user speed. The obtained results show that this combined admission control provides better system performance than PLEBAC or PABAC alone. Within this context, the paper is organized as follows. In section 2, the admission control algorithms are presented. The simulation model is presented in section 3. The obtained results are shown in section 4 and in section 5 the conclusions are summarized.

II. ADMISSION CONTROL DESCRIPTION

In the downlink case, the main resource that must be shared among all the users connected to a Node-B is the available base station transmission power. For this reason, downlink admission control is usually based on power consumption. Power based admission control must take into account whether the Node-B has enough power to satisfy all user power demands, of the new user and the already accepted users, in order to satisfy the user QoS requirements. The general expression of this power estimation based admission control can be represented by [7]:

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

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. When the term $P_{AV}(i)+\Delta P_T(i)$ is higher than the admission threshold P_T^*, the connection request is rejected. Otherwise, it will be admitted. Observe that the correct estimation of both $P_{AV}(i)$ and $\Delta P_T(i)$ become crucial in order to assure that the admission control takes correct decisions of admission and rejection. Moreover, an adequate admission threshold P_T^* must be set.

In order to provide a good estimation of the BS power to satisfy user QoS, 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 [7]:

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

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:

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

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.

A correct estimation of the power increase ΔP_T in (1) is another important issue because for high bit rate services this term can become relevant. In this paper different estimations are presented and 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. It can be expressed as [7]:

$$\Delta P_T(i) = \frac{P_{AV}(i) - P_c}{N} \tag{4}$$

where N is the current number of users already accepted in the cell at frame i. It is worth noting that this estimation assume that all users have equal bit rate requirements. 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.

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 [8], 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:

$$PL_k(dB) = PL_0(dB) + k\Delta(dB) \tag{5}$$

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.

In [6], it was shown that depending on service bit rate, the value of ΔP_T is different. Then, for each service bit rate r_b, a correspondence is established between each path loss range and a power increase estimation ΔP_T. So, this correspondence is obtained from the average with a slide window of T frames of the transmitted power to already accepted users with service rate r_b and whose reported path loss falls within the k-th 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 and for certain service rate rb is defined as:

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

where $N_{k,i-j}$ is the number of accepted users with service bit rate rb, 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 $\Delta P_T(k,i,rb)$.

Algorithm #3: Combined PLEBAC/PABAC Based Admission Control (CPBAC)

As shown in [6], PLEBAC provides better behaviour than PABAC for static users. The proposed CPBAC algorithm consists on a combined admission control algorithm that takes advantage of user speed information in order to obtain a more accurate estimation of the power increase estimation ΔP_T. Then, depending on the requesting user speed the CPBAC algorithm will use either PLEBAC or PABAC estimation.

```
If(requesting user speed < Speed Threshold)
    Make PLEBAC estimation according to (6)
else
    Make PABAC estimation according to (4)
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In order to set a proper value of this *Speed Threshold*, PLEBAC and PABAC behaviour must be studied under different user speed scenarios.

III. SYSTEM MODEL

For the evaluation of radio resource strategies, a system level simulator has been developed. The considered cell layout can be seen in figure 1 where 16 macro-cells and a building with indoor users have been considered. The statistics are taken only in the Study Node-Bs and the Border Node-Bs are considered in order to take into account interference aspects. Outdoor users are uniformly distributed in the scenario while indoor users are uniformly distributed inside the building. A 50% of indoor users has been considered.

Simulations consider CBR 384 kb/s and 64kbp/s services. The mobility and propagation models are defined in [9] for macro-cellular 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 [10]. 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.

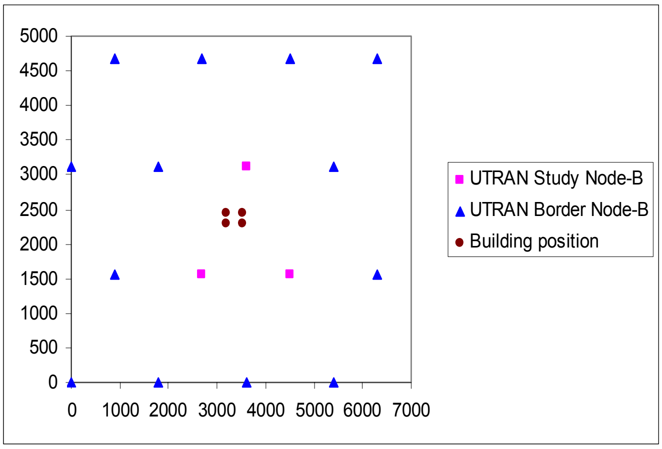

Figure 1.- Base Station locations and building position

Table I. Simulation parameters

Parameter	**Value**
Chip rate W	3.84 Mcps
Frame duration	10 ms
BS parameters	
Base Station Spacing	1800m
Cell type	Omnidirectional
Maximum DL power P_{max}	43 dBm
Maximum DL power per user $P_{max,n}$	40 dBm
Maximum admission power threshold 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
Handover parameters	
Active Set maximum size	1
Time to trigger HO	0.5 s
Traffic model	
Call duration	120 s
Offered bit rate	384 kb/s or 64kb/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, which 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) [11].

IV. SIMULATION RESULTS

This section presents some results in order to determine the behaviour of PLEBAC and PABAC algorithms in different scenarios. In order to gain insight of the advantages and disadvantages of each algorithm, figure 2 presents the power increase estimation made by PLEBAC, PABAC and the real transmitted power as a function of the path loss for the case of 384kbps. As shown, PLEBAC algorithm provides a more precise estimation of the power required by a user in a certain path loss range. On the contrary, PABAC algorithm does not take into account the current path loss of the requesting user and then provides an almost constant value of the power increase estimation.

For static or low-speed users, the users' path loss variations are constant or almost constant, and then, the required power to satisfy the user QoS has very low changes. In these situations, PLEBAC power increase estimation is valid during all the call duration providing better system performance. However, for high speed users, the path loss variation due to the user mobility will cause that the user requirements in terms of power will change very much along the connection lifetime. In such a situation PLEBAC algorithm estimation may be wrong because the required power to guarantee the user QoS have changed very much during the connection time. For high mobility users, PABAC may provide more adequate power increase estimation. Thus, depending on the path loss variability either PLEBAC or PABAC will provide a better performance.

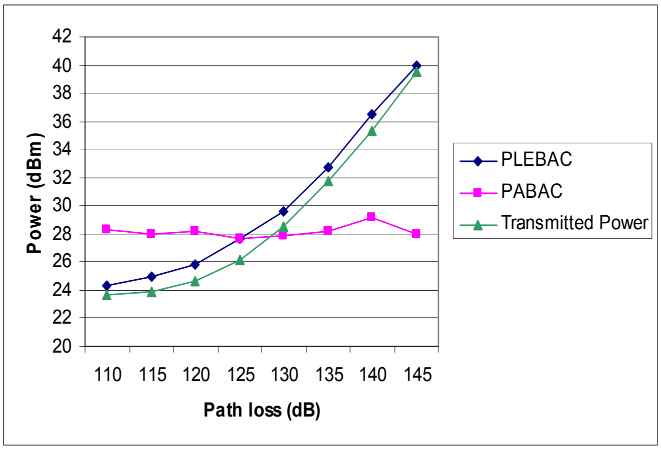

Figure 2 Transmitted power and power increase estimation as a function of path loss.

In the following, a comparison between PLEBAC and PABAC will be presented for different values of user speed and call duration. It is worth noting that both parameters affect to user path loss variability during the connection lifetime. Indoor users are considered to be static or to move at 3km/h while outdoor users speed has been varied in different simulations. An interesting statistic to compare both algorithms is the difference between the power increase estimation in the admission control and the real transmitted power by a user along its connection lifetime. The standard deviation (dB) of this error is presented in table II for the case of indoor users and in table III for outdoor users. As shown, for static or 3km/h not many differences arise in the obtained error for indoor and outdoor users. However, the effect of user speed and call duration is quite noticeable. As shown, PLEBAC provides lower error for short call duration and low user mobility because the estimation provided in the instant of admission is valid during all the connection lifetime. The higher the call duration or the user mobility is, the higher the path loss variability will be and this will produce higher error in the power increase estimation of PLEBAC. However, the obtained error for PABAC does not depend so much on the scenario.

Table II Standard error deviation (dB) for indoor users (384kbps) for different call duration.

		30 seconds	3 minutes
Static	PABAC	5.02	4.98
	PLEBAC	1.97	2.02
3km/h	PABAC	4.87	4.76
	PLEBAC	2.47	2.95

Table III Standard error deviation (dB) for outdoor users (384kbps) for different call duration.

		30 seconds	3 minutes
Static	PABAC	5.13	5.01
	PLEBAC	2.11	2.12
3km/h	PABAC	4.93	4.74
	PLEBAC	2.55	3.05
50km/h	PABAC	4.97	5.26
	PLEBAC	4.12	5.83
120km/h	PABAC	5.73	5.61
	PLEBAC	7.63	7.74

Notice that the standard error deviation depends basically on user speed and call duration, but it is quite similar if the user is indoor or outdoor. In Table IV, the effect of user mobility and call duration on the base station throughput gain of PLEBAC with respect to PABAC is presented. Note that a negative sign means that PABAC behaves better than PLEBAC. As it can be observed, a reduction in power increase estimation error (see table III) corresponds to a higher throughput gain, see table IV. The impact of user bit rate on throughput gain is also presented. It is worth noting that for both situations (better behaviour of PLEBAC or better behaviour of PABAC), the higher the service rate is, the higher the improvement in terms of throughput gain because for high service bit rate, the contribution of a user to the total system throughput will be high and consequently, a bad admission or a bad rejection turns into larger throughput reductions.

Table IV Throughput gain PLEBAC vs PABAC for different call duration and bit service and user speed.

	384kbps		64kbps	
Speed	30seconds	3minutes	30seconds	3minutes
Static	9.45%	8.90%	6.12%	5.30%
3km/h	2.64%	2.49%	2.60%	1.82%
50km/h	1.06%	-2.75%	0.58%	-2.94%
120km/h	-5.49%	-8.40%	-3.8%	-4.30%

The obtained results show that for low speed users, PLEBAC algorithm is more adequate while for high speed users PABAC provides better performance. In table V, the obtained throughput for PLEBAC, PABAC and this new proposed CPBAC algorithm is shown. It has been considered 50% of indoor users at 3km/h and 50% of outdoor users at 50km/h, in both cases the bit rate is 384kbps. If the call duration is 30seconds, PLEBAC performs better than PABAC which could also be derived from table IV. If the call duration is 3 minutes, PABAC performs better than PLEBAC. However, in both cases, CPBAC provides higher throughput, as shown in table V. In this scenario, CPBAC algorithm, leads to an improvement in the base station throughput of around 3% higher than PLEBAC or PABAC algorithms alone.

Table V. Obtained throughput: Indoor 3km/h, outdoor 50km/h (rb=384kbps).

Call duration	PLEBAC	PABAC	CPBAC
30 seconds	757.789 kbps	734.975 kbps	773.073 kbps
3 minutes	749.181 kbps	755.229 kbps	774.421 kbps

If indoor users remain static and outdoor users move at 50km/h, PLEBAC provides better results than PABAC because PLEBAC provides high throughput gain for static users (see table IV). In any case, CPBAC provides lower standard error deviation (see table VI). The throughput gain obtained with CPBAC is around 8.5% higher than PLEBAC and 12% higher than PABAC as shown in table VII.

Table VI. Standard error deviation (dB) Indoor static, outdoor 50km/h (rb=384kbps).

Call duration	PLEBAC	PABAC	CPBAC
30 seconds	3.05	4.99	1.65
3 minutes	3.92	5.12	2.11

Table VII. Obtained throughput: Indoor static, outdoor 50km/h (rb=384kbps).

Call duration	PLEBAC	PABAC	CPBAC
30 seconds	761.326 kbps	737.257 kbps	828.734 kbps
3 minutes	757.710 kbps	736.241 kbps	823.457 kbps

V. CONCLUSIONS

In this paper, a new downlink admission control strategy named CPBAC (Combined PLEBAC/PABAC Based Admission Control) has been proposed and analysed. This algorithm takes into account user speed information in order to make a more accurate estimation of the power increase that would cause the admission of the requesting user. First of all, the obtained error in PLEBAC and PABAC estimations has been determined under different call duration, mobility conditions and service bit rate. Moreover, the system performance in terms of base station throughput has been determined for both admission control strategies. Higher improvement in terms of base station throughput has been observed when considering high bit rates, where higher power consumption is required and therefore, bad admissions or bad rejections in the admission control phase lead to important degradations for all the accepted users. Finally, the improvement provided by CPBAC algorithm which makes PLEBAC estimation for low-speed users (e.g. indoor users) and PABAC estimation for medium/high-speed users (typically outdoor users) has been presented.

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