A Downlink Admission Control Algorithm for UTRA-FDD

J. Pérez-Romero, O. Sallent, R. Agustí, G. Parés
Universitat Politècnica de Catalunya
c/ Jordi Girona 1-3, 08034 Barcelona, Spain
email: [jorperez, sallent, ramon @ tsc.upc.es]

Abstract - **This paper deals with the problem of admission control in the downlink of UTRA-FDD. Significant differences with respect to the uplink admission control arise. While in the uplink admission control strategies based on the load factor are suitable, in the downlink an admission strategy based on measured power levels appears more suitable. This paper proposes and analyses an algorithm that is based on monitoring the Node-B transmitted power level, estimating the power demand that results from a new user and accepting this new user only if the resulting power is below an admission threshold. The impact of the different algorithm parameters are studied.**

Keywords – **UTRA, W-CDMA, RRM, Admission Control, Downlink, Power.**

1.- INTRODUCTION

Future 3G mobile communications systems like UMTS will offer an optimization of capacity in the air interface by means of efficient algorithms for Radio Resource and QoS Management dealing with power control, handover, admission control, congestion control and packet scheduling [1]. The system relies on these functionalities to guarantee a certain target QoS, to maintain the planned coverage area and to offer a high capacity for a set of mobile multimedia services. These functions are crucial because in W-CDMA based systems there is not a constant value for the maximum available capacity, since it is tightly coupled to the amount of interference in the air interface.

The above mentioned RRM strategies should be devised from the perspective of both the uplink and downlink requirements [2]. Downlink direction is a quite unexplored field, initially on the presumption that the uplink is the limiting direction. However, in the context of asymmetric services, the system may become downlink limited and, consequently, downlink management is gaining momentum [3]. Despite some uplink concepts can be applied to downlink, significant differences arise. In particular, the restrictions imposed by each link are not of the same nature: while in the downlink the maximum transmitted power is the same regardless the number of users, in the uplink each user has its own power amplifier. Therefore, as the transmitted power should be shared among all the users, their instantaneous locations have a high impact over the performance of the rest of users in the same cell, even for low loads, while in the uplink a particular user location has only impact over its own performance. As a result, the amount of downlink radio resources that should be allocated to this user vary as this user moves around the cell.

This paper proposes and analyses a downlink admission control algorithm based on monitoring the Node-B transmitted power level along time. To this end, Section 2 justifies the chosen admission strategy, Section 3 describes the simulation platform and model and, finally, Section 4 presents a range of significant results. Conclusions close the paper in Section 5.

2.- DOWNLINK ADMISSION CONTROL

Within a W-CDMA cell, all users share the common bandwidth and each new connection increases the interference level of other connections, affecting their quality expressed in terms of a certain (E_b/N_o). For n users receiving simultaneously from a given cell, the following inequality for the i-th user must be satisfied:

$$\frac{\dfrac{P_{Ti}}{L_p(d_i)}\times SF_i}{P_N+\chi_i+\rho\times\left[\dfrac{P_T-P_{Ti}}{L_p(d_i)}\right]}\geq\left(\frac{E_b}{N_o}\right)_i r \qquad (1)$$

$$P_T=\sum_{i=1}^{n}P_{Ti} \qquad (2)$$

P_T being the base station transmitted power, P_{Ti} being the power devoted to the i-th user, χ_i representing the intercell interference observed by the i-th user, $L_p(d_i)$ being the path loss at distance d_i (including shadowing), r the coding rate and P_N the background noise. SF compares the bit duration to the chip period and ρ is the orthogonality factor since orthogonal codes are used in the downlink direction. Notice that, differently from the uplink case, in downlink the intercell interference is user-specific. Additionally, physical limitations into the power levels are given by the maximum base station transmitted power, P_{Tmax}. Then, it can be obtained that the total transmitted power to satisfy all the users demands should be:

$$P_{T,\max} \ge P_T = \frac{\sum_{i=1}^{n} \frac{\left(P_N+\chi_i\right)}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i r}+\rho} L_p(d_i)}{1-\sum_{i=1}^{n}\frac{\rho}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i r}+\rho}} \qquad (3)$$

Then, the power devoted to the i-th user, P_{Ti} , is given by:

$$P_{Ti} \ge L_p(d_i)\frac{P_N+\chi_i+\rho\times\frac{P_T}{L_p(d_i)}}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i r}+\rho} \qquad (4)$$

Claiming in (3) for the inherent positivity of P_N (i.e. $P_N > 0$) leads to:

$$\eta_{DL} = \sum_{i=1}^{n}\frac{\left(\rho+\frac{\chi_i\times L_P(d_i)}{P_T}\right)}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i r}+\rho} < 1 \qquad (5)$$

The later expression is commonly known as the downlink load factor [2]. The total transmitted power by the base station can be expressed in terms of the load factor as:

$$P_T = \frac{P_N}{(1-\eta_{DL})}\sum_{i=1}^{n}\frac{L_p(d_i)}{\frac{SF_i}{\left(\frac{E_b}{N_o}\right)_i r}+\rho} = \frac{P_N}{(1-\eta_{DL})}X \qquad (6)$$

where it can be observed that as the load factor increases the power demands also increase. Notice that in the right-hand of (6) the term X has been defined. Figure 1 shows the probability density function of X for different number of users n in a scenario where the cell radii is 0.5 Km. It can be observed that X may take a broad range of values, depending on the specific positions of the users to be served. The deviation decreases at some extent as the number of users increases.

On the other hand, for a maximum transmitted power, $P_{T,max}$, the maximum allowable cell load factor shows a quite sharp variation depending on X (see Figure 2) as given by the following expression that combines (5) and (6):

$$\eta_{DL,\max} = 1-\frac{P_N}{P_{T,\max}}X \qquad (7)$$

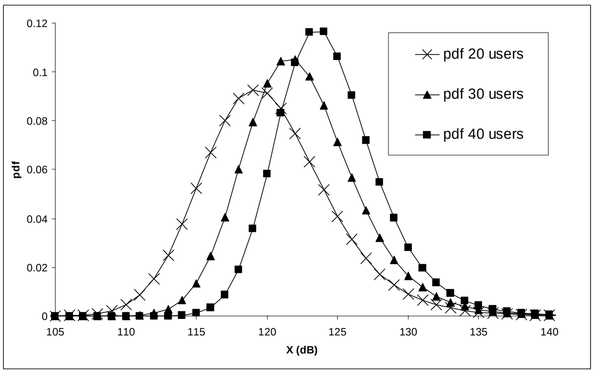

Figure 1. Pdf of the term *X* in (6).

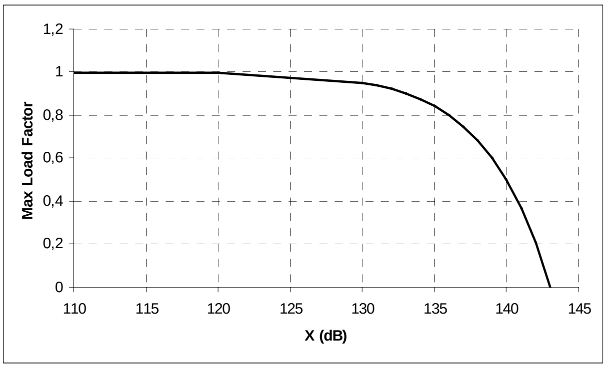

Figure 2. Maximum cell load in downlink as a function of *X*.

From both Figures 1 and 2 it can be concluded that the maximum cell load allowable in the cell for a sufficient transmitted power may change quite rapidly depending on how users are distributed in the cell, given that even for a low load the probability of X being higher than 125 dB is not negligible. Therefore, the maximum cell load factor and the transmitted power are coupled in the downlink and related by a time varying factor that depends on user locations. Consequently, it may seem more reasonable to control the downlink operation through the transmitted power rather than through the cell load factor, as it uses to be the case in the uplink. Furthermore, according to (5), a control based on the load factor would eventually require that mobile terminals report intercell measurements unless statistical average values were considered.

Within this context, the considered admission control algorithm checks the following condition to decide the acceptance of a new connection request in the system, arriving at the i-th frame:

$$P_{AV}(i)+\Delta P_T(i) \le P_T^*(i) \qquad (8)$$

$$P_{AV}(i) = \frac{\sum_{j=1}^{T} P_T(i-j)}{T} \qquad (9)$$

where $P_{AV}(i)$ is the average transmitted power during the last T frames, $\Delta P_T(i)$ is the power increase estimation due to the new request (notice that it may vary along time) and $P_T^*(i)$ is the admission threshold that may also be adaptive.

Despite of the simplicity of the algorithm, it can offer an efficient performance provided that their design parameters are suitably set. Particularly, in this paper we focus on the following aspects to be analysed:

a) How the increase in power demand ΔP_T is estimated.

b) The impact of the power admission threshold P_T^*. By modifying this threshold the admission can become softer or stricter at the expense of the performance perceived by the admitted users.

c) Impact of the measurement period *T*. In order to overcome the high variability of the mobile radio channel as well as interference patterns, transmitted power measurements should be time averaged and again a trade-off will appear.

3.- SIMULATION MODEL

A multiuser, multicell and multiservice system level simulator using the OPNET tool platform has been developed for performance evaluation. The developed simulator allows the support of a wide range of RABs (Radio Access Bearers) from those defined in 3GPP TS 34.108, traffic models as well as deployment scenarios [4]. The simulation model includes 7 cells with radii 0.5 km. The maximum base station transmitted power is 43 dBm. A single service scenario is considered. The radio access bearer selected for videophone service has a constant bit rate of 64 Kbps when transmitting, as shown in Table 1. Packet error rate target is 2%. The average call duration is 3 minutes. Admission requests from handover users are always accepted. In the physical layer the rate 1/3 turbo code effect, the 1500 Hz closed loop power control and a realistic channel impulse response estimator are taken into account and the performance is obtained also from a developed link level simulator [5]. The mobility model and propagation models included in the OPNET simulator are the standards used in UTRA evaluation, taking a mobile speed of 3 km/h and a standard deviation for shadowing fading of 10 dB [6]. The orthogonality factor is 0.4.

Table 1. Transport formats for videophone RABs.

TrCH type		DCH
TB sizes, bit		640
TFS	TF0, bits	0×640
	TF1, bits	2×640 (64 Kb/s)
TTI, ms		20

4.- RESULTS

As mentioned before, in the case of downlink direction some differences compared to the uplink case arise. In particular, the intercell interference is user-specific since it depends on the user location, the base station transmitted power is shared by all users and the power allocations depend on the user location as well. In order to observe the differences that this behaviour originates, Figure 3 plots the probability density function of the required transmitted powers to each user in the cell, P_{Ti} expressed in (4). High deviations from the average value are observed.

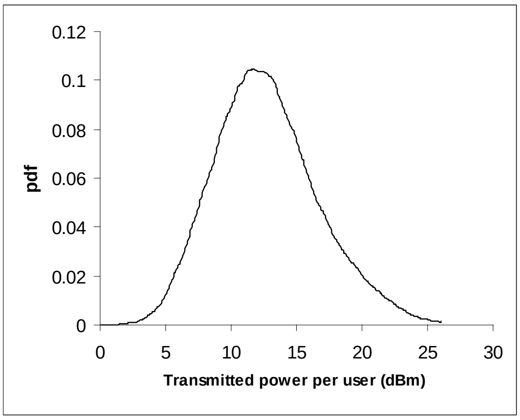

Figure 3. Pdf of the transmitted power devoted to every single user.

With respect to the admission control algorithm parameters, the impact of the estimated power increase due to the requesting user, ΔP_T, is firstly studied. A reasonable criterion could be to estimate the power demand as a time average along the last T frames of the required transmitted power to every user, so that it leads to an adaptive estimation:

$$\Delta P_T(i) = \frac{\sum_{j=1}^{T} \left(\frac{\sum_{k=1}^{n_{i-j}} P_{Tk}(i-j)}{n_{i-j}} \right)}{T} \qquad (10)$$

n_{i-j} being the number of users transmitting in the (i-j)-th frame. For comparison purposes, and in order to assess the importance of the term ΔP_T in the overall admission procedure, a pessimistic estimation is considered:

$$\Delta P_T = P_{Ti}(90\% CDF) \qquad (11)$$

In this case the estimation is fixed and assumed to be the 90% percentile of the required transmitted power per user. Deriving the CDF (Cumulative Distribution Function) from Figure 3, it is found that ΔP_T =17.48 dBm for an offered load of 160 Erlangs in the overall scenario. Also from further simulations it is obtained that ΔP_T = 9.63 dBm for 120 Erlangs and ΔP_T = 22.1 dBm for 200 Erlangs.

Table 2 presents the admission probability (i.e. the probability that a connection request is accepted) for the two different criteria and in the case of $P_{AV}(i)$ averaged over T=100 frames and a fixed threshold P_T^* = 35 dBm. No significant differences are found. From the achieved performance point of view, also Table 2 presents the Packet Error Rate. In both cases, a quite similar performance is achieved, and it is concluded that the ΔP_T estimation has a limited impact on the overall admission procedure.

Table 2. Admission probability and PER for two different ΔP_T estimations.

	Admission probability		Packet Error Rate	
Offered Load (Erlangs)	Time Average	90% CDF	Time Average	90% CDF
120	100 %	100 %	2.00 %	2.00 %
160	94.33 %	93.97 %	2.87 %	2.83 %
200	56.31 %	55.34 %	8.20 %	7.83 %

The impact of the maximum power, P_T^*, is shown in Figure 4 and Figure 5. At this stage, fixed thresholds of P_T^* = 25, 30, 35 dBm are considered. In particular, Figure 4 plots the admission probability for different numbers of users in the system and it can be observed that for a restrictive value as 25 dBm, many requests are rejected for 160 Erlangs in the scenario. On the other hand, softer admission policies (35 dBm) provide a much higher power limitation probability (i.e. the probability that the base station does not have enough power at a given frame to serve all users), and as a consequence the Packet Error Rate increases (see Figure 5).

The previous results indicate the existence of an optimum threshold for each load level, suggesting an adaptive admission control procedure based on a load estimation. Table 3 summarises the approximated optimum threshold for a twofold objective: 1) To obtain a controlled performance (i.e. PER<2.5%), and 2) To obtain as high as possible admission probability.

Another important issue in the admission phase is the estimation of the transmitted power $P_{AV}(i)$ used in (8) because as mentioned above, the instantaneous transmitted power may exhibit significant fluctuations. Figure 6 to 9 analyse the impact of different averaging periods, focusing on the P_T^* =25 dBm case. In all cases a representative 5 minutes segment is shown. Different cases are analised:

1)Medium load (i.e. 120 Erlangs).

1.a) If T is low (T=100 in Figure 6) there are short periods where, due to the high variability on the required Node-B transmitted power, it happens that $P_{AV}(i) > P_T^*$ and, consequently, some calls are rejected (in this case the admission probability is around 98% and PER=2%).

1.b) If T is high (T=5000 in Figure 7), the smoothing due to the longer averaging periods avoids unnecessary call rejections (in this case the admission probability is 100% and PER=2%).

Consequently, a relatively high averaging period T is desirable to avoid effects from instantaneous and seldom high transmitted power situations (if the load is low the required power will also use to be low).

2)High load (i.e. 200 Erlangs).

2.a) If T is low (T=100 in Figure 8) it is possible to take advantage of the periods where the required Node-B transmitted power is lower than usual (in this case the admission probability is around 41% and PER=2.25%).

2.b) If T is high (T=5000 in Figure 9), a wave-like effect arises in the $P_{AV}(i)$ form and the periods where calls can be accepted are reduced (in this case the admission probability is 35% and PER= 2.23%).

Consequently, a relatively short averaging period T is desirable to avoid long memory effects, which would produce a high rejection rate because the required transmitted power will usually be high.

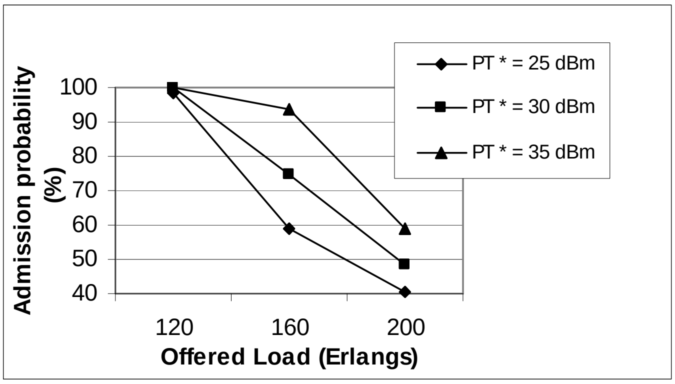

Figure 4. Admission acceptance ratio for different power thresholds

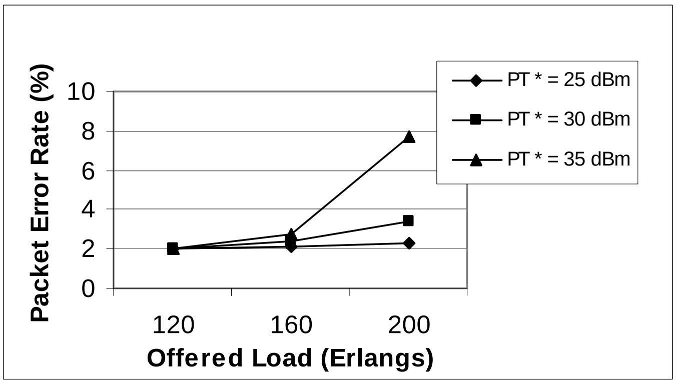

Figure 5. Packet Error Rate for different power thresholds

Table 3. Optimum threshold for different loads.

Offered load (Erlangs)	Optimum threshold
120	>35 dBm
160	30 dBm
200	25 dBm

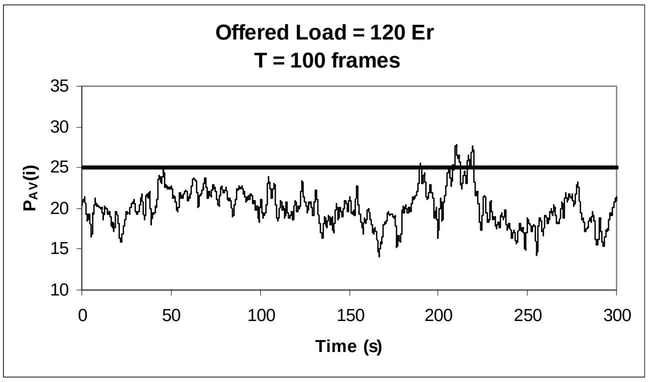

Figure 6. Plot of the time averaged transmitted power .

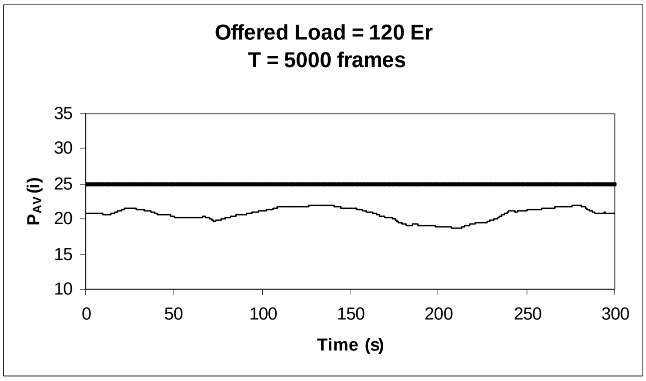

Figure 7. Plot of the time averaged transmitted power.

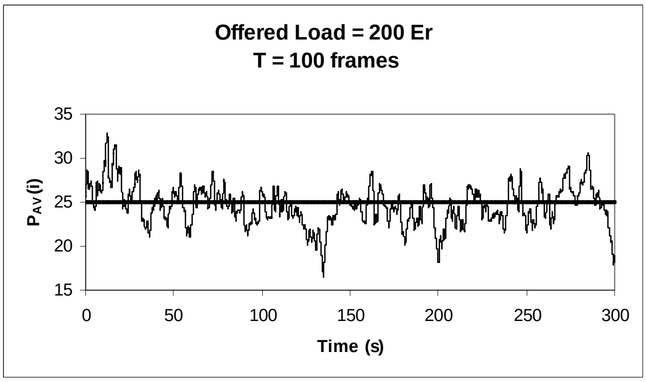

Figure 8. Plot of the time averaged transmitted power.

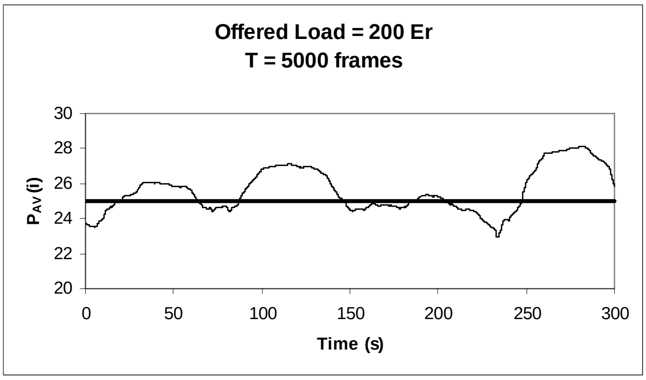

Figure 9. Plot of the time averaged transmitted power.

5.- CONCLUSIONS

A power based downlink admission scheme has been proposed and analysed. Results may indicate that the way how ΔP_T is estimated has a limited impact on the overall strategy behaviour. On the other hand, an optimum admission threshold P_T^* can be found for each load level, suggesting an adaptive admission control. Finally, the averaging period required for $P_{AV}(i)$ evaluation depends on the load level relative to the admission threshold P_T^*. For low loads long averaging periods are more suitable (in the order of a minute), while for high load situations shorter averaging periods (in the order of a second) lead to a better performance.

6.- ACKNOWLEDGEMENTS

This work is part of the ARROWS project, partially funded by the European Commission under the IST framework (IST 2000-25133) and by the Spanish Research Council under grant TIC2001-2222.

7.- REFERENCES

[1] 3GPP TR 25.922 v4.0.0, "Radio resource management strategies"

[2] H. Holma, A. Toskala (editors), *W-CDMA for UMTS*, John Wiley and Sons, 2000.

[3] K. Sipilä, Z. Honkasalo, J. Laiho-Steffens, A. Wacker, "Estimation of Capacity and Required Transmission Power of WCDMA Downlink Based on a Downlink Pole Equation", *Proceedings VTC2000 Spring*, 2000.

[4] 3G TS 34.108 v.3.2.0, "Common Test Environment for User Equipment. Conformance Testing"

[5] J. Olmos, S. Ruiz, "UTRA-FDD Link Level Simulator for the ARROWS Project", *IST'01 Conference Proceedings*, pp. 782-787.

[6] 3GPP TR 25.942 v.2.1.3, "RF System Scenarios"