Downlink Radio Resource Management Approach for 3G W-CDMA Networks

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Abstract— **The design of Radio Resource Management strategies is an important issue in the context of 3G W-CDMA-based systems such as UTRAN. In this paper some of the relevant elements influencing downlink RRM are identified and presented. In particular, the downlink admission threshold and the importance of establishing some limits on the maximum power per connection. The effect of these two parameters will be studied for different cell radius scenarios. Moreover, the capacity of the system will be determined under certain established quality of service requirements, in terms of admission probability, Block Error Rate and dropping probability.**

Keywords: W-CDMA, Radio Resource Management, admission control.

I. INTRODUCTION

One of the most important challenges of 3G mobile communications systems is to support different kinds of multimedia services, maintaining at the same time the agreed quality of service, the planned coverage area and optimizing the capacity of the system. This objective cannot be achieved without Radio Resource Management (RRM) strategies, which must determine how the radio interface is used and shared by the different users. RRM functions become crucial in W-CDMA based systems because 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. In W-CDMA, soft capacity gives some flexibility to accept or reject connections, because the number of simultaneous connections is not limited by a fixed value, like in 2G systems. Although for relatively low loads an efficient management of radio resources may not involve an important benefit, when the number of users increases to a critical value, a good management will be necessary in order to prevent network congestion situations. Taking into account the constraints imposed by the radio interface architecture, the RRM functions are responsible of taking decisions regarding the setting of the parameters such as Transport Format (i.e. instantaneous bit rate), Transport Format Set (i.e. maximum bit rate), as well as other such as power level, code sequences, etc. RRM functions need to be consistent for both uplink and downlink, although the different nature of these links introduces some differences in the considered approach [1][2].

While in the uplink control strategies include a decentralized component and power limitations have only impact over the specific user whose transmitter cannot provide the required power, in the downlink direction, the power transmitted by the Node-B is shared by all the users. Therefore, there is a constraint for the maximum available power, depending on how users are located in a given moment, power limitations may arise and these limitations can have an impact not only over the user located at the cell edge but also to other users. Therefore, user location has an important impact on the downlink [3]. Consequently, the amount of power devoted to a single user must be controlled in order to avoid extreme situations when a user gets a significant part of the transmitted power, and the rest have to share a lower part, which is not sufficient to achieve their quality requirements.

This paper presents an overview of different RRM components that should be considered in the downlink. The main objective of this paper is to determine which are the main parameters that must be considered in the downlink RRM. It is worth noting that depending on the considered scenario (cell radii, speed of the users, service class…), the optimum value of these parameters will be different. The paper is organized as follows. Section 2 provides an overview of the downlink radio resource management strategies. In section 3, the simulation model will be shown. Section 4 presents the obtained results and the conclusions are summarized in section 5.

II. DOWNLINK RADIO RESOURCE MANAGEMENT

A. *Downlink power allocation*

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 transmitting simultaneously at a given cell, the following inequality for the i-th user must be satisfied:

$$\frac{\frac{P_{Ti}}{L_p(d_i)}\frac{W}{R_{b,i}}}{P_N+\chi_i+\rho\times\left[\frac{P_T-P_{Ti}}{L_p(d_i)}\right]}\geq\left(\frac{E_b}{N_o}\right)_i \tag{1}$$

$$P_T = P_p + \sum_{i=1}^{n} P_{Ti} \tag{2}$$

P_T being the total base station transmitted power, P_{Ti} being the power devoted to the i-th user, P_p the power devoted to pilot and common control channels, χ_i representing the intercell interference observed by the i-th user, $L_p(d_i)$ being its path loss and P_N the background noise. W is the total bandwith after spreading, $R_{b,i}$ is the i-th instantaneous bit rate. ρ is the orthogonality factor since some orthogonality is lost due to multipath. (Eb/No)i is the i-th user quality requirement. Differently from the uplink case, in downlink 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. Physical limitation of the power levels is given by the maximum base station transmitted power $P_{T\max}$. Then, it can be obtained that the total transmission power at the base station in order to satisfy all user demands is:

$$P_{\max}\geq P_T=\frac{\displaystyle\sum_{i=1}^{n}\frac{(P_N+\chi_i)Lp(d_i)}{\frac{W}{\left(\frac{E_b}{N_o}\right)_i R_{b,i}}+\rho}}{1-\displaystyle\sum_{i=1}^{n}\frac{\rho}{\frac{W}{\left(\frac{E_b}{N_o}\right)_i R_{b,i}}+\rho}} \tag{3}$$

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

$$P_{Ti}\geq L_p(d_i)\frac{P_N+\chi_i+\rho\times\frac{P_T}{L_p(d_i)}}{\frac{W}{\left(\frac{E_b}{N_o}\right)_i R_{b,i}}+\rho} \tag{4}$$

As the downlink power must be shared by all the users, it is reasonable to put some limits on the maximum power devoted to a single connection $P_{c,\max}$, otherwise high demanding users could retrieve from service to a number of users of the same cell. Then, the following restriction will be considered along the connection dynamics:

$$P_{Ti}\leq P_{c,\max} \tag{5}$$

B. Downlink admission control

The admission control decides whether to accept or reject a new connection request depending on the available power in the Node-B and the power increase estimation of this new request. As the power consumption will vary dynamically and the admission control algorithm decision must be taken in a specific time instant, (i.e. upon the new connection request), it is necessary to predict the future availability of power resources. Consequently, either call admission or rejection brings some uncertainty and the algorithm solution should deal with the unpredictable future in the best possible way. Within this context, the reference 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:

$$P_{AV}+\Delta P_T\leq P_T^* \tag{6}$$

where P_{AV} is the averaged power transmitted during the last T frames, ΔP_T is the power increase estimation due to the new request (it may vary along time) and P_T^* is the admission threshold that may be adaptive. Obviously, if P_T^* is very low, the admission will be very strict and the BLER will be close to the target value, although the admission probability will decrease rapidly as traffic increases. If P_T^* is set to a higher value, the accepted traffic will be high, although the achieved BLER may be too degraded.

On the other hand, the power increase required by the new user can be estimated as:

$$\Delta P_T=\frac{P_{AV}-P_p}{K} \tag{7}$$

where K is the current number of users already accepted in the cell.

III. SYSTEM MODEL

In the simulations several scenarios with different cell radius has been considered. In the physical layer, a link level simulator which includes the 1500 Hz closed loop power control, 1/3 turbo coding effect, and channel impulse response estimator provides BLER (Block Error Rate) statistics which are used by the system level simulator [4]. The simulation parameters are summarized in table 1. The mobility model and propagation models from macrocellular scenarios are defined in [5], taking a mobile speed of 3km/h and a standard deviation for shadowing fading of 10 dB. The service considered in the simulations is videophone, taking a radio access bearer of constant bit rate of 64kbps. The average call duration is 2 minutes. The characteristics of the radio access bearer are taken from [6] and given by a Transmission Time

Interval (TTI) of 20ms, a Transport Block (TB) size of 640 bits and Transport Format allowing to send 2 Transport Blocks per TTI.

Table 1. Simulation parameters

BS parameters	
Cell radius	1500 m
Cell type	Omnidirectional
Maximum transmitted power	43 dBm
Thermal noise	-106 dBm
Power devoted to pilot and common control channels	30 dBm
Shadowing deviation	10 dB
Shadowing decorrelation length	20 m
Orthogonality factor	0.4
Measurement period of Transmitted Power T	1 s
UE parameters	
Maximum transmitted power	21 dBm
Minimum transmitted power	-44 dBm
Thermal noise	-100 dBm
Mobile speed	3 km/h
Handover parameters	
Active Set maximum size	2
AS_Th (Threshold to enter Active Set)	3 dB
AS_Th_Hyst (Hysteresis for AS_Th)	1 dB
AS_Rep_Hyst (replacement hysteresis)	1 dB
Time to Trigger	1 measurement period
Measurement period T_{HO}	0.5s
Traffic model	
Call duration	120s
Offered bit rate	64 kb/s (CBR)
Activity factor	1
Call rate	29 calls/h/user
QoS parameters	
Block Error Rate (BLER) target	1%

IV. RESULTS

In this section, the importance of the admission power threshold and the maximum power per connection will be shown. Finally, estimation of the system capacity will be provided.

A set of simulations have been carried out varying the offered traffic in the system and considering different values of the P_T^* and $P_{c,max.}$ Moreover, it has been obtained the maximum capacity in each scenario to ensure a minimum admission probability of 98%, maximum Block Error Rate of 1.2% when the target is set to 1% and maximum dropping probability of 1%. A connection is dropped when the obtained Eb/No is 1dB below the target value during 50 consecutive frames.

A. *Admission control threshold*

One key parameter in the admission control algorithm expressed in (6) is the admission threshold P_T^*. The following results try to explore the role of this parameter. To this end, fig. 1, 2 and 3 show the effect of the power admission threshold in terms of admission probability, obtained BLER and dropping probability as a function of the total offered traffic. As it can be observed, a low admission threshold causes a poor admission probability. However, a higher threshold in the admission control provides higher admission probability maintaining the system under the 1.2% of tolerable BLER. Obviously, if the offered load is too high (more than 160 Erlangs in this scenario) the quality of service requirements will not be achieved (neither the admission probability nor the BLER condition nor the dropping probability). Therefore, if the cell radius is 1500m, the optimum admission threshold is 43 dBm.

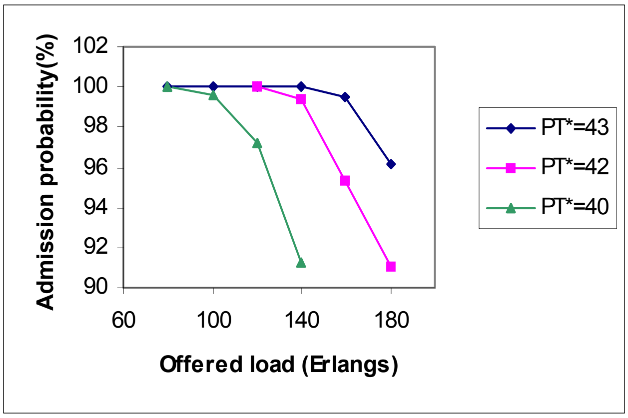

Figure 1.- Admission probability for different values of P_T^*

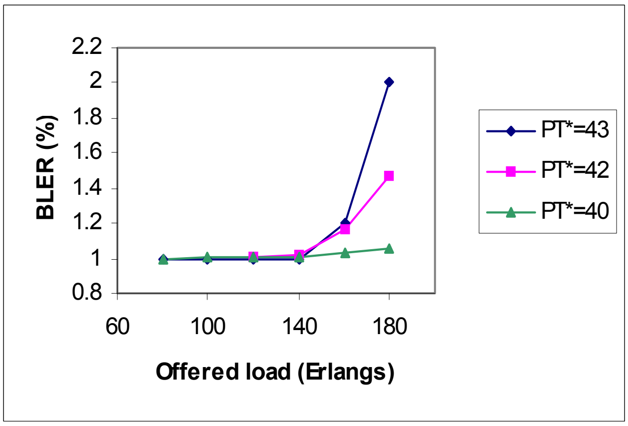

Figure 2. Obtained BLER for different values of P_T^*

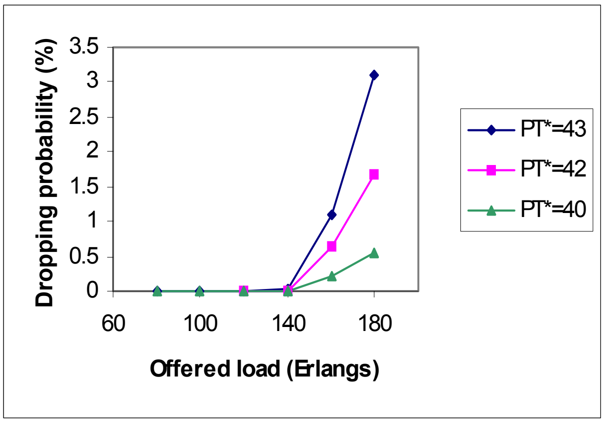

Figure 3. Dropping probability for different values of P_T^*

B. *Maximum power per connection*

In the following some illustrative results of limiting the maximum power per connection are shown. In particular, the relevance of such parameter arises in large coverage areas. Some results considering cell radius of 1500m and admission threshold of 43dBm will be shown. Fig. 4 and 5 show the obtained BLER and the dropping probability as a function of the $P_{c,max}$ for two high load levels. The admission probability is over 98% for both load levels. If the offered traffic in the system is under 140 Erlangs, the BLER is 1% (i.e. the target value). The dropping probability is near zero. With a higher value of offered traffic, 160 Erlangs, the obtained BLER and the dropping probability are considerably higher. It can be seen that there is an optimum value of the maximum power per connection $P_{c,max}$ which will allow to obtain a minimum value of dropping probability and BLER. In this scenario, this optimum value is 37dBm. When considering higher offered traffic than 160 Erlangs, none of the quality requirements can be accomplished.

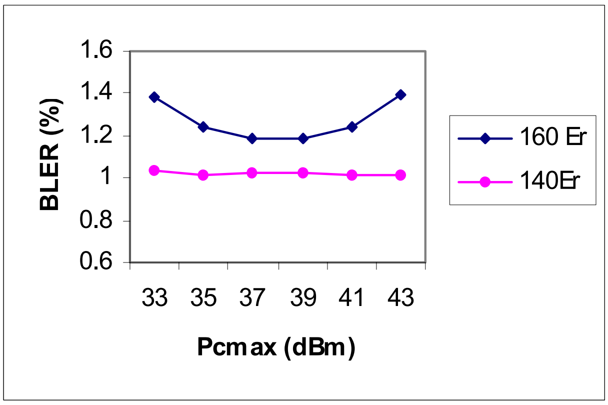

Figure 4. Effect of Pc,max in the obtained BLER

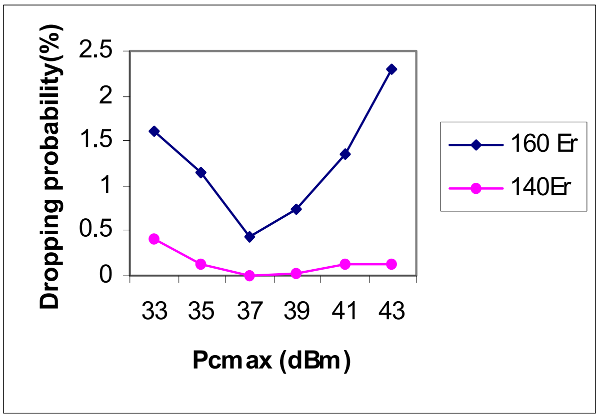

Figure 5. Effect of Pc,max in the dropping probability

In the following, the dropping location distribution is shown when the offered load in the system is 160Er. Important differences can be observed depending on $P_{c,max}$. Fig. 6 and 7 plot the dropping location in the considered 6750m x 6750m scenario (cell radius equal to 1500m). Fig. 6 shows this distribution when the $P_{c,max}$ is set to 33dBm.

As it can be observed, the droppings are located in positions at the edge of the cell (i.e. far from the Node-Bs). The reason is that users far from the node-B cannot satisfy their quality of service requirements because of power limitations. So, the coverage of these users is not assured. It is worth noting that in the central cell, there are few droppings.

In Fig. 7, when $P_{c,max}$ is set to 43dBm (i.e. no restriction in power per connection) the dropping location distribution is more uniform because excessive power expense for some users far from the Node-B reduces the power availability for the rest of accepted users.

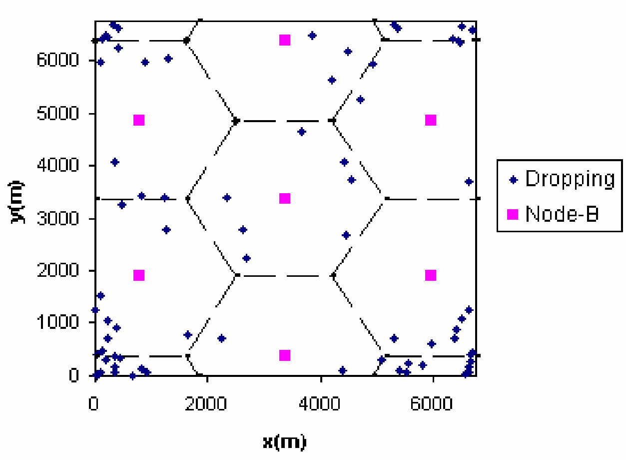

Figure 6.- Dropping positions with $P_{c,max}$=33

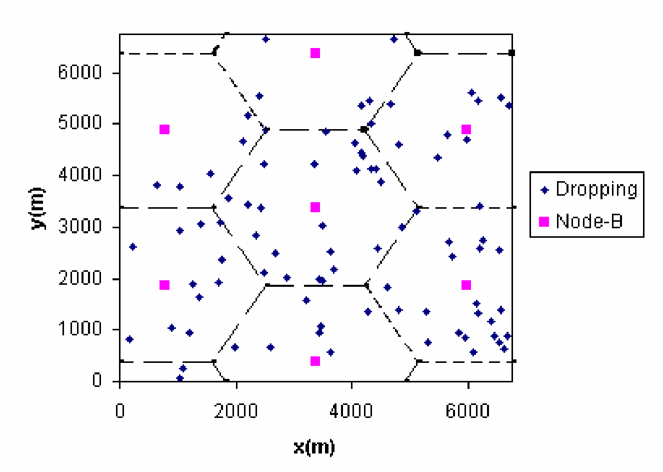

Figure 7.- Dropping positions with $P_{c,max}$=43

When considering a lower cell radius (e.g. R=500m), the value of the maximum power per connection $P_{c,max}$ will not have an important impact on the network performance. The reason is that users will not suffer power limitations because they do not need high power level to satisfy their quality requirements.

C.- Capacity evaluation

For different cell radius and different offered load, a set of simulations have been run in order to find the most adequate value of $P_{c,max}$. It has been observed that for low cell radius $P_{c,max}$ is not a relevant factor. However, for high cell radius the optimum value of $P_{c,max}$ is 37dBm.

Fig. 8 shows the capacity of the system as a function of the cell radius when considering the optimum value of $P_{c,max}$. As it can be observed, the higher the cell radius is, the lower the capacity of the system will be because users far from the base station will need higher power level to obtain the Eb/No target, reducing the available power for the rest of the users.

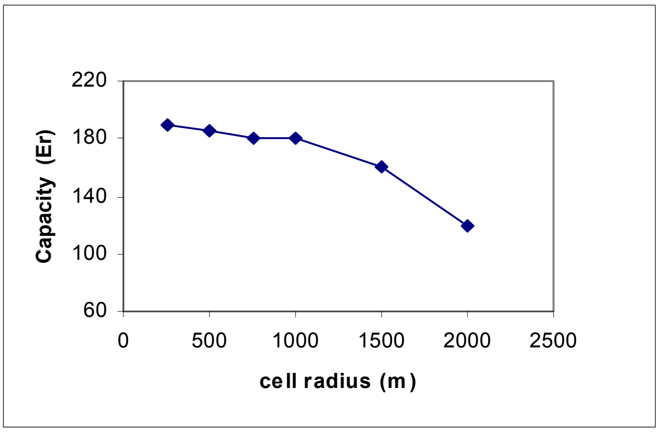

Figure 8.- System capacity as a function of the cell radius

The capacity shown in fig. 8 has been obtained setting the optimum value of $P_{c,max}$ in each scenario. In table 2, the deterioration of the cell capacity when choosing a non-optimum value of $P_{c,max}$ is shown in terms of percentage reduction in the system capacity. It is worth noting that the higher the cell radius is, the higher the difference between the optimum and the obtained capacity will be.

Table 2. Effect of $P_{c,max}$ on network capacity.

Cell radius	Pc,max=33dBm	Pc,max=43dBm
1000	0 %	0 %
1500	-6.25 %	-6.25 %
2000	-25 %	-16.66 %

V. CONCLUSIONS

In this paper some of the relevant elements influencing downlink RRM have been identified and presented. In particular, the downlink admission threshold and the maximum power per connection have been studied for different scenarios. It has been observed that a low admission threshold provides a poor admission probability. However, if P_T^*=43dBm, a better performance is obtained in terms of admission probability, BLER and dropping probability. If the offered load in the system is too high, these requirements will not be guaranteed. The importance to set a maximum power per connection has been shown, especially in large coverage areas, in order to balance the coverage assurance and the fair sharing of the power resources. For the considered cell radius of 1500m, an optimum $P_{c,max}$ of 37dBm has been found. Moreover, the improvement in cell capacity due to an adequate selection of the maximum power per connection has been shown.

ACKNOWLEDGEMENTS

This work has been funded by the Spanish Research Council under the grant TIC2001-2222.

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