On WCDMA Base Station Selection Criteria

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***Abstract*—This letter presents a BS selection criterion for WCDMA that allows selecting the base station requiring the minimum transmission power in both the uplink and downlink direction. The importance of minimizing transmitted power lies on the associated interference reduction and, consequently, the capacity increase. Furthermore, it is shown that, with a proper setting of the parameters, the criterion used in practical WCDMA systems based on Ec/Io measurements can be adjusted to provide results similar to the proposed method.**

***Index Terms*—WCDMA, base station selection, CPICH, handover.**

I. INTRODUCTION

THIRD generation mobile communications systems emerged as the solution to support different types of multimedia services. This new generation, which is mainly based on Wideband Code Division Multiple Access (WCDMA), takes advantage of the inherent flexibility provided by the air interface. In WCDMA based systems, the capacity is highly dependant on the existing interference, and so transmitted power should be properly managed in order to maximize the number of supported users under quality of service (QoS) constraints while keeping the desired coverage area. In this context, the optimisation of the Base Station (BS) selection mechanism becomes a key point in any WCDMA cellular system, and is the focus of this letter. In particular, a BS selection criterion based on the minimization of the transmitted power levels is derived for both the uplink and the downlink. Then, this criterion is compared to the current practical solutions based only on downlink measurements of pilot signals [1]. Furthermore, this letter shows that, by means of a proper setting of the parameters in this practical criterion, it is possible to achieve a performance close to the one obtained with the minimum transmitted power criterion .

II. WCDMA BASE STATION SELECTION CRITERIA

In this section the practical base station selection criterion in WCDMA systems is firstly introduced. Then, the minimum transmitted power criterion providing optimum base station selection is developed. Finally, some representative results demonstrate how to set the parameters of the practical criterion to achieve the minimum transmitted power criterion.

A. (E_c/I_0)-based Criterion

The BS selection criterion used in WCDMA cellular networks is based on downlink measurements in the Common Pilot Channel (CPICH). In particular, the mobile is connected to the base station with the best received (E_c/I_0) [1], measured as the ratio between the received pilot power and the total received power at the antenna input [2]. Notice that this criterion does not take into account uplink measurements, so it may not necessarily lead to a suitable choice from the uplink point of view. On the other hand, in WCDMA it is possible that the terminal is connected simultaneously to more than one base station (i.e. the terminal being in soft handover). The set of cells that the terminal is simultaneously connected to is denoted as active set, and the same criterion based on (E_c/I_0) measurements is used to add cells to the active set (with additional hysteresis margins to avoid ping-pong effect) [1]. More precisely, a cell i will be in the active set if the received $(E_c/I_0)_i$ is higher than $(E_c/I_0)_{Best} - \Delta_{HO}$, where $(E_c/I_0)_{Best}$ is the highest (E_c/I_0) amongst all cells in the active set and Δ_{HO} (dB) is the soft handover margin. Let assume for simplicity and without loss of generality a two cell scenario with base stations i and k. A terminal will have both base stations in the active set provided that:

$$-\Delta_{HO}(dB) < (E_c/I_0)_k(dB) - (E_c/I_0)_i(dB) < \Delta_{HO}(dB) \quad (1)$$

where the $(E_c/I_0)_i$ for the i-th cell is given as a function of the CPICH power P_{pi}, the total path loss L_{pi} that includes shadowing and the total received power at the antenna input, including background noise, I_{TOT}.

$$(E_c/I_0)_i(dB) = P_{pi}(dBm) - L_{pi}(dB) - I_{TOT}(dB) \quad (2)$$

Consequently, the set of path losses where the mobile have both cells in the active set will be given by:

$$-\Delta_{HO}(dB) < \Delta P_p(dB) + L_{pi}(dB) - L_{pk}(dB) < \Delta_{HO}(dB) \quad (3)$$

where it has been defined the difference between pilot powers $\Delta P_p(dB) = P_{pk}(dB) - P_{pi}(dB)$.

B. Minimum Transmitted Power BS Selection Criterion

In an interference-limited scenario like WCDMA, minimizing the interference in the air interface becomes a key point. This can be ensured if the QoS requirements in terms of bit error rate (BER) are obtained with minimum transmitted power. Taking this into account, in the following the BS selection criterion that minimizes the transmitted power is presented. Due to differences in the air interface behaviour, the criterion must be defined separately for uplink and downlink. Regarding uplink, the required transmitted power is expressed as [3]:

$$P_{Ti} = L_{pi} \frac{P_N \frac{1}{1-\eta_i}}{\frac{W}{(E_b/N_0)_i} + 1} \quad (4)$$

where P_{Ti} is the transmitted power, L_{pi} is the path loss, P_N is the uplink background noise power, R_{bi} is the user instantaneous bit rate, W is the total bandwidth after spreading, η_i is the uplink load factor and $(E_b/N_0)_i$ stands for the user link quality corresponding to the required bit error rate. According to (4), in a scenario with N cells, the best cell for a given user is the one which satisfies:

$$\min_i \left(\frac{L_{pi}}{1-\eta_i} \right) \; i = 0, \ldots, N-1 \tag{5}$$

Then, in the case that two cells are considered in the scenario (BS i and BS k), the user should be connected to the cell k if:

$$L_{pi}(dB) > L_{pk}(dB) + 10 \log \left(\frac{1-\eta_i}{1-\eta_k} \right) = L_{pk}(dB) + \alpha_{UL} \tag{6}$$

It is worth noting that, in the uplink case, the decision is only affected by path loss and load factor. Therefore, in a homogeneously distributed traffic scenario with similar load factor levels in all cells, the criterion is equivalent to a minimum path loss based criterion. On the contrary, in non-homogeneous traffic scenarios, low loaded cells will be more appealing than high loaded cells. In downlink case, the power devoted to a user by a certain base station is given by [3]:

$$P_u = L_{pi} \frac{P_N + \chi_i + \rho \frac{P_i + P_{Ti}}{L_{pi}}}{\frac{W}{(E_b/N_0)R_b} + \rho} \tag{7}$$

where L_{pi} is the path loss, χ_i is the intercell interference observed by the user, P_{pi} and P_{Ti} are the powers transmitted by the base station devoted, respectively, to the CPICH and to the rest of transmissions. ρ is the orthogonality factor, P_N the downlink noise power and the user requirements are given by R_b and (E_b/N_0). According to (7), in a scenario with N cells, the optimum cell from the point of view of downlink transmission power will be the one satisfying:

$$\min_i \left(L_{pi} \left(P_N + \chi_i + \rho \frac{P_{pi} + P_{Ti}}{L_{pi}} \right) \right) \; i = 0, \ldots, N-1 \tag{8}$$

Particularizing the analysis for the case with two cells i, k in the system the user should be connected to base station k in the downlink if:

$$\frac{L_{pi}}{L_{pk}} \frac{P_N + \chi_i + \rho \frac{P_{pi} + P_{Ti}}{L_{pi}}}{P_N + \chi_k + \rho \frac{P_{pk} + P_{Tk}}{L_{pk}}} =$$

$$= \frac{L_{pi}}{L_{pk}} \frac{P_N + \frac{P_{pk} + P_{Tk}}{L_{pk}} + \rho \frac{P_{pi} + P_{Ti}}{L_{pi}}}{P_N + \frac{P_{pi} + P_{Ti}}{L_{pi}} + \rho \frac{P_{pk} + P_{Tk}}{L_{pk}}} > 1.0 \tag{9}$$

It has been numerically checked that (9) may be approximated by the expression $L_{pi}(dB) > L_{pk}(dB) + \alpha_{DL}$ for a wide range of path losses, being α_{DL} a factor that depends on the power transmitted by each cell, on the noise power and the orthogonality factor.

Notice that the combination of the conditions in (6) and (9) define three different regions for BS selection in the uplink and the downlink, as depicted in Fig. 1a, obtained with parameters listed in Table 1: Region A, in which both uplink and downlink should be connected to cell k, region C, in which both uplink and downlink should be connected to cell i, and region B, in which uplink and downlink should be connected to different cells. For comparison purposes, Fig. 1b depicts, the corresponding regions according to the (E_c/I_0) based criterion for BS selection given by (3). In this case, also three regions exist: region A'where mobile users are connected to cell k; region B', where users are connected to both cells i and k, and finally region C', where cell i becomes the serving cell. With the minimum transmitted power criterion, region B can be achieved in practice when the terminal has both selection diversity is used to choose the best cell and therefore, the uplink direction will be inherently connected according to the minimum transmitting power requirement. In turn, in the downlink, it is possible to apply the SSDT (Site Selection Diversity Transmit) procedure, which allows transmitting the data channels only through one of the cells that the user is connected to [4].

TABLE I: Simulation Parameters

Parameter	Value
W	3.84 MHz
(E_b/N_0)	3 dB
R_b	64 Kb/s
ρ	0.4
P_N (UL)	-103 dBm
P_N (DL)	-99 dBm

C. Adjustment of (E_c/I_0)-based Criterion for Minimum Transmission Power

Fig. 1a and Fig. 1b reveal that the regions obtained with the minimum transmission power and the (E_c/I_0) based criteria have essentially the same shape. Consequently, in this section it is explored the feasibility of adjusting the available parameters of the (E_c/I_0) criterion (Δ_{HO} and pilot power P_p) in order to ensure a BS selection as close as possible to the minimum transmission power criterion. Let consider a two cell system. In particular, given the scenario conditions η_i, η_k, P_{Ti} and P_{Tk}, notice that, according to (3), by controlling Δ_{HO} the width of region B'can be adjusted to the width of region B whereas by controlling the difference between pilot powers $\Delta P_p = P_{pk} - P_{pi}$ the position of region B' is shifted to the position of region B (see Fig. 1a and Fig. 1b).

Table 2 shows some examples of the setting of P_{pi}, P_{pk} and Δ_{HO} to meet the minimum transmitted power criterion for different situations. Situations exposed in Table 2 cover different representative situations depending on the asymmetry and traffic characteristics. Case 1 corresponds to a homogeneously distributed traffic scenario, where both base stations have the same transmitted power 20 dBm devoted to users as well as the same load factor 0.7. In this case the intermediate region B does not exist and therefore Δ_{HO} should be equal to 0 and the pilot power is the same in both cells. In this particular situation the mobile will be always connected to the cell having the minimum path loss because both cells have the same load. Case 2 corresponds to a situation in which cell i presents a higher load than cell k in both uplink and downlink directions. In this situation the minimum transmission power criterion is achieved with a higher pilot power in cell k and

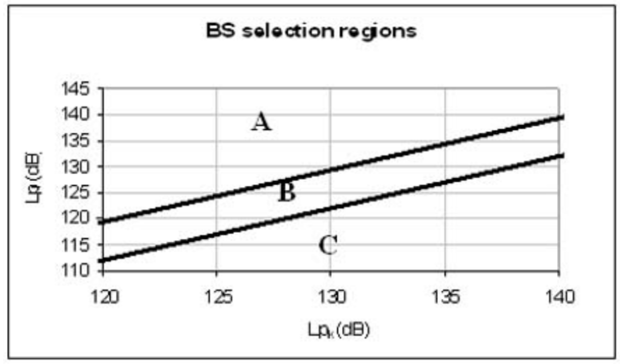
TABLE II: Results of the adjusting process

	System Parameters				Setting of (E_c/I_0) criterion		
	P_{Ti} (dBm)	P_{Tk} (dBm)	η_i	η_k	P_{pi} (dBm)	P_{pk} (dBm)	Δ_{HO} (dBm)
Case 1	20	20	0.7	0.7	30	30	0
Case 2	26	24	0.9	0.4	23	27	3.8
Case 3	23	29	0.1	0.8	25	22	3.5
Case 4	21	31	0.8	0.9	25	24	2.0

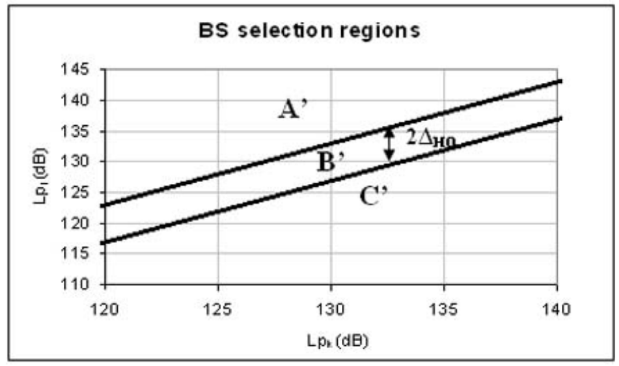
a handover margin of 3.8 dB in order that users at the edge of cell i can be connected to cell k. Case 3 corresponds to the case in which very high differences in the cell load exist in the uplink direction (i.e. the load factor for one cell is 0.1 while for the other it is 0.8) while the differences are smaller in the downlink (i.e. the transmitted powers devoted to traffic are 23 dBm and 29 dBm). Similarly, Case 4 reflects the case in which the differences in load levels are higher in the downlink direction while similar uplink load exists. These two cases could be representative of unbalanced situations in terms of traffic characteristics, in which cell k could contain a large amount of symmetric traffic, thus leading to a high uplink load factor and downlink transmitted power. In turn, the traffic in cell i would be asymmetric, with a higher amount of downlink traffic in case 3 and a higher amount of uplink traffic in case 4. In both cases a proper setting of the pilot powers and the handover margin leads to a BS selection according to the minimum transmission power requirement. The results presented here have considered for simplicity a two-cell scenario to better illustrate the proof-of-concept of the proposed base station selection method. In that sense, equations (5) and (8) already consider the method in a multi-cell case. Furthermore, regarding the adjustment of the pilot powers and handover margins of the different cells to fulfil the minimum transmitted power selection strategy, the methodology for the two-cell case could be easily extended. Although this is out of the scope of this letter, the envisaged approach is to consider a system of equations with a higher number of variables to set (i.e. the corresponding pilots and handover margins for each cell). Notice also that, in practice, for a properly planned WCDMA system, the number of possible base stations to select would be reduced, which would limit the complexity increase of the system then ensuring the practical feasibility of the proposed methodology.

III. Conclusion

The BS selection criterion based on minimum transmitted power has been presented in this letter for both uplink and downlink directions in a WCDMA system. This criterion is claimed to achieve a reduction in system interference and, consequently, a capacity increase. Likewise, it has been also shown that base selection criteria used in practical WCDMA systems, such as the (E_c/I_0) based criterion, may perform very close to the minimum transmitted power criterion with a proper setting of the pilot powers and soft handover algorithm margin. Then, a second contribution of the letter is to provide the guidelines for setting the parameters of the currently used (E_c/I_0) based criterion in order to reduce the system interference.



(a)



(b)

Fig. 1: BS selection regions with the (a) minimum transmitted power criterion and (b) with the (E_c/I_0) based criterion.

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