On Managing Dynamic Traffic Hotspots in WCDMA Networks

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***Abstract*—This paper evaluates the impact of static and dynamic hotspots in the performance of a WCDMA network and provides certain guidelines and mechanisms in order to manage in an appropriate way the use of radio resources under non-homogeneities in the traffic spatial distribution. First of all, the impact of the geographical location of a static hotspot on downlink system performance has been analysed. Then, dynamic hotspots (i.e. hotspots that move following a certain mobility pattern) have been studied, indicating how the hotspot movement affects on the network performance. Moreover, a pilot power adjustment algorithm that equalises the base station transmission power of the hotspot cell and its adjacent cells has been proposed and analysed. The improvement provided by this pilot power adjustment algorithm has been evaluated in terms of base station transmission power, transmission power of pilot channel, dropping probability and rate of handovers per user.**

Keywords: WCDMA, Radio network planning, Hotspot, Pilot power.

I. INTRODUCTION

In a real mobile network, there are certain geographical areas with high density of users. In these areas, a high demand of radio resources may appear. In order to assure the user QoS (Quality of Service) requirements in a hotspot, it is necessary a proper radio network planning (e.g. by a proper definition of the different base station locations, transmission powers, pilot channel power, etc.). However, hotspots characteristics (such as geographical location, etc.) are not always known a priori, so an unexpected increase in the demand of resources by a hotspot can have a relevant impact on network performance. Therefore, it is prime important a proper evaluation of the effect of these hotspot peculiarities on the network behaviour. Moreover, the existence of dynamic hotspots (i.e. a group of mobile users that move following a certain mobility pattern, such as the way out of a railway station, the exit of a football match, etc) and its impact on system performance is as well an important issue, especially on the forward link, where the user location distribution affects directly on the base station power allocation [1] (i.e. many users far from the Node-B may demand high levels of power causing that the base station has not enough power to satisfy all users demands).

These dynamic changes in the network may cause overload situations where the user QoS requirements can not be guaranteed. These overload situations can be prevented by RRM (Radio Resource Management) mechanisms (e.g. admission control or congestion control algorithms) which determine how the radio interface is used and shared among the users. Another technique that is commonly used is to adjust the transmission pilot power of the hotspot cells and its adjacent cells [2][3]. The base station pilot power of an overloaded cell must be reduced and the pilot for the low-loaded base stations must be increased. By doing this, users that are connected to an overloaded cell can be handed over to lower-loaded cells.

For the downlink case, the main resource that is shared among users is the base station transmission power. A proper balance of the different base station transmission power provides better network performance because the base station power limitation probability (i.e. the probability that a base station has not enough power to satisfy all users demands) is reduced. However, these balancing techniques based on the pilot power can increase the overall interference, because certain users may not be connected to the nearest base station, which will increase the transmission power. This is a critical issue, especially in interference-limited networks (such as WCDMA). There is a trade-off between the capacity gain obtained by pilot adjustment and the capacity loss due to interference rise. Moreover, these pilot power adjustment techniques will introduce higher number of handover procedures, increasing the network signalling.

In order to solve the effects of non-homogeneities in the user spatial distribution different proposals can be found in the open literature[2-5]. A pilot power adjustment is proposed in [4] using a cost minimization method to guarantee certain target of load and coverage. In [5] an adaptive soft handover algorithm is proposed in order to shed traffic from overloaded cells to low-loaded cells. [6] proposes a load balancing algorithm which adjusts the pilot power of the base stations in order to equalise the base station transmission powers.

The objective of this paper is twofold. On one hand, to evaluate the impact of static and dynamic hotspots on network performance and provide certain guidelines which must be considered in a radio network planning exercise. The importance of the hotspot location and its mobility pattern (static, directional or random mobility) has been analysed. On the other hand, this paper proposes and evaluates a pilot power adjustment algorithm which equalises the load of the different cells in order to prevent overload situations that may be caused by mobile hotspots. The most influencing parameters of the proposed algorithm have been identified and their impact in terms of base station transmission power, pilot channel power, dropping probability and number of handover procedures has been studied. Within this context, this paper is organised as follows. Section 2 presents the considered hotspots scenarios and the impact of the hotspot location and the mobility model on system performance. The proposed pilot power adjustment algorithm is presented in Section 3. Section 4 shows the obtained results for static and dynamic hotspots, and the performance of the proposed algorithm is presented in Section 5. The conclusions are summarised in Section 6.

II. HOTSPOT SCENARIOS

The considered cell layout consists of 12 omni-directional cells with base spacing of 1000m. The different base stations have been numbered as shown in Figure 1. Two kinds of users have been considered. On one hand, 50 conversational users have been distributed uniformly in all the scenario. These users move at 3km/h with random movement taking into account the model mobility of [7]. On the other hand, a hotspot is located in a rectangular region whose position and mobility pattern can be chosen at the beginning of the simulation. The number of users in the hotspot has been varied form 45 to 75 in different simulations. The hotspot users can remain static, move together with a rectilineous trajectory (e.g. users move together along a main road) or a random movement (i.e. users located at certain point which disperse in a random way). These group of users are assumed to move at 3km/h.

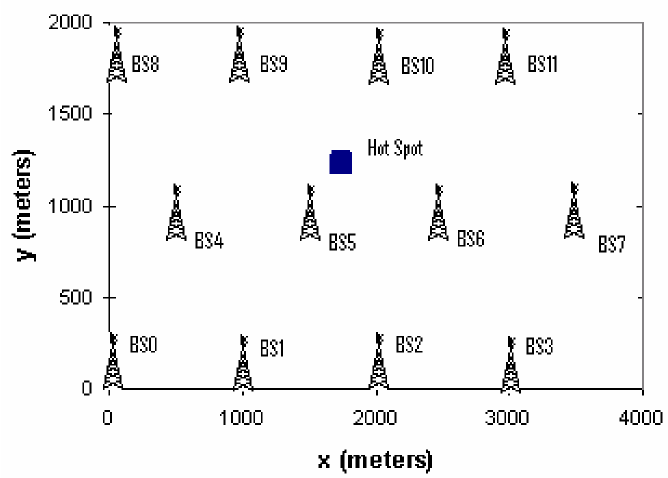

Figure 1.-Simulation scenario.

The simulation considers CBR 64kbps conversational services. 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 [8]. 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) [9]. Table 1 shows the simulation parameters.

Table 1 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
Pilot and common control channels power P_c	30 dBm
Thermal noise	-106 dBm
Shadowing deviation	6 dB
Shadowing decorrelation length	20 m
Orthogonality factor	0.4
Measurement period (*T*)	1 s
Handover parameters	
Active Set maximum size	1
Time to trigger HO	0.5 s
Traffic model	
Call duration	120 s
Offered bit rate	64kb/s (CBR)
Activity factor	1
Call rate	29 calls/h/user
QoS parameters	
Block Error Rate (BLER) target	1 %

A. Static hotspot

First of all, for comparison purposes, two simulations have been run locating a static hotspot at 50m and 200m from Base Station 5 respectively. Figure 2 shows the impact of the hotspot location on the transmission power of base station 5 and 10. As shown, when the hotspot is located far from Base Station 5 (HS at 200m), the power increase is higher than when the hotspot is nearer (HS at 50m). This is because hotspot users located far from the base station demand higher level of power to guarantee the (Eb/No)target. So, if the hotspot is located relatively far from its base station, it can happen that the Base Station may not have enough power to satisfy all user requirements, causing bad signal quality. Note that the location of the static hotspot does not affect on transmission power of base station 10, because the hotspot is too far from this base station. If the hotspot location is a priori known, the impact of a static hotspot can be reduced by an adequate network planning (e.g. by locating a base station near the hotspot area).

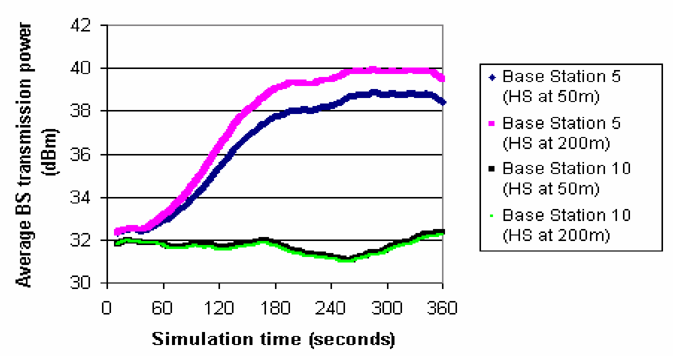

Figure 2 Effect of static hotspot location on BS power

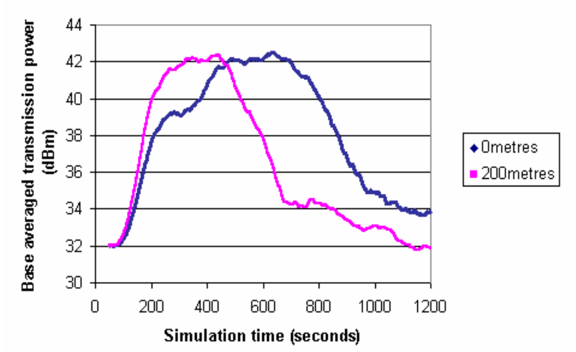

Figure 3.- Impact of hotspot movement on BS5 transmission power

B. Dynamic hotspot

In the following, the impact of dynamic hotspots on network performance will be studied. Two different hotspot mobility models have been analysed. First, the named "hotspot rectilineous movement", which considers a group of users that move together along a main road, and secondly, the so-called "hotspot random movement", which considers a hotspot initially located at certain position from which users begin to disperse randomly.

With respect to the "rectilineous movement" it is assumed that the hotspot users will move from BS5 to BS10 following a directional trajectory. For comparison purposes, two different initial positions of the hotspot have been considered (at 0meters and 200 meters from BS 5). Figure 3 shows the BS 5 averaged transmission power for both cases. Moreover, in order to evaluate the system performance, the dropping probability as a function of time (i.e. the probability of dropping a connection due to bad signal quality calculated in ranges of 50seconds) has been plotted in Figure 4. A connection is dropped if the current (Eb/No) is 1dB below the target value during the 90% of time in 1second. As shown in Figure 3, as the hotspot users move far from BS5, the average base station power is increased. Higher increase can be observed when the hotspot appears at 200meters, for the same reason as explained in Figure 2. At certain instants of time the base station has not enough power to satisfy all user demands and certain connections will be dropped, as shown in Figure 4. When hotspot users arrive near the cell edge, they will begin to handover to BS 10, and then, the BS 5 transmission power will be reduced. Obviously, this fact will happen first if the hotspot is initially located at 200m from BS 5.

It is worth noting that if the hotspot users were initially located at 0metres from BS5, the overload situation in BS5 would last longer because the hotspot users connected to BS5 would need much time to reach the coverage area of BS10 and make handovers. Moreover, when the hotspot is initially located near BS5 the overload situation and the droppings occur later, and then the available time to prevent this overload is higher.

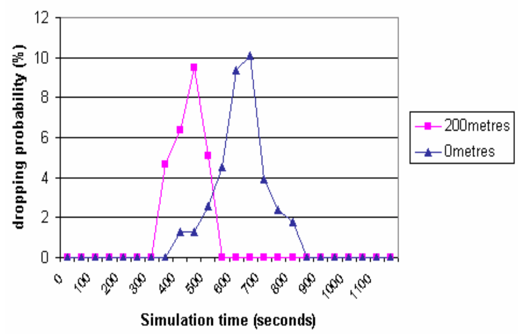

Figure 4 Impact of hotspot movement on dropping probability

In the following, the effect of the hotspot mobility model is studied. The "hotspot rectilineous movement" pattern is compared to the "random movement" model where the hotspot users disperse in a random way. Figure 5 shows the effect of user movement on average transmission power of BS5 and BS10. As shown, the movement model does not affect so much on BS5 transmission power but on BS10. For the rectilineous movement, when the hotspot users reach BS 10 coverage area, they begin to handover to BS10, shifting the overload situation from BS5 to BS10. However, when the users move randomly, the overload occurs only in BS5 and as the users disperse, the overload disappears. As shown, given certain base station locations, the existence of mobile hotspots and its mobility pattern have a relevant impact on the performance of the different cells of the network.

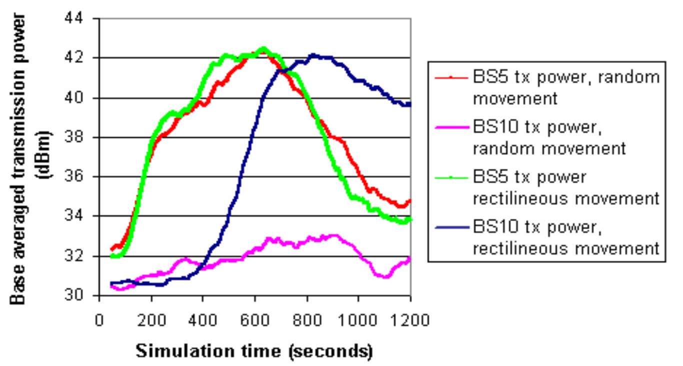

Figure 5 Impact of hotspot mobility model on BS transmission power

III. PILOT ADJUSTMENT ALGORITHM

In order to manage dynamic traffic hotspots not only network planning but also RRM algorithms must be considered. Non-uniform user distributions make that certain cells may be overloaded while the load of other cells is quite low. The objective of the proposed pilot adjustment algorithm is to reduce these differences in the load of the different cells by shedding traffic of overloaded cells to low loaded cells. By doing this, a more uniform traffic distribution will be obtained and then, these overload situations will be reduced. For the downlink case, the base station power is the resource that is shared among the users. Therefore, the target of the balancing algorithm is to adjust the base stations pilot power in order to equalise the transmission power of all the base stations. So, given all the base station powers, the pilot is determined following the algorithm proposed below.

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

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

In order to explain the performance of the proposed pilot adjusting algorithm, let us define $\overline{Ptot}(i)$ as the average of the transmission powers of all the base stations.

$$\overline{Ptot}(i) = \frac{\sum_{k=1}^{NumBS} P_{AV}(i,k)}{NumBS} \quad (2)$$

Where *NumBS* is the number of Base Stations where the pilot adjustment algorithm is applied and $P_{AV}(i,k)$ is the average transmission power of the k-th Base Station at the i-th frame. Notice that it is assumed that all of them are macro-cell base stations.

Then, the pilot power of k-th Base Station is changed with a period of *Tp* as follows:

$$Ppilot(i,k) = Ppilot(i-1,k) + \Delta(i,k) \quad (3)$$

Where $\Delta(i,k)$ is the pilot adjustment of the k-th Base Station in each iteration *i*.

$$\Delta(i,k) = 10 \cdot \alpha \cdot \log \frac{\overline{Ptot}(i)}{P_{AV}(i,k)} \quad (4)$$

It is worth noting that the increase or reduction of the k-th base station pilot depends on the relationship between the k-th base station transmission power and the average power of all the base stations. By doing this, the pilot power of each base station is modified in order to make that all the base station powers converge to the same average value. The parameter α determines the sensitivity in the changes of the pilot power.

IV. RESULTS

In order to observe the improvement obtained with the pilot balancing algorithm, the hotspot is located next to BS5. These users move from BS5 to BS10 at 3km/h in a directional trajectory. Figure 6, compares the transmission power of BS5 and BS10 with the proposed pilot adjustment algorithm (with load balancing) and without the proposed pilot adjustment algorithm. The pilot power is changed once in a second (Tp=1second) and α=1. As shown, when no load balancing is considered, an overload of BS5 and BS10 can be observed as users move from BS5 to BS10. With the load balancing technique, the transmission power of BS5 and BS10 is equalised (see Figure 6) adjusting the pilot in an adequate way as shown in Figure 7, where the average value of the pilot power of different BS is plotted. The load balancing technique reduces the power limitation probability of the different base stations, and this will reduce the dropping probability as it is shown in Table 2.

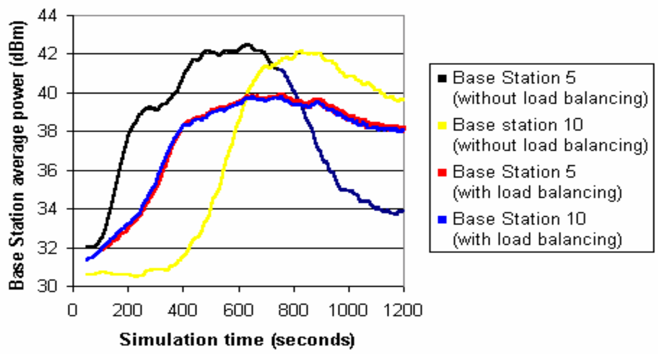

Figure 6 Impact of load balancing in BS transmission power

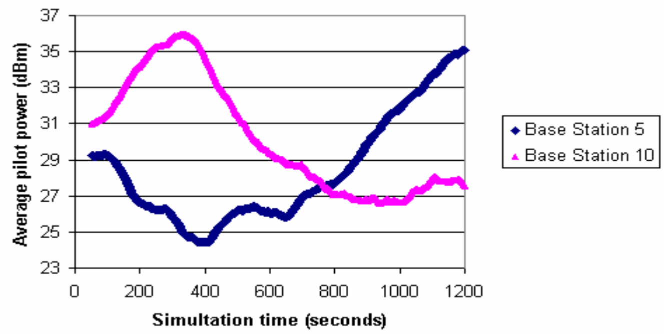

Figure 7 Evolution of the pilot power of different BS when the proposed pilot adjustment algorithm is applied

Different simulations have been run in order to observe the effect of the sensitivity in the pilot adjustment *α* and the time between pilot adjustments *Tp*. Too high values of *Tp* cause a too slow reaction of the pilot balancing algorithms while a too low value of *Tp* causes wrong decisions in the load balance because then, decisions are taken with measurements that are not enough averaged. In previous results, which are not shown in this paper, an optimum value of *Tp*=1second was obtained. Related to the sensitivity, Figure 8 shows the effect of α in the pilot adjustment technique. As shown, higher values of α provide higher sensitivity in the pilot adjustment and then, higher changes in the pilot power can be observed.

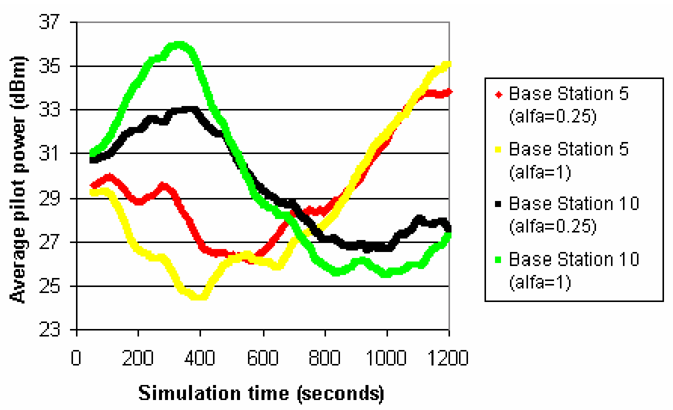

Figure 8 Impact of α in the pilot power.

Table 2 shows the dropping probability and the average time between handovers per user, for different values of α and when no load balancing is carried out. As shown, the proposed algorithm reduces the dropping probability with respect to the non-load balancing case, but it increases the rate of handovers causing an increase in network signalling. Moreover, the importance of a proper selection of α in the load balancing is provided. A too high value of α may increase the overall interference (because of higher values in the pilot power, as it was shown in Figure 8). This will increase the dropping probability, as shown in Table 2. On the other hand, Table 2 shows that a high value of α increases the number of handovers per user. The most appropriate value of α is between 0.1 and 0.25.

Table 2. Impact of α in dropping and handover statistics.

	No Balance	α =0.1	α =0.25	α =1
Dropping prob.	2.38	0.16	0.14	0.51
Avg. Time between HO per user (sec.)	42.93	34.71	23.47	12.24

V. CONCLUSIONS

This paper has analysed the impact of static and dynamic hotspots on the performance of a WCDMA network. First of all, the impact of the hotspot location on the base station transmission power has been presented. Then, the impact of dynamic hotspots has been shown in terms of base station power and dropping probability. The effect of the hotspot mobility model has been studied showing that rectilineous hotspot movement can cause longer overload situations than when hotspot users disperse in a random way because in the latter case, as the users tend to disperse the hotspot disappears. Moreover, a pilot adjustment strategy has been proposed in order to shed load from overloaded cells to low-loaded cells. As shown, this algorithm equalises the different base station transmission powers reducing the dropping probability. Moreover, the impact of the sensitivity in the pilot power adjustment has been presented indicating that an excessive balance of load may increase too much the overall interference (increasing the dropping probability) and, as well, increase the network signalling due to higher number of handover procedures.

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