Interactions Among UMTS Microcells and Macrocells Supporting Data Traffic in a Real Airport Scenario

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Abstract - **This paper analyses a solution to provide UMTS coverage in a real airport scenario by reusing existing GSM infrastructure. In this case, macrocell and microcell layers are highly decoupled in terms of interference, so that it is shown that CPICH power adjustment does not play a significant role in interlayer traffic distribution. On the other hand, with respect to in-building coverage, it has been observed that by reducing the number of repeaters per microcell an increase in capacity can be obtained.**

***Keywords* – UMTS, WDCMA, macrocell, microcell**

I.- INTRODUCTION

The mobile communications industry is currently shifting its focus from 2G to 3G technology. While current 2G wireless networks, in particular GSM, will continue to evolve and to bring new facilities and services onto the market aided by GPRS functionalities, more and more radio engineers are becoming familiar with W-CDMA radio technology and are involved in building and launching 3G networks.

Introduction and roll-out of 3G networks is costly and happens within a very competitive and mature 2G environment. Therefore, operators are using their existing GSM network to the fullest possible extent, with co-siting 3G sites with existing 2G sites to reduce cost and overheads during site acquisition and maintenance. Besides, initial UMTS market targets will focus in business-active environments, such as airports, hotels, commercial and office areas, etc. These strategies are backed by business plans for both the future service demand and the requirement for investment in network infrastructure.

System deployment must be preceded by careful network planning. Planning tools and mechanisms must accurately model system behaviour when loaded with the expected traffic profile. Compared to 2G, much more simulation work regarding 3G networks is necessary because of the multiple issues impacting the network performance and the much higher degree of coupling among them deriving from the W-CDMA nature, where users transmit at the same time and on the same carrier [1]. Additionally, the number of tunable parameters in a W-CDMA network is significantly higher than that of a 2G TDMA-based one [2].

The present study focuses on a real airport scenario, which is expected to be one of the most UMTS relevant business environments. Pre-existing GSM infrastructure includes intensive in-building microcells and partially overlaying outdoor macrocells. The analysed UMTS deployment solution makes use of intensive co-siting by considering the existing outdoor macrocell sites (i.e. a UMTS node B located in an existing GSM macrocell). With respect to in-building coverage, it is provided by distributing through fiber optic a UMTS node B signal to a set of repeaters which are located in the existing GSM microcells. So given a number of GSM microcells, several configurations can be considered (e.g. one single UMTS microcell that distributes the signal between all the repeaters, two UMTS microcells each with half the number of repeaters, etc.). The purpose of this paper is to study the coexistence of the two layers of UMTS macro and microcells in the considered scenario, analysing the limiting factors in each case, and finally studying the improvement in terms of capacity that can be achieved by varying the microcells configuration. Nevertheless, the ultimate objective of this work falls far beyond the analysis and optimisation of the considered airport and targets and aims at providing general guidelines for UMTS network deployment by identifying the key parameters and providing criteria to set their values based on relevant scenario and services characteristics.

The rest of the paper is organized as follows. Section 2 describes the analysed scenario and presents the considered simulation approach. Then, Section 3 further develops the study of the scenario by means of obtained results. Finally, Section 4 summarises the reached conclusions and the future work.

II.- SCENARIO AND SIMULATION APPROACH

The considered scenario is a real airport scenario, where different UMTS deployment configurations can be simulated. It is assumed that all existing GSM cells are re-used to deploy UMTS equipments. In particular, the scenario is composed of in-building microcells and partially overlaying outdoor macrocells. By means of a tracing tool, all GSM900/1800 Measurement Reports generated by mobile terminals in the interest area (i.e. the airport) and during the busy hour are recorded and processed in order to build a database containing realistic propagation conditions. Because of the GSM-UMTS co-siting, the collected propagation data is valid for simulating the UMTS scenario simply by making some corrections due to frequency (from 2G bands to UMTS band) and antenna downtilting in case. This avoids the inaccuracy of using propagation models in the simulation model. Then, by feeding the simulator with this propagation database, radioelectrical traffic distribution (i.e. path losses distribution) is captured in a realistic way.

With respect to UMTS in-building microcells, the scenario considers that one microcell distributes the signal between a number of repeaters located in existing GSM microcells. Notice that all these repeaters are transmitting exactly the same signal generated by the UMTS microcells. It should be pointed out that these distribution impacts over the measured thermal noise in the uplink direction, in the sense that the higher the number of repeaters per UMTS microcell the higher the noise power will be.

The simulations consider a 64 kb/s data service, and the main radio transmission parameters considered in the simulations are shown in Table 1. Both uplink and downlink are analysed and different load conditions are considered in the simulations. The considered notation is BS0, BS1 and BS2 for the outdoor macrocells and BS3 in the case of a single indoor microcell (i.e. all repeaters belong to one microcell).

The steps carried out in a UMTS simulation snapshot are the following:

1. Decide the number of users present in the scenario, *N*.
2. Distribute the users in the scenario (i.e. to select a Measurement Report from the database for each user). The traffic distribution can be either the same extracted from the network measurements or can be modified at will according to the expected spatial service distribution.
3. Once all users are scattered in the scenario, run the power control module to decide the transmitted power levels for all users. Each user aims at achieving a certain target quality level, expressed in terms of a $(Eb/No)_{target}$, according to the required QoS and service class. Notice that this allows an exact analysis of the interference pattern arisen in the snapshot.
4. Collect statistics and performance figures of interest.

As a preliminary result, and to gain insight in the scenario, Figure 1 plots the cumulative distribution function (cdf) of the path loss difference between the best macrocell (PLmacro) and the best microcell (PLmicro) included in the Measurement Reports extracted from the radio access network tracing. This distribution provides important information about the analysed scenario and about users' connectivity. It can be observed that:

- Users scattered throughout the airport detect only in-building microcell in 15% of the cases (i.e. notice that in 15% of the cases PLmacro -PLmicro tends to ∞, meaning only microcell coverage)
- In 21% of the cases they only detect outdoor macrocell (i.e. in 21% of the cases PLmacro-PLmicro tends to –∞, meaning only macrocell coverage)
- In the remainder of the cases both layers are detected simultaneously

Table 1. Main radio transmission parameters.

RAB	UL: 64 Kbps / DL: 64 Kbps
Maximum power UE	24 dBm
Minimum power UE	-41 dBm
Orthogonality factor	0.4
Eb/No target UL (dB)	4.3
Eb/No target DL (dB)	6.7
Maximum Power BS	Macros: 43 dBm Micros: 17 dBm
Maximum power per connection	Macros: 35 dBm Micros: 10 dBm
Pilot power	Macros: 29.5 dBm Micros: 3.5 dBm
Thermal noise UL	Macros:-104 dBm Micros: -86 (all repeaters in a UMTS microcell), -91 dBm (repeaters distributed in 3 UMTS microcells)
Thermal noise DL	-100 dBm
Soft HO margin	5 dB

Real traffic measurements of the existing GSM cells are also considered in order to decide the connectivity to the UMTS cells (i.e. to select the cell with minimum path loss), but notice also that users will be connected to the microcell provided that its measured Ec/Io exceeds that of the macrocell, where Ec is the chip energy of the pilot channel (CPICH) and Io is the total power density in the UMTS band. Then, given that Io is the same for both the microcell and the macrocell, a user will be connected to the microcell if Ecmicro > Ecmacro or, equivalently, if the path loss difference is higher than the difference Δ between the transmitted pilot powers (i.e., PLmacro-PLmicro>Δ (dB)). Thus, the role played by the corresponding microcell and macrocell pilot power strengths is clearly reflected. In particular, for a typical macrocell pilot power of 29.5 dBm and a typical microcell pilot power in the range of 3.5-7 dBm, 42 to 44% of the users would remain connected to the microcells because of the specific form of the cdf found in Figure 1. This indicates that in the current scenario, where microcells and macrocells are fairly decoupled (i.e. there is not a tight macrocell acting as umbrella on the microcells), CPICH power adjustment is not very useful for interlayer traffic distribution. For the same traffic distribution obtained in the GSM tracing, the connectivity results are shown in Figure 2.

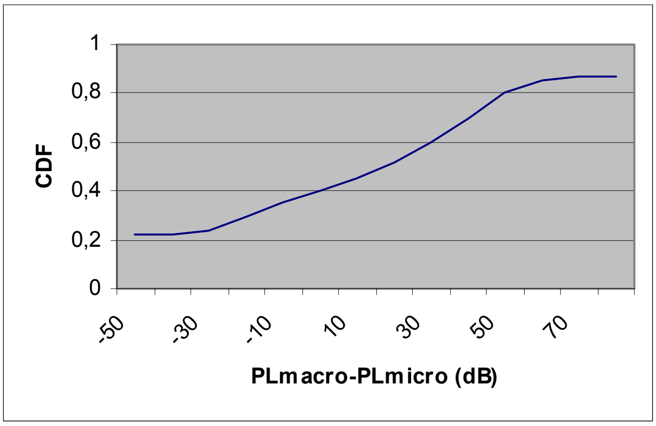

Figure 1 Cdf of the path loss difference between macro and microcell

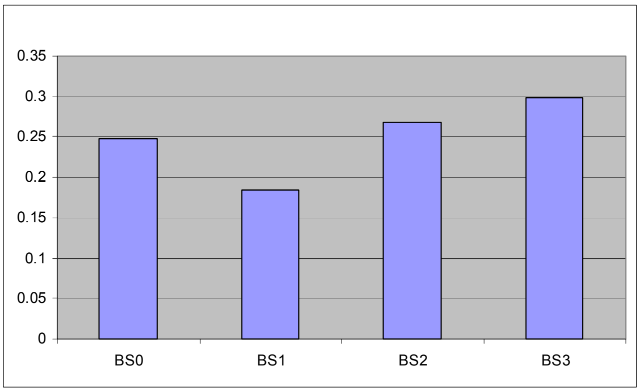

Figure 2 Histogram of the serving cell

III.- RESULTS

For the uplink, Figures 3 and 4 show the cdf of the UL transmitted power for different total number of users in the scenario. Maximum UE transmitted power is 21 dBm. In these results, in-building coverage is provided by a single microcell with all the repeaters connected to it. It can be seen that:

- For the microcell (Figure 3), as the number of users in the scenario increases, UEs suffer from power limitation. In addition to the cell load level, power limitations are also due to the higher noise level in the microcell uplink compared to macrocell because of the fiber-optic repeater configuration (i.e. -86 dBm for the microcell and -104 dBm for the macrocell).
- For the macrocell (Figure 4), as the number of users in the scenario increases, a similar effect is observed. However, in this case it is due to cell load as well as the higher path losses associated to macrocell.

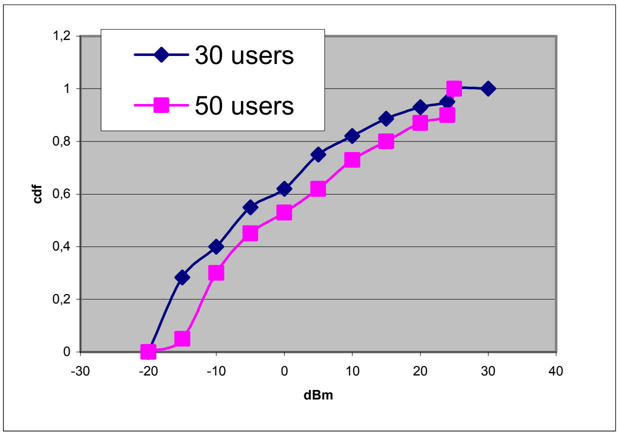

Figure 3 cdf of the UL Tx power when a user is connected to a microcell

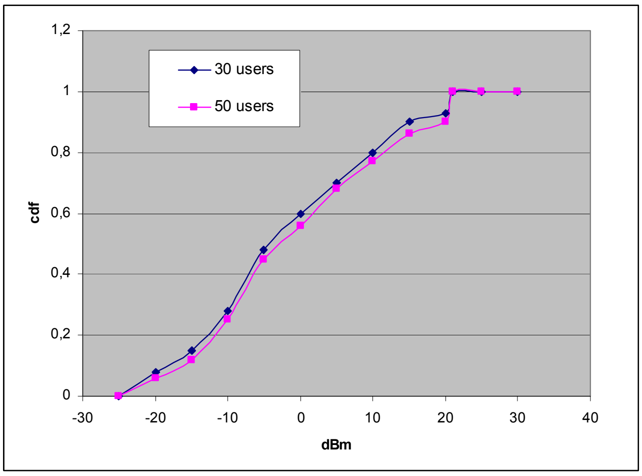

Figure 4 cdf of the UL Tx power when a user is connected to a macrocell

For the downlink, Figures 5 and 6 show the DL transmitted power to a user when it is connected to the macrocell or to the microcell respectively. Similar effects as in the UL can be observed. Specifically, the degradation observed by the microcell is much more significant than that of the macrocell. In this case it is because of the much lower power availability in the microcell downlink.

Additionally, Figure 7 and 8 present the outage probability for uplink and downlink respectively (i.e. the probability of not reaching the required Eb/No target) as a function of the number of users in the scenario. It can be observed that for low load conditions there is a non null outage probability in both uplink and downlink. This is reflecting some locations in the considered scenario that are out of coverage, particularly in outdoor macrocell BS0. Thus, BS0 is the most limiting one in uplink. On the contrary, the microcell BS3 is the limiting element in downlink and forces that the scenario comes to be downlink limited because of the low downlink power available for the large proportion of traffic supported in BS3.

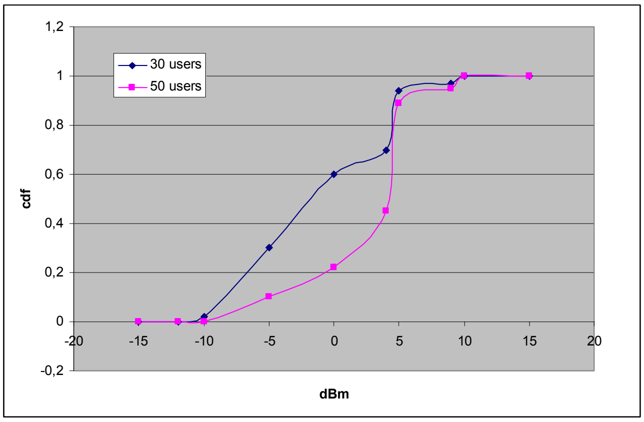

Figure 5 Cdf of the transmitted power in the DL when the user is connected to a microcell

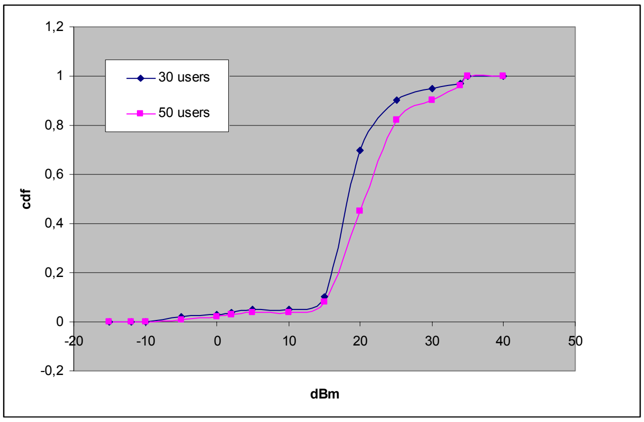

Figure 6 Cdf of the transmitted power in the DL when the user is connected to a macrocell

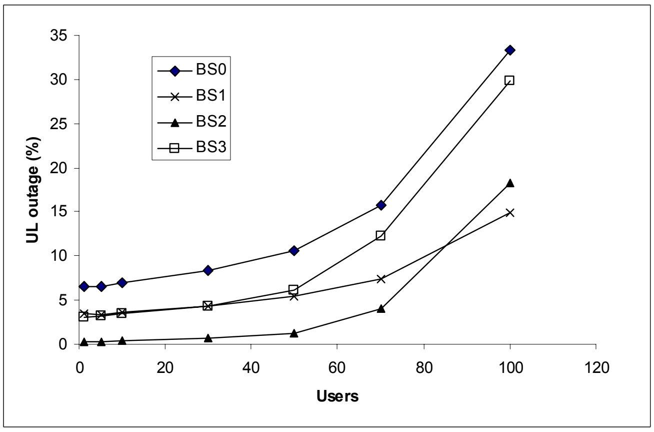

Figure 7 Uplink outage probability per cell

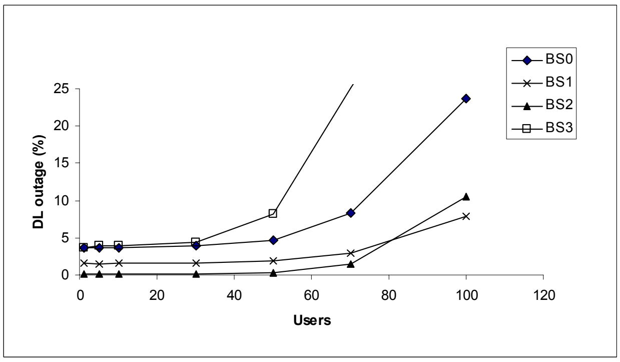

Figure 8 Downlink outage probability per cell

Based on the above results, the scenario can be improved in terms of capacity by considering other possibilities at microcell layer, which constitutes the limiting element. One possibility would be to consider equipment with higher transmitted power levels (e.g. 30 dBm instead of 17 dBm). Another possibility is to increase the number of microcells while maintaining the number of repeater terminations, so that readily the number of repeaters per cell is reduced. Thus, on one hand the uplink noise level is reduced and on the other hand for a given load in the scenario the load per cell is lowered, then requiring less power.

Let consider the case of a 3 microcell configuration (i.e. BS3 formerly with all repeaters connected to it is now split into 3 microcells with a third of the repeater connected to each microcell). Table 2 shows the total capacity in the scenario for a 10% overall outage probability in the 1 and 3 microcell configurations.
The gain is about 40% for downlink, mainly due to more radio resources available (the same power per microcell is in charge of a smaller coverage area), and 20% for uplink, mainly due to lower thermal noise level.
Besides, it can be observed that for one microcell configuration the scenario becomes slightly downlink-limited while for the 3 microcell case it becomes uplink limited. This is because the 3 microcell effects are more noticeable in downlink, as much power resources are available.

Table 2. Capacities for a 10% overall outage probability

	1 micro	3 micros
Uplink	70	83
Downlink	68	95

IV.- CONCLUSIONS

This paper has analysed a solution to provide UMTS coverage in a real airport scenario by reusing existing GSM infrastructure. It has been shown that in the analysed scenario, where macrocell and microcell layers are highly decoupled in terms of interference, CPICH power adjustment does not play a significant role in interlayer traffic distribution. On the other hand, with respect to in-building coverage, it has been observed that by reducing the number of repeaters per microcell an increase in capacity can be obtained, since this allows a redistribution of the in-building traffic that avoids power limitations. Finally, the considered scenario becomes uplink limited in a 3 microcell configuration, as the more downlink power resources available alleviates power limitation problems in downlink.

ACKNOWLEDGEMENTS

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