An Analysis of Deployment Alternatives in a Real UMTS Scenario to Support Voice and Data Traffic

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Abstract— **This paper focuses on the deployment of UMTS in a real airport scenario, which is expected to be one of the most UMTS relevant business environments, by means of reusing the existing GSM network infrastructure. In this framework, the paper considers that outdoor macrocells and in-building microcells provide coverage to the area of interest through co-siting 3G sites in existing 2G sites. Different deployment solutions are analysed in terms of number of microcells and maximum power per microcell. The study identifies the suitable configurations and parameters depending on the considered service mix and taking into account both technical and economical issues.**

Keywords- UMTS; macrocell ; microcell; 2G and 3G co-siting

I. INTRODUCTION

Nowadays the mobile communications industry is shifting its focus from 2G to 3G technology. In parallel with the evolution of current 2G wireless networks like GSM with the introduction of 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.

In most cases, and since introduction and roll-out of 3G networks is costly and happens within a very competitive and mature 2G environment, operators are using their existing GSM network to the fullest possible extent, by means of co-siting 3G sites with existing 2G sites. This allows reducing cost and overheads during site acquisition and maintenance and denotes that the deployment of 3G networks should result not strictly from technical issues but from the combination of technical with economical aspects. 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][2]. Additionally, the number of tunable parameters in a W-CDMA network is significantly higher than that of a 2G TDMA-based one.

This paper focuses on the deployment of a 3G network in a real airport scenario, which is expected to be one of the most UMTS relevant business environments, based on reusing pre-existing GSM infrastructure. Such 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 the signals of different UMTS nodes B to a set of repeaters which are located in the existing GSM microcells [3][4]. 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.).

In [4] we presented a method, based on the same scenario, to know the degree of coupling between macro and microcells, which allowed setting the CPICH power in both layers. Furthermore it was shown 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. In this context, the purpose of this paper is to study the feasibility of different scenario deployment configurations, mainly in terms of number of microcells and maximum power per microcell. The study is presented in a first step from a technical point of view, quantifying the achievable capacity for each configuration as well as identifying the limiting direction (uplink or downlink). Then, the deployment cost of the scenario based on available commercial products is assessed, so that the best solution from a techno-economical point of view can be identified. Furthermore, the analysis considers data only scenario, voice only scenario as well as mix of voice and data traffic according to forecasted figures.

The paper is organized as follows. Section II provides an overview of the scenario and the considered simulation model, based on real data. Section III presents the obtained results, first when only data services are considered, then with only voice and finally with a mix of voice and data. Conclusions are summarized in Section IV.

II. Scenario and Simulator Description

As it has been mentioned in section I, the analysis is done in 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 order to avoid the inaccuracy of using propagation models in the simulation model, the simulator is fed with data collected from a tracing tool. It captures all GSM900/1800 Measurement Reports generated by mobile terminals in the interest area (i.e. the airport) and during the busy hour. These data are 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. Then, by feeding the simulator with this propagation database, radioelectrical traffic distribution (i.e. path losses distribution) is captured in a realistic way. The developed simulation tool can be used in other environments, provided that it is fed with the appropriate propagation data.

The scenario is composed of in-building microcells and partially overlaying outdoor macrocells. 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 in the downlink direction all these repeaters are transmitting exactly the same signal generated by the UMTS microcells. In turn, in the uplink direction the signals received from each repeater are combined in the node B. Therefore, and since each connection with a repeater represents a noise source, the microcell configuration has a direct impact 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 since more noise sources are present.

Four scenarios are considered in the simulations, depending on how the existing GSM microcells are distributed into UMTS microcells. Scenario SCN-1 assumes that a single UMTS microcell distributes the signal between all the existing GSM microcells. Scenario SCN-2 assumes two UMTS microcells and scenarios SCN-3A and SCN-3B assume three UMTS microcells. In SCN-3A the existing GSM infrastructure is distributed in UMTS microcells taking into account geographical proximity and in SCN-3B the distribution is done taking into account traffic criteria, in order to balance the offered traffic to the three microcells. In all the scenarios three outdoor macrocells are considered.

The simulations consider voice and data services, and the main radio transmission parameters are shown in Table I. Both uplink and downlink are analysed and different load conditions are considered in the simulations. The specific Radio Access Bearers are defined in [5].

TABLE I. Simulation Parameters

RAB UL/DL bit rate			**Voice 12.2 / 12.2 kb/s**	**Data 64 / 384 kb/s**
UE maximum power			21 dBm	24 dBm
UE minimum power			-44 dBm	-41 dBm
Activity factor			0.5	1
Eb/No target UL (dB)			6.0	4.3
Eb/No target DL (dB)			7.9	6.6
Maximum DL power per user		Macrocells	29.5 dBm	34.3 dBm
		Microcells	3.5 dBm	15 dBm
Orthogonality factor			0.4	0.4
Node B maximum power		Macrocells	43 dBm	
		Microcells	17 / 30 dBm	
CPICH power		Macrocells	29.5 dBm	
		Microcells	3.5 dBm	
Thermal Noise UL	Macrocells		-104 dBm	
	Microcells	SCN-1	-86 dBm	
		SCN-2	-89 dBm	
		SCN-3 A/B	-91 dBm	
Thermal Noise DL			-100 dBm	
Maximum number of cells in Active Set			2	
Soft Handover margin			5 dB	

With respect to traffic distribution, it is assumed that 50% of voice users are connected to the macrocells and 50% to the microcells. On the contrary, data users are more likely to be connected to the in-building microcells and the distribution is 20% to macrocells and 80% to microcells. Notice that this traffic distribution is only used to select the cell with minimum path loss, but in order to decide the serving cell, Common Pilot Channel (CPICH) measurements should also be considered. Then 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 and Io is the total power density in the UMTS band. As a result of this process, the final traffic distribution is shown in Table II.

The developed UMTS simulation tool is static and executes the following steps in each snapshot:

1. Decide the number of users present in the scenario, *N*, for each service.
2. Distribute the users in the scenario by selecting for each user a Measurement Report from the database. This report includes the path loss with respect to the different cells in the scenario. The selection is done taking into account the expected spatial distribution for each service.
3. Once a measurement report has been selected, choose the serving cells for each user taking into account the received CPICH power level for each cell.
4. Once all users are scattered in the scenario, run the power control module to decide the transmitted power levels for all users in both the uplink and downlink directions and to compute the measured Eb/No. Each user aims at achieving a certain target quality level, expressed in terms of an $(Eb/No)_{target}$, according to the required QoS and service class. Notice that this allows an exact analysis of the interference pattern arisen in the snapshot.
5. Collect statistics and performance figures of interest. In particular, the study focuses on the outage probability in the uplink and downlink, defined as the probability of measuring an Eb/No below the target.

TABLE II. TRAFFIC DISTRIBUTION IN MACRO AND MICROCELL LAYERS

Service	Macrocells	Microcells
Voice	68%	32%
Data	48%	52%

III. RESULTS

In the following some relevant results are presented that take into account the two considered services and both technical and economical aspects of the deployment. The analysis focuses on the different microcell configurations as well as on the maximum available power in the microcell.

A. Only data traffic

A capacity evaluation is initially provided when there is only data traffic in the scenario. Figure 1 and Figure 2 present the outage probability for both the uplink and the downlink direction, respectively, when the total microcell power is 17 dBm. Notice that even for a low number of users, outage probability is not zero due to coverage holes existing in the scenario. In the uplink direction, the highest outage is observed in SCN-1, due to the highest thermal noise of this configuration. Such noise can be reduced by making use of 2 and 3 microcells turning into an outage reduction. In any case, it is found that the limiting direction is the downlink, and consequently, one the most important factors to be set is the available power at the microcells. In that sense Figure 3 shows the outage probability in the downlink direction when the microcell power is set to 30 dBm. An overall improvement for all the scenarios is observed when compared to Figure 2.

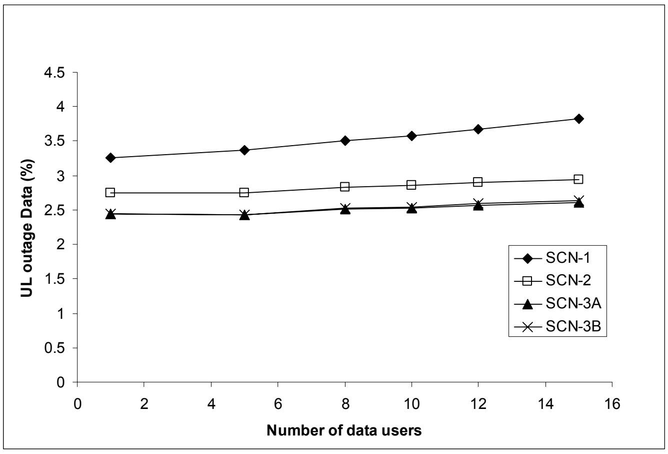

Figure 1. Outage of data users in the UL direction with microcell power 17 dBm

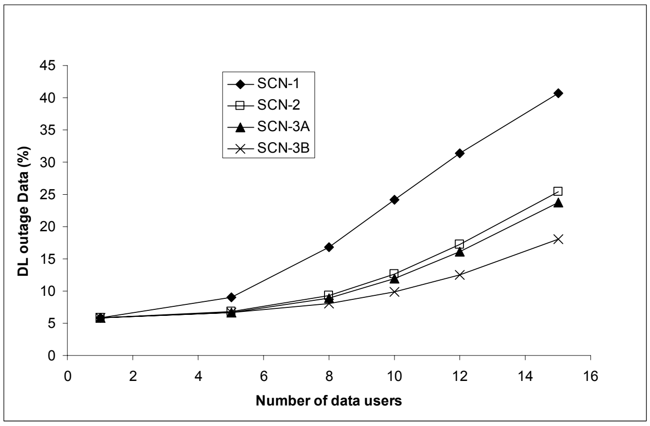

Figure 2. Outage of data users in the DL direction with microcell power 17 dBm

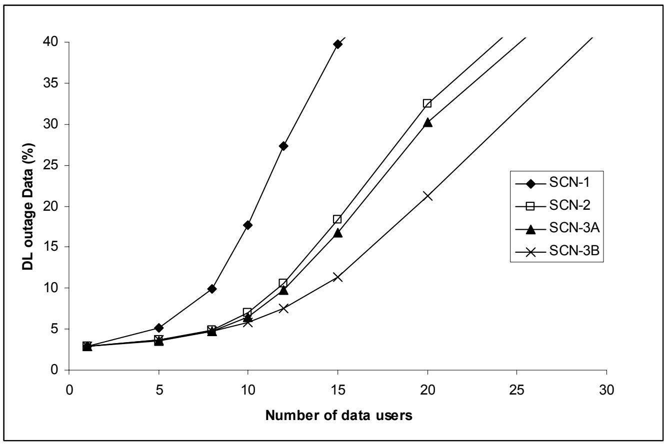

Figure 3. Outage of data users in the DL direction with microcell power 30 dBm

Table III shows the achieved capacity for the different scenarios and for the two considered microcell power levels of

17 and 30 dBm. The capacity is measured as the maximum number of users in the scenario that ensures that the outage probability is below 10%. For the 17 dBm case, it can be observed that the scenario SCN-3B with three microcells distributed according to traffic criteria provides the highest system capacity, which is twice the capacity of the scenario SCN-1 with a single microcell. The reason is that with three microcells there is more available power to be shared between users. However, notice also the importance of appropriately distributing the existing GSM infrastructure into UMTS microcells, since the performance of scenarios SCN-2 and SCN-3A is similar although the latter contains one microcell more. The reason is that a simple geographical distribution originates a high traffic unbalance between the microcells and consequently the scenario capacity is limited by the microcell with the highest load. It is also observed that the highest capacity improvement is achieved when increasing from 1 to 2 microcells, with an increase of 60%. However, when increasing from 2 to 3 microcells (SCN-3B) the improvement is only of 25%.

TABLE III. CAPACITY FOR THE DIFFERENT SCENARIOS WHEN ONLY DATA TRAFFIC IS CONSIDERED

	SCN-1	SCN-2	SCN-3A	SCN-3B
17 dBm	5	8	8	10
30 dBm	8	11	12	13

However, the suitability of a given scenario over another one results not only from capacity aspects but also from economical aspects. To this end, and taking into account that a deployment with three microcells is more expensive that a deployment with only one, the increase of capacity must be compared with the increase in investment. Based on available commercial products, the cost of the scenario for each configuration is quantified. The most economical configuration, which is the complete scenario including both macro and microcells with SCN-1 and 17 dBm is taken as a reference and assumed to have a cost of 1 CU (Cost Unit). Then, the cost increase for SCN-2 is about 3% and for a SCN-3 is about 6%. Nevertheless, to pass from 17 dBm to 30 dBm increases the cost in a 100% factor. Table IV shows the capacity relative to the investment for the considered scenarios (i.e. the capacity divided by the cost) measured in users/CU. It is clearly observed that SCN-3B is the best configuration not only from the technical point of view but also from an economical point of view. On the other hand, notice that SCN-3A is poorer than SCN-2, since the investment in the additional microcell didn't turn into a capacity increase.

As it has been stated, one of the important parameters that affect capacity in a downlink limited scenario is the power available at the microcells. Particularly, when increasing the microcell power to 30 dBm a significant increase in capacity is observed with respect to the 17 dBm case (see Table III), ranging from 60% for SCN-1 to 30% for SCN-3B. Nevertheless, since the scenario cost is about twice the cost with 17 dBm microcells, the increase in capacity does not compensate the investment, as Table IV shows.

TABLE IV. CAPACITY RELATIVE TO THE SCENARIO COST WHEN ONLY DATA TRAFFIC IS CONSIDERED

	SCN-1	SCN-2	SCN-3 A	SCN-3 B
17 dBm	5.00	7.79	7.57	9.47
30 dBm	3.94	5.35	5.75	6.23

B. *Only voice traffic*

Figure 4 and Figure 5 show the outage probability of voice users in the uplink and downlink, respectively, when there is not data traffic in the scenario. The microcell power is 17 dBm. As it can be observed, in this case the uplink is the limiting direction, although differences with respect to the downlink are not very high. The resulting capacity for a 10% outage is given in Table V, which also includes the capacity relative to scenario cost. Similar trends are observed like in the previous sub-section with only data traffic, in the sense that the higher the number of microcells the higher the capacity. However, it should be pointed out that in the uplink direction, the capacity improvement when increasing the number of microcells is mainly related with the reduction in thermal noise in the microcell fiber optic distribution. The configuration SCN-3B provides again the best performance both from the technical and economical points of view, while the configuration SCN-3A is not able to translate the higher investment with respect to SCN-2 into a higher capacity/cost.

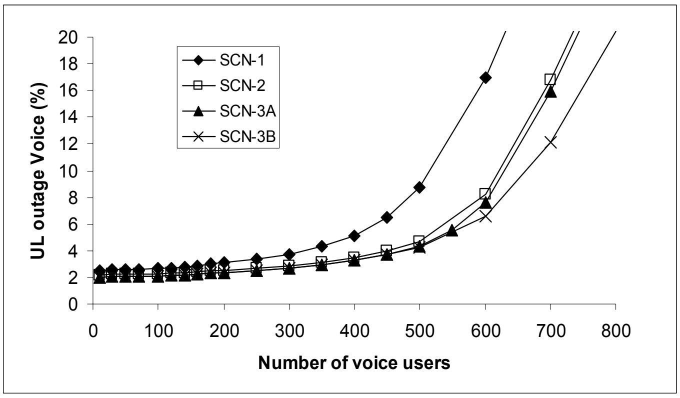

Figure 4. Outage of voice users in the UL direction in the absence of data traffic

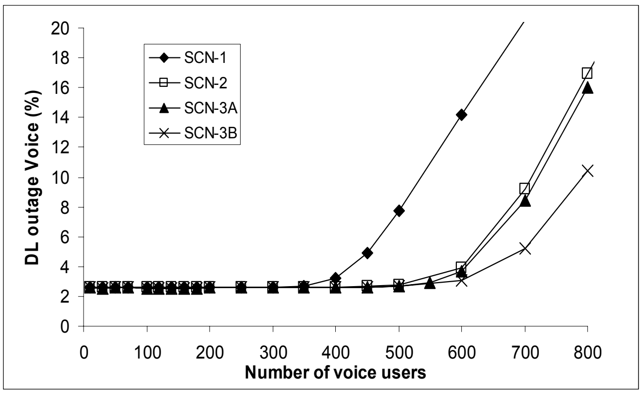

Figure 5. Outage of voice users in the DL direction in the absence of data traffic

TABLE V. CAPACITY OF VOICE USERS

	SCN-1	SCN-2	SCN-3 A	SCN-3 B
Capacity (users)	515	620	628	661
Capacity relative to cost (users/CU)	515	604	595	626

C. Voice and data traffic

When mixing voice and data, Figure 6 shows the resulting capacity region to ensure a 10% outage probability in all the services and in both uplink and downlink. The microcell available power is in all the cases 17 dBm, since it has been shown in section III.A that the configuration with 30 dBm is not efficient from the techno-economic point of view. Again, the best performance is achieved by SCN-3B, although the most significant capacity increase is achieved when passing from SCN-1 to SCN-2. Results taking into account the techno-economic perspective follow a similar trend like in previous sub-sections, and therefore are not shown in the sake of brevity.

From Figure 6 it is also possible to see that approximately 1 data user is equivalent in terms of capacity to around 45 voice users (i.e. the slope of the curve is 1/45). Notice that this relationship is higher than the ratio between bit rates of both services (i.e. 384 kb/s / 12.2 kb/s=31), thus reflecting the higher multiplexing gain that exists with voice users.

Another important parameter to be set in the presence of high bit rate data traffic is the maximum power per user, since high values can originate that some users far from the Node-B demand too much power while low values may lead to outage situations even under low load conditions. This effect is illustrated in Figure 7, that shows the capacity region when the maximum power per connection is set to 8.3 dBm for data users in the microcell. As it can be observed, capacity is highly degraded with respect to Figure 6.

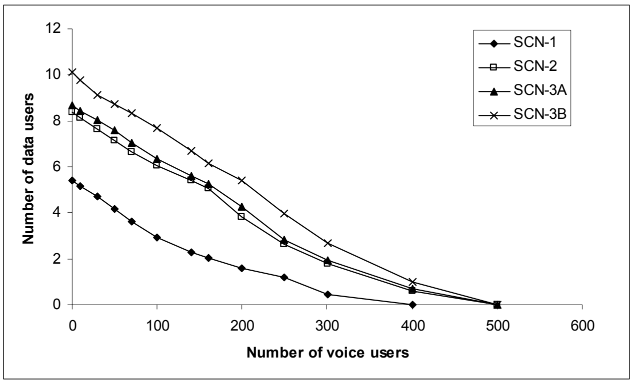

Figure 6. Capacity region with a maximum power per data connection of 15 dBm in the microcells

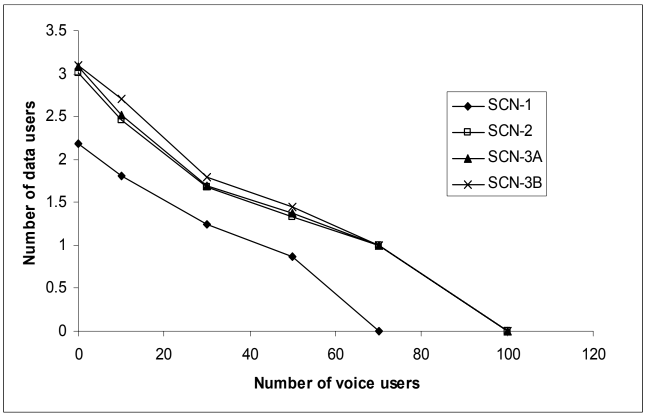

Figure 7. Capacity region with a maximum power per data connection of 8.3 dBm in the microcells

IV. CONCLUSIONS

This paper has studied the deployment of UMTS in a real airport scenario by reusing existing GSM/DCS1800 infrastructure which consists in macro and microcells. Different microcell configurations have been studied depending on how the node B signal is distributed to the existing repeaters. The different alternatives have been compared not only from the technical point of view but also following economic criteria, showing that depending on the microcell configuration the increase in investment is higher than the benefit obtained in terms of capacity. This has been the case for an increase in the available microcell power from 17 to 30 dBm.

Different mixes of voice and data traffic have been studied. It has been shown that the voice only scenario is uplink limited while the data only scenario is downlink limited. Furthermore, a higher multiplexing gain exists with voice users. For data traffic, it has been shown that an appropriate setting of the maximum power per connection is prime important in terms of capacity.

ACKNOWLEDGEMENTS

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