

Analysing UTRA-FDD Pilot Power and Active Set Configuration in a Real Urban Scenario

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Abstract— Assuming the use of GSM/UMTS co-sitting for initial 3G network deployment, real data extracted from the GSM network can be used to optimise 3G planning and RRM issues. It has been developed a 3G planning simulation tool which instead of using theoretical models, benefits from the availability of realistic propagation, mobility, as well as spatial and temporal traffic distributions. The tool is used in this paper to study the effects of Pilot Power and Active Set parameters in both, uplink and downlink capacity, in a real urban scenario, thus anticipating the expected behaviour of UTRA-FDD in such conditions.

I. INTRODUCTION

Whereas in 2G networks capacity and coverage could be treated as independent issues, the W-CDMA nature and the use of Radio Resource Management means that static planning is not enough for 3G networks. Moreover, since different operators and manufacturers will use different RRM strategies, much more simulation work will be required in 3G systems compared with 2G.

Typically, system level simulations are based on Monte Carlo runs where users are scattered around the network based on an expected traffic distribution. The simulations can be carried out in a static or a dynamic way. The static approach consists of a significant amount of uncorrelated snapshots and it is suitable to obtain average results on networks performance with low computational requirements. On the other hand, in the dynamic approach the successive runs represent different time slices of the real time. The users are allowed to move around the network and behave as real users. Therefore the simulations are very appropriated to optimise RRM algorithms and to provide statistics about time varying system parameters. Time consumption and computational cost arise as the main weak points. Both approaches are complementary and they are actually used for different purposes.

During the simulation process, not only an expected traffic distribution has to be assumed, it also has to be chosen an appropriate propagation model and key parameters such as the shadowing standard deviation. Inaccurate adjustments of these elements will result in predicted behaviours different from those achieved in practice.

On the other hand, 3G networks development will happen within a very competitive and mature 2G environment and it is expected that operators will use their existing infrastructure by means of co-sitting 3G with existing 2G sites to reduce cost and overheads during site acquisition and maintenance.

Taking these points into account, a different approach based on real data from a GSM network has been developed for 3G planning. Measurement Reports performed by mobile terminals in a given interest area are recorded and processed in order to build a database containing realistic propagation conditions. It is important to note that indoor traffic (typically hardly represented) will be implicitly included in the simulations. This database was also used to derive realistic traffic distributions. Thus, both realistic propagation data and realistic traffic distributions were used to feed a UMTS static simulator in order to obtain reliable statistics (Figure 1).

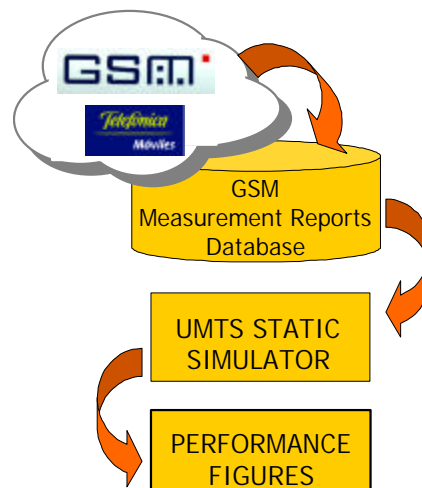


Figure 1. Structure of the developed simulator

With this simulation platform, the influence of several parameters over system planning can be evaluated. In particular, this paper is focused in the study of the impact on system capacity of two parameters with most importance on cell selection procedures: Active Set and the Primary

Scrambling Code of the Common Pilot Channel (CPICH or pilot signal).

Due to the utilization of Rake receivers in UTRA-FDD, a mobile can combine different multipath components from the serving base station (BS). Moreover, since a soft(er) handover scheme has been introduced, it is possible to combine different signals from different sectors/cells coherently. As a result, there are areas of operation in which the user equipment (UE) is connected to more than one BS. The set of BS's the UE is simultaneously connected to is known as the "Active Set" (AS).

UTRA-FDD soft handover scheme is based on a mobile assisted policy. Specifically, the network orders the UE to add (remove) a BS to (from) its AS according to quality measurements made by the UE on the CPICH signal. The quality of the CPICH signal is evaluated in terms of E_c/I_o , i.e., the ratio of the received energy per chip for the CPICH to the total received power spectral density at the UE antenna connector [1]. These measurements are reported to the network whenever certain thresholds are crossed during a certain time.

On this basis, it may be inferred that if the CPICH level is sufficiently reduced, some of the mobiles being served by the BS will expel it from their AS. On the other hand, an increase in the CPICH level will induce that mobiles being served by other BS's initiate an incoming handover. It is important to remark that the second, third and so on BS's in the AS are only included if the difference in dB between the measured CPICH E_c/I_o and the one of the first BS in the AS is below a certain value, the so called macrodiversity window. Thus, an increase in a certain CPICH level may provoke the expelling of other BS's and vice versa. Consequently, not only is it important to choose appropriate CPICH powers during the planning process, but also it is desirable to use appropriate enough AS configurations.

The organization of the paper is as follows: in Section 2 a detailed description of the developed simulation approach will be presented. Next, simulations that have been carried out will be explained and accompanying results will be analysed. Finally, the last section will contain conclusions and the work that is currently in progress.

II. UMTS SIMULATION TOOL

The first step in the simulator consists in, as mentioned before, the construction of a database with real GSM propagation measurements. The record of these data will have to be made for a long enough period of time, and for all the BS in the scenario. During a call, GSM terminals report the measured R_x_Lev from the serving cell and up to 6 neighbouring cells with a periodicity of 480 ms. Knowing BS transmitted powers, the path loss vector can be calculated directly: $[L_1(t), \dots, L_n(t)]$ being $L_i(t)$ the attenuation from the i -th BS to the mobile at a

certain time. Each row of the database will contain the values of a vector ordered from the lowest to the highest attenuation level.

Not only is the database providing a realistic propagation model, it is also indirectly giving information about realistic traffic distributions. If S_i is defined as the radioelectrical region (we are dealing directly with path loss, not with geographical distances) where the i -th BS is the best server, S_{ij} represents the sub-region in which the j -th BS is the second best server and so on, then, the probability $P(S_i)$ that a mobile is in the area S_i , can be estimated by simply counting how many of the total number of Measurement_Reports (database rows) have $L_i(t)$ in the first position. Similarly $P(S_{ij})$, $P(S_{ijk})$, etc. can be easily estimated. As a consequence the simulator tool scatters the users in the scenario according to real traffic distribution, as it is illustrated in Figure 2.

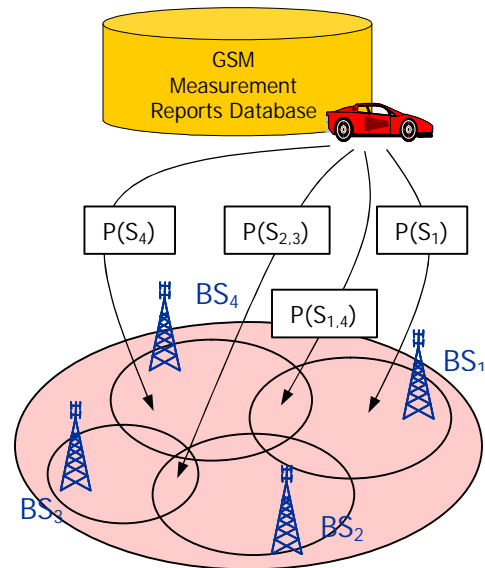


Figure 2. Procedure to scatter the users around the network

The steps carried out in a UMTS simulation snapshot are:

1. Decide the number of UE in the scenario, for each service.
2. Decide the subset depth to be considered (1 level - S_i -, 2 levels - S_{ij} -, 3 levels - S_{ijk} -, etc.). For illustrative purposes, let consider 2 levels in the following.
3. For each user
 - a. Decide the subset S_i according to $P(S_i)$
 - b. Decide the subset S_{ij} according to $P(S_{ij})$
 - c. Choose randomly a sample from the database belonging to the S_{ij} subset:
 $[L_i(t), L_j(t), \dots, L_n(t)]$.
4. After scattering all users in the scenario, run the power control module to decide the transmitted power levels (UL and DL) in order to obtain a certain $(E_b/N_o)_{target}$ considering power restrictions.

It is important to note that the simulation platform has been developed accounting for UL and DL connections and soft/softer handover.

Statistics on many parameters of interest can be collected, as for example: total received power at the BS, cells load factor, interference factor and contribution from each neighbouring cell to this factor, number of users connected to each cell (either in soft handover or not), percentage of users well served (i.e. achieving the target E_b/N_0) etc.

III. SIMULATIONS AND RESULTS

The purpose of this set of simulations is to study the influence of CPICH power variations and Active Set parameters (number of BS and macrodiversity window) over the system capacity. Both Uplink and Downlink have been studied and compared in order to obtain a general rule about appropriate values for these parameters.

Regarding CPICH variation, it is assumed that all the BS have the same CPICH level and that only the central one is susceptible to change. Simulations and results will be given for variations of central BS CPICH power from 6 dB lower than the rest to 6 dB higher than the rest.

In the following, AS configurations will be referred as a pair of numbers (n,m), 'n' being the maximum number of BS to be included in the set and 'm' the macrodiversity window size. Both values 'n' and 'm' will be modified in order to study their impact.

Results have been obtained for conversational users with the main parameters summarised in Table 1. Note that S_{ij} type radioelectrical regions were also taken into account though for the sake of brevity they are not listed here.

TABLE I.
SIMULATIONS PARAMETERS

UL spreading factor	256
DL spreading factor	512
E_b/N_0 target	2 dB
Number of cells in the scenario	13
$P(S_1)$	4,66
$P(S_2)$	12
$P(S_3)$	9,73
$P(S_4)$	4,29
$P(S_5)$ -central cell-	11,66
$P(S_6)$	9,65
$P(S_7)$	10,67
$P(S_8)$	7,8
$P(S_9)$	9,22
$P(S_{10})$	5,76
$P(S_{11})$	4,66
$P(S_{12})$	5,41
$P(S_{13})$	4,49
Number of snapshots	1000

Initially, the study is focused in the uplink. Maximum capacity conditions have been defined as the situation when one of the cells have a 5% (or more) of users in degraded mode, that is to say users that have not got enough power to reach the target E_b/N_0 .

It can be seen from figure 3 the maximum number of UEs in the scenario as a function of the central pilot power and for different AS parameters.

Maximum capacity is almost always obtained when the pilots are equal. The only case in which capacity was maximum for a pilot 3dB lower than the rest of the cells was with an AS equal to (1,0) (Best Server Site Selection). This is due to the fact that the central cell was one of the most loaded in the system, therefore with no macrodiversity options the pilot power should be chosen slightly lower than the other cells. With this reduction the traffic is equalized, balanced among the cells and so the performance of the network is better. However, as a hard handover scenario is not expected in UMTS networks we could conclude that, in the studied scenario, the optimum situation in the uplink would be the choice of equal pilot powers.

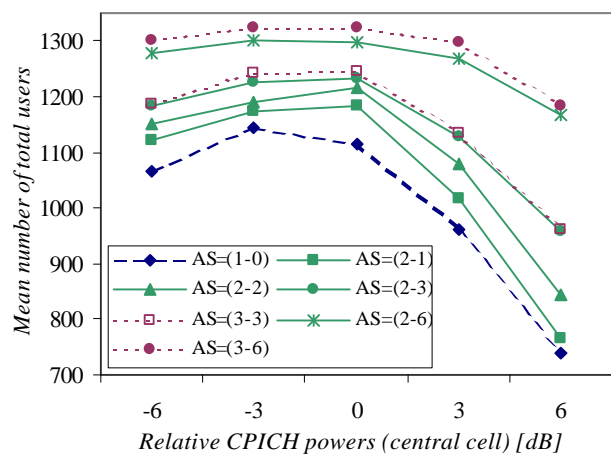


Figure 3. Overall scenario maximum number of UE for different AS and central BS pilot powers (Uplink)

According to the curves in figure 3, the higher the size of the AS is, the better, since the system can serve more users. This rule is true regardless the value of the central CPICH power. In particular, the capacity increase between AS=(1,0) and the best case (AS=(2,6) or AS=(3,6)) is around 18% when all the pilot powers are equal. When the central pilot is 6 dB higher than the rest, the increase in capacity is even higher (60%) but the absolute capacity figures are considerably lower than the best case.

This behaviour is due to the fact that a UE is able to choose among a higher set of BS and set its transmission power to the lowest required value. Figure 4 contributes to this statement since it shows the probability of a UE having a certain number of BS in the AS for different AS configurations.

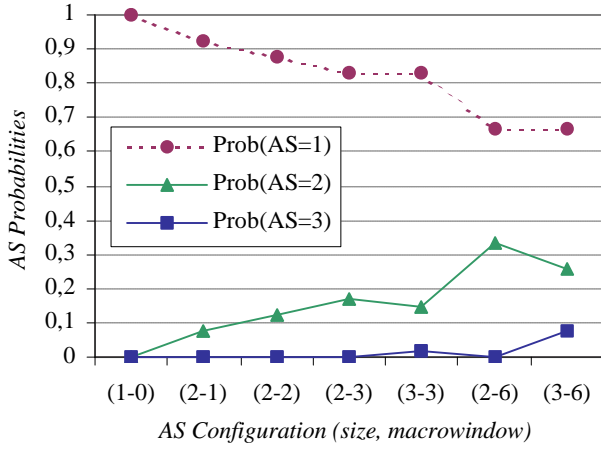


Figure 4. Probabilities of having a certain number of BS in the AS as a function of different AS configurations.

The same analysis has been done for the downlink, though the maximum capacity condition is defined in a different way. The system will be considered to have reached the capacity peak when one of the BS in the scenario is transmitting at its maximum power.

The overall maximum number of UE in the scenario as a function of CPICH powers and for different AS configurations can be seen in Figure 5. Notice that absolute values in the vertical axis represent simultaneous users (users transmitting at a time).

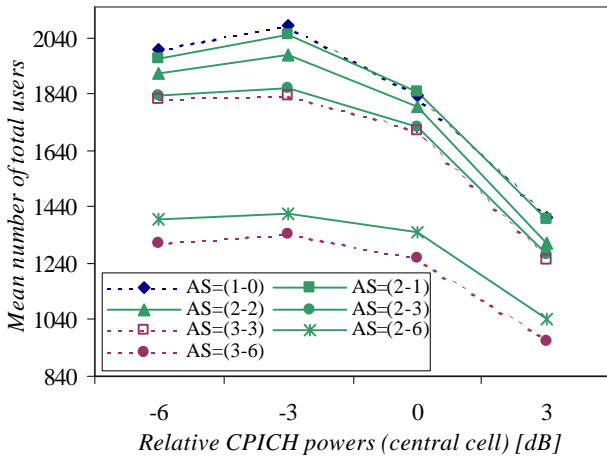


Figure 5. Overall scenario maximum number of UE for different AS and central BS pilot powers (Downlink)

According to Figure 5, the maximum capacity is achieved when the central pilot power is 3dB lower than the rest. In this way, a more efficient balancing of the load is obtained than when all the pilots are equal. This result is consistent with the fact that the central cell in the system is more loaded than the rest (see Table 1), as it was also seen in the uplink.

On the other hand, when the pilot power increases, the downward trend of the curve is sharper since not only the network is leaving the optimal situation but also more power is devoted to signalling and therefore less power to traffic. It can be seen that a reduction in the pilot power from the optimum value, results in a smaller decrease of the maximum number of users. It is also important to point out that, as the central cell is one of the most loaded in the system it was also the limiting one in many snapshots.

Regarding AS configuration and in contrast with the uplink, it may be seen that smaller AS's lead the system to better performance. When the UEs make their AS's larger (in terms of 'n' and 'm'), they are able to listen more BS and put into effect Maximal Ratio Combining (MRC). As a consequence, the BS will suffer a certain reduction in the power needed for those terminals. However, it will also have to transmit towards new and distanced users and the global effect is worse. Only when all the pilots are equal a small rise in the value of the macrodiversity window results in a better performance. Consequently it can be concluded that the optimum AS values for the downlink would be those under a (2,2) configuration.

It is also interesting to observe that capacity is very sensitive to macrowindow increases. On the other hand, it is less sensitive to AS modifications. For example, it can be seen that there are no differences between AS(2,3) and AS(3,3) meaning that the fact of increasing the maximum number of BS in the AS does not represent a significant reduction in downlink capacity.

Finally, a great reduction is obtained when increasing the window size from 3 to 6dB (the BS is forced to serve a UE with high attenuation which requires a high power level, reducing the number of UE the BS is able to serve). Under these conditions DL capacity could be jeopardized and the situation could be even more aggravated if asymmetric traffic was included.

Given all these results, it certainly arises the problem to find a good trade-off between the uplink and the downlink capacity, since the AS has opposite effects in each link. Hence, Figure 6 aims to compare in a direct way what can be expected from each configuration. It shows the difference between the maximum number of users the DL could support and the maximum number of users in the UL.

Thus, the positive area (positive values) shows those configurations of AS and pilot power (central cell) in which the UL is the limiting link in the system. On the other hand, the negative area represent the opposite case: DL being the limiting link.

In order to select a good trade-off between the uplink and the downlink some points should be kept in mind. Firstly, only conversational users were taken into account in the simulations, so when asymmetric data services are introduced

the downlink capacity will be lower, the same will occur in those scenarios with a particular lack of orthogonality among the DL signals. And secondly, the pilot power signalled from the network to the BS is considered to match the power measured at the antenna if this is within the limits $\pm 2,9\text{dB}$ [2] (an exact match is unlikely). So not only must be observed the peaks of the curves, surrounding points have to be taken into consideration too.

Consequently, AS=(3,3) arises as a good option for both the UL and the DL.

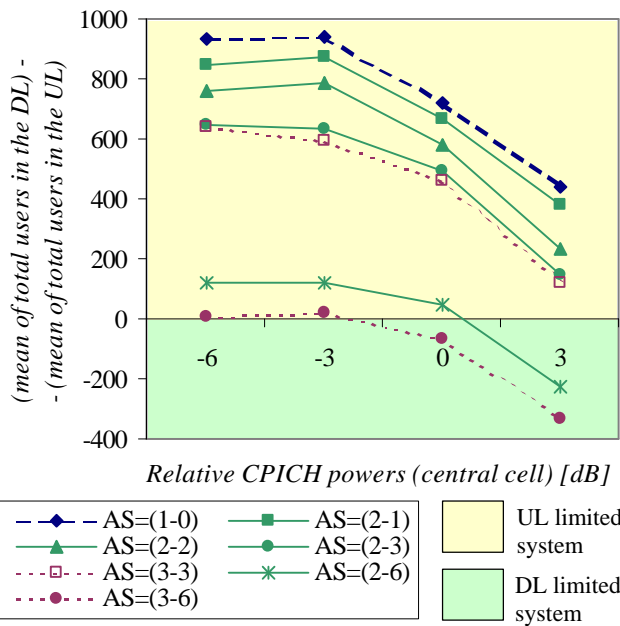


Figure 6. Difference in number of users between the UL and the DL under maximum capacity conditions

IV. CONCLUSIONS AND WORK IN PROGRESS

A new approach for 3G simulation and evaluation has been presented as a consequence of the fact that for 3G roll-out operators will use their existing GSM network to the fullest possible extent, with co-siting 3G sites with existing 2G sites. By processing measured and reported data by mobile terminals both a database with real propagation conditions and a realistic traffic distribution were obtained. Results presented reveal that the set up of such a realistic scenario is highly valuable since it provides a more detailed view of the network behaviour and performance.

This simulation platform has been used in this paper to test the influence of the variations of the CPICH transmitted power and different mobile Active Set parameters in the system capacity for a real urban scenario. It has been shown that for the UL, there is always an absolute capacity increase when increasing the AS size and window, but for AS size higher than 3 and window size higher than 3 dB a lower relative increase is obtained. Moreover, the absolute gain depends on

the configuration of CPICH values, being the best case when all the BS's in the scenario transmit the same CPICH power. On the other hand, the DL is very sensitive to CPICH values and a fast decrease in capacity is obtained when increasing the pilot power and AS parameters. The capacity reduces considerably when increasing the UE AS window but is less sensitive to the number of BS in the UE AS. So, jointly considering UL and DL, the best AS configuration is (3,3). Usually, it is the UL who limits the capacity but in some configurations, depending on the pilots and AS parameters, could be the DL who limits the capacity.

The simulation tool [3] is at present being used to evaluate and compare different admission control algorithms and has also been updated to be able to perform dynamic simulations in order to study different congestion control algorithms.

ACKNOWLEDGMENT

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