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Using Measurements Extracted from GSM/UMTS Networks for 3G Planning and RRM Evaluation

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***Abstract*—This paper describes a simulation tool developed for 3G planning and suitable also for some RRM strategies evaluation. The innovative issue is that the simulator is based on data extracted from real GSM/UMTS networks. Considering the extensive use of GSM/UMTS co-siting for 3G network deployment, an accurate representation of propagation, mobility as well as traffic distribution is achieved compared to classical statistical and modelling approaches in simulators. Results presented reveal that the availability of real data is highly valuable since it provides a more detailed view of the network behaviour and performance.**

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 preparing to build and launch 3G networks.

The problem faced by a network operator is to offer a system where the network usage is maximized for a given set of QoS requirements. In this problem two aspects can be clearly distinguished: the network planning (e.g. the design of the fixed network infrastructure in terms of number of cell sites, cell site location, number and architecture of concentration nodes, etc.) and the radio resource allocation (e.g. for a given network deployment, the way in which radio resources are dynamically managed in order to meet the instantaneous demand of the users moving around the network).

In the framework of 2G mobile systems (i.e. GSM), the network planning is key. The QoS for voice service is mainly controlled through a suitable frequency assignment among cell sites in order to provide a sufficient C/I. On the other hand, the call blocking probability is the other fundamental QoS parameter and it is controlled through providing in a first step several frequencies to a given cell site and in a second step by adding new sites. For a given network configuration, there is an almost constant value for the maximum capacity because radio resource allocation actions in the short term scale have a limited impact. Additionally, radio resource allocation in the short term (e. g. in the order of tenths/hundreds of milliseconds) has not much to do in a scenario where the supported service (e. g. voice) requires for a channel with constant quality and tight delay constraints. In the framework of 3G mobile systems the situation is significantly different. First, in W-CDMA based systems there is not a constant value for the maximum available capacity, since it is tightly coupled to the amount of interference in the air interface. Second, the multiservice scenario drops for some services the constant delay requirement and, consequently, opens the ability to exploit RRM (Radio Resource Management) functions to guarantee a certain target QoS, to maintain the planned coverage area and to offer a high capacity while using the radio resources in an efficient way. In terms of radio network planning, a range of new planning challenges specific to W-CDMA arise: soft-handover overhead, cell dominance and isolation, etc.

Introduction and roll-out of 3G networks will be costly and will happen within a very competitive and mature 2G environment. Therefore, operators will use 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.

From all of the above it becomes clear that, 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. This simulation work can be at two different levels: static (for radio network planning) and dynamic (for RRM evaluation). Although radio network planning is the most immediate problem that an operator may face, the second issue should not be forgotten because RRM functions can be implemented in many different ways and this will have an impact on the overall system efficiency and on the operator infrastructure cost. Additionally, RRM strategies are not subject of standardisation, so that they can be a differentiation issue among manufacturers and among operators.

3G simulation tools must be able to combine information about the network configuration (e.g. cell sites, transmitted powers, etc.) with information about the position of the mobiles and the traffic that they are likely to generate in order to build a realistic picture of the network in terms of its coverage and the QoS it is likely to offer. Most simulations are based on Monte Carlo runs, where users are scattered around the network based on a expected traffic distribution and then users are allowed to initiate calls. In the case of static simulators, the users do not move and so the tool builds a picture of the network for a particular distribution of the users (usually referred as a snapshot), and many snapshots with different distributions of users are run in order to obtain a composite view of the network performance. In the case of dynamic simulations, the users are allowed to move around and, as far as possible, behave like real users.

Obviously, the more accurate the information provided about the network and the characteristics of the users the more representative the obtained network performance will be. The purpose of this paper is to describe a simulation tool developed for 3G planning and suitable also for some RRM strategies evaluation which is based on data extracted from a real GSM network. In particular, GSM *Measurement_Reports* provided by mobile terminals, where the measured *Rx_Lev* from the serving cell as well as up to 6 neighbouring cells is reported, are collected. Notice that, assuming GSM/UMTS co-siting, this information provides measured propagation data useful for UMTS studies with the corresponding propagation corrections when applicable. Also, this approach implicitly captures indoor traffic, traffic from higher floors inside buildings, etc. which otherwise can be hardly represented by statistical modelling. User's mobility in the considered scenario is also realistically represented. These reports are further processed in order to generate a propagation database that feeds the UMTS simulator, as depicted in Figure 1. The resulting simulator is claimed to provide more reliable information for analysing specific areas of interest, where mobile operators will offer 3G services in the near future. The developed simulator is useful to test different parameters combinations, to estimate the network evolution by progressively increasing the offered traffic, to adjust the coverage in order to reduce interference, etc.

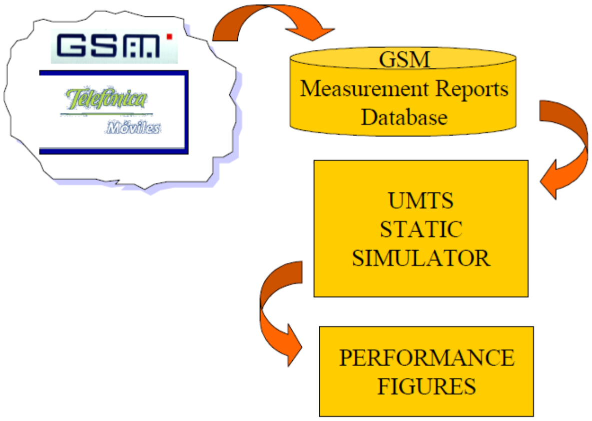

Fig. 1. Structure of the developed simulator.

It is worth noting here that, when UMTS networks become fully and commercially operational, the simulator can be easily updated with UMTS measurements. In the meantime, and for initial designs and capacity estimations, traffic distributions inherited from GSM networks may suffice, especially for voice traffic. For data traffic, traces from GSM MO-SMS could be considered as starting point for data traffic spatial distribution, since those locations where users stop to write down an SMS (for example bus stops, etc.) are also likely locations for UMTS data transfers.

The rest of the paper is organised as follows. In Section 2, the simulation tool is detailed. In Section 3, some sample results are presented and the interest of the developed tool is strengthened. Finally, Section 4 summarises the main conclusions reached.

II. SIMULATION TOOL

A. Collecting GSM data

In a GSM network mobile terminals in a call report through SACCH (Slow Associated Control Channel) with a periodicity of 480 ms the measured *Rx_Lev* from the serving cell and up to 6 neighbouring cells [1]. If the respective BTS transmitted powers are known, it is straightforward to derive the following vector: $[L_1(t), L_2(t), \ldots, L_n(t)]$, $L_i(t)$ being the measured path loss from the i-th BTS to the mobile at a certain time. Network monitoring tools may record this information for all the calls in a group of cells simultaneously while keeping the identity of the successive reports to a certain call. Thus, for a certain interest area and once all BTS involved are identified, the first step is to record all *Measurement_Reports* for a long enough period of time.
Since results presented here will be of static nature (although the simulator has been extended to operate dynamically), the link of each *Measurement_Report* to a certain call is not retained, and the record is considered to be simply a set of vectors $[L_1(t), L_2(t), ..., L_n(t)]$, which are ordered from lowest to highest attenuation (i.e. $L_i(t) < L_j(t)$ if $i < j$). Notice that real propagation data is contained here, including indoor users who are one of the most difficult issues to model and include in a standard simulation tool.

B. Database generation

Recording all BTS simultaneously, a footprint of the traffic distribution in the interest area is obtained. Thus, defining $P(S_i)$ as the probability that a mobile is in the area of the i-th BTS (in the sense that this BTS provides the lowest path-loss), it can be estimated by simply counting how many of the total number of *Measurement_Reports* have $L_i(t)$ in the first position of the vector. Similarly, $P(S_{ij})$ can be defined as the radioelectrical region (notice that since we are dealing with path-losses we are not interested in geographical distances but in "radioelectrical distances") where the i-th BTS is the best server and the j-th BTS is the second best.

Then, the scattering of users in the interest area could be done according to real traffic distributions. That is, users are thrown to the scenario according to the calculated probabilities, with the desired degree of precision (S_i, S_{ij} , S_{ijk} etc.). For example, if there is a hot spot close to BTS1, many of the collected *Measurement_Reports* will include BTS1 as the best server and so it may be reasonable to consider this spatial traffic distribution for UMTS evaluation purposes. Of course, these probabilities may be modified at will if another traffic distribution is to be studied. Figure 2 presents this procedure, although it should be strengthened that what it is in reality obtained is the radio distribution rather than the geographical distribution shown in Figure 2.

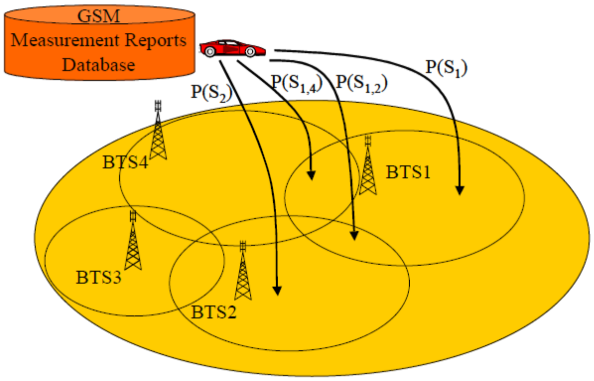

Fig. 2. Users scattering procedure.

Figure 3 plots $P(S_i)$ for a scenario in downtown Sevilla (large city in the south of Spain), where for convenience each cell is represented by a convenient ID number. It can be observed how traffic is not uniformly distributed in that area and is significantly concentrated around cells #0 and #4. So, for UMTS dimensioning it could also be reasonable to consider the same traffic distribution. All 13 GSM cell sites (a reference cell, cell #4, plus 12 neighbouring cells) or only a subset of them could be assumed to be the initial UMTS network deployment.

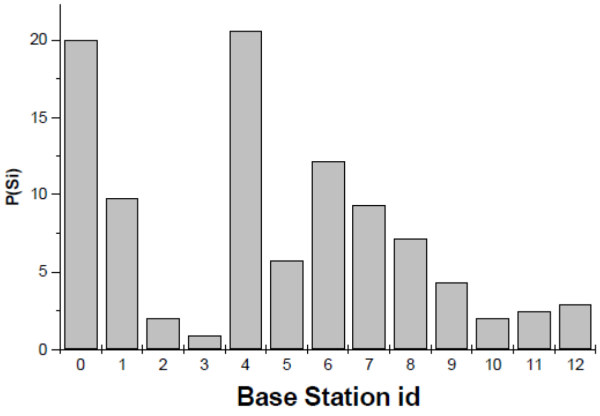

Fig. 3. $P(S_i)$ for a case study in downtown Sevilla.

C. *Simulation snapshot*

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

1) Decide the number of users present in the scenario, N (in case of a service mix scenario decide the number of users 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 Si according to $P(S_i)$, that can be either derived from the database or set according to a desired traffic distribution.
    b) Decide the subset S_{ij} according to $P(S_{ij})$, that can be either derived from the database or set according to a desired traffic distribution.
    c) Once the subset S_{ij} has been selected, choose randomly a sample from the database belonging to this subset: $[L_i(t), L_j(t), \ldots, L_n(t)]$.
4) 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 $(E_b/N_0)_{target}$, according to the required QoS and service class. Notice that this allow an exact analysis of the interference pattern arisen in the snapshot.
5) Collect statistics and performance figures of interest. Statistics for a given scenario are only collected in the reference cell in order to avoid edge effects from those cells whose neighbouring cells have not been captured by the network monitoring tool. System and performance parameters of interest are such as:
    a) Total received power at the reference cell
    b) Reference cell load factor
    c) Intercell to intracell interference ratio
    d) Contribution from each neighbouring cell to the intercell to intracell interference ratio
    e) Number of users connected to the reference cell site (either in soft handover or not)
    f) Percentage of users well served (i.e. achieving the target E_b/N_0)
    g) Downlink transmitted power
    h) Downlink intercell interference distribution
    i) Etc.

III. RESULTS

In this section some illustrative uplink results obtained with the developed simulator are presented. Parameters considered are summarised in Table 1. It worth noting that if the required transmitted power for achieving the target E_b/N_0 is higher than the maximum, the mobile is assumed to transmit at *Max_Pow* and is said to be degraded. Macrowindow indicates the window size for macrodiversity (i.e. if the path-loss difference from the best to the second best cell is less than Macrowindow the mobile is assumed to be in soft handover). For a window of 3 dB, it is found that 20% of the cases mobiles are in soft handover.

In case that 250 users are scattered in the scenario, the total received power I_{total} (including intracell, intercell and noise components) histogram in the reference cell after 1000 snapshots is shown in Figure 4. The average value is -97.61 dBm.

TABLE I
UPLINK SIMULATION PARAMETERS

Parameter	Value
Max_Pow	33 dBm
(E_b/N_0)	5 dB
Noise Figure	5 dB
Spreading factor	128
Coding rate	1/2
Thermal noise	-103 dBm
Macrowindow	3 dB
Active Set Size	2

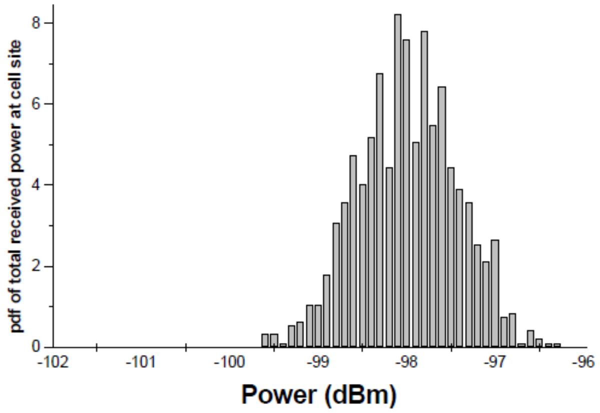

Fig. 4. Total received power distribution at the reference cell.

One common parameter used to measure the theoretical spectral efficiency of a W-CDMA cell is the load factor, η_{UL}, defined as [2]:

$$\eta_{UL} = 1 - \frac{P_N}{I_{total}} \tag{1}$$

PN being the background noise power. The cell load factor distribution is shown in Figure 5. It can be observed that for 250 users in the scenario the reference cell is highly loaded, as for planning purposes values around η_{UL}=0.6 use to be considered.

One important characteristic of the presented simulator is its ability to provide a detailed interference analysis, based not only in power control considerations but also on real propagation data. Then, while for radio network planning purposes it is quite common to use an average value of the other-to-own cell interference ratio also known as f-factor, it could be also of interest to analyse and study the real behaviour of this parameter since it has an strong and direct impact on the overall estimated performance. The intercell to intracell interference ratio, $f = I_{intercell}/I_{intracell}$, is plotted in Figure 6.

In this realistic scenario it is also possible to identify those neighbouring cells contributing more to the intercell interference perceived at the reference cell. This information may be valuable for planning purposes. Thus, Figure 7 provides the percentage contribution to the overall f-factor coming from all the cells in the scenario to the reference cell (cell #4). A high contribution may indicate that this specific cell is close to the reference cell and/or that this specific cell is highly loaded.

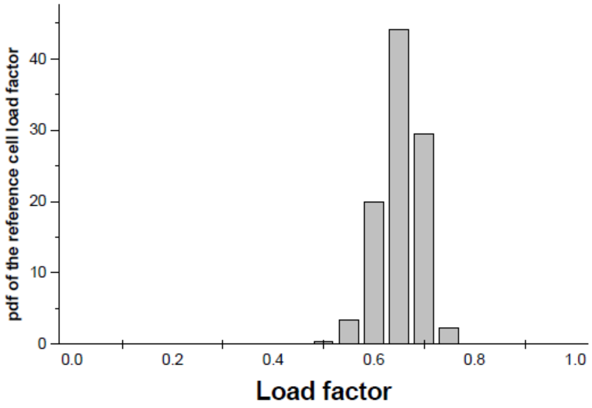

Fig. 5. Load factor distribution.

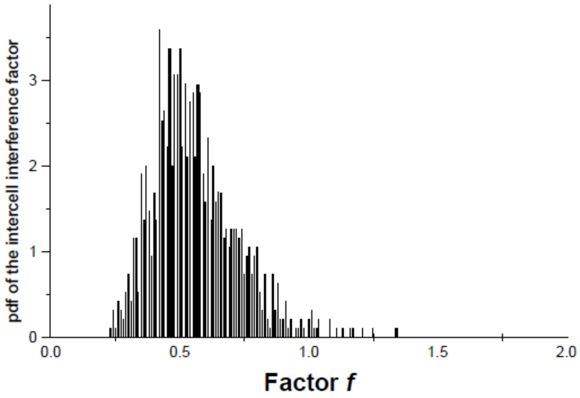

Fig. 6. f-factor distribution.

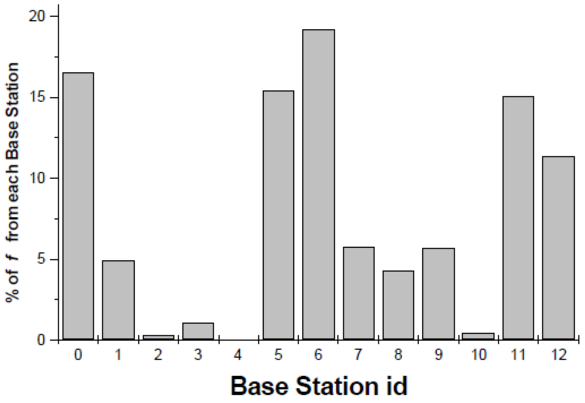

Fig. 7. Contributions to the f-factor from the different neighbouring cells.

Occupancy and capacity figures can also be obtained and provide a good idea of the suitability of a certain network configuration. For example, Figure 8 shows the distribution of number of users connected to the reference cell and Figure 9 presents the percentage of users well served by the reference cell when 250 users are scattered around the scenario.

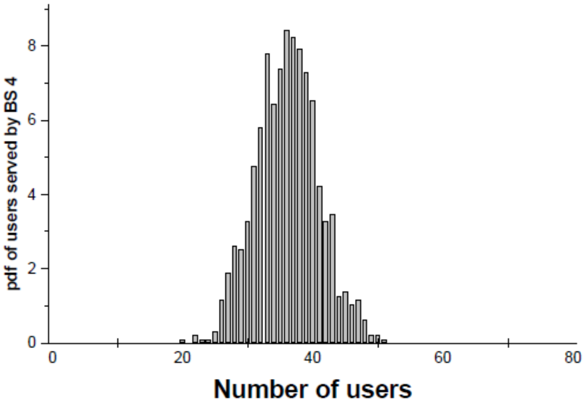

Fig. 8. Distribution of users connected to the reference cell.

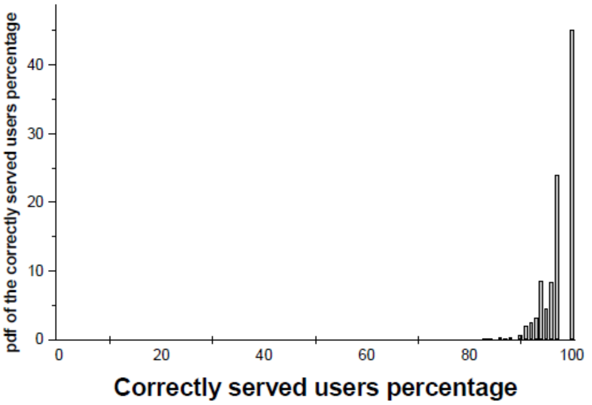

Fig. 9. Distribution of users well served.

IV. CONCLUSIONS

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 recording GSM *Measurement_Reports*, real propagation, mobility and traffic distribution can be collected and applied to UMTS studies and estimations. 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.

V. WORK IN PROGRESS

With the availability of the above explained simulator, additional work is being carried out. In particular, the following issues are being studied:

1) Study an optimisation of the pilot transmitted power for each Node-B in the scenario, according to E_c/I_o measurements analysis.
2) Evaluation and comparison of different admission control algorithms.

Moreover, the simulation tool has been updated in order to introduce some dynamics in the system. This will allow, for example, to study different congestion control algorithms.

ACKNOWLEDGMENT

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