Fast Planning of Efficient WCDMA Radio Networks

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Abstract - **The introduction of 3rd generation cellular networks and their various bit rate services require new techniques in the field of radio network planning and dimensioning. This paper describes a simulation tool on system level in order to support the planning process by analyzing the performance of a given network constellation. Finally, an example scenario for a coverage and capacity analysis is presented and simulation results gained with the system simulator are discussed.**

I. INTRODUCTION

The radio network planning of GSM based systems which utilize a combined TDMA/FDMA access scheme can be summarized as indicated in figure 1. In the first step predictions of the path loss are evaluated in order to ensure the coverage of the specified area.

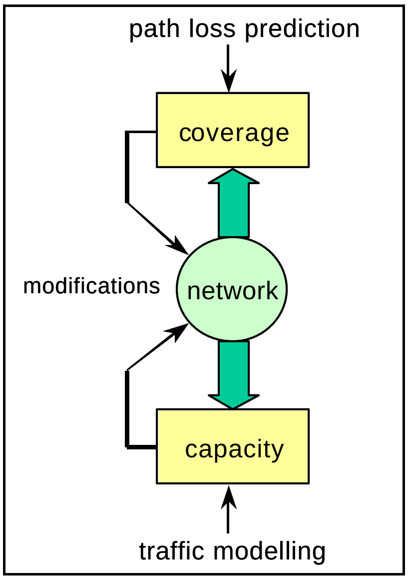

Fig. 1: Planning of TDMA/FDMA systems

The capacity is dimensioned in the second step by utilizing a frequency planning based on the predicted traffic in the area taken into account. Usually only speech service is considered which leads to constant cell capacities given by the number of available channels. Therefore a separate planning of coverage and capacity can be performed.

New challenges in radio network planning that come along with the introduction of 3rd generation cellular networks emerge from the demand for various bit rate services and the characteristics of the WCDMA technique. According to the utilized principle of spreading the different services lead to different processing gains and in combination with the speed of the mobile to different C/I requirements.

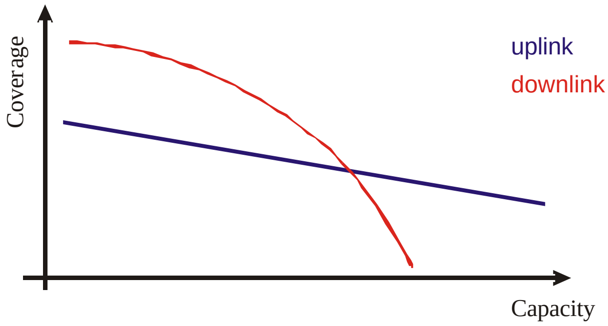

Fig. 2: Mutual influence of coverage and capacity

In contrast to TDMA/FDMA (i.e. GSM) based systems the interference should be taken into account already in the coverage prediction, because the sensitivities of the base stations depend on the number of users and used bit rates in all cells [1]. Furthermore, both up- and downlink have to be analyzed in view of the possibility of different loads (asymmetric).

Special emphasis has to be given to the consideration of the mutual influence of coverage and capacity (as indicated in figure 2). While the coverage is limited by the uplink because of the maximum available transmitting power of the mobile, the downlink sets limitations on the capacity due to the increasing interference.

The impact of specific WCDMA features as the fast transmit power control (TPC), the gain due to soft and softer handover (SHO) and the implemented Rake receiver should be considered for the performance analysis as well. Apart from the soft limiting effects typical for a CDMA system (due to interference limitations), hard limitations (e.g. hardware limitations) should also be taken into account within an overall performance analysis [2,3].

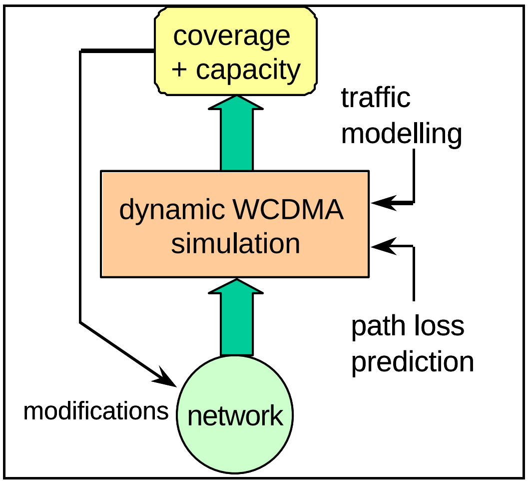

Fig. 3: Radio network planning of WCDMA systems

As coverage and capacity depend on the instantaneous traffic distribution and influence each another, a dynamic simulation is required which combines the uplink and downlink analysis in an adequate way (as indicated in fig. 3).

II. System Simulator

The realized simulator is an efficient tool for analyzing the performance of a given network constellation. It can be utilized for planning the different phases throughout a network roll-out. While the service providers intend to offer speech and moderate bit rate services in a first step within urban areas, the service area will be extended continuously and additionally high bit rate services will be provided in limited regions.

The network layout can be freely configured concerning the base station scenario, including locations, antenna configurations and service dependent parameters. Another important input is the user distribution. Realistic scenarios for a given area based on service dependent probability maps (mean arrival rate per m^2) are applied in the simulations. Possible scenarios for the simulation include rural and urban areas.

Different standard services, as e.g. 12.2 kbps voice, 64 and 144 kbps as well as 384 kbps real-time data are defined and the ratio between the user numbers of these services can be selected according to the expected values. In order to enable a dynamic simulation the traffic modeling includes two statistical processes. The arrival process determines the time between connection setups and the serving process evaluates the connection duration. For the generation of new users a Poisson process is evaluated for each service considering the location dependent traffic distribution (e.g. hot spots). The duration of each connection is determined randomly according to an adjustable characteristic depending on the type of service (as indicated in figure 4).

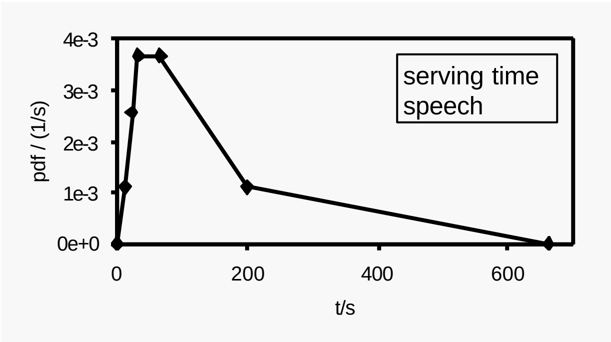

Fig. 4: PDF for the serving time of the speech service

Consequently it is possible to investigate the data user dominated case, where the service provider handles the speech service over the existing 2nd generation network. But also the case of the service provider without any 2nd generation infrastructure, handling the complete traffic mix within the new system, can be studied.

A. Initialization

At the beginning of the simulation all parameters, e.g. base station configuration and service dependent settings, are initialized. The set of active users (location, service, speed) is generated in each time step of the dynamic simulation according to the traffic modeling mentioned above. Some preprocessing is applied to these data including the computation of the path loss according to the utilized propagation model and the determination of an active server table for every mobile station.

B. Radio wave propagation

For the simulation of the various radio links highly advanced propagation models are applied. In large macro-cellular areas semi-empirical models based on terrain databases using knife-edge-diffraction are utilized.

The radio wave propagation within urban environments is characterized by a multipath situation. Dominant phenomena are diffraction on building corners, reflection at building walls and wave guiding in street canyons. Therefore ray-optical models based on building databases have been developed [4, 5]. Due to several years of experience these models combine short computation times with the high accuracy of a deterministic approach (see fig. 5 for a ray-optical prediction indicating the different path losses). The models consider the effect of slow fading as e.g. the shadowing by buildings or hills. The effect of fast fading is taken into account by a corresponding fast fading margin in order to allow the transmit power control to compensate the notches particularly at the cell edge.

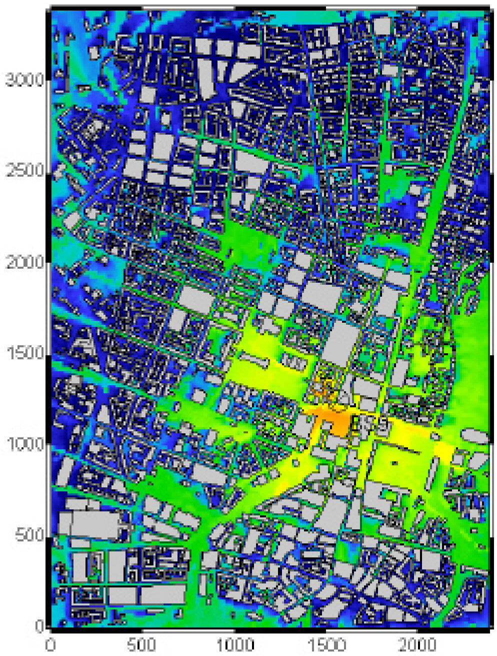

Fig. 5: Path loss prediction

Due to the increasing influence of the interference on the performance of 3G systems the usage of accurate propagation models within the planning process for calculating the path loss predictions becomes a must.

C. Uplink and downlink analyses

In the uplink analysis a specific tolerable transmit power is assigned to every mobile station with minimum overall interference. As the power levels required from the different mobiles depend on the interference and also influence it, this process needs iteration and the possibility of reducing the number of mobile stations served. As criterion for the termination the change of the interference power in comparison to the thermal noise power is evaluated.

The analysis in the downlink determines the total transmitted power of each base station. For this purpose the contributions of all established links are summed up taking into account the sensitivities of the mobile stations and the corresponding path losses. An additional amount of common channel power is considered. If no base station exceeds its maximum power level, no established link has to be cancelled and the instantaneous C/I can be calculated for every mobile station of each cell. The transmit powers of the base stations are adjusted for every link according to the difference between the instantaneous C/I and the target C/I. With the updated transmitter power levels the procedure is repeated until each transmitter power level has converged.

Both the analysis in up- and downlink consider a power budget (as given in fig. 6) including the noise rise, the diversity and spreading gain, the loss of transmitter and receiver, the antenna gains as well as the path loss. In order to combine the uplink and downlink analyses, the deactivated links from the uplink iteration are not considered during the downlink process. For accelerated convergence of both processes a memory function is included, which neglects oscillation effects.

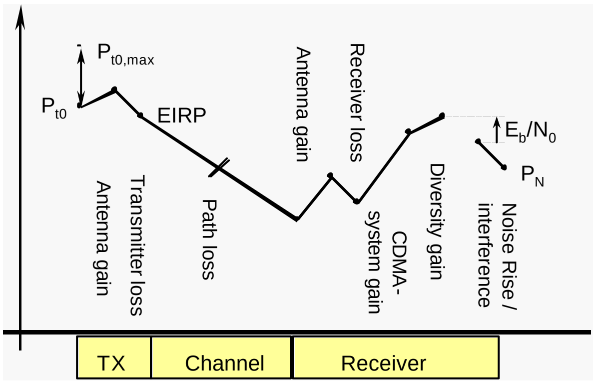

Fig. 6: Power budget

D. Performance parameters

After the uplink and downlink analyses a coverage test over the whole area is performed for each service by using an additional test mobile.

The performance parameters calculated by the simulator include best server maps, coverage per service maps and SHO areas. Output concerning the mobile station transmit power, base station transmit power, throughput per cell, load per cell, blocking and SHO probability as well as number of active base stations per mobile are given in a statistical manner, i.e. distribution, mean value and standard deviation. The so called cell breathing can be demonstrated to show the complex interaction between coverage and capacity.

III. SIMULATION EXAMPLE

In order to visualize the results when utilizing the dynamic simulator for the performance analysis of a given WCDMA radio network the following example in downtown Munich is presented.

A. Scenario

A fixed number of users for each service according to table I is uniformly distributed among an area of about 10 km^2, which is covered by a radio network consisting of 16 base stations with omni-directional antennas. Half of the base stations are located below rooftop-level (micro-cells), while the others are installed on the rooftops (mini-cells). The most important parameters concerning the system simulation are given in table II.

These values represent the typical configuration of a WCDMA radio network.

TABLE I:
USER DISTRIBUTION

Service	mean offered user number	mean served user number
12.2 kbps	300	270
64 kbps	75	48
144 kbps	25	13
384 kbps	8	2

Nevertheless, by using the simulator the influence of the different parameters on the performance results can be investigated very efficiently. In order to get more generalized results 1000 steps have been investigated. The users are updated in each step, i.e. only in the first step the user numbers correspond to the values of table 1, while in the following steps the user numbers are modified according to the specified traffic parameters (see chapter 2).

TABLE II:
SIMULATION PARAMETERS

Path loss model	Ray Tracing [4]
Max. mobile power (speech / data)	21 / 24 dBm
Max. base station power	43 dBm
Common channel power	30 dBm
Max. downlink power per link (speech / data)	33 / 43 dBm
Max. uplink load	0.8
Activity (speech / data)	0.6 / 1.0
Downlink orthogonality	0.4
Soft handover gain	3 dB
Active server table window	6 dB
Required E_b/N_0 in uplink	5 dB
Required E_b/N_0 in downlink	6 dB
BS / MS noise figure	5 / 7 dB
MS fast fading margin	4 dB

B. Results

The best server plot of this scenario after uplink and downlink iteration is indicated in fig. 7 (for the speech service), where the different colors correspond to different cells. Obviously the cell areas are strongly split-up which is typical for such a micro-cellular scenario.

Figure 8 presents the coverage area of the speech service. The white colored areas indicate that small parts of the considered scenario are without coverage (mostly inside buildings because of the additional penetration loss). Nevertheless a coverage degree of 100% does not correspond to a situation without call drops, because the test mobile determines the coverage degree after uplink and downlink analyses. Generally, during these iterative processes a specific part of the offered traffic is put to outage depending on the individual service (as indicated in table 1).

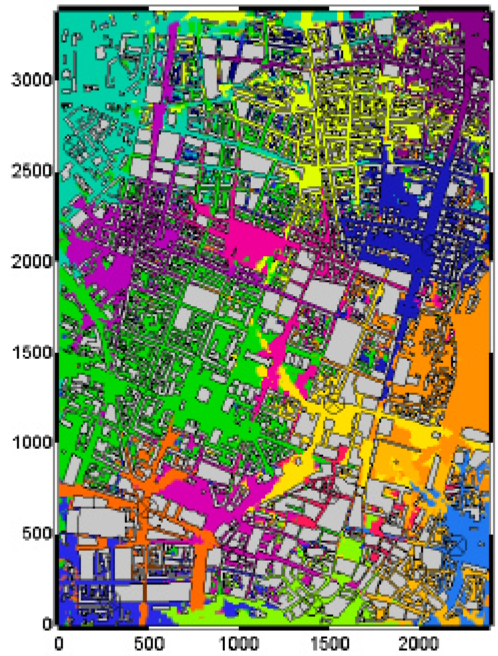

Fig. 7: Best server plot of the speech service

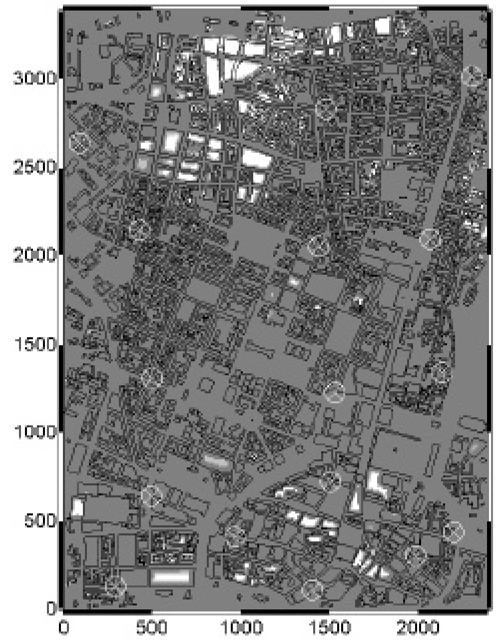

Fig. 8: Coverage area of the speech service

The uplink iteration determines the transmit powers of the mobile stations ensuring minimum overall interference. Fig. 9 shows the required transmit powers of the 144 kbps data service averaged over all simulation steps. Corresponding to fig. 8 there are higher values within buildings whereas close to the base stations only low transmit powers are necessary.

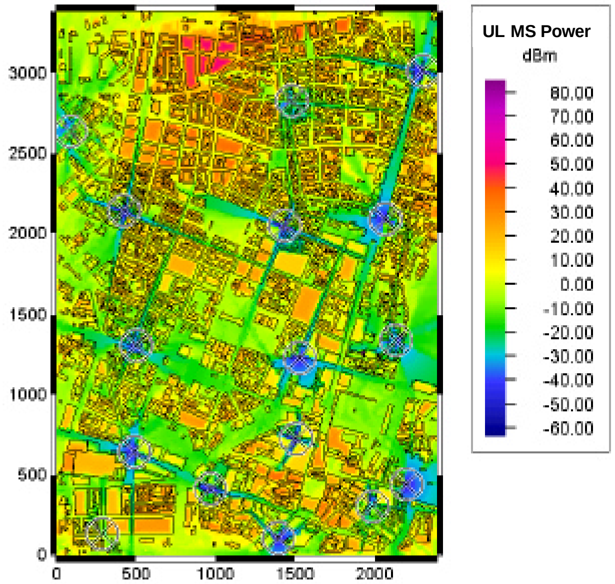

Fig. 9: Required transmit powers in the uplink (144 kbps data service)

In the downlink iteration, which is performed directly after the uplink iteration, the power of each base station is assigned according to the established links. Fig. 10 shows the CDF of the base station powers for two different cells (BS 5 represents a micro-cell while BS 8 corresponds to a mini-cell). The differences between the diverse base stations occur because of different cell sizes due to local propagation conditions and limited cell ranges at the borders of the considered area. The base station powers are well below the max. allowed power [6]. As the transmit power of the mobile stations is limited, links with high path losses cannot be established, which leads to the reduced powers at the base stations (coverage is uplink limited).

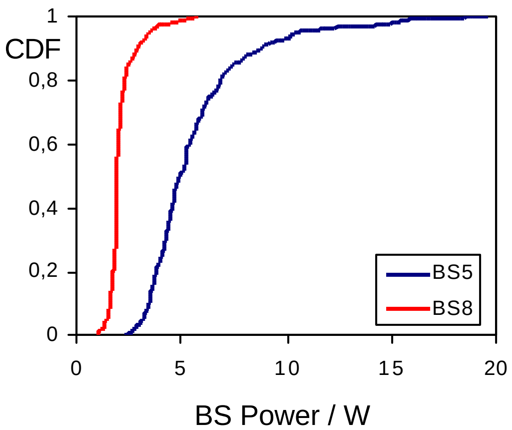

Fig. 10: CDF for the powers of two base stations

In order to generate the cumulative distribution functions of the various performance parameters the user distribution was performed 1000 times, which corresponds to different snapshots of the mobile radio network.

Concerning the soft handover about 29 % of the mobiles are in connection with more than one base station, which results in a soft handover gain due to better reception conditions (diversity). Thereby SHO is an important characteristic of 3rd generation radio networks.

In contrast to a static approach with this dynamic simulator the cell breathing and the close relationship between coverage and capacity can be visualized. By analyzing the different parameters it is possible to predict the performance of a given radio network and to investigate adequate modifications.

IV. Conclusions

The introduction of 3rd generation cellular systems and their new services requires advanced methods concerning the radio network planning and dimensioning. In this paper a dynamic simulator for the evaluation of cellular radio networks according to the WCDMA standard is presented. The simulator supports the planning process by analyzing the performance of a specified network constellation. Therefore this simulator can be utilized to implement 3rd generation radio networks more efficiently. An example visualizing the complex interaction of coverage and capacity is shown.

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