

Dynamic Simulator for Studying WCDMA Radio Network Performance

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Abstract

With the introduction of 3rd generation cellular networks and their high bit rate services new techniques in the field of radio network planning and dimensioning are required. This paper presents a simulation tool to support the planning process by analysing the performance of a given network constellation. Additionally, an example for a coverage and capacity analysis is given and simulation results gained with the dynamic simulator are discussed.

1. Introduction

Most of the challenges in radio network planning that come along with the new generation emerge from the demand for various bit rate services and the characteristics of the WCDMA technique. The different services lead to different processing gains and in combination with the speed of the mobile station to different C/I requirements. In contrast to TDMA/FDMA (i.e. GSM) based systems interference should be taken into account already in the coverage prediction, because the sensitivity of the base station depends on the number of users and used bit rates in all cells [1]. Furthermore, both up- and downlink have to be analysed in view of the possibility of different loads. Special emphasis has to be given to the consideration of the mutual influence of coverage and capacity by combining the uplink and downlink analysis.

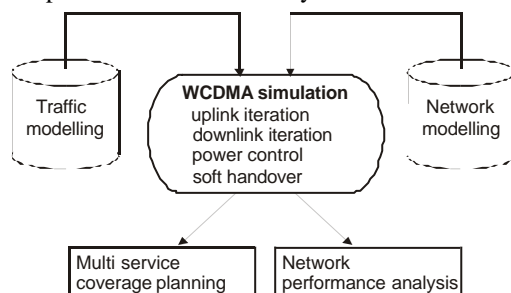


Fig. 1: Principle of the simulator

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

2. Description of the simulator

The realised simulator is an efficient tool for analysing the performance of a given network constellation. It can be utilised for planning the different phases throughout an UMTS 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, sectorisation and service dependent parameters. Another important input is the user distribution. Realistic scenarios for a given area using service dependent probability maps (mean arrival rate per m²) 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 corresponding traffic parameters have to be considered, which includes the mean inter arrival time between connection setups and the mean 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.

Consequently it is possible to investigate the data user dominated case, where the service provider handles the speech service over the existing 2nd generation networks. 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.

2.1 Initialisation

At the beginning of the simulation all parameters, e.g. base station configuration and service dependent settings, are read from files. The set of active users (location, service, speed) is generated in each time step of the dynamic simulation according to the traffic modelling mentioned above. Some preprocessing is applied to these data including the computation of the path loss according to the utilised propagation model and the determination of an active server table for every mobile station. The structure of the simulator is indicated in fig. 1.

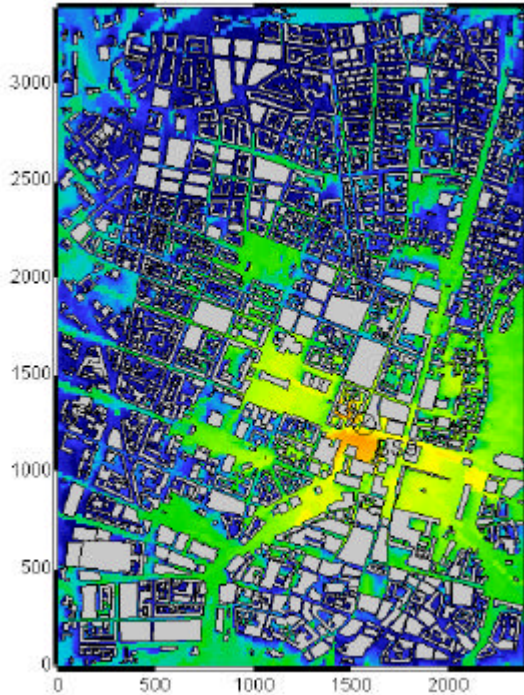


Fig. 2: Path loss prediction

2.2 Propagation modelling

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 utilised. For urban scenarios ray-optical models have been developed [4, 5]. Due to many years of experience these models combine

short computation times with the high accuracy of a deterministic approach (see fig. 2 for a ray-optical prediction indicating the different path losses). These 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.

2.3 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.

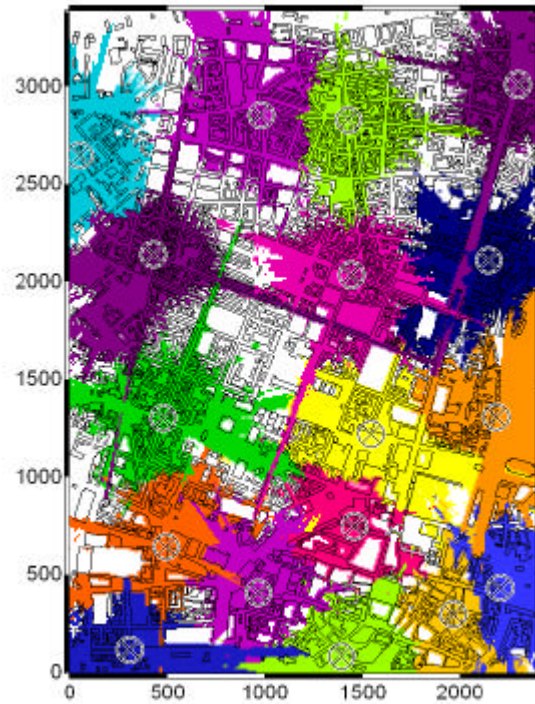


Fig. 3: Best server plot for the speech service

In the downlink the total transmitted power of each base station is summed up over all established links 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.

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.

2.4 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 (see fig. 3), 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 interaction between coverage and capacity.

3. Simulation example

In order to visualise the results when utilising the dynamic simulator for the performance analysis of a given WCDMA radio network the following example in downtown Munich is presented. A fixed number of users with different services according to table 1 is uniformly distributed among an area, which is covered by a radio network consisting of 17 base stations with omni-directional antennas. All the base stations are located close to rooftop-level. The most important parameters concerning the simulation process are given in table 2.

Table 1: User distribution

Service	mean user number
12.2 kbps	750
64 kbps	120
144 kbps	50

These values represent the typical configuration of a WCDMA radio network. 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 generalised 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 in table 1, while in the following steps the user numbers are modified according to the given traffic parameters (see chapter 2).

4. Simulation results

The best server plot of this micro-cellular scenario after uplink and downlink iteration is indicated in fig. 3 (for the speech service), where the different colours correspond to different cells.

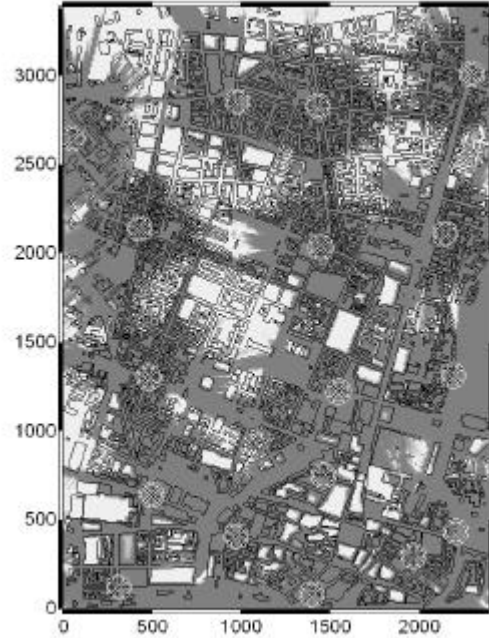


Fig. 4: Coverage area of the speech service

Figures 4 and 5 present the coverage area of the speech and the 384 kbps data service respectively, indicating a better coverage for low bit rate services.

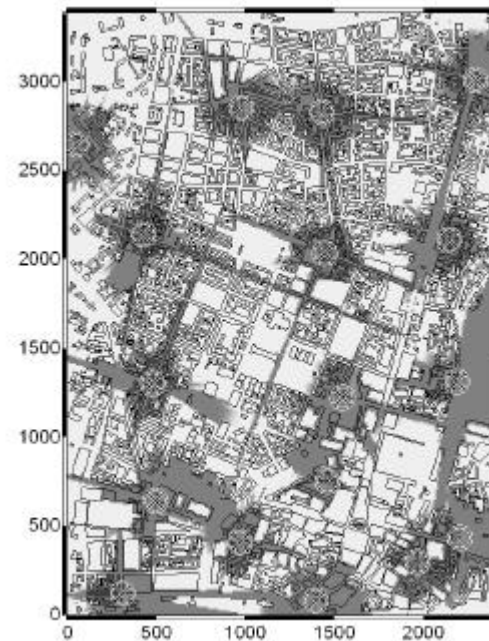


Fig. 5: Coverage area of the 384 kbps data service

While for the speech service only a small part of the considered area is without coverage (mostly inside buildings because of the penetration loss), the coverage for the 384 kbps data service is rather incomplete.

Table 2: 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

The uplink iteration determines the transmit powers of the mobile stations ensuring minimum overall interference. Fig. 6 shows the cumulative distribution function (CDF) of the transmit powers averaged over all services and simulation steps.

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. 7 shows the CDF of the base station powers for the different cells. 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 area considered. 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).

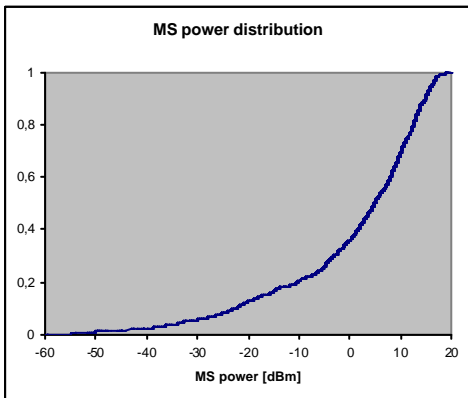


Fig. 6: CDF for the powers of the mobile stations

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. Further results on this page show the distribution of the uplink load (see fig. 8) and the distribution of the downlink throughput (see fig. 9) for each cell.

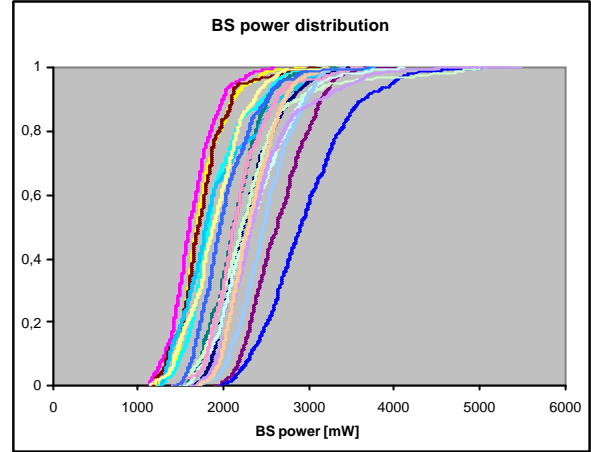


Fig. 7: CDF for the powers of the base stations

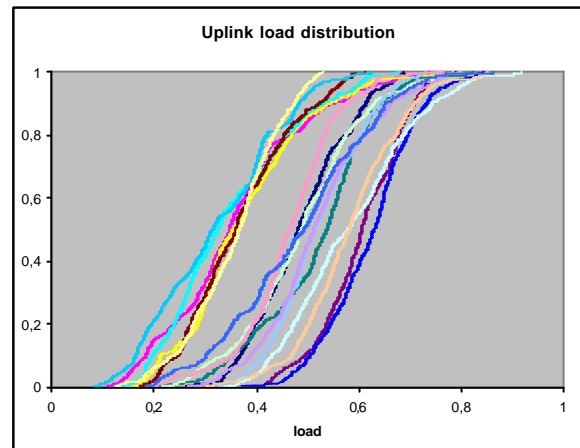


Fig. 8: CDF of the uplink load

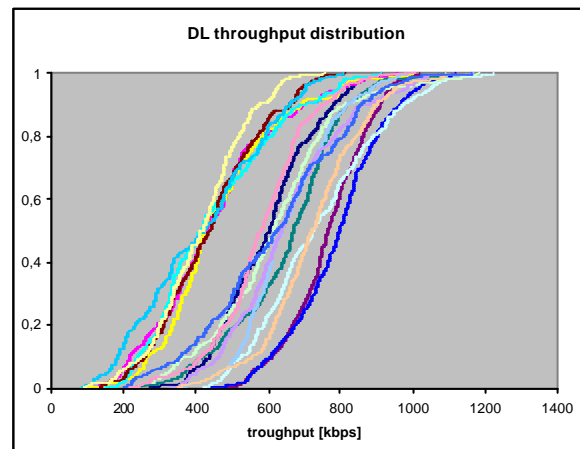


Fig. 9: CDF of the downlink throughput

As already indicated above, the accuracy of the results at the borders of the simulation area is limited by the lack of interference from bordering cells. This leads to reduced values for the uplink load and the downlink throughput for cells located at the borders.

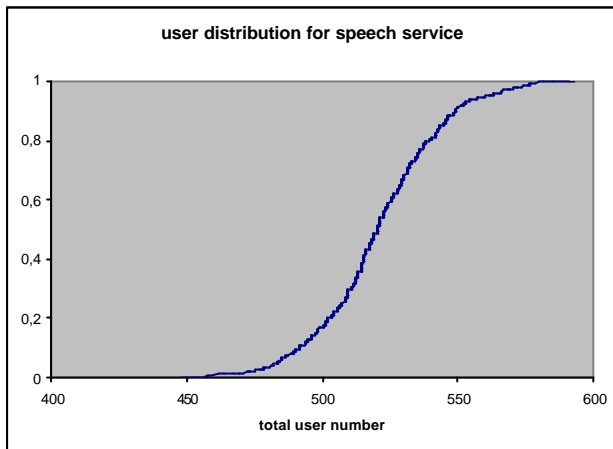


Fig. 10: CDF of the user distribution (speech service)

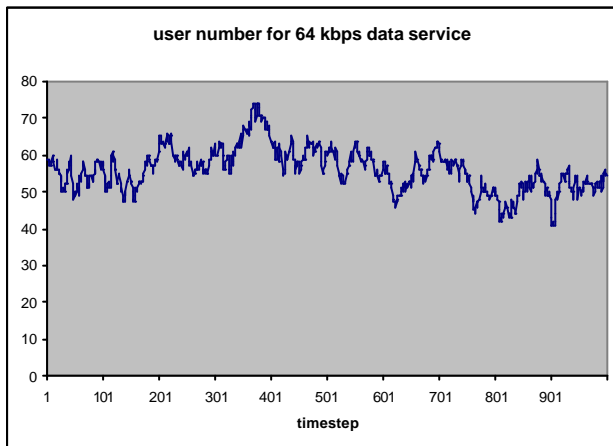


Fig. 11: User number vs. time (64 kbps data service)

Fig. 10 presents the user distribution for the speech service in all cells (mean value about 520). The temporal variation of the number of 64 kbps users in the total area with fluctuations up to 30% (indicated in fig. 11) justify the dynamic approach for the simulator. The different values correspond to the dynamic traffic modelling. With higher bit rate services an increase of the relative fluctuations can be observed.

Table 3: Soft handover in the uplink

number of servers in active set	percentage of users over all time steps
1	86.3 %
2	12.3 %
> 2	1.4 %

Concerning the soft handover the values given in table 3 have been determined for the uplink. About 14 %

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

5. 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 analysing the performance of a specified network constellation. Therefore this simulator can be utilised to implement a 3rd generation radio network more efficiently. A simulation example visualising the complex interaction of coverage and capacity is shown.

6. References

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