Performance of static WCDMA simulator

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***Abstract*— The aim of this paper is to evaluate the performance of a static WCDMA simulator in terms of absolute and relative error in available capacity for an urban UMTS network using field measurement results as a reference. A relative error in capacity is estimated from the measurement and simulation results in a network where antenna mechanical downtilt angles have been changed. The simulations have been carried out using an enhanced COST-231-Hata and a deterministic ray tracing model. The results illustrate how both models have their limitations in providing accurate simulation results. On one hand, ray tracing model provides relatively accurate estimation of the available capacity of the particular route used in the measurements. On the other hand, with the enhanced COST-231-Hata propagation model, a static simulator overestimates clearly the network capacity by 50% due to underestimation of coverage overlapping. Regarding the modified configuration, ray tracing model underestimates the gain provided by mechanical downtilt, whereas COST-231-Hata estimates the gain with reasonable accuracy. Moreover, ray tracing model seems to somewhat overestimate the sector overlapping, and hence overestimates the SHO probability as well.**

Key words: Field measurements, propagation models, static planning tool, WCDMA.

1. INTRODUCTION

For an operator, utilization of a radio network planning tool in WCDMA (wideband code division multiple access) planning process is economically and technically extremely beneficial. In the initial network deployment process, the use of planning tools results in a network consisting of sufficient number of sites to provide users the required QoS (quality of service). Therefore, the usage of planning tools minimizes the costs and the effort for the operator, and also fasten certain processes. Moreover, during network optimization and evolution when new sites are possibly dimensioned to the plan, a radio network planning tool can provide assistance for the planner. However, in this stage, a question concerning the reliability of the planning tool raises: whether it is able to provide sufficiently accurate estimates of the network performance, so that a planner can strictly trust on the outcomes of simulations.

Radio network planning tools rely typically on static analysis, which utilizes Monte Carlo approach. This method is widely used in commercial static radio network planning tools. A static planning tool provides an estimate of the average network behavior using a given network configuration and traffic layer (including service requirements and distribution). Due to their static nature, a static planning tool is not able to model time-dependent phenomena, but the analysis relies on having multiple independent snap shots of the network performance (i.e., average network performance). The other alternativity is to utilise dynamic tools for radio network planning [1]. The advantage of dynamic tools over static ones is their ability to model the behavior of different radio resource management (RRM) functions. Hence, they can be used, e.g., for benchmarking new RRM function or for some parameter optimization problems. However, the major disadvantage is their heavy computational load that actually excludes the possibility of achieving rapid performance evaluations of a network.

In a static planning tool, the actual performance estimation is normally divided into two parts—namely *coverage predictions* and *performance analysis*. In the coverage calculations, path loss matrixes are created based on propagation path loss models, network configuration, and digital maps of the planning area. Propagation is predicted according to a certain model for each pixel on the digital map[1]. Hence, in addition to reliable coverage prediction model, also the resolution of a digital map should be high enough. In the performance analysis part, predicted path losses are utilized for solving the required transmit power needs in the uplink (UL) and downlink (DL) by taking into account different phenomena, e.g., fast fading, SHO gain or required power control head room. Hence, the fundamental part of the performance of the simulator comes from the coverage predictions. The importance of coverage predictions has been outlined already in [2]. The simulation results showed mostly the limited dynamics of COST-231-Hata propagation model against ray tracing model in dense urban environment. With COST-231-Hata model, the capacity was observed to be 15% larger than with ray tracing model due to underestimation of cell overlapping. On the other hand, the performance of static tool is expected to be similar

[1]Pixel corresponds to the resolution of digital map.

to dynamic one as a static simulator has been observed to provide sufficiently accurate results compared to a dynamic simulator [3].

The aim of this paper is to provide an insight to the performance of a static WCDMA (wideband code division multiple access) simulator (primarily intended for radio network planning purposes) using measurement results as a reference. Furthermore, the paper targets in solving the absolute error of a static WCDMA simulator, as well as the relative error in case of a modified network configuration. The performance verification is carried out using an enhanced COST-231-Hata and a deterministic ray tracing model for coverage predictions in an urban UMTS network.

2. MEASUREMENT SETUP

The reference measurements for the comparison were conducted in a pre-commercial UMTS FDD (Universal Mobile Telecommunications System Frequency Division Duplex) network deployed in urban environment. The average antenna height was close to average roof top level, hence forming a combination of macro and micro-cellular environments. The site configuration consisted of 3-sectored cells with an average site spacing of 300-400 m. Moreover, the average distance of the measurement route from the base station was less than 300 m. Thus, any coverage limitations were not observed within the measurements route that covered approximately 20 cells (Fig. 1).

In order to observe the impact of a modified network configuration, some of the mechanical downtilt (MDT) angles were removed from selected sites around the measurement route, and the measurements were conducted again. In addition to mechanical downtilt angles, all sectors were equipped also with electrical downtilt angles (Fig. 1).

The measurements were conducted with two mobiles (placed in a car). The requested bearer speed was in the downlink 384 kbps (non-real time service using HTTP and background service class). Uplink direction was loaded, in addition to DPCCH (dedicated physical control channel), only with ACK/NACK responses of TCP (transport control protocol). All the measurement results of mobile stations were captured with an air interface measurement tool.

3. SIMULATION ENVIRONMENT

In order to model the measured network as accurately as possible, the whole radio network plan was imported into the WCDMA planning tool [4] including exact site locations and antenna configurations. Information of the measurement area was provided by a digital map with 5 m x 5 m resolution. Moreover, building information was included in a vector format.

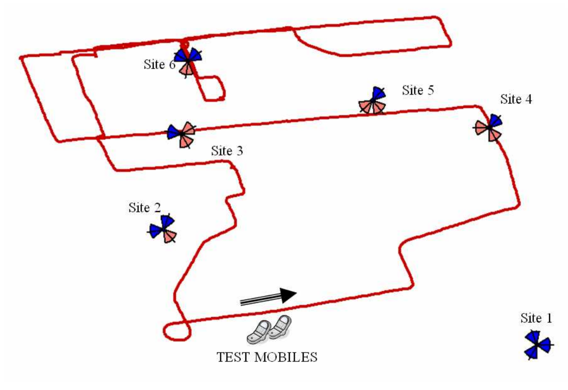

Figure 1. Network layout in the area of the measurement route together with site locations and antenna directions. Sectors that included mechanical downtilt angle are shown as red/light.

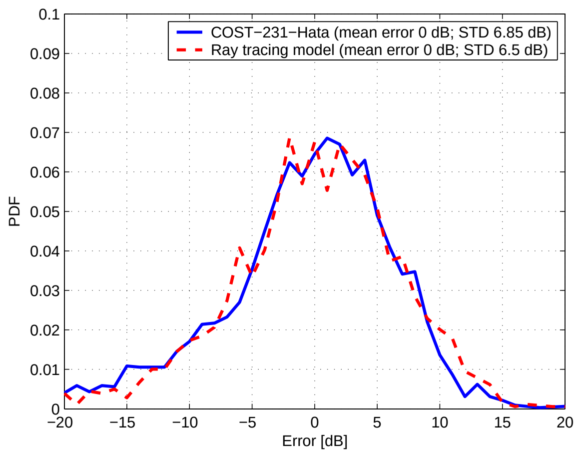

Figure 2. PDF (probability distribution function) of the error of the propagation model predictions after tuning process.

Simulations were run with an extended COST-231-Hata[2] and a ray tracing model [6]. Both propagation models were tuned in order to match the propagation of the measurement area. After the propagation model tuning process, both models provided a 0 dB error with standard deviation of 6.85 dB (COST-231-Hata) and 6.50 dB (ray tracing) (Fig.2). In addition to this, simulations parameters were selected in such a manner that most of those were the same. Naturally, all time-dependent RRM algorithms were not used in the simulations due to its' static nature. Finally, in order to have comparable results from the measurements and simulations, the traffic raster in the simulations covered only exactly the measurement route. Thus, traffic was distributed only within the used measurement route (i.e., on the route shown in Fig. 1).

4. PERFORMANCE COMPARISON

The performance comparison of the measurements and simulations is mainly focused on downlink di-

[2]See [5] for detailed information about extended COST-231-Hata

rection. The main emphasis here is in the capacity estimation between the measurements and simulations, but also on coverage analysis. The downlink capacity estimations presented here concerning the measurements are based on the method presented and verified in [7].

4.1. Average Cell Capacity

The average cell capacity was evaluated using the measured or simulated information of average E_c/N_0, i.e., RSCP/RSSI (received signal code power / received signal strength indicator) together with the recorded throughput in the downlink. In WCDMA, the average interference level increases as a function of load of a cell, which decreases as well the average E_c/N_0. Using predefined values in the DL load equations (see, e.g., [8]), a curve of E_c/N_0 as a function of DL throughput can be formed. The load curve of E_c/N_0 and DL throughput is fitted to a single load point by changing other-to-own-cell interference factor[3]. The reference point for this single load point is achieved either from measurements or simulations, and it allows to estimate the average cell capacity. The evaluated cell capacity depends naturally on the selected measurement route, and e.g., on the average distance to the base station. However, since the allowed user positions in the simulations were only within the measurement route, the outcomes of measurements and simulations should thus be comparable. Nevertheless, one fundamental property of this analysis is that the higher is the initial E_c/N_0 value (corresponds to E_c/N_0 measured in the idle mode), the higher is also the final capacity of a cell. Finally, providing an absolute capacity value naturally presumes certain assumption regarding service parameters and downlink orthogonality factor as well.

The measurement and simulation results together with estimations of the downlink capacities are shown in Fig. 3. These results are provided for the network where mechanical downtilt angles were utilized. The solid blue curve shows the estimated load curve based on a measured average E_c/N_0 of -5.30 dB and on the corresponding DL throughput of 336 kbps. The estimation of the load curve is made such that it passed the load point. The maximum average cell capacity of the cells under this particular measurement route is estimated from 3 dB noise increase (i.e., 3 dB decrease of the average E_c/N_0). According to the measurements and the estimation method, the maximum cell capacity would be at the level of 880 kbps, which forms a realistic value in micro/macrocellular environment [9].

The red (dashed) and black (dotted) curves show the corresponding results from the simulations with the enhanced COST-231-Hata and ray tracing model, respectively. The results indicate that ray tracing model

[3]Note that E_c/N_0 at 0 kbps throughput depends on the other-to-own-cell interference factor [7].

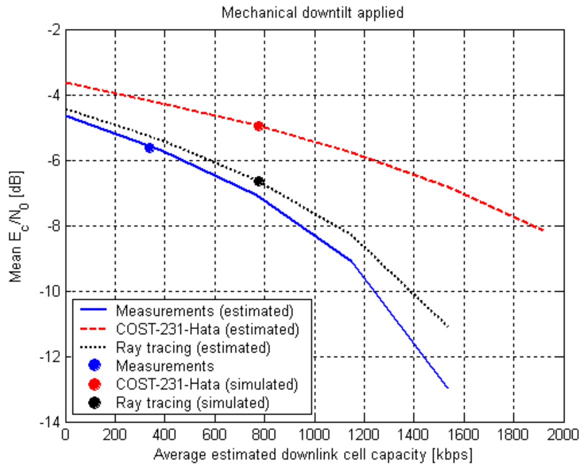

Figure 3. Measurement and simulation results together with estimated load curves for the downlink direction with part of the antennas mechanically downtilted. Service parameters assumed for the load curves: bit rate=384 kbps, chip rate=3.84 Mcps, downlink orthogonality factor α=0.7, service activity factor v=1.

performs accurately with respect to the measurements and provides average cell capacity of 960 kbps (error less than 10%), whereas COST-231-Hata model overestimates clearly the average cell capacity (1475 kbps). Hence, the error of COST-231-Hata model in the downlink capacity would be over 60%. One interesting result from the analysis is that according to the simulations, both mobiles would have achieved the maximum throughput continuously, where as in the measurements, only half of the requested throughput was achieved. Partly this reflects from the functionality of non-optimal RRM algorithms (which cannot be modeled with a static simulator) rather than error of the simulator itself. However, the impact of possible problems in RRM functions should be minimized, since the capacity estimation method is based on the sensitiveness of the network configuration for an increase of throughput. In addition, at least one limitation of the simulator is that it treats DL orthogonality factor as constant all over the cell, which is not true in practice.

The measurement and simulation results of the network configuration without mechanical downtilt angles are depicted in Fig. 4. Removing some of the mechanical downtilt (MDT) angles from particular cells does not change dramatically the capacity estimate based on the measurements. The average E_c/N_0 was decreased down to -5.50 dB, but the measured throughput was higher (402 kbps). Hence, the average cell throughput in this configuration would be 830 kbps with 3 dB DL noise rise. This small capacity gain (6%) can be explained with the fact that only a minor other-cell interference component was occurred due to measurement configuration (two mobiles simultaneously in the same cell). Regarding the performance of the simulator and

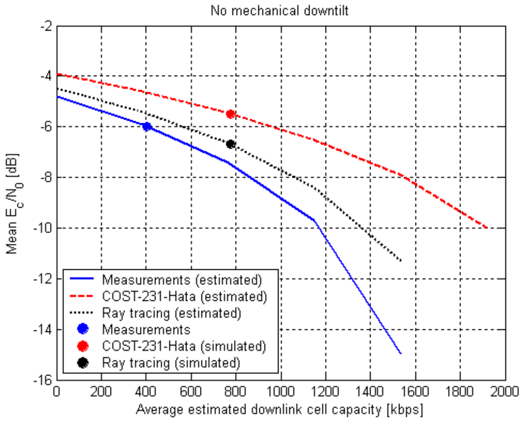

Figure 4. Measurement and simulation results together with estimated load curves for the downlink direction without mechanical downtilt. Service parameters assumed for the load curves: bit rate=384 kbps, chip rate=3.84 Mcps, downlink orthogonality factor α=0.7, service activity factor v=1.

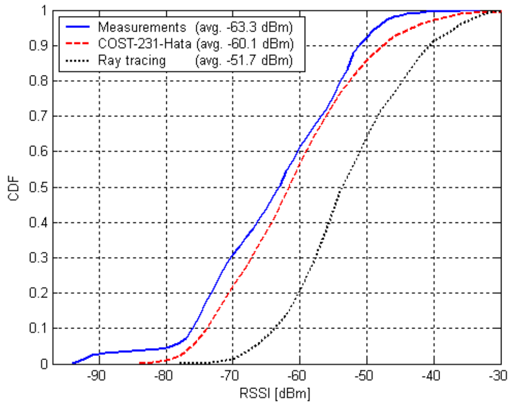

Figure 5. CDF (cumulative distribution function) of RSSI within the measurement route.

propagation models, ray tracing model provides almost the same capacity also in this scenario (950 kbps), hence predicting the low capacity gain. However, COST-231-Hata still overestimates the cell capacity and shows some gain from using MDT in the particular measurement route. Moreover, the cell capacity is this scenario would correspond to 1260 kbps. The errors in the downlink capacity estimate for COST-231-Hata and ray tracing models would hence be 50% and 15%, respectively. Notice that both models overestimate the average cell capacity with both network configurations. Possible reasons for these could be incorrect estimate of E_b/N_0 (i.e., evaluated E_b/N_0 different in measurements and simulations). Moreover, inherent lack of modeling of RRM functions and their functionality might cause these offsets.

Simulations provide naturally an easy assessment of the capacity of the whole network, and the performance or the results are not limited to any geographical area (as measurement route). Therefore, simulations were conducted to cover also all other areas than only the measurement route. With mechanical downtilt angles for the whole area, the average cell capacity (based on 39 dBm average downlink transmit power, i.e., 50% of load) would correspond to 1290 kbps and 780 kbps for COST-231-Hata and ray tracing models, respectively. This is intuitively lower than the capacity estimate for the measurement route, since the measurement route covered more favorable location (e.g., antenna main beam directions). However, the mutual difference between estimated capacities based on COST-231-Hata and ray tracing model seem to be roughly the same. Without any mechanical downtilt angles, COST-231-Hata provides 1140 kbps average cell capacity, whereas ray tracing model 750 kbps. With COST-231-Hata model, the capacity gain of mechanical downtilt would hence be 13%, whereas with ray tracing model only 4%. Thus, it strongly seems that ray tracing model underestimates the impact of mechanical downtilt as the capacity gains vary typically between 15%-20% [10]-[11].

4.2. Coverage and SHO Probability Analysis

Comparison of E_c/N_0 levels from the measurements and simulations together with DL throughput information is typically more convenient, since E_c/N_0 takes into account simultaneously coverage and capacity (relative measure). However, in some scenarios information about coverage is also needed. Fig. 5 provides the measured and simulated RSSI with mechanical downtilt angles. The measured RSSI is based on averaged value over the whole measurement route and three measurement rounds. The graphs clearly illustrate how ray tracing model overestimates the actual field strength within the measurement route. Note that part of the difference is caused by the higher throughput in the simulations. However, both simulation models fail in predicting poor coverage areas that were actually observed in the measurements. Average values of distributions presented in Fig. 5 are provided in parenthesis.

Fig. 6 depicts the measured and simulated UL TX (transmit) power values with mechanical downtilt angles (measured values are averaged over measurement route and three rounds). The results further illustrate the limited dynamics of both propagation models, since they overestimate the actual coverage within the measurement route.

As a last part, comparison is provided between average active set (AS) sizes and soft handover (SHO) probabilities (Table 1). In the measurements, the average AS was 1.15 and SHO probability 13.5% (including softer handovers) over the whole measurement route and three measurement round in mechanically downtilted network. The required SHO overhead is rather the

Table 1. AS and SHO probabilities within the measurement route

Parameter	MDT			No MDT		
	Measurements	COST-231-Hata	Ray tracing	Measurements	COST-231-Hata	Ray tracing
AS	1.15	1.15	1.31	1.22	1.18	1.32
SHO [%]	13.5	12.8	29.2	19.9	17.2	29.4

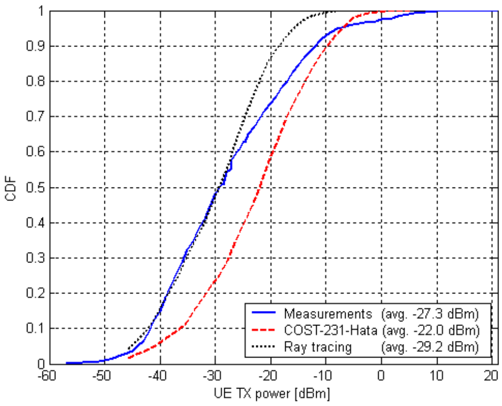

Figure 6. CDF of UL TX power within the measurement route.

same with COST-231-Hata (AS 1.15 and SHO 12.8%). However, overestimation of coverage overlapping with ray tracing model causes actually too high estimates of required SHO overhead as the average AS size is 1.31 and the corresponding SHO probability nearly 30% (overestimation with over 15% percentage unit).

Without mechanical downtilt angles, average AS size and SHO probability from the measurements was roughly 1.22 and 20%, respectively. COST-231-Hata model underestimates this slightly more than with mechanical downtilt angles, whereas the rough overestimation still continues with ray tracing model. This is one reason for low capacity gain for mechanical downtilt with ray tracing model.

5. DISCUSSION AND CONCLUSIONS

The performance of static WCDMA simulator with two different propagation models has been compared with the outcomes of measurements with two different configurations (with and without mechanical downtilt angles) in terms of downlink capacity together with coverage and SHO probabilities in urban environment. The network layout and configuration together with the measurement setup were imported to a WCDMA radio network planning tool in order to compare the performance exactly in the same environment and with the same parameters. The outcomes of this paper indicate that both propagation models–COST-231-Hata and ray tracing model–have their own limitations. Regarding the downlink capacity analysis, ray tracing model overestimates the available average cell capacity roughly by 10%, whereas COST-231-Hata by over 50%. This sort of offset should be taken into account if network capacity is estimated with planning tool, and moreover, if planning tool is utilized in optimization during network evolution. On the other hand, ray tracing model seems to underestimate the impact of mechanical downtilt, and it also overestimates coverage overlapping, which results in an excessive estimation of SHO overhead.

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