# WCDMA Systems Planning, Coverage and Optimization

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***Abstract*** ***–Detailed capacity and coverage planning are presented. In the detailed planning phase real propagation data from the planned area is needed, together with the estimated user density and user traffic. Also, information about the existing base station sites is needed in order to utilise the existing site investments. The output of the detailed capacity and coverage planning are the base station locations, configurations and parameters.***

***Keywords:*** ***WCDMA-uplink, WCDMA-downlink, coverage, handover, CPICH (common pilot channel)***

## I. INTRODUCTION

In WCDMA (Wideband Code Division Multiple Acces) all users are sharing the same interference resources in the air interface, so they cannot be analysed independently. Therefore, the whole prediction process has to be done iteratively until the transmission powers are stabilised. This iterative process is illustrated in Fig. 1.

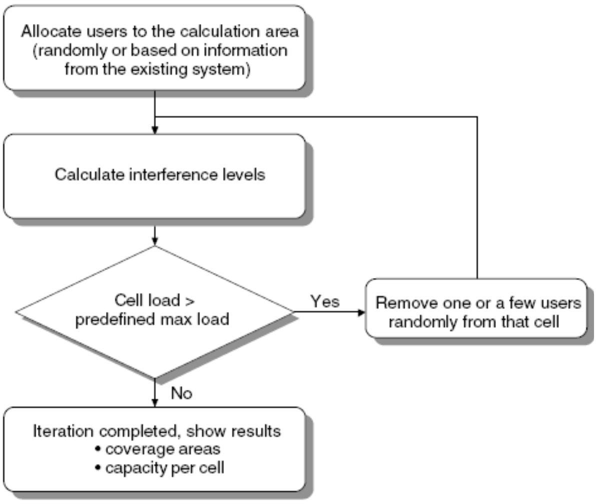

Fig. 1. Iteration for capacity and coverage calculations

Each user is influencing the others and causing their transmission powers to change. These changes themselves again cause changes, and so on. Also, the mobile speeds, multipath channel profiles, bit rates and type of services (TOS) used play a more important role than in second generation TDMA/FDMA systems. Furthermore, in WCDMA fast power control in both uplink and downlink, soft/softer handover and orthogonal downlink channels are included, which also impacts on system performance. The main difference between WCDMA and TDMA/FDMA coverage prediction is that the interference estimation is already crucial in the coverage prediction phase in WCDMA.. In the current GSM coverage planning processes the base station sensitivity is typically assumed to be constant and the coverage threshold is the same for each base station.

In the case of WCDMA the base station (BS) sensitivity depends on the number of users and used bit rates in all cells, thus it is cell- and service-specific. Note also that in third generation 3G networks, the downlink can be loaded higher than the uplink or vice versa.

## II. PLANNING TOOL

In second generation systems detailed planning concentrated strongly on coverage planning; in third generation systems a more detailed interference planning and capacity analysis than simple coverage optimisation is needed [1]. The tool should aid the planner to optimise the base station configurations, the antenna selections and antenna directions and even the site locations, in order to meet the quality of service (QOS) and the capacity and service requirements at minimum cost. To achieve the optimum result the tool must have knowledge of the radio resource algorithms. Uplink and downlink coverage probability is determined for a specific service by testing the service availability in each location of the plan. A detailed description of the planning tool can be found in [3].

The actual detailed planning phase does not differ very much from second generation planning. The sites and sectors are placed in the tool. The main difference is the importance of the traffic layer. The proposed detailed analysis methods (see the following sections) use discrete mobile stations (MS) in the WCDMA analysis. The mobile station density in different cells should be based on actual traffic information. The hotspots should be identified as an input for accurate analysis.

One source of information concerning user density would be the data from the operator's second generation network or later from the third generation. An example of a WCDMA planning tool (TEMS Investigation) [4] is shown in Fig. 2.

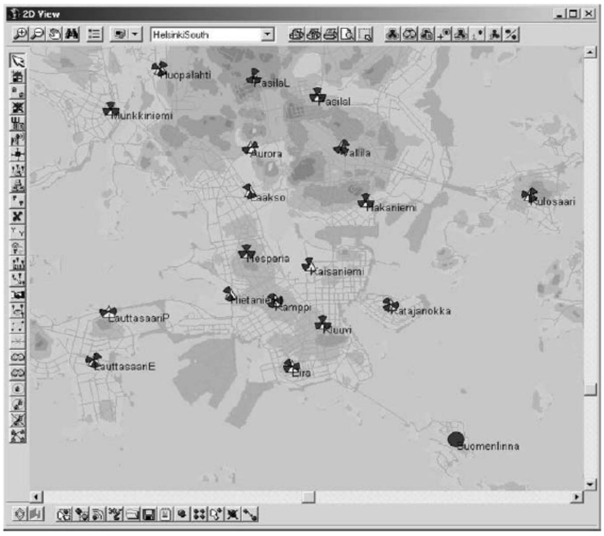

Fig. 2. TEMS Investigation network planning tool.

## III. UPLINK AND DOWNLINK ITERATIONS

The target in the uplink iteration is to allocate the simulated mobile stations transmission powers so that the interference levels and the base station sensitivity values converge. The base station sensitivity level is corrected by the estimated uplink interference level (noise rise) and therefore is cell specific. The impact of the uplink loading on the sensitivity is taken into account with a term - 10log$_{10}$(1-$\eta_{UL}$), where $\eta_{UL}$ is given by :

$$\eta_{UL} = (1+\mathrm{i})\sum_{j=1}^{N} L_j = (1+\mathrm{i})\sum_{j=1}^{N}\frac{1}{1+\dfrac{W}{(E_b/N_0)_j R_j v_j}}$$

where: i – other cell to own cell interference ratio seen by Bs.

$L_j$ – load factor of one connection ( j ).

$v_j$ - activity factor for j user (0.67-speech, 1-Data Tx in DPCCH)

w - wcdma chip rate 3,84 Mpcs

$R_j$ - Bit rate of user j

In the uplink iteration the transmission powers of the mobile stations are estimated based on the sensitivity level of the best server, the service, the speed and the link losses. Transmission powers are then compared to the maximum allowed transmission power of the mobile stations, and mobile stations exceeding this limit are put to outage.

The interference can then be re-estimated and new loading values and sensitivities for each base station assigned. If the uplink load factor is higher than the set limit, the mobile stations are randomly moved from the highly loaded cell to another carrier (if the spectrum allows) or to outage.

The aim of the downlink iteration is to allocate correct base station transmission powers to each mobile station until the received signal at the mobile station meets the required Eb/No target.

### *A. Modeling of link level performance*

In radio network dimensioning and planning it is necessary to make simplifying assumptions concerning the multipath propagation channel, transmitter and receiver. A traditional model is to use the average received Eb/No ensuring the required quality of service as the basic number, which includes the effect of the power delay profile. In systems using fast power control the average received Eb/No is not enough to characterise the influence of the radio channel on network performance. Also, the transmission power distribution must be taken into account when modelling link level performance in network level calculations. An appropriate approach is presented in [7] for the WCDMA uplink. It has been demonstrated that, due to the fast power control in the multipath fading environment, in addition to the average received $E_b/N_0$ requirement, an average transmission power rise is needed in interference calculations. Furthermore, a power control headroom must be included in the link budget estimation to allow power control to follow the fast fading at the cell edge. Multiple links are taken into account in the simulator when estimating the soft handover gains in the average received and transmitted power and also in the required power control headroom. During the simulations the transmission powers are corrected by the voice activity factor, soft handover gain and average power rise for each mobile station.

### *B. Case Study*

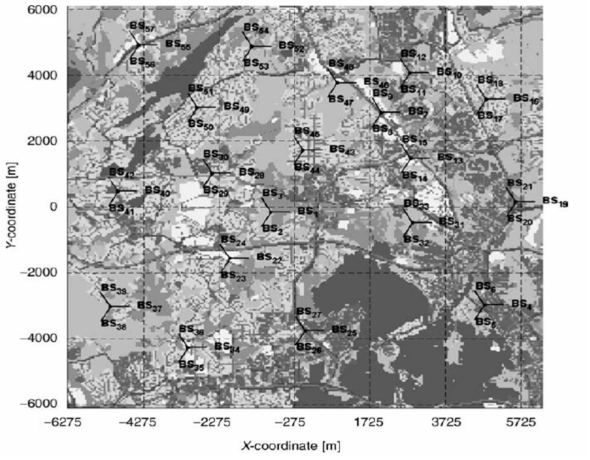

Fig. 3. The network scenario. The area measures 10x10 km$^2$ and is covered with 19 sites, each with three sectors.

In this case study an area, was planned, comprising roughly 10x10 km$^2$, as shown in Fig. 3.

The network planning tool described in Section II was utilised in this case study [3], [4]. The operator's coverage probability requirement for the 8 kbps, 64 kbps and 384 kbps services was set, respectively, to 95 %, 80% and 50 %, or better. The planning phase started with radio link budget estimation and site location selections. In the next planning step the dominance areas for each cell were optimised. In this context the dominance is related only to the propagation conditions. Antenna tilting, bearing and site locations can be tuned to achieve clear dominance areas for the cells. Dominance area optimisation is crucial for interference and soft handover area and soft handover probability control. The improved soft/softer handover and interference performance is automatically seen in the improved network capacity. The plan consists of 19 three-sectored macro sites, and the average site area is 7.6 $km^2$. In the city area, the uplink loading limitation was set to 75 %, corresponding to a 6 dB noise rise. In case the loading was exceeded, the necessary number of mobile stations was randomly set to outage (or moved to another carrier) from the highly loaded cells. Table 1. shows the user distribution in the simulations

*TABLE 1. The user distribution*

| Service in Kbps | User/service |
|---|---|
| 8 | 1620 |
| 64 | 230 |
| 384 | 12 |

other simulation parameters are listed in Table 2.

*TABLE 2. Parameters used*

| | |
|---|---|
| Uplink loading limit | 75% |
| Bs maximum Tx power | 20W (43dB) |
| Ms maximum Tx power | 300mW (25dB) |
| Ms power control range | 70dB |
| Slow fading correlation between Bs | 50% |
| Standard deviation for slow fading | 6dB |
| Channel profile multipath | ITU Vehicular A |
| Ms speed | 3/50 km/h |
| Ms/Bs noise | 7dB/5dB |
| Soft handover addition window | - 6dB |
| CPICH power | 30dB |
| Downlink Orthogonality | 0.5 |
| Activity speech/data | 50% / 100% |
| Ms antennas speech/data | Omni/1.5 dBi |
| Bs antennas | $65^0$/17 dBi |
| | |

The maximum uplink loading was set to 75% according to Table 2. In all three simulation cases the cell throughput in kbps and the coverage probability for each service were of interest. Furthermore, the soft handover probability and loading results were collected.

## IV CONCLUSION

Tables 3 and 4 show the results for cell throughput and coverage probabilities. Note that in Table 3 in some cells the loading is lower than 75 %, and, correspondingly, the throughput is also lower than the achievable maximum value. The reason is that there was not enough offered traffic in the area to fully load the cells. The loading in cell 5 was 75 %. Cell 5 is located in the lower right corner in Figure 3, and there is no other cell close to cell 5. Therefore, that cell can collect more traffic than the other cells.

*TABLE 3. Cell throughtput, loading and soft handover (SHO) overhead.*

| Basic loading : Ms speed 3 km/h, users: 1800 | | | | |
|---|---|---|---|---|
| Cell ID | Troughput UL (kbps) | Troughput DL (kbps) | UL loading | SHO overhead |
| 1 | 729.00 | 720.00 | 0.49 | 0.34 |
| 2 | 208.50 | 216.00 | 0.24 | 0.49 |
| 3 | 231.00 | 191.00 | 0.24 | 0.36 |
| 4 | 722.00 | 759.00 | 0.42 | 0.17 |
| 5 | 1509.00 | 1131.00 | 0.75 | 0.21 |
| 6 | 763.00 | 800.00 | 0.52 | 0.29 |
| Mean | 519.00 | 507.00 | 0.36 | 0.38 |
| Basic loading : Ms speed 50 km/h, users: 1772 | | | | |
| 1 | 670.00 | 718.00 | 0.57 | 0.27 |
| 2 | 207.70 | 215.00 | 0.32 | 0.50 |
| 3 | 227.00 | 191.00 | 0.28 | 0.35 |
| 4 | 721.50 | 758.00 | 0.49 | 0.11 |
| 5 | 1101.60 | 628.13 | 0.73 | 0.28 |
| 6 | 771.57 | 798.00 | 0.58 | 0.26 |
| Mean | 528.04 | 505.42 | 0.43 | 0.38 |
| Basic loading : Ms speed 50 km/h and 3km/h, users: 1797 | | | | |
| 1 | 727.00 | 718.00 | 0.50 | 0.34 |
| 2 | 207.80 | 214.00 | 0.27 | 0.48 |
| 3 | 239.00 | 198.00 | 0.25 | 0.34 |
| 4 | 730.00 | 758.00 | 0.44 | 0.19 |
| 5 | 1163.00 | 778.50 | 0.68 | 0.33 |
| 6 | 773.00 | 798.00 | 0.54 | 0.31 |
| Mean | 525.00 | 512.50 | 0.39 | 0.38 |

When mobile stations are moving at 50 km/h, fewer can be served, the throughput is lower and the resulting loading is higher than when mobile stations are moving at 3 km/h. If the throughput values are normalised to correspond to the same loading value, the difference between the 3 km/h and 50 km/h cases is more than 20 %. The better capacity with the slower-moving mobile stations can be explained by the better Eb/No performance. The fast power control is able to follow the fading signal and the required Eb/No target is reduced. The lower target value reduces the overall interference level and more users can be served in the network.

For example, cells 2 and 3 are in the middle of the area and there is not enough traffic to fully load the cells. Table 4. shows that mobile station speed has an impact on both throughput and coverage probability.

*TABLE 4. Coverage probability results*

| Basic loading: Ms speed 3Km/h | Test Ms speed: 3km/h | / 50Km/h |
|---|---|---|
| 8 kbps | 94.6% | 96.9% |
| 64 kbps | 83.5% | 89.0% |
| 384 kbps | 65.9% | 71.6% |
| Basic loading: Ms speed 50Km/h | Test Ms speed: 3km/h | / 50Km/h |
| 8 kbps | 93.4% | 96.4% |
| 64 kbps | 81.3% | 87.7% |
| 384 kbps | 62.0% | 68.5% |
| Basic loading: Ms2 speed 50Km/h | Test Ms speed: 3km/h | / 50Km/h |
| 8 kbps | 94.0% | 96.7% |
| 64 kbps | 82.8% | 88.6% |
| 384 kbps | 64.8% | 69.4% |

As finally conclusion we present a Network Optimization process to improve the overall network quality as experienced by the mobile subscribers and to ensure that network resources are used efficiently.
The optimization process is shown in Fig. 4.

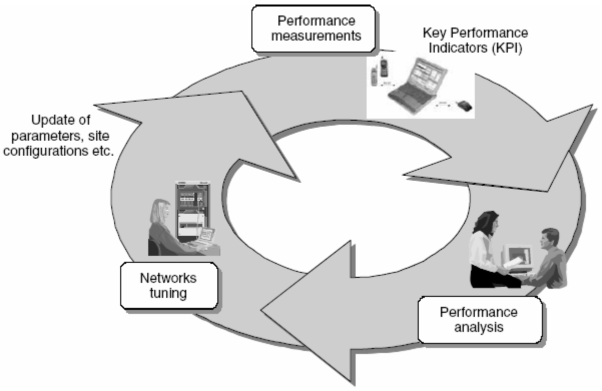

Fig. 4. Network optimization process

Optimization includes performance measurements, analysis of the measurement results, updates in the network configuration and parameters. The measurement tools can provide lots of results. In order to speed up the measurement analysis it is beneficial to define those measurement results that are considered the most important ones, Key Performance Indicators (KPIs). Examples of KPIs are total base station transmission power, soft handover overhead, drop call rate and packet data delay. The comparison of KPIs and desired target values indicates the problem areas in the network where the network tuning can be focused.

A clear picture of the current network performance is needed for the performance optimization. Typical measurement tools (test mobile, radio network elements) we can used to obtain relevant measurement data, e.g. uplink transmission power, soft handover rate and probabilities, CPICH Ec/No and downlink BLER (Block Error Rate).

The radio network can typically provide connection level and cell level measurements. Examples of the connection measurements include uplink BLER and downlink transmission power. The connection level measurements both from the mobile and from the network are important to get the network running and provide the required quality for the end users.

The cell level measurements become more important in the capacity optimization phase. The cell level measurements may include total received power and total transmitted power, the same parameters that are used by the radio resource management algorithms.

Also, test equipments can be used to provide some of the downlink measurements, like CPICH measurements [5] for the neighbors list optimization.

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