STATIC SIMULATOR FOR STUDYING WCDMA RADIO NETWORK PLANNING ISSUES

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Abstract – A static radio network simulator for studying various topics of 3rd generation WCDMA radio network planning is presented. The simulator allows analyzing coverage, capacity and quality of service related issues. Input to the simulator is the network scenario and the user information as a mobile station map. Uplink and downlink are separately analyzed and the outputs are presented in form of maps of best server, number of users, served traffic, SHO areas, AS size, SHO statistics for the area and for the users, Perch C/I plots. In the analysis, impact of the 3rd generations fast power control and soft(er) handover possibility are taken into account by importing link level simulations into the analyses. The whole simulator is entirely based on Matlab® software.

I. INTRODUCTION

The main difference between WCDMA and TDMA/FDMA coverage prediction is that the interference estimation is crucial already in the coverage prediction phase. In addition to that, the different services (voice, data) have different processing gains and thus different receiver Eb/No requirements. In traditional coverage planning processes the base station sensitivity is constant and the coverage threshold is the same for each base station. In the case of WCDMA the coverage threshold is dependent on the number of users and used bit rates in all cells, thus it is cell and service specific. Common features for coverage prediction also exist. In all the systems both of the links have to be analyzed. In current standards the links tend to be in balance, in the case of third generation the downlink can be higher loaded than the uplink. This fact has nothing to do with the coverage planning, it is based on the different nature of services that these systems offer. The propagation calculation is basically the same for all standards, with the exception that different propagation models could be used. Another common feature is the interference analysis. In the case of WCDMA this is needed for loading and sensitivity analysis, in the case of TDMA/FDMA it is needed for frequency planning.

To study various topics related to radio network planning for WCDMA a static network simulator has been created.

The simulator is based on the assumption that the traffic distribution is given in form of a user map. Various scenarios can be studied separately like voice users or (high) data rate users only, but also mixed traffic scenarios can be analyzed.

II. STRUCTURE OF THE SIMULATOR

The simulator consists of basically four parts. First the network configuration is read in from parameter files for base stations, mobiles stations and the network area. Some system parameters are set and initial calculations are performed. Uplink and downlink are then analyzed separately and in the final step, the results of the uplink and downlink analyses are post processed.

A. Initialization phase

In the first part of the initialization phase system parameters as well as the map size and resolution are set. Then the parameters for the base stations and mobile stations are read in together with some default values for the radio network performance.

The main task of the initialization is the calculation of the link losses from each base station to each position in its calculation area. Various propagation models, base station sectorisation and antenna configurations can be selected. Basic implemented path loss models include Okumura-Hata and different slope models but any kind of model can be applied as an interface to import link loss data from other tools (e. g, ray tracing) has been implemented. Slow fading is modeled as Gaussian random variable with adjustable standard deviation. Correlation of the path loss from MS to different base stations is taken into account according a method described in [1].

B. Uplink iteration

The target in the uplink iteration is to allocate the mobile stations' transmit powers so, that the interference levels and thus the base station sensitivity values converge. The

transmit power of the mobile stations to each base station are estimated so that they fulfil the base stations Eb/No requirements. The mobile station's transmit powers are based on the sensitivity level of the base station, service (data rate) and speed of the mobile station and the link losses to the base station. These average powers are then corrected by taking into account the voice activity, the soft handover (SHO) gains and average power raise due to fast transmit power control (TPC). The latter two ones are imported in form of look up tables based on extended link level simulations and SHO analyses [2] and [3]. For each channel type a separate set of tables has to be generated. Influence of the fast TPC can be seen in an increase of the average transmit power and in the headroom (fast fading margin) a MS needs above the average transmit power to follow the fast fading. SHO gains on the contrary help to alleviate the situation by reducing the average needed transmit power and the headroom. For the amount of reduction in average transmit power and headroom in the SHO case, tables have been generated from link level simulations for various mobile speeds, bit rates and average level difference of the SHO links. Not simulated intermediate values are interpolated.

When the transmit powers of the mobiles stations to each base station are estimated the best server is determined as the base station, to which the mobile station has to transmit with minimum power. The minimum transmit powers are then compared to the maximum allowed transmit power of a mobile and terminals exceeding this limit are excluded during this iteration step. If this happens a specified number of iterations in a row, the MS is finally put to outage. After the transmit powers of all mobile stations have been allocated, the interference at each BS can be re-estimated and new loading value and sensitivity is estimated. The impact of the loading on the sensitivity is taken into account by adjusting it with $(1-\eta)$, where η is defined according to (1) as

$$\eta = \frac{I}{I+N} = \frac{I_{own} + I_{oth}}{I_{own} + I_{oth} + N} \qquad (1)$$

with I_{own} and I_{oth} as interference from own and other cell respectively and N is the background and receiver noise.

Now the mobile station can be re-allocated to a new base station, the mobile station transmit powers are re-estimated and the interference analysis is performed again. This is repeated until the changes in the BS sensitivity values are smaller than specified. In case the loading of a cell exceeds the specified value another carrier can be automatically added and mobile stations are moved to the new carrier. Different strategies to share the traffic between the additional carrier(s) are implemented. The methods include a) moving randomly mobile stations from the whole network to a new carrier, b) randomly moving mobile stations from overloaded cells to a second

carrier or c) moving mobile stations at overloaded cells according their needed transmit power. While method a) ensures that the whole traffic distribution in the network is not changed compared to the initial situation, it has the disadvantage, that the second carrier is taken into account simultaneously at all base stations even if it is not needed.

C. Downlink iteration

The aim of the downlink iteration is to allocate the correct base station transmit powers towards each mobile station until it has reached the targeted C/I value according (2).

$$TargetCI = Eb/No_{MS} \cdot W/R \qquad (2)$$

where Eb/No_{MS} is the received Eb/No requirement of the MS depending on speed and service, W is the modulation bandwidth and R is the data rate. The estimation of the correct transmit power requires iteration, since the C/I at each mobile station is dependent on all the powers allocated to the other mobile stations. In the interference calculation, the orthogonality α of the WCDMA downlink is taken into account, reducing the own cell interference by $(1-\alpha)$ as well as the gain due to the SHO by combining all SHO connections at a mobile station. Finally a service dependent voice activity is applied, which can be different from the uplink value of that MS.

In downlink direction the best server is determined as the base station whose Perch channel is received best. Then all other base stations are determined whose Perch channels are also received within the specified threshold (WINDOW_ADD) below the best server value and the links to all these base stations are combined. The first step in the downlink iteration therefore is the allocation of the correct Perch channel power. Different strategies are implemented, which include a) allocating every base station a fixed Perch power as such, b) correcting this fixed power by the amount uplink interference and c) allocating each base station a free settable Perch power.

Next step is the allocation of the initial transmit power of each link. To get good starting values to increase the convergence of the iteration a mobile station sensitivity is introduced. The mobile station gets the sensitivity of its best server adjusted by the difference in Eb/No requirements for the correct service and speed. With this sensitivity and the link loss to the best server the needed transmit power to the MS is estimated and all links to that MS use the same transmit power.

Before the estimation of the C/I can be performed, the total transmit powers of the base stations must be checked. In case they exceed the allowed maximum, several methods for reduction are implemented including a) dropping randomly links, b) dropping links using the highest powers and c) dropping links using the smallest

powers from too high loaded cells. Method a) gives the most realistic capacity numbers from the three methods. Method b) is too optimistic favoring low power links and c) is too pessimistic preferring high power links. Methods b) and c) also change the initial traffic distribution, because in b) links to MSs at the cell edge and in c) links to MSs close to the BSs are removed more likely. Links are removed until the total power of all traffic channels stays below the maximum base stations transmit power reduced by the Perch power and the other common channels. If one of the dropped links was a link to the best server of a MS, all links to that mobile are dropped and it is excluded from the current iteration step. After this happened a certain number of consecutive iterations, the MS is finally put to outage.

After all links got allocated their transmit powers, the received C/I for each link is calculated. In interference calculation, the total transmit power of a BS including the Perch and other common channels' powers are taken into account. Interference coming from the own cell's BS, is reduced because of the downlink orthogonality by $(1-\alpha)$. The C/I's of all links to a MS are then added together in linear scale and compared to the targeted C/I of that mobile station. If the difference is bigger than a specified threshold, the transmit powers of all links to that mobile are adjusted by the difference between actual and target C/I and the iteration is repeated.

D. Post processing phase

In the post-processing phase basically all outputs are generated. Different kinds of formats are used to display the various outputs. First, there is information plotted as maps. To this type of information belong the plots of best server in UL and DL, the uplink loading, the SHO overhead, Perch C/I, dominance and SHO areas, active set size (number of received Perch channels within a certain threshold), proposed number of carriers. Second output format presents the results in form of tables and histograms. Third output format is the UL coverage estimation for a specific user. Input parameters to this analysis are the used service (bit rate) and the MS speed. Other plots show visualize all the SHO connections a MS is having or all MSs which are connected to a certain BS.

Final analysis in the post-processing phase after the downlink iteration has converged, is the estimation of the Perch channel C/I of the best server at each spot. It is basically following the same procedure than the C/I calculation for the traffic channels. Also here, the interference coming from the own cell is reduced by the downlink orthogonality.

III. ANALYSIS EXAMPLE - DISCUSSION

In this section an example for a possible coverage/ capacity analysis is given. First the network scenario and the traffic distribution are introduced. Then the needed parameters are presented and example outputs are given.

A. The example network scenario

The example scenario was a regular network consisting of 19 3-sectored sites leading to 57 cells. One center site was surrounded by two tiers of sites on a hexagonal grid. For the traffic map a homogeneous distribution of 1500 speech users (8 kBit/s, 50 km/h) has been used, overlaid two hotspots of totally 30 data users (144 kBit/s, 3 km/h). The network scenario and the user distribution are depicted in Figure 1. The most important parameters used in the simulation are introduced in Table 1.

Table 1. Parameters used in the example

| max. MS TX power	21 dBm
max. BS TX power	43 dBm
max. allowed uplink load	50 %
path loss model	Okumura-Hata
slow fading	$\sigma = 6$ dB, correlation = ½
WINDOW_ADD	6 dB
max. Perch power, fixed for all BSs	30 dBm
other common channel powers	30 dBm
voice activity	0.67 (speech); 1.0 (data)
downlink orthogonality per cell	0.5
load control in UL / total BS TX power control in DL	links randomly out from overloaded cells
BS antennas	65° / 17 dBi
MS antennas	Omni / 1.5 dBi
BS/MS noise figure	5 dB / 7 dB
BS/MS losses	3 dB /1.5 dB
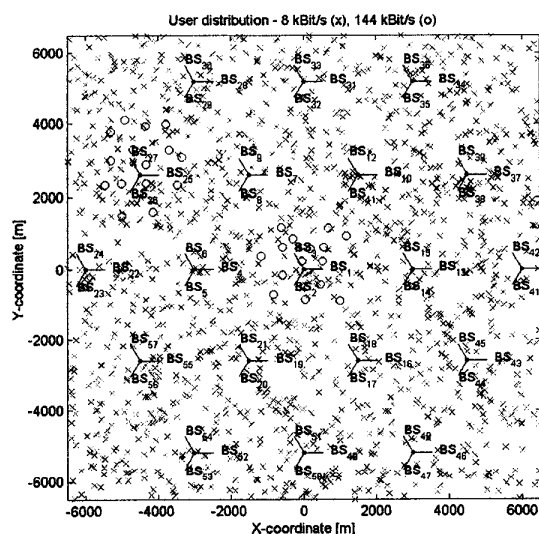
Figure 1. The network scenario and user distribution.

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B. Results from uplink analysis

B.1. Best server, UL coverage and cell loading

In this section, examples for the uplink iteration results are introduced. Figure 2 presents the best server in uplink, i.e. the base station to which the reference mobile station would transmit with minimum power. The size of the cells where the additional data users have been placed is significantly smaller than in the other cells. The coverage probability in 3rd generation networks is hard to characterize. It will be different, depending on the current load situation, what service the MS will be using and what speed it has. Figure 2 also shows the result of the coverage probability analysis for a 144 kBit/s user with a speed of 3 km/h. Black parts indicate no coverage. The service probability within the marked area was about 72% whereas for the speech user it was almost 98%.
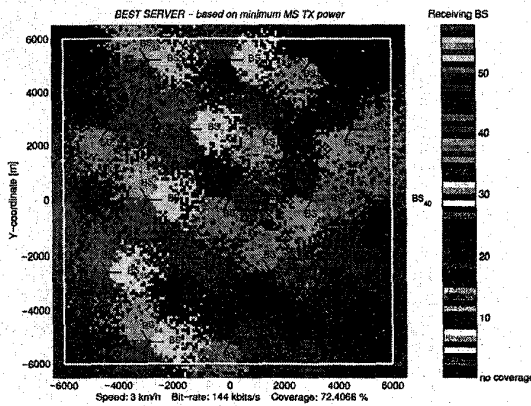

Figure 2. Best server after UL iteration and UL coverage probability for a 144 kBit/s user with 3 km/h.

In Figure 3 the loading of the cells is depicted. In the cells with speech users only it was well below the specified maximum load of 50 %. In the cells with the data users, the loading was almost twice as high.
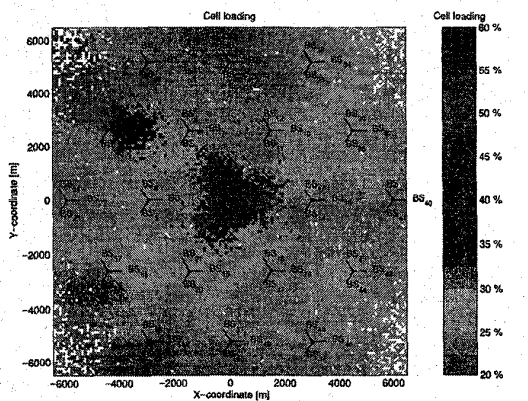

Figure 3. The loading of the cells.

C. Results from the downlink analysis

C.1. Received signal level and SHO analysis

In CDMA systems it is of utmost interest to control the areas where SHO occurs. Therefor the simulator offers the possibility the estimate the soft handover areas and the probabilities depending on the parameter settings in the soft handover algorithm. As an example the analysis results for a simple threshold based algorithm [4] are presented. All base stations whose Perch power is received with in a WINDOW_ADD range of the best server are taken into the active set, provided the maximum power of the base station is not exceeded.
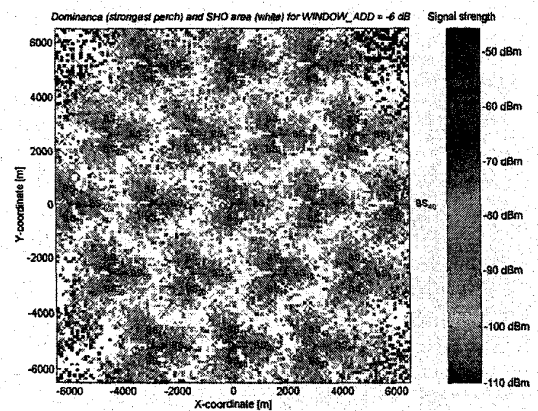

Figure 4. The dominance and SHO areas (white).

For WINDOW_ADD of 6 dB, Figure 4 shows the level of the strongest received base station together with the SHO area. In Figure 5 is presented the resulting overhead due to the SHO. It can be as much as 100% or even more. From the Figure 6 one can read, that roughly 40% of the MSs have been in SHO and active set size was going up to 7.
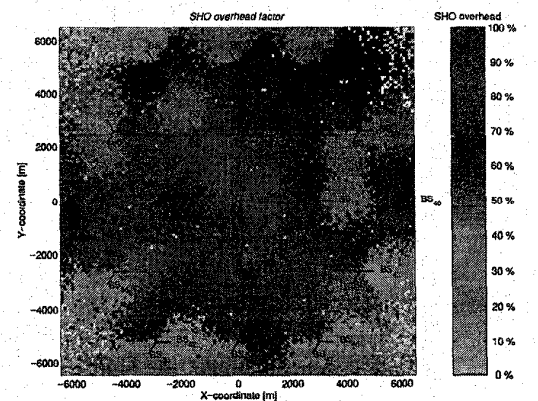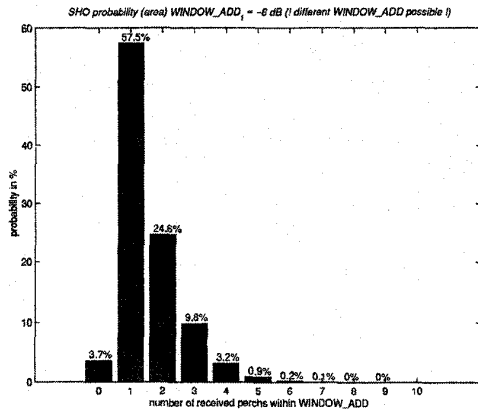

Figure 5. The overhead due to SHO.

Figure 6. The SHO probabilities.

D.2. Cell capacity

Another interesting figure of merit is the total throughput at the different cells. It is calculated as the sum of the bit rates of all users connected to that cell. SHO connections are not taken into account. The Figure 7 shows the result for this example. Another possibility of estimating the capacity of the cells is e.g. to put there as many users as possible until the specified loading is exceeded or the base stations run out of power.
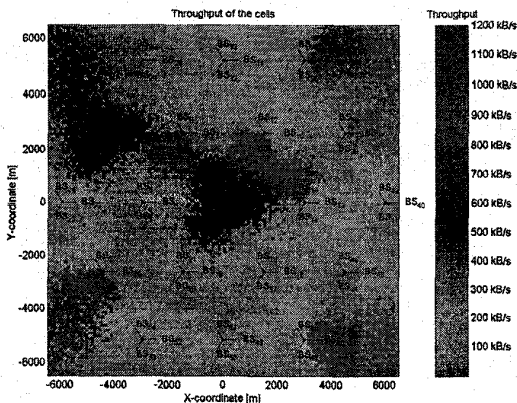

Figure 7. The throughput of the cells.

D.3. Perch C/I analysis

To achieve the maximum performance of the network, it is very important to control to which base stations the MSs will be connected. This is done by setting the Perch channel powers to the appropriate values. For this, the Eb/No requirements of the Perch channel must be known and a C/I analysis has to be performed. Figure 8 shows an example for such an analysis.
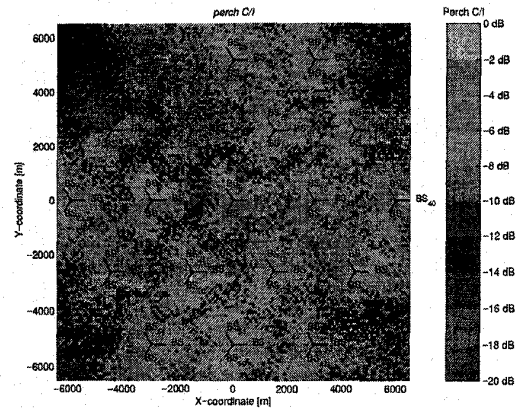

Figure 8. The Perch C/I.

IV. CONCLUSIONS

In order to examine the complex interaction of coverage and capacity in network performance analysis of WCDMA a static network simulator has been developed. It allows in an easy way to implement and study various different approaches to optimize the strategies for planning 3rd generation radio networks. Furthermore it allows examining different radio resource management algorithms and their parameterization as well as analyzing their influence on the key performance indicators of such a network.

ACKNOWLEDGEMENTS

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