Planning and Pre-Operational Performance Optimization of WCDMA for Multimedia Wireless Networks

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***Abstract* – In this paper we present important role of detailed planning and optimization of radio network in the design of next generation wireless networks that offers multimedia traffic. Wireless operators that are adapting 3G mobile technologies are facing more and more challenges connected to the design and planning of the factual multi service radio networks as WCDMA itself. These challenges are not independent and must be considered together with the user's demand and performance analyses as key factors of designing process, dimensioning and pre-operational optimization of network infrastructure.**

Keywords* – *WCDMA, Detailed Planning, Pre-Operational Optimization, Wireless Multimedia Networks, Multimedia Traffic.

I. Introduction

WCDMA radio network planning process, as defined by 3GPP, basically can be consisted of: modeling of radio network planning tools and preoperational control of network (optimization) [1]. At the beginning we gave overview of the existing simulation approaches that deal with the estimation of the number of simultaneously active users in the next generation multimedia mobile systems on statistical representative way, so the simulation results reflect the system reaction on certain traffic demand. We come up with MATLAB® based simulator performing the distribution of these active users in the network topology at given moment. Than these generated snapshots we used as input for the static WCDMA simulator in order to present the importance of the proper and efficient dimensioning of radio network.

From these reasons we conducted the study for the simulation of the UMTS system for the purpose of validation of the WCDMA planning. As planning tool the MATLAB based NPSW (Nokia®) static simulator is used. In this direction, a couple of user distribution scenarios for a given snapshot are analyzed, compared and evaluated for multiple purposes as identification of the main metrics of the system capacity and verification of the impact of each scenarios on the capacity and coverage improvement.

In the last phase we performed on more study related to the optimization of previously obtained results for the scenarios analyzed during the WCDMA planning. We demonstrated the impact of the antenna selection, antenna tilt, antenna beamwidth and application of the sectorisation on the interference, with the purpose of finding optimal solutions that will improve the capacity and coverage of the mobile systems from next generations, as 3G.

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II. Geographical Distribution of the Snapshots Consisting Active Users

The number of active users for any user profile may be presented as random variable that follows its multiplexing distribution [2]. Once the number of active users is known, they have to be randomly distributed on the spatial plane following the proportions of the geographical user distribution. For the realization of these steps, we create a MATLAB code which on its input uses the number of active mobile stations in a given moment, as well as the dimensions of the area in which the users are located. In the absence of real demographic data for the area with known geographical user distribution (census), in this paper the analyses are performed over the predicted 16.9 km² test area (3G system with 19 three-sectored base stations), whit randomly distributed users. The active users will follow the same random distribution, too. On its output, the code generates *x* and *y* coordinates of the each active mobile station within the test area and are used as input in the NPSW simulator (Network Planning Strategies for Wideband CDMA created by Nokia®) 5.0.0 version [4-6]. For the analyses we assumed a snapshot consisting 11 randomly distributed active users. Based on simulation result all 11 active users are served by the system.

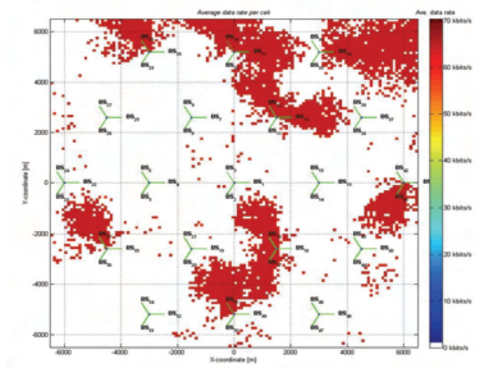

Fig. 1. Average data rate per cell in uplink.

On the Fig. 1 we depicted NPSW graphical simulation results how is distributed the average data rate per cell in uplink on the locations of the 11 served active users. We may conclude that accurate snapshot generation that can serve as proper input to the simulator for WCDMA planning and optimization discussed next with the aim to be estimated the respond of 3G system on offered traffic.

III. Detailed WCDMA Planning with Static Simulations

In this Section in details will be described pre-operational phase of the WCDMA planning process as described by 3GPP [1], [3]. Initial planning (the system dimensioning) provides the very first estimation of the network size and the capacity of the RAN. In the detailed planning phase multiple analyses are performed in order to be achieved the set of requirements. Then optimizing procedures are conducted for interference control by proper configuration of the sites and antennas.

Here the priority will be kept on showing how can be verified detailed planning aspects of WCDMA with the help of static simulations. We will perform UMTS case study by performing a couple of scenarios (different user profiles and distributions), which results we used to discuss the validity of the methodology and its sensitivity to certain demands. The principles of detailed WCDMA radio network planning in this paper are presented with the help of static radio network simulator – NPSW [4-6]. This simulator, is used in this Section and in the Section 4 where are shown the optimization results for WCDMA.

A. Simulation Scenarios Configurations

We chose two basic simulation scenarios that will be evaluated in multiple purposes: Scenario A – One user profile, and Scenario B – Multiple user profiles, both with heterogeneous traffic distribution. The main purpose is to identify the main metrics of the system capacity (throughput per sector, transmit power per sector and uplink load) in case of different users traffic demand. For the simplification and comparison purposes all analyses are based on one snapshot that in given moment of time presents in total 1140 active user in the system. The 13.5 km² test radio network has 10 three-sectored identical base stations (antenna tilt is 7 degrees in all sectors, and azimuths 90, 210 and 330 degrees) [2].

Fig. 2. Graphical representation of Scenario A snapshot.

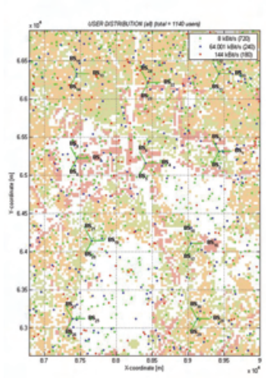

Fig. 3. Graphical representation of Scenario B snapshot.

B. Scenario A – One User Profile, Heterogeneous Traffic Distribution

Regarding the traffic related input parameters for Scenario A, we have: 1140 active users with 8 kbit/s data rate service, heterogeneously distributed in the network layout for which is needed 9120 kbit/s throughput. Simulations were terminated after 8 iterations and graphical results were saved. The graphical result for the snapshot of Scenario A is depicted on the Fig. 2. Other relevant statistics are summarized in Table I.

C. Scenario B: Multiple User Profiles, Heterogeneous Traffic Distribution

In comparison with the previous scenario this is more complex one, since in the same time three different user profiles are active. All the rest configurable parameters are kept the same. Table II consist the simulation inputs. At Fig. 3 we depicted the graphical representation of snapshot for Scenario B as output from NPSW. After analyzes of all graphical results the next discussion is valid:

- Served users: 600 (A: 1116);
- Refused users: 540, based on additional reasons 33% (limitations on the maximal power of the MSs and transmit power of BSs);
- Aggregated throughput = 389*8kbps + 124*64kbps + 87*144kbps = 24.78 Mbit/s (A: 8.72 Mbit/s);
- Uplink load factor: 0.63 (A: 0.42);
- Transmit terminal power is increased because of the increased speed of the users (8.26 dBm).
- The average shot handover overhead factor is 40.7% and it is slightly lower than in Scenario A;
- Soft handover: 20.2% from the total number of served users (121 connections).

IV. Pre-Operational Performance Optimization of WCDMA

In this Section we present study for optimization of radio network plan with the aim to perform the optimization early in the planning phase. Since WCDMA based 3G systems are very sensitive regarding the interference, it is from highest interest not to cause or receive a significant part of it. The most efficient ways to improve capacity and coverage performance, e.g. to control the interference in the RNP phase [1], is through setting the site locations and configurations (sectroization) and setting the height, beamwidth and tilt of antennas.

For realization of the current study we use the network topology and snapshot used in the scenario B. Multi path "ITU vehicular A" channel profile is assumed [8]. In addition, in the NPSW simulator we activate 4- and 6- sector configurations. Besides already used antenna with 65º beamwidth (Scenarios A, B) with 3 dB and tilt 7º, we used here four additional and different 3 dB antenna types at 120º, 90º and 33º and additional tilts from 0º, 4º 10º and 14º. First we simulate different antenna tilts in case of different sectorization, for determining the optimal tilt, and after, we describe an environment for determining the capacity as a function of sectorisation and antenna choice.

TABLE I
OVERVIEW OF THE RESULTS OF SCENARIO A

	Avg. Sector	Sum
Requested Connections	38	1140
Served Connections	37.2	1116
SHO connections (22.1 % from MS are connected to two BS)	16.5	493.3
Total connections	53.7	1611
Throughput (kbit/s)	297.6	8928
Total Rate (kbit/s)	429.6	12888
SHO overhead	46.54%	46.54%
Not served - Downlink power per link limit	0.7	21
Not served – too bed CPICH	0.1	3
Not served - Uplink power limit	0	0
Total power of traffic channels (TCH) in downlink (dBm/W)	35.26/3.4	50/102
Uplink load factor	0.42	

TABLE II
INPUT TRAFFIC PARAMETERS FOR SIMULATING SCENARIO B.

Number of 8 Kbit/S users	720
Number of 64 kbit/s users	240
Number of 144 kbit/s users	180
Throughput requested kbit/s	47040
Total simulation iterations	22

A. Optimization of Radio Network by changing the down tilt

Simulations shown that optimal tilt angle is between 7º and 10º. This relatively high optimal angle can be explained by the very high installation height of the antenna (50m). Other-cell to same-cell interference ratio, *i*, goes down as tilt goes up. This is the case since the antenna beamwidth doesn't radiates too much power to other base stations and therefore a bigger amount from the radiated power goes to the area for which it is intention to be served by the analyzed base station. From the other side, the results show that network can serve more users in cases without or with small antenna tilting. Always there is some optimal value of the tilt depending from environment and base stations sites [9-11]. If the angle is too high, the service will decrease and the base station will not be in position to serve a big area as in the case with sufficient tilt. Due to the existence of lobs and wing at the sides of the antenna radiation pattern results show that coverage probability as a function of tilt angle may have certain variations of the *i* value[12]. All of this may be considered on Figs. 4 - 7.

B. Optimization of Radio Network by changing the antenna beamwidth

In the second case we illustrate the capacity improvement as a function of sectorisation when each base station is simulated as site with 3, 4 or 6 sectors. We simulate a couple of scenarios with different antennas beamwidth. We emphasized the validity of the correct antenna selection for the sectored configuration. Some of the graphical results are summarized on the Figs. 8 - 12.

After performed analyses it can be concluded that the network is overloaded in uplink. In all three sectorisation cases, the reason for uplink outages is because some mobile stations suffer from having not enough power. Nevertheless, the downlink is more limiting and more mobile stations go to outage. With the higher sectorisation may be served bigger number of users (bigger capacity). Other observation shows that for each sectorisation case the antenna bemawidth selection plays important role. Better choice is antenna with the bemawidth that is as small as possible, e.g. antenna with 65º is optimal for 3-sectored case and antenna with 33º is best for the 4 and 6 sectored scenarios. In order to achieve higher possible number of served users it is very important to control the interface on the effective way. If the sector overlapping is too big, the interference may pass in other sector directly reducing its capacity.

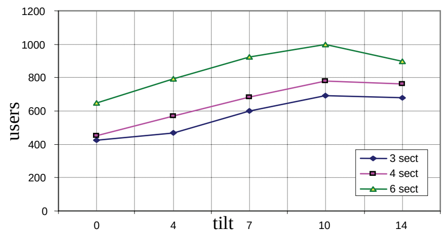

Fig. 4. Impact of the antenna tilt on the capacity.

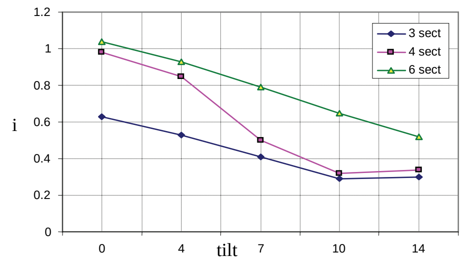

Fig. 5. Impact of the antenna tilt on *i* value.

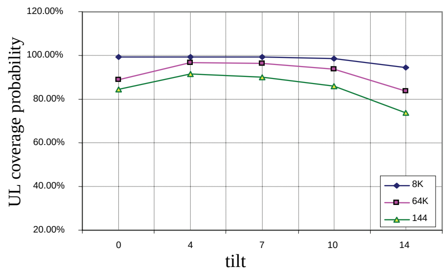

Fig. 6. Impact of the antenna tilt on the UL coverage probability, for 6 sectored configurations and for all services.

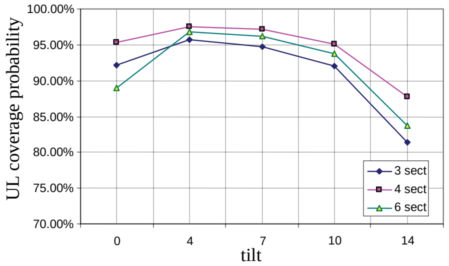

Fig. 7. Impact of the antenna tilt on the UL coverage probability, for 64 kbit/s service.

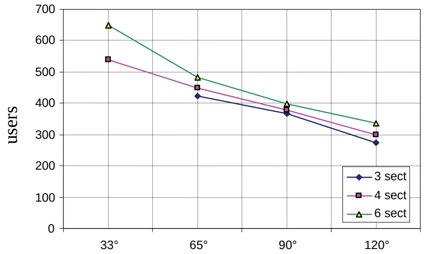

Fig. 8. Impact of the antenna beamwidth on the capacity.

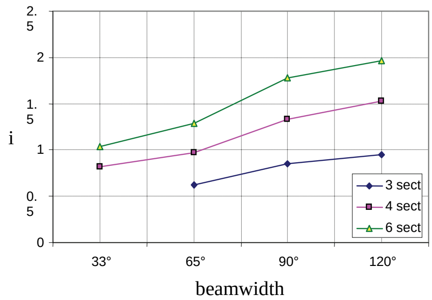

Fig. 9. Impact of the antenna beamwidth on *i* value.

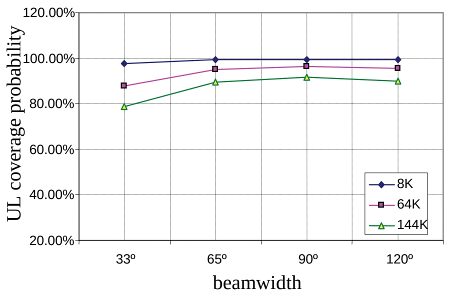

Fig. 10. Impact of the antenna beamwidth on the UL coverage probability, for 4 sectored configurations, all services.

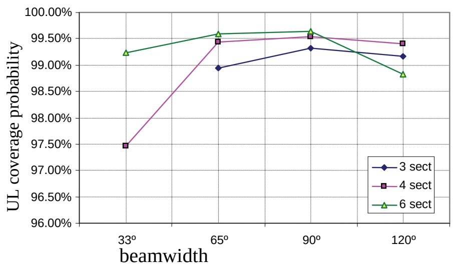

Fig. 12. Impact of the antenna beamwidth on the UL coverage probability, for 8 kbit/s service.

V. Conclusion

Although we can still relay on the fact that data traffic in today mobile networks is in the beginning emerging phase, also it is true that enormous investments are made in order to bring closer those networks to the real multimedia systems. The only mean for turning back the investments includes proper dimensioning of the systems that will handle the data traffic with required QoS, without sacrificing the dominant voice users. All of this combined with the analyzed framework for detailed WCDMA radio network planning and its optimization, leads to conclusion that whenever it will be changed the business strategy of the mobile operator (introduced new services, price policy changes, etc.), it is more than needed support from the planning tool in sense of base station location selection, quality analyses, efficient resource allocation and optimization of the mobile network when with relatively simple means (antenna tilting and correct antenna selection for any scenario) the interference may be controlled and the capacity and coverage may be balanced and improved.

References

[1] Jaana laiho, Achim Wacker, Tomas Novosad (ed.), “Radio Network Planning and Optimization for UMTS”, John Wiley and Sons, LTD 2002.

[2] Leila Zurba Ribeiro, “Traffic Dimensioning for Multimedia Wireless Networks”, Dissertation submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy In Electrical Engineering, April 17, 2003.

[3] Jaana Laiho, “Radio Network Planning and Optimization for WCDMA”, Thesis for the degree of Doctor of Science in Technology, Helsinki University of Technology Radio Laboratory Publications, Espoo, 2002.

[4] Achim Wacker, Jaana Laiho, Kari Sipila, Kari Heiska, Kai Heikkinen, “NPSW Matlab implementation of static radio network planning tool for WCDMA”, Documentation;Version 5.0.0, 2001.

[5] Achim Wacker, Jaana Laiho, Kari Sipila, Kari Heiska, Kai Heikkinen, “NPSW Matlab implementation of static radio network planning tool for WCDMA”, Scenarios; Version 5.0.0, 2001

[6] Achim Wacker, Jaana Laiho, Kari Sipila, Kari Heiska, Kai Heikkinen, “NPSW Matlab implementation of static radio network planning tool for WCDMA”, Code; Version 5.0.0, 2001

[7] Trung Van Nguyen, “Capacity Improvement Using Adaptive Sectorisation in WCDMA Cellular Systems with Non-Uniform and Packet Mode Traffic”, Submitted in fulfillment for the requirements of the degree of Doctor of Philosophy in Victoria University of Technology, March 2005.

[8] Guidelines for evaluation of Radio Transmission Technologies for IMT-2000, Recommendation ITU-R M.1225, 1997.

[9] Jaana Laiho-Steffens, Achim Wacker, Pauli Aikio, “The impact of Radio Network Planning and Site Configuration on the WCDMA Network Capacity and Quality of Service”, Nokia Networks, 2000 IEEE.

[10] Toskala A., Holma H. and Muszynski P., ETSI WCDMA for UTMS, Proc. ISSSTA 1998, South Africa, September 1998.

[11] Jaana Laiho-Steffens, Achim Wacker, “Radio Network Planning Process and Methods for WCDMA”,

[12] Jarno Niemala, “Impact of Base Station Site and Antenna Configuration on Capacity in WCDMA Cellular Networks”, Masters of Science Thesis, Tampere University of Technology, Tampere, August 7th, 2004.