Multimedia Traffic Dimensioning and Advanced Planning of WCDMA by using Static Simulations

Toni Janevski[1], Vladimir Nikolic[2]

Abstract – **In this paper we refer to the very important role of detailed and advanced planning, as well as to the optimization of radio network of the next generation wireless networks that offers multimedia traffic. Next generation mobile operators that are adapting 3G mobile technologies and beyond 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 the radio network infrastructure.**

Keywords – ***Mobile Networks, Optimization, Planning, Performance, WCDMA.***

I. Introduction

The development of radio mobile networks is going towards more efficient usage of Wideband CDMA technology. The 3G denoted introduction of several new services over mobile networks based mainly on IP protocol and some proprietary 3G protocols. Further development is targeted to more bits/s/Hz in the radio interface as the main scarce resource in mobile environments. In that manner, improvements regarding the WCDMA technology where made in the recent years that led to HSPA (High Speed Packet Access). However, to get maximization of the utilization of the available resources in the WCDMA based networks, there is need for precise planning and even more optimization of such radio networks.

In this paper we consider WCDMA radio network planning process as defined by 3GPP [1]. We first developed the 3G simulator in Matlab, by which the number of active users in the system can be determined in any moment of time. Then we have developed the simulator to be able to create a distribution of obtained active users under given network topology for a given time moment, something that we refer to as a snapshot. Then, generated snapshots are used as an input for the static WCDMA simulator, which is targeted to efficient dimensioning of the radio network. Finally, we perform optimization of WCDMA, especially regarding the antenna tilt and beamwidth which is very important indeed, but there is no given adequate attention in the literature.

This paper is organized as follows. In next chapter we refer to multimedia traffic dimensioning. Statistical simulation of the traffic and traffic simulators are covered in Chapter III and IV, respectively. In Chapter V is discussed geographical distribution of the users in the network. Further, Chapter VI describes detailed WCDMA planning with static simulations. Influence of the users' speed on the planning process is evaluated in Chapter VII. Pre-operational WCDMA optimization is a subject in Chapter VIII. Finally, Chapter IX concludes the paper.

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II. Principles of Multimedia Traffic Dimensioning

Fig. 1, shows a 3GPP traffic model [2] that presents the packet traffic mode. According to it, the session layer presents the speed of connection arrivals in connection oriented services or in less formal definition, the amount of "awakeness" of the users that belong to certain profile (user profile stands for given mixture of service class (determining given application, performance requests and traffic characteristics) propagation environment and terminal type [3])

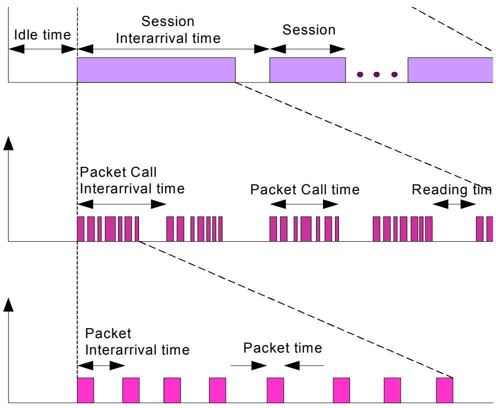

Fig.1. 3GPP traffic model representing www traffic.

The session of the packet service is consisted of one or more packet calls depending from application (e.g. in the www browsing session, packet call is equal to the download of the www document [4]). After the full arrival of the document (a packet call) the user needs certain time (interval-reading time) for studying the info.

There are many studies and specifications, such as [3], and [5], where the bursts are analyzed as packet sequence, small enough so the packet lengths and inter-arrival times within the burst period are treated as constant. Due to that the statistical nature of the received data is considered on the packet call level. Nevertheless, in reality exists non-uniform distribution of inter-arrivals on packet level as well [4], as it is depicted on the bottom of the Fig. 1, that we will consider as our model in this paper.

III. Statistical Simulation of Multimedia Traffic and Snapshot Generation

The 3G and next generation mobile systems are more complex than the 2G systems. This is the reason why we have to choose careful the simulation approach and we must take into account the possibility to find out how the principles of statistical simulations may be applied on the multimedia mobile systems.

Statistical simulation should precisely present the traffic offered to the system in each snapshot, due to the fact that different user profiles shows different traffic behaviors. We have to estimate the number of simultaneously active users in next generation multimedia mobile systems on statistical representative way, so the simulation results reflect the reaction of system on certain traffic forecast or demand. In [3] we present a new approach, where only the active users are used as input for the WCDMA simulation (Fig. 2).

Fig.2. Approach for WCDMA simulations

The main challenge of the simulation approach is the correct presentation of the traffic offered to the system in each snapshot, due to the fact that different user profiles (service classes) show different traffic behavior. The proper reproduction of the traffic load in sense of statistically representative snapshots, needs the following two key factors: appropriate traffic demand characterization that defines how the users of each service are geographically distributed (GIS, census data, business database, road traffic, morphology weighting, market penetration forecast [3]); and appropriate statistical modeling of the distribution of the traffic in order to achieve accurate distribution of simultaneously active users at a given time.

The proposed framework in [3] consists of splitting the procedures of temporal randomness (creation of traffic bursts) and spatial randomness (geographical distribution and movements) for the purpose of system statistical simulation, through performing the "multiplexing simulation" that will provide practical distributions for the number of active users that uses non-real time packet based service classes (that can not be modeled with a Poisson process). The snapshot generation consists of determination of the number of active users for a given user profile, which is done on the basis of the factual user's geographical distribution and the traffic parameters assigned to that profile. The main traffic parameters for the users of certain profile are as follows [4]: Number of packet calls per session, Npc (geometrically distributed random variable with a mean μ_{Npc}); Time between packet calls, Dpc geometrically distributed random variable with a mean μ_{Dpc}; Number of packets within a packet call, Nd (geometrically distributed random variable with a mean μ_{Nd}); Inter arrival time between packets, Dd (geometrically distributed random variable with a mean μ_{Dd}); and Packet size, Sd (Pareto distribution with cut-off). The framework that enables the snapshot generation in general can be divided in two steps [3]. First step covers a design of traffic simulator for determination of the effect of statistical multiplexing of the self-similar multimedia traffic for the given user profile [6], [7]. The result is the distribution of active users for that profile as a function of time. In the second step we generate the snapshots from the obtained multiplexing distributions, which are generated for each profile (the number of active users for certain profile is a random variable that follows its multiplexing distribution). The known active users are randomly distributed on the spatial plane following the geographical user distribution.

IV. 3GPP Multimedia Traffic Simulator

Following the step 1, a 3GPP traffic model simulator was created as time driven program which takes the events into account as simulated time advances. The Internet service simulation is treated together with its typical parameters shown in Table 1. The traffic model is based on the www traffic due to the fact that www is the dominant application in Internet today.

TABLE1
SIMULATION PARAMETERS USED IN THE 3GPP TRAFFIC SIMULATOR

TOTAL NUMBER OF USERS IN THE SYSTEM, N	100
Sessions per user	1
Data Rate, R	64 kbps
Maximal size of packet, m	1000bytes
Minimal size of packet, k	81.5 bytes
Tail parameter, α	1.1
N_{pc} (Geometric mean)	5
D_{pc} (Geometric mean)	10 s
N_d (Geometric mean)	25
D_d (fix value)	0.0625 s
Idle time, D_i (Exp. mean)	30 s
Simulation time step	0.01 sec

The events are recognized as the start and ending of idle times, arrival of sessions, the departure of sessions, arrivals of packet-calls, and packets. In this example each user is generating only one www browsing session with the data rate of 64 kbps which means packet call length is 12 Kbytes [4], [2]. The active state of a user is indicated by the presence of a packet within a packet call. When the system completes serving a user, the number of users remaining in the system is used to determine whether the system will become idle or go on to serve a new user in the queue. An arrival event causes the system status to change from idle to busy or the number of users in the system to increase by 1. The departure event causes the system status to change from busy to idle or the number of users remaining in the system to decrease by 1. The number of users in the system gives a direct estimation of the system capacity. An active user is one that is engaged in the transmission of a packet. The simulation begins with the system in empty state and a user enters the system starting with a given idle time period.

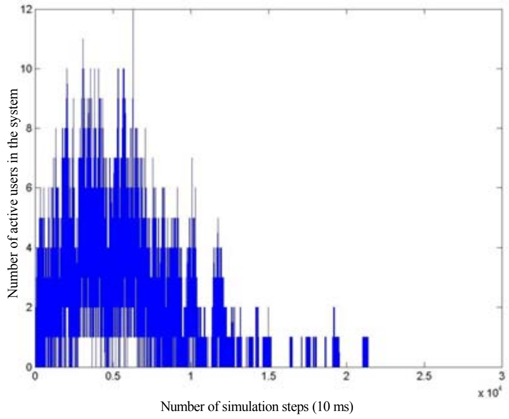

Fig. 3. Number of active users using the www service as function of the number of simulations steps (total number of users is 100)

Using the 3GPP traffic simulator we obtained the graphical result given in Fig. 3, which show how the number of active users in the 3G system and its dynamics. One can notice the bursty nature of the aggregated traffic. The statistically multiplexed burst data flows of each separate user have tendency to produce bursty aggregate traffic, which is based on the input data given in Table 1. Such traffic is self-similar i.e. it has Long Range Dependency (LRD) phenomenon due to self similarity of the www traffic and overall Internet traffic. Self-similarity is the main reason why we need to use simulations to be able to perform dimensioning of the radio mobile network instead of analytical approach characteristic for the circuit-switched PLMN (Public Land Mobile Networks) i.e. 2G mobile networks.

V. Geographical distribution of the snapshots consisting of active users

After obtaining the multiplexing distributions one should generate the snapshots that contain the active users randomly distributed on the spatial plane following the proportions of the geographical user distribution.

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 [3]. Thus, we have created a simulator which on its input uses the number of active MSs in a given moment, as well as the dimensions of the area. The analyses are performed over the 16.9 km² test 3G system area (19 three-sectored BSs), with randomly distributed users. On its output, the code generates x and y coordinates of the active MSs. This way we complete the process for snapshot generation that can serve as input to the NPSW simulator for WCDMA planning [8-10].

In our simulation we have used 3G network consisted of 19 tri-sectored base stations, as shown in Fig.4. According to the scenario given in the Fig. 4, the simulator obtains at any moment the random distribution of the currently active 64 kbps users in the analyzed system (with dimensions ± 6500 meters), that in total serves 100 users. For example, if we consider the time instant when 11 users are active in the given area, then the appropriate snapshot (result of the simulation) will be the one shown in Fig. 4.

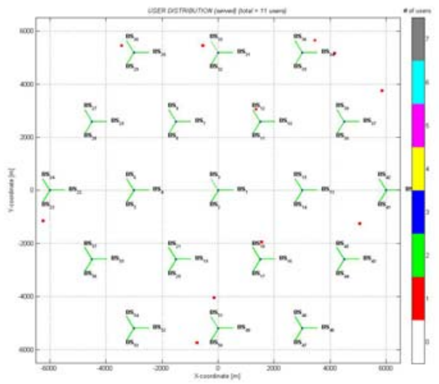

Fig. 4. Distribution of served users.

Simulations had shown that system served all the 11 active users, which was expected. Further, in Fig. 5 is shown graphical simulation result for the distribution of average data rate per cell in the uplink, but now with different geographical distribution of the users.

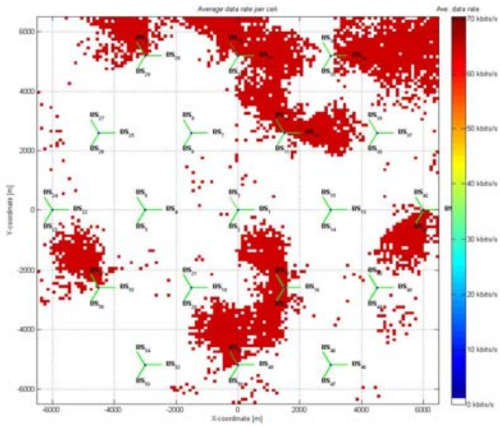

Fig. 5 Average data rate per cell in uplink

So far, we have explained the process for snapshot generation that serves as input to the simulator for WCDMA planning [8-10].

VI. Detailed WCDMA planning with static simulations

In this Section we present pre-operational phase of the WCDMA planning process as described by 3GPP [11], [1]. Initial planning (the system dimensioning) provides the very first estimation of the network size and the capacity of the involved elements (Radio Access Network and Core Network). In the detailed planning phase, dimensioned density of the base stations (and sectors) is transferred on the digital map. The analysis of WCDMA is an iterative process, where the capacity requirements are considered as discrete mobile events in the simulations [12]. In this phase of WCDMA planning one must perform multiple analyses in order to detect when a given set of requirements will be met by the network. Within the planning phase, one may use procedures for interference control, which are targeted to proper site selection, configuration of the sites and antennas, antenna tilting etc.

Here the priority will be kept on showing how can be verified detailed planning aspects of WCDMA with help of static simulations process as described by 3GPP [1], [12].

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 profiles with heterogeneous traffic in the radio network. The main purpose is to identify the main metrics of the system capacity (throughput per sector, transmitting power per sector and uplink load). For the simplification and comparison purposes all analyses are based on one snapshot (obtained using the explained procedure) which refers to a given moment of time with total 1140 active user in the system (in all cells).

The 13.5 km² test radio network consists of 10 base stations with identical configurations [11]. Namely, we have 3-sector 50m cells, with 7 degrees of tilt in all sectors, and azimuths 90, 210 and 330 degrees.

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. All users need in total 9120 kbit/s throughput. Simulations were terminated after 8 iterations and graphical results were saved. Relevant statistics are summarized in Table 2.

C. Comparison with the expected results from the theory

In this Section we compare the results from Scenario A (heterogeneously distributed users) with the results of theoretically ideal scenario where all users are homogenously distributed and belong to single profile (defined by the data rate, Eb/Io requirements, and voice activity factor). In [3] the similar comparison is conducted, but with scenario having homogenously distributed users that belong to same profile. Other, simulation results in [3] shows that results for scenario with homogeneous traffic distribution are only slightly different from those in heterogeneous distribution when users belong to the same profile. From here fully justified we will make comparison with the expected results from the theory and results in Scenario A, with that addition that we will assume 100% voice activity in a new Scenario A(1). This will decrease the number of served users to 1085. As result, the average load factor is increased to 0.46. The uplink load factor can be calculated as follows [1], [12]:

$$\eta_{UL} = (1+i)\frac{N}{1+\dfrac{W}{\rho_k \cdot R_k \cdot \nu}} \qquad (1)$$

where R_k is bit rate (8 Kbit/s), ρ_k is required linear $E_b / N_o = 4.47$, W is bandwidth (3840 KHz), $\nu = 1$ is voice activity factor and N is number of served users by sector. We assume $i = 0.38$ (the other to same-cell interference ratio [11]). Using the simulation results from A(1) we received that i = 0.378. Based on Table II results we found an almost perfect matching between simulated results and theory.

D. 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 (Table 4). Other parameters are the same as in the previous scenario. In Fig. 6 we depict graphical representation of the snapshot for Scenario B as an output result from the simulator. The analysis of the graphical results show that in this case the network served 600 users (for instance, in scenario A number of served users was 1116). In 33% of the cases the additional reasons for refusing were the limitations on the maximal power of the MSs and transmitting power of BSs. The aggregated throughput was 24.78 Mbit/s and it is almost 3 times bigger than the throughput in Scenario A (8.72 Mbit/s). The uplink load factor was 0.63 (In Scenario A the result was 0.42). The transmitted terminal power was 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 happened in 20.2% cases from the total number of served users (121 connections).

VII. MOBILE STATIONS SPEED AS FACTOR IN THE PLANNING PROCESS

In this Section we analyzed the advanced radio network planning considering the impact of the mobile stations speed [12], [13]. Besides Scenario B we introduced two additional scenarios C and D, each consisting different speeds of MSs. For evaluating we consider 6 sectors. Table 5 contains results from the simulator regarding the capacity. The mobile station with smaller speed provides better capacity. Oppositely, for coverage probability as Table 6 shows, higher velocity leads to better coverage probability (increasing of the speed reduces the fast fading margin [12]).

The additional challenge of the coverage analysis is related to finding solution for achieving balance between the uplink and the downlink coverage [12].

We have performed the analyses for the downlink coverage via cumulative distribution function of the required power per link. In Fig. 7 we have shown how one can set the coverage probability in downlink to the same value as coverage probability in uplink [12]. It can be noticed that if we chose exact limitation of the power per link, the coverage probability in downlink can be set on the same value as

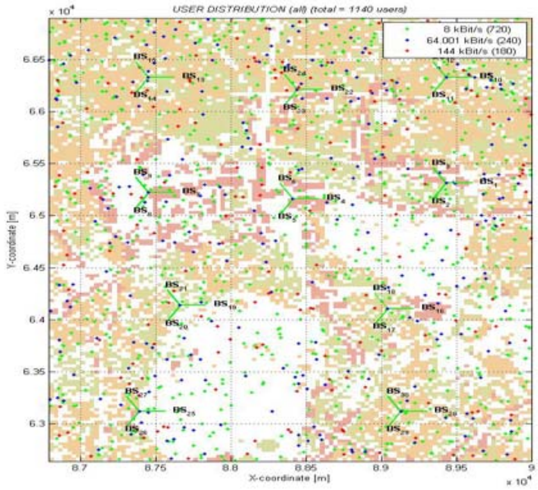

Fig. 6. Graphical representation of Scenario B snapshot

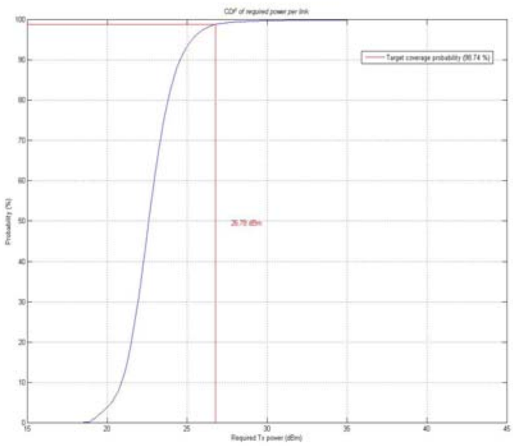

Fig. 7. Example for analyses of downlink coverage

TABLE 2
OVERVIEW OF THE RESULTS OF SCENARIO A

	AVG. SECTOR	SUM
Requested Connections	38	1140
Served Connections	37.2	1116
SHO connections	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 - Power per link limit	0.7	21
Not served – too bed CPICH	0.1	3
Total power of traffic channels (W)	3.4	102
Uplink load factor	0.42	

TABLE 3
RESULTS FOR COMPARISON: THEORY VS. SCENARIO A(1)

	Theory	Scenario A(1)
Served users	1084	1085
Served users per sector, *N*	36.13	36.16
Average load factor per sector	0.461	0.460

TABLE 4
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

TABLE 5
UPLINK AND DOWNLINK THROUGHPUT AND UPLINK LOAD FACTOR.

B: MS SPEED 3 KM/H, SERVED USERS: 600			
Sector	DL thr. kbit/s	UL thr. kbit/s	UL load
5	560	540	0.58
6	540	530	0.52
19	1060	1020	0.68
20	720	710	0.64
21	740	730	0.60
28	1160	1180	0.74
Av. value	796.67	785.00	0.627
C: MS speed 50 km/h, served users: 532			
Sector	DL thr. kbit/s	UL thr. kbit/s	UL load
5	720	700	0.68
6	660	650	0.64
19	980	960	0.72
20	640	700	0.68
21	660	620	0.66
28	1100	1100	0.78
Av. value	793.33	788.33	0.69
D: MS speed 50 km/h and 3 km/h, served users: 556			
Sector	DL thr. kbit/s	UL thr. kbit/s	UL load
5	660	650	0.60
6	840	720	0.76
19	840	880	0.62
20	460	480	0.66
21	680	680	0.66
28	1140	1160	0.76
Av. value	770.00	761.67	0.677

coverage probability in uplink (98.74% for the MS using voice service and moving with velocity 50 km/h, i.e. Scenario B). This way, we can balance very accurately the service area in downlink and uplink, if the limitation of the downlink power per link is set to 26.78 dBm.

TABLE 6
RESULTS FOR THE COVERAGE PROBABILITY

B – MS: 3 KM/H	TEST MS: 3 KM/H	TEST MS: 50 KM/H
8 kbit/s	98.88%	99.06%
64 kbit/s	94.57%	95.37%
144 kbit/s	89.56%	91.31%
C – MS: 50 km/h	Test MS: 3 km/h	Test MS: 50 km/h
8 kbit/s	98.48%	98.74%
64 kbit/s	92.53%	93.73%
144 kbit/s	85.92%	88.10%
D – MS: 3 and 50 km/h	Test MS: 3 km/h	Test MS: 50 km/h
8 kbit/s	98.83%	99.04%
64 kbit/s	64.26%	95.05%
144 kbit/s	88.92%	90.69%

VIII. 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 (interference control) in the RNP phase [3] is through setting the site locations and configurations (sectorization), and setting the beamwidth and tilt of antennas.

For this part of the design process we use the network topology and snapshot used in the scenario B. Multi path "ITU vehicular A" channel profile is assumed [9], propagation looses are calculated with the Okumura-Hata model with average correction factor of the area – 4.1 dB. Also, with NPSW simulator we activate 4-sector and 6-sector configurations. Besides already used antenna with 65° beamwidth (Scenarios A, B) with 3 dB and tilt 7°, we used here four additional and different 3 dB antenna types at 120°, 90° and 33°, and also additional tilts from 0°, 4° 10° and 14°. Antenna gains are set at 15 dBi, and for SHO window we use value – 4 dB, e.g. all P-CPICH channels are included in the active set [1]. The two cases are separately simulated. In the first case the interest is to estimate the impact from tilting the antennas. Different antenna tilts are simulated in case of different sectorization, for determining the optimal tilt. In the second part we illustrate an environment for determining the capacity as a function of sectorization and antenna selection.

A. Optimization of Radio Network by changing the down tilt

Graphical results are obtained with the NPSW simulator. Simulations show that optimal tilt angle is between 7° and 10°. 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.

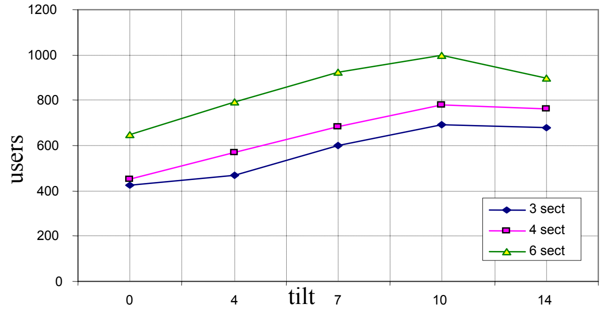

Fig. 8. Impact of the antenna tilt on the capacity.

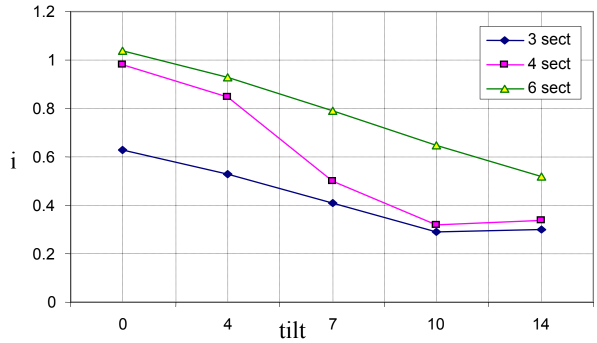

Fig. 9. Impact of the antenna tilt on *i* value.

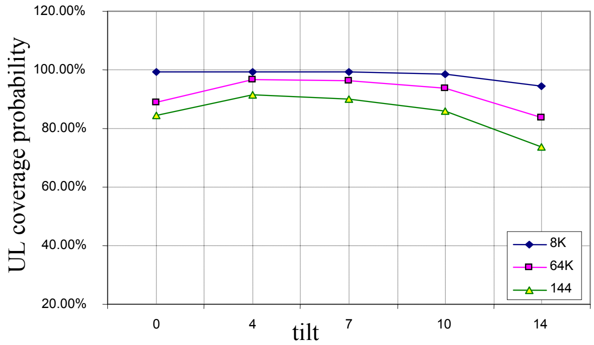

Fig. 10. Impact of the antenna tilt on the UL coverage probability, for 6 sectored configurations and for all services.

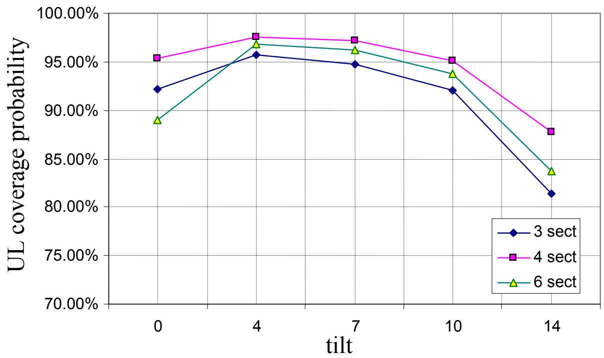

Fig. 11. Impact of the antenna tilt on the UL coverage probability, for 64 kbit/s service.

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 of the targeted base station (i.e. the analyzed base station). On 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 the environment; base stations sites etc. [14], [11], [15]. If the angle is too high, the service will decrease and the base station will not be in position to serve a large area as in the case with sufficient tilt. Due to the existence of lobs and wings at the sides of the antenna radiation pattern [16] results show that coverage probability (as a function of tilt angle) may have certain influence on the *i* value.

The results from simulations are given in Figs. 8 - 11. For instance, Fig. 8 shows the impact of the antenna tilt on the capacity (i.e. number of served users). Fig. 9 describes the influence of the tilting effect on the value *i*. On the Fig. 10 the coverage probability for each service is depicted, but only for the 6-sector case. Fig. 11 shows the impact of the tilting on the coverage probability for the 64 kbit/s service.

B. Optimization of Radio Network by changing the antenna beamwidth

In the second case we illustrate the capacity improvement as a function of sectorization when each BS is considered as site with 3, 4 or 6 sectors by simulating different antennas beamwidth. By using different examples we emphasized the validity of the correct antenna selection for the sectorized configuration. In this case the maximal transmitting power of mobile stations is 24 dBm and antennas are without tilt. The graphical results from these analyses are shown in Figs.12-14.

In all three sectorization 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. Hence, using higher sectorization we may serve more users (higher capacity) as shown in Fig.12.

Other observation shows that for each sectorization case the antenna beamwidth selection plays an important role. The results show that antennas with smaller beamwidths are better choice, 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 Fig. 13, the effect of the beamwidth on the value *i* is described, i.e. the *i* value increases with increment in antenna's beamwidths. Also, *i* increases with the number of sectors, which one can expect due to higher interference from neighboring cells when base station has more sectors.

Fig. 14 shows the uplink coverage probability versus beamwidth for each service separately. One may conclude that higher data rates lead to lower coverage probability (uplink is considered in this case) and vice versa. Also, Fig.12 and Fig.14 show the tradeoff between the capacity and coverage regarding the antenna beamwidth (in other words number of sectors per site). More sectors per site (i.e. smaller beamwidths) give higher capacity and lower coverage probability, and vice versa. The optimal solution is in between.

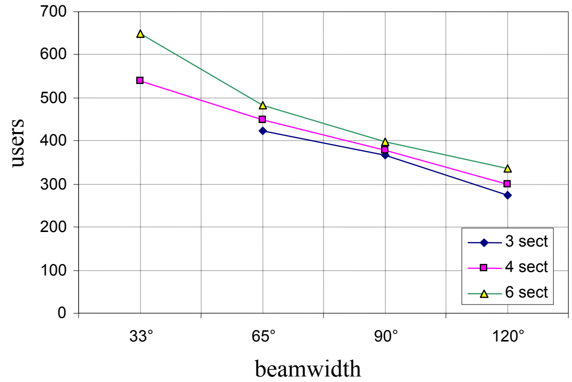

Fig. 12. Impact of the antenna beamwidth on the capacity.

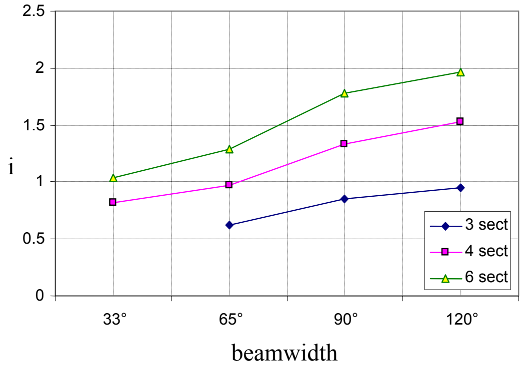

Fig. 13. Impact of the antenna beamwidth on *i* value.

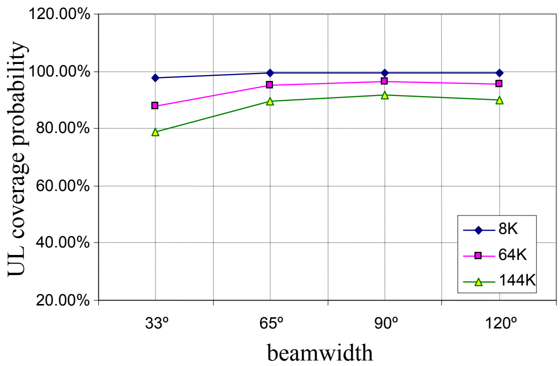

Fig. 14. Impact of the antenna beamwidth on the UL coverage probability, for 4 sectored configurations and for all services.

Hence, it may be concluded that by using relatively simple cases for optimization of the radio mobile network plan, we may control the interference as the most important capacity parameter in WCDMA, and, the capacity and coverage may be balanced and optimized.

IX. CONCLUSION

This paper investigates the principles of detailed WCDMA mobile network planning by using static simulations. Through number of simulation scenarios with different user profiles, distributions and velocities, we have researched, analyzed and improved the UMTS planning methodology and its sensitivity to certain demands. We show the perfect mach of the simulation results with the theory. It is clear that the speed of the mobile station as one attribute of the planning process has impact on the throughput results. I was shown that one can accurately balance the service area in downlink and uplink in WCDMA networks. Thus, the mobile stations with smaller velocities provide better capacity, while higher mobile velocities lead to better coverage probability.

Simulation results for pre-operational performance optimization of WCDMA showed that there is always an optimal tilt angle in a certain network layout and environment. The network may serve more users in cases with lower angles of the antenna tilts. On other side, better choice is antenna with the beamwidth that is as smaller as possible. With higher sectorization, capacity is improving, but at the same time interference is increasing and thus affecting the services which require higher bit-rates.

All of these combined leads to conclusion that whenever it will be changed the business strategy of the mobile operator (new services introduced), 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 with relatively simple means (antenna tilting and correct antenna selection). Thus, the interference may be controlled and the capacity and coverage may be balanced and improved.

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