Radio Network Simulator "Netsim"

"Netsim" was developed to study Cellular Radio Network Control Algorithms and Planning methods. It is able to provide detail information about system capacity, coverage and network control algorithms performances. NetSim output files consist of information about call dropping, blocking and time and spatial references for these events, statistics can be easily collected and translated into visual form with help of MATLAB or other tools. NetSim is written on C language and can be updated for different radio interfaces (GSM, WCDMA), various statistical and deterministic channel models and different types of Radio Network Control Algorithms (handover, power control, admission control).

NetSim is a time driven simulator, which purpose is to fill the gap between simulators developed for study link level signal processing algorithms like COSSAP and higher level network simulators like OPNET and BONES. Based on C language, NetSim can be easily extended to include link level simulation or fixed network simulation and can be combined with COSSAP or OPNET tools. NetSim can simulate: users behavior, various types of teletraffic, interference, power and admission control algorithms, adaptive antennas beamforming, soft and hard handover. Current version uses a deterministic propagation model for microcellular urban environment based on well known ray tracing methods. Deterministic models gives opportunity to study different radio network planning methodologies. Existing propagation model also provides information about spatial properties of radio channel for simulations radio networks with adaptive antennas at BS.

The main blocks of the NetSim shown on the Figure 1. NetSim blocks can be logically divided in to four main models related to the : reference scenarios, radio propagation, signal processing algorithms and radio network control issues.

Reference scenario module

The output data of the reference scenario module are MS location , velocity and activated service type data. It consist of users and teletraffic models.

Users model generate information about users location and velocities. Users in the current version are assumed to be pedestrians randomly distributed along predefined path. Current version can also model spatially non-uniform users distribution. Model for domestic users and car passengers using mobile phones is under development.

Teletraffic model for voice service simulate control and traffic channels behavior taking in to account voice activity detection. Netsim has also model of data transmission relates to Internet services [4]. Models for multirate data services are included in the current plans. Additionally, model of different switching technologies (packet/circuit switched) will be included in the NetSim.

Propagation module

The propagation module calculates received signal power for each MS locations. It uses propagation data of the raytracing program [1]. Because the distance between two calculated impulse responses is a quarter of wavelength , the cubic convolution interpolation method is used to predict the received signal strength. It is planned in future to use real time impulse response calculations that avoid need of interpolation procedure. Also parallel impulse responses processing for each BS will considerably save program execution time.

Signal Processing Module

Signal processing module simulates antenna and receiver algorithms. The output information of this module is post -processing signal to interference ratio for the each link.

Antenna model can simulate different types of antennas at BS :

- single omnidirectional and directional antenna
- distributed antennas
- switched beam system
- adaptive antennas beamforming based on maximum received signal power or CIR

In the current NetSim version antenna array is modeled as a single element antenna with reconfigurable antenna diagram. Antenna can change its pattern during call initialization. (for example: omnidirectional diagram → directional beams) Further steps will include more detailed adaptive antennas models with separate impulse responses calculations for each antenna element. It will make possible to study network performance with antenna algorithms based on optimum combining and to simulate dynamic behavior of tracking algorithms.

The *RAKE receiver and interference model* calculates the signal-to-interference ratio after despreading and combining in all radio links. The total signal-to-interference ratio is obtained by summing the signal-to-interference ratios of different paths corresponding to maximal ratio combining. Another technique that can also be used is the selection combining. In this technique the receiver selects the path with the best signal-to-interference ratio. The interference consists of the thermal noise of the receiver, self-interference, and interference from the users in the same radio channel. Self-interference means here interference that is caused by the multipath propagation. All interference is modeled as additive Gaussian white noise. Combination of Adaptive Antennas technology with RAKE receiver - so called 2D-RAKE receiver can be interesting extension of this model.

Radio Network Control Module

Radio Network Control Module simulates power control, admission and handover control algorithms. One of the most important function of radio network control algorithms is radio resource management. Transmitted power is the only resource of proposed single carrier DS-CDMA systems. It can be controlled at different systems levels and also jointly in combination with other network control methods like BS assignment and beamforming.

Network Control model is also responsible for constant monitoring SIR of all active radio links .

The output data of Network Control Module are amount of call dropping and blocking events and other system control failures with correspondent spatial and temporal references .

Admission Control Model in the current NetSim version uses information about BS total received power, signal quality measurements and its variation in time for making decision about admission. More complex admission control algorithms can be further studied.

Power Control Model for up-link and down-link use SIR based distributed power control algorithm. Program includes return channel error and loop delay models. Open loop power control is used during call initialization period. Multiservice version of NetSim will includes SIR_{target}-> service adjustment and adaptively adjusted power control step size. With this model different types of power control algorithms during soft handover can be studied.

Handover Model includes soft and hard handover algorithms. Optimum combining in the up-link during mobile assisted (MAHO) soft handover used in the current version of NetSim. Next version of NetSim will have possibility to choose optimum combining or switched diversity techniques in simulation setup as well as type of handover control (network, mobile, MAHO) .

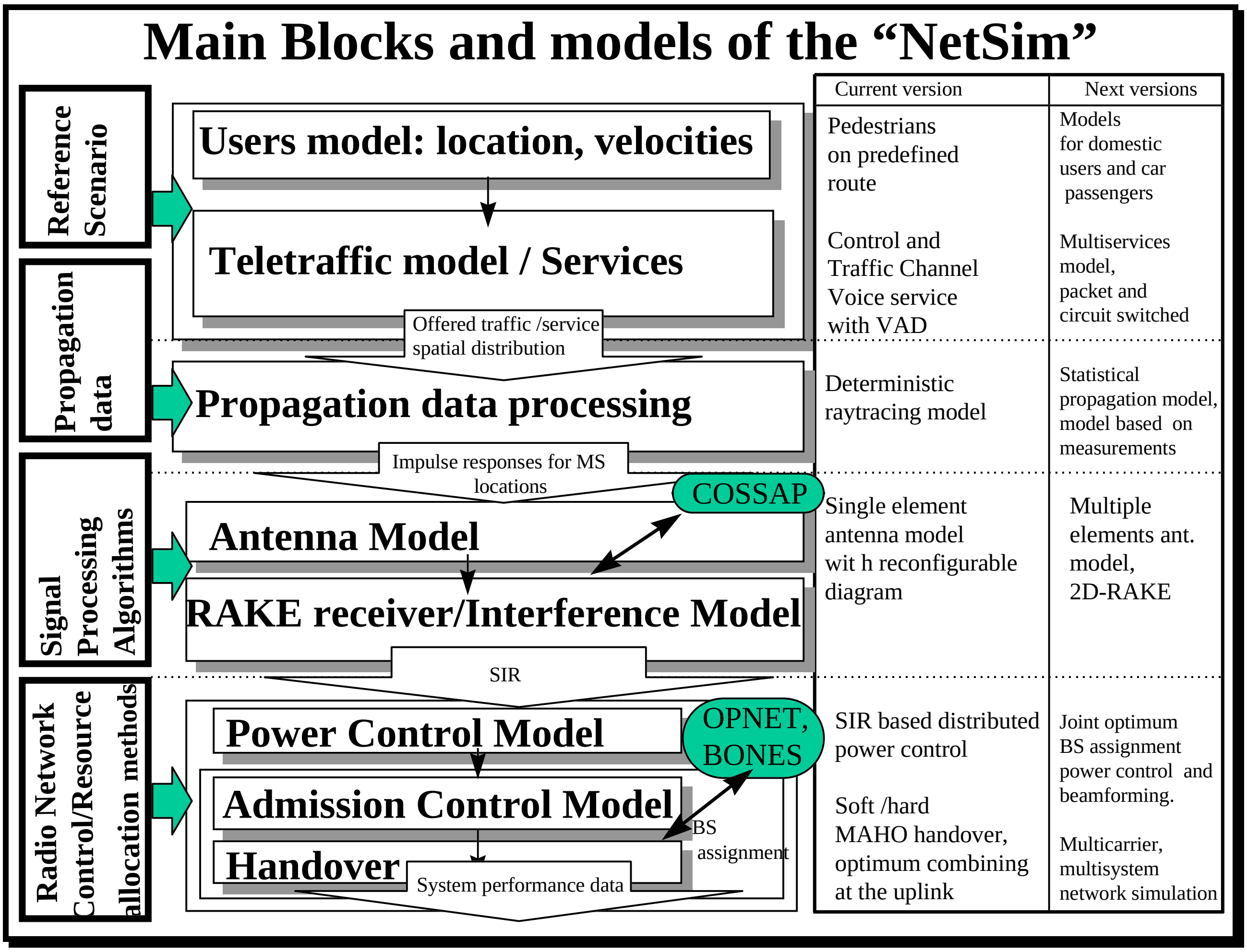

Figure 1. Main blocks and models of the NetSim and directions of further developments.

Simulation results

Results of some simulation studies based on parameters defined by CODIT (EU/RACE) project were obtained with help of the NetSim .

System performance study for traffic model with voce activity detection. Power control algorithm study.

System performance of CDMA system was studied with the Netsim [2,3] based on CODIT project parameters. On the Figure 2. can be found distribution of call dropping probability of single cell DS-CDMA network with voice activity detection. The probability density function of the transmitter power shown on the Figure 3. and the cumulative distribution function per-fame signal to interference ratio on the Figure 4. In the case without voice activity detection. Figure 5. shows call loss probability as a function of the call birth rate for different power control step sizes.

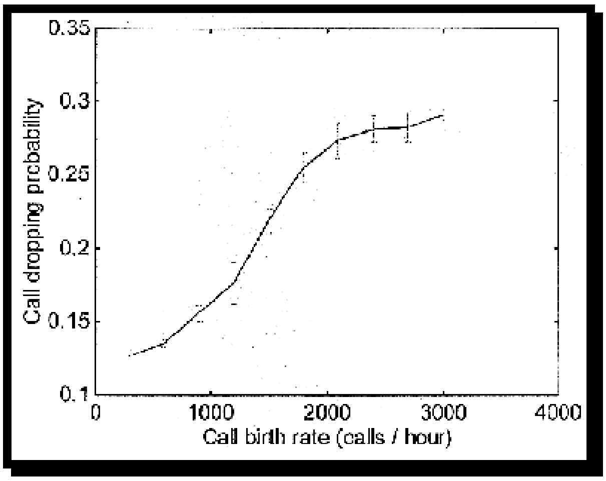

Fig. 2. Distribution of call dropping probability of single cell DS-CDMA network with voice activity detection

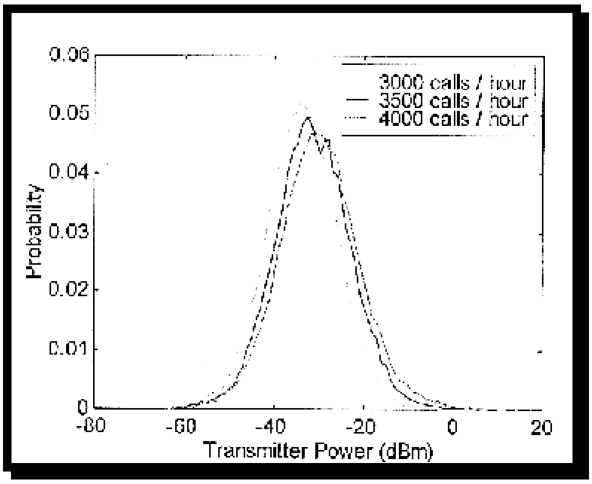

Fig. 3. Probability density function of the transmitter power

Handover algorithms study

In [ ] is studied network performance with different handover algorithms. Simulation results shows that three BS network can support between 60 and 90 simultaneous users in hard handover case and between 120 and 150 users in soft handover case.

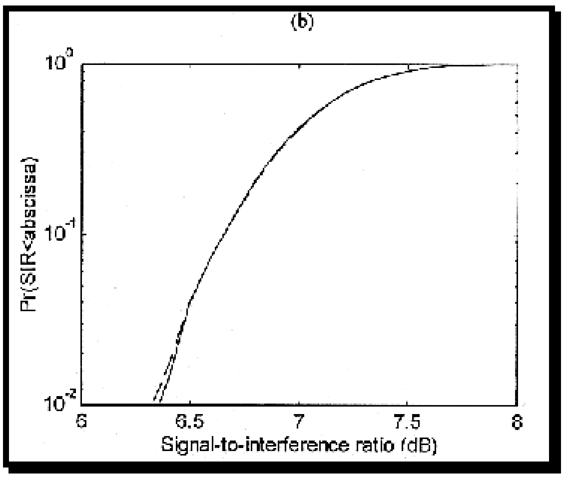

Fig. 4. Cumulative distribution function per-fame signal to interference ratio

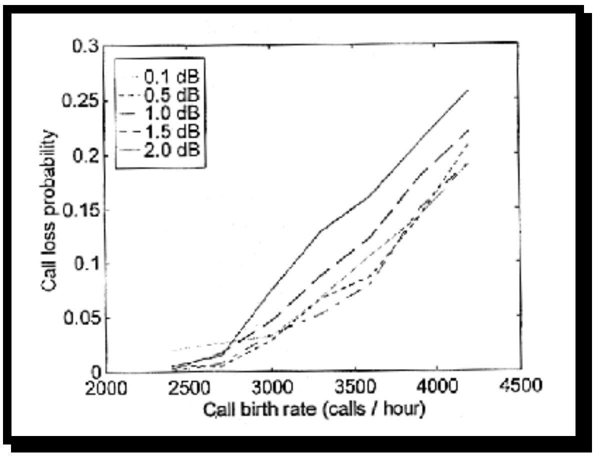

Fig.5. Call loss probability as a function of call birth rate for different power control step sizes.

Study DS-CDMA system performance with different types of Adaptive Antennas.

Series of simulation was done with newly developed antenna module. It is possible to simulate with help of the Netsim different types of adaptive antennas and antenna algorithms. On the Figure 6. shown Helsinki downtown area with two MS and one BS. Angle of arrival and amplitudes of incoming signals from each MS can be seen on the same picture. Antenna program use information about amplitudes and angles of arrival for desired and interfering signals and dynamically adjusts pattern based on CIR or maximum received power criteria. Switched beam antenna system was also simulated with this model. Figure 7 shows capacity improvement with different types of adaptive antennas. Simulation results shows capacity improvement in order of 3 for 6 sectors switched beam antenna at up-link and in order of 4 for adaptive antenna with CIR measurements based algorithm.   Further capacity improvement for angle of arrival based algorithms can be potentially achieved with more complicated signal processing algorithms or (and) in propagation environment with less multipaths.

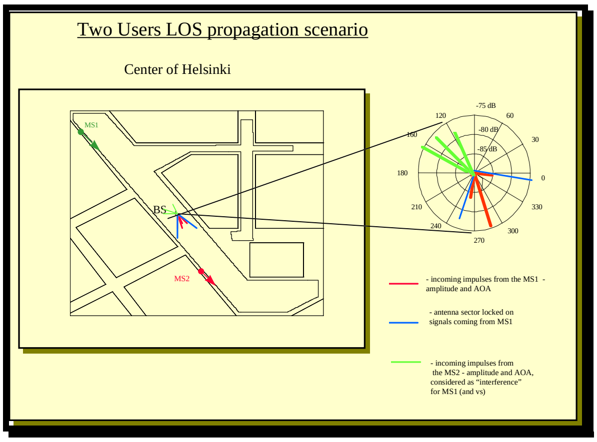

Fig.6. Helsinki downtown area with two MS and one BS with Adaptive Antennas.

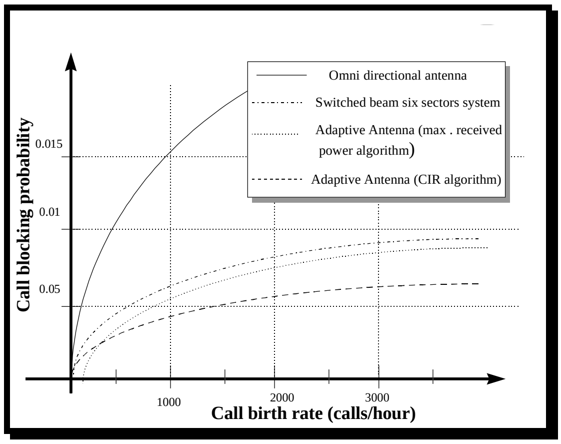

Fig. 7 Capacity with the Different types of Adaptive Antennas algorithms

Fragment of Radio Network Planning procedure.

In figures 7 and 8 are examples of Netsim simulation results with larger amount of BS . In the figures are marked positions of the seven base stations and positions where either the uplink or downlink quality failures have occurred. Criteria for the quality failures has been the Signal to Interference Ratio of each user, if SIR has been below certain limit (here: 6 dB) for a certain time (here: 200 ms), the call has been dropped. SIR is calculated separately for both up- and downlinks. In the network there has been simultaniously 160-200 mobile users, users have been randomly generated over the pre-defined route. They have been given also randomly generated speed, walking direction and call length. These simulations would indicate that the weakest network quality in uplink is where the field strengths are the weakest, that is the street which has at least two street corners to the closest base station. In the downlink direction most of the quality failures occurs in places where the downlink interference is the strongest, like in places which have the line of sight connection to two base stations. Based on this information it is possible to find by iterations optimum BS positions.

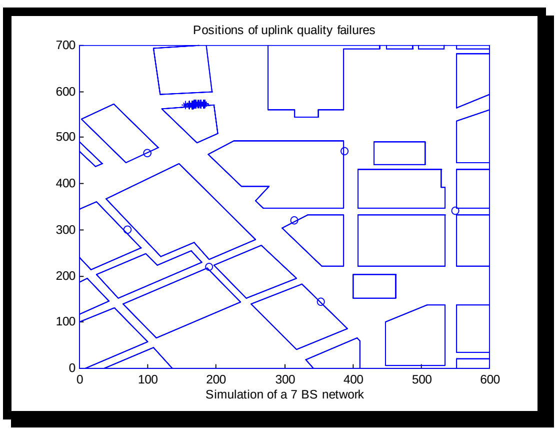

Fig. 7. Map with locations with up-link quality failures .

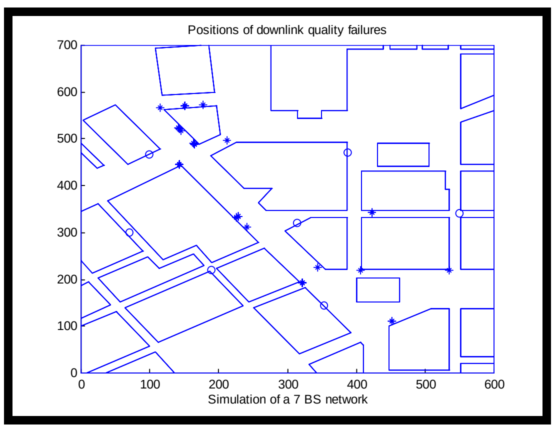

Fig.8. Map with locations with down-link quality failures

Handover algorithms study .

On the figure 9 are shown simulation results of effect of different handover mechanisms for the call dropping probabilities. Three different combinations of soft and hard handover in up/downlink have been used.

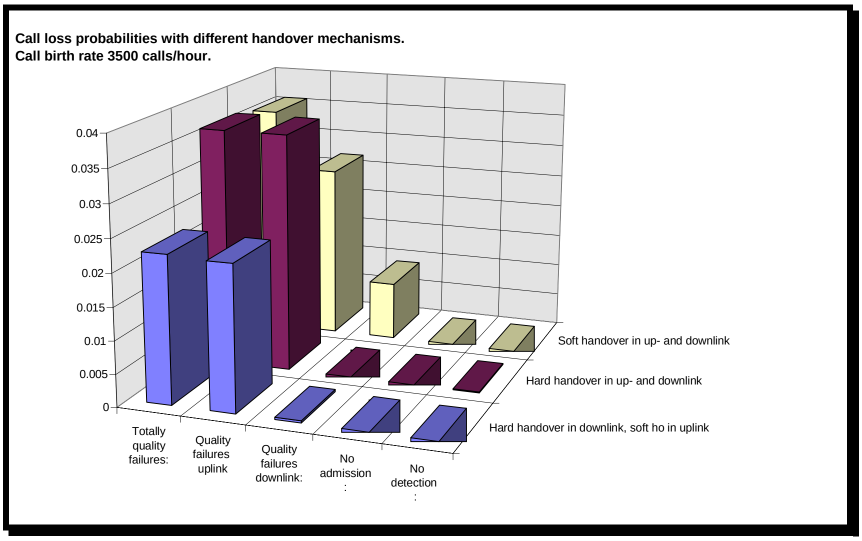

Fig. 9. Results of the different handover algorithms study.

System requirements

Operation system: UNIX (Windows is under development)

Memory Requirements : there are no special memory requirements for running Netsim program, practically requirements for memory only defined by size of files contains propagation data

Platform: Unix workstation (Pentium PC for Windows)

References:

1. Mauri Honkanen , Techical Report 31.12.1995. TEKES - Project ,"Simulation and Signal Processing in radio Systms", Sbproject 2.3. "Development of a DS-CDMA Radio Network Simulator." The Ray Tracing Program.

2. Petri Bergholm, Mauri Honkanen, Sven-Gustav Häggman , "Simulation of a Microcellular DS-CDMA Radio Network", IEEE VTC (?)1995, pp. 838 -842

3. Petri Bergholm, Techical Report 31.12.1995. TEKES - Project ,"Simulation and Signal Processing in radio Systms", Sbproject 2.3. "Development of a DS-CDMA Radio Network Simulator.

4. Antti Pietila , "Develompent of the Netsim program", Proceeding of the IRC Workshop'97, pp. 90 -91.