A DYNAMIC SYSTEM-LEVEL SIMULATION TOOL FOR UMTS FDD

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Keywords: Simulation, Modelling, UMTS, WCDMA

Abstract: This paper presents a tool for dynamic simulation of radio resources in UMTS FDD. The developed tool provides an integrated environment for users scenario definition, environment edition, base stations planning, simulation and analysis. This tool can also be used to evaluate the impact of new services, different system settings or new subscriber profiles, in the system's global performance. For implementing the different mechanisms of WCDMA radio technology, the simulation tool kernel was supported by a system-level, dynamic, stochastic and event driven simulation model. Both uplink and downlink directions are considered, including soft handover connections. The final results confirm the developed tool validity and its good functionality in relation to simulation scenario definition, simulation and analysis phases.

1 INTRODUCTION

The new third generation (3G) services and user profiles, as well the radio access technology itself puts important challenges when planning and design a wideband code division multiple access (WCDMA) based network. The multi-service characteristic of these networks lead to different bit rates in combination with different profile mobility settings, different link level gains, margins and E_b/N_0 requirements. Furthermore, WCDMA radio resources management mechanisms like transmit power control, admission control, load control or soft-handover, associated with the characteristic of implicit interference limited capacity in WCDMA, imply simulation tools usage in the planning process.

Static simulation has been extensively used on second generation (2G) networks planning. However, the use of this type of simulators carries some limitations for 3G network performance analysis. The multi-service aspect, combined with the radio resource mechanisms, constitutes the main limitation of static simulation. Another aspect that will not be able to be included in a static simulation is the subscriber mobility. This aspect has a significant impact in the system performance, mainly in WCDMA where, due to the systems characteristics, handover has a considerable influence in the cell resources usage. Therefore, the use of dynamic simulation tools has a crucial importance in the radio resources performance evaluation on WCDMA networks. The main purpose of this paper is to present a tool for system level and dynamic simulation of radio resources in UMTS FDD. This tool considers the main aspects of 3G network usage, like multi-service, multi-profile and non uniform traffic distribution. Moreover the mobility characterization of user's profiles is considered, which gives a more realistic approach.

2 SIMULATOR CHARACTERIZATION

The developed software application provides an integrated environment for simulation, where a single application can be used in the different phases of the simulation process, including the scenario definition, environment morphology edition, system simulation and system performance analysis. The

Cota N. and Rodrigues A. (2004).
A DYNAMIC SYSTEM-LEVEL SIMULATION TOOL FOR UMTS FDD.
In *Proceedings of the First International Conference on E-Business and Telecommunication Networks*, pages 17-23
DOI: 10.5220/0001389700170023

application runs in Windows™ operating system, providing a user friendly interface for parameters input, simulation and results analysis. In this section, the main characteristics of the simulator tool will be explained.

2.1 Application Structure

The simulation tool usage can be structured on three consecutive phases, as is presented in Figure 1. One of the main aspects considered on the developed tool is its flexibility. To obtain this, we use a flexible simulation scenario, allowing new scenarios creation for a system planning or system behaviour study purposes. Thus, the application provides three types of windows based interfaces to allow simulation scenario edition. First, a scenario layout is displayed, in which environment and base stations settings are presented that can be edited. On the second window interface, all morphologic information from simulated environment, including roads and buildings data, can be edited. The third configuration interface provides a visual tool for subscriber's density areas creation and edition. Beyond these three main types of interfaces, a collection of general parameters, which configures several aspects of the simulation scenario and tool, can be set by several dialog boxes.

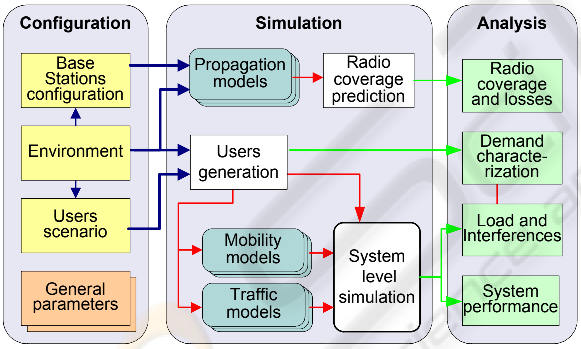

Figure 1: Application structure.

In the simulation phase several modules are considered including the traffic, mobility and propagation models. Furthermore, three simulation modules are implemented, of which the most important is the system level simulation. This module uses the mobility and traffic models with the users generation module output to simulate system subscriber's behaviour, and conjugates it with the output of radio coverage prediction module.

The purpose of the users generation module is to populate the system by setting the initial location, services and profiles from all system subscribers. In the radio coverage prediction module all static radio link calculations will be made, based on propagation models, which in turn depends on base stations configuration and environment settings. All outputs from simulation modules can be analyzed separately or can be saved on a file for later analysis.

Finally, based on the results taken from simulation, the software user is able to continue the analysis phase. Different kinds of formats can be used to display all outputs taken from simulation modules.

2.2 Simulation Scenario

The structure adopted to store all simulation related data was designed to give a great flexibility on new scenarios definition and on independency preservation between scenario components.

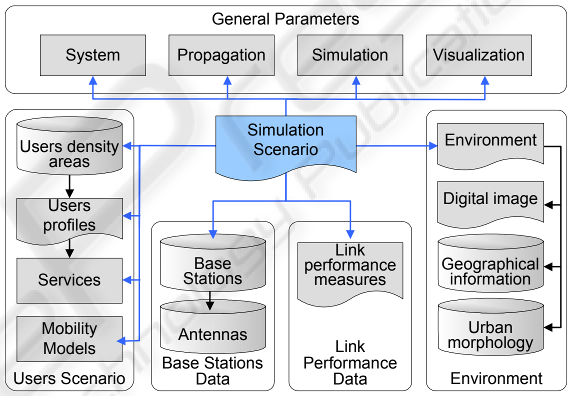

Figure 2: Simulation scenario components.

On Figure 2 we depict the information set that, defines the simulation scenario, which is structured and collected on five different groups:

- General parameters – auxiliary information set to several purposes that allow the definition of the working conditions of simulation model and application;
- Environment – this information group defines the geographic context where the system is installed, and contains geographic and morphologic information;
- Base stations data – this information set defines all system radio equipment. The site location, radio and system operating parameters and antennas types and placement information constitute this database. To define the antennas physical parameters we use an equipment database, which includes the horizontal and vertical radiation pattern information and gains;
- Users scenario – contains all subscriber's behaviour, services and profiles information that ensures the characterization of simulation scenario. All this information will be described on Section 3;

- Link performance data – information obtained from link level simulations, allowing the radio link modelling at the system level simulation model.

2.3 Environment Data

The geographical information consists on a raster database, where each entry has the ground height and needed classification information to predict the link path losses. Besides the geographical information, a vector database is essential to know the building limits and roads definition. This information is compiled in a database denominated by urban morphology. Buildings are represented by two dimensional polygons which describes the boundary of the area containing the building. Roads are described by lines, which represent a subscriber trajectory. The positions resulting from lines overlapping constitutes possible crossroads. Each road structure also includes information about allowed speed.

The developed tool has the particularity to include a visual edition environment to make it possible to create and change buildings and roads on the studied environment.

2.4 Radio Link Modelling

On the system-level simulation model that constitutes the tool kernel, the modelling of all aspects, concerning radio link, has a crucial importance. This modelling gives us an abstraction level relatively to the link physical layer. Thus, several tables could be imported from link-level simulators or radio-link measures, changed and used on simulation model. These tables contain:

- Uplink (UL) and downlink (DL) E_b/N_0 requirements, for different channel rates and speeds;
- Downlink orthogonality factor;
- Link gains due the soft handover;
- Fast fading margins.

The link path loss is predicted by a propagation model, which is chosen according to the environment type. In large macro-cellular areas the COST 231 Hata model (Damoso, 1999) is used. For a micro-cellular urban environments the tool considers the model COST 231 Walfish Ikegami. Finally, for the particular case where the environment is a Manhattan model like, a specific model is used.

Regarding to slow fading, a method defined in (Viterbi, 1995) was used. On this method, it is considered that the link resulting slow fading is modelled by a Gaussian random variable, and its value depends on the sector and site location, and the subscriber location. Fast fading effects are considered by a link margin (Cota, 2004).

3 DEMAND CHARACTERIZATION

In 3G wireless multimedia systems, each subscriber can use one or more simultaneous services. Besides, performance requirements within a service may differ depending on the user's mobility and propagation environment. On the other hand, subscriber's location may not be uniform, which means that several density areas and hotspots existence has to be considered.

Thus, for an accurate demand characterization, a flexible and scalable demand modelling must be included in the tool, making a new demand scenarios possible and a system resources utilization growth. In this section we propose a flexible and modular user scenario for a complete demand characterization. Figure 3 presents the user scenario structure.

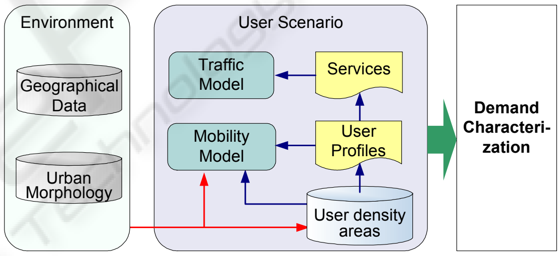

Figure 3: User scenario structure.

The main components of user scenario are the services and user profiles. They summarize the main system resources demand aspects. The traffic models will be responsible for the event generation that will characterize the traffic and resources usage. Several models had been considered according to service type. Another aspect that needs to be included on user scenario is the subscriber mobility, since it will go to influence all system performance. Each subscriber mobility is described by the mobility model, which in turn is defined on their own profile. Besides profile settings, mobility models also need information about urban morphology to characterize the subscriber mobility behaviour. The user density areas database defines the subscriber initial placement and movement limits.

3.1 Services

The information set that constitutes a service will define the network resources usage context by subscribers. Service structure contains information about traffic behaviour, resources usage relative information and the maximum values of supported packet delay. All service parameters defined will ensure the tool versatility to create new services and to change the existing services parameters. These parameters are:

- Source bit rate – average UL and DL source bit rate;
- Channel bit rate – average UL and DL physical source rate. For this value estimation the signalling channel has been taken into account, as well as CRC and tail bits attachment, coding and final rate matching into UMTS standard channel bit rates;
- Switching mode – packet or circuit switched mode;
- Maximum transfer delay – a quality of service parameter. If the delay experimented by a packet exceed this value, the session will be dropped.
- Source traffic model – one of three available models. Choice depends on switching mode and service characteristics;
- Source traffic model parameters – values that define traffic behaviour.

3.2 Traffic Models

In order to generate the UMTS multi-service traffic, three source models had been implemented. Traffic models choice not only considers resources usage behaviour, but also the flexibility to create new services and implementation viability on a reasonable computational platform. On this basis, the models that had been implemented are:

- *Poisson* – model indicated to circuit switched services. In this model calls are generated according to a Poisson process and call duration may be described by several probability distributions, which depends on service applications type.
- *ON-OFF* – a simple packet services model, that includes inactivity periods and activity periods into a packet session. For both UL and DL direction packets generation configuration, several parameters are provided. A complete model description can be found in (Cota, 2004).
- *ETSI* – the implementation of ETSI TR 101-112 (UMTS, 1998) model for packet-switched traffic. In this model it is considered that a session consists of a sequence of packet calls. During a packet call, several packets may be generated with different sizes. This model considers only traffic in DL direction.

3.3 Mobility

In mobile systems, the terminal mobility has an important influence on service performance. Due to the UMTS characteristics, this influence must be considered and quantified on simulation tools, in order to achieve an accurate performance evaluation. On the other hand, mobility inclusion brings an increased complexity of simulation model. Based on these facts, a simple but flexible mobility model was included.

The simulation tool considers five classes that describe the existing mobility types in an urban scenario:

- Static;
- Pedestrian;
- Low speed vehicular;
- Medium speed vehicular;
- High speed vehicular.

The model adopted to describe subscriber's motion direction and speed was the Gauss-Markov Mobility Model (Liang, 1999) that was designed to adapt to different levels of randomness via two tuning parameters. At fixed intervals of time, movement occurs by updating the speed and direction of each terminal. Specifically, the value of speed and direction at one instance is calculated based upon the value of speed and direction at the previous instance and a random variable using equations (Cota, 2004).

However, this mobility model has a limitation due the fact that he does not consider the urban morphology. In order to become a more realistic model, an improvement was made, considering the vector data of streets and crossroads. Thus, it is considered that vehicles moves along streets and may turn at cross streets with a given probability. However, streets change only occurs if new street support terminal speed. Speed limitation can be configured to each road of the database.

3.4 User Profiles

To evaluate the demand of WCDMA resources, it is necessary to identify different types of customers, since their calling patterns, usage and mobility behaviour may differ. Thus, system subscribers population would be classified according to their user profiles, which includes information about service usage, mobility and placement.

User profile contains a service list with the busy hour call attempts (BHCA) respected values. Placement information refers to location limits during simulation, e.g., a high-speed vehicular subscriber cannot transit to an indoor environment.

Finally, mobility information classifies user profiles concerning their mobility class.

3.5 User Density Areas

Due to the fact that real spatial distribution of subscribers is not uniform, the determination of initial position and mobility boundaries of all users is an important task of demand characterization. This information is determined based on user density areas database contained on user scenario.

Each user density area includes a user profiles list where each entry has a profile and its probability. This probability refers to percentage from the total users contained on area. Each area boundary is defined by a polygon that can be defined or edited on the tool. In this way any spatial distribution of users may be defined according to real distributions. Users are uniformly distributed inside each area. This distribution also respects the profile settings concerning mobility limits. An example showing several user density areas in Lisbon urban area is depicted in Figure 4.

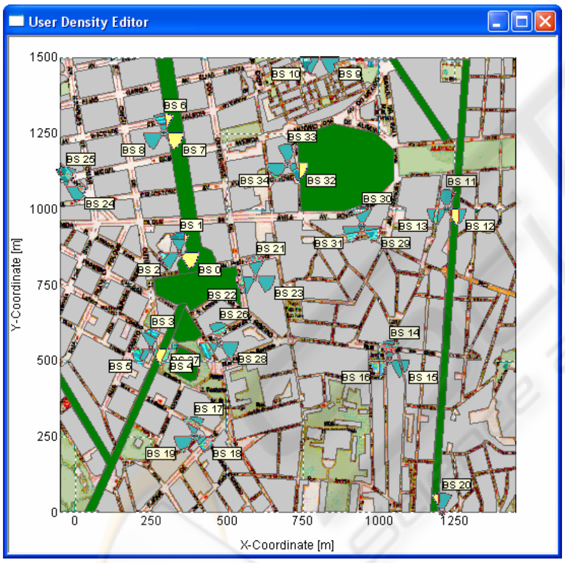

Figure 4: User density areas definition example.

4 SIMULATION MODEL

The simulation model is the most critical component of the simulator and it must reflect UMTS system behaviour. Thus, several radio resources management mechanisms has to be considered on simulation model design. In this section, we explain the main characteristics of system-level simulation model.

The main system related aspects considered in the simulation model, are:

- UL and DL directions;
- Open and closed loop power control;
- Admission and load control;
- Handover and soft handover;
- Simultaneous services usage by a single terminal;
- User mobility;
- Circuit and packet switching modes;

In order to implement these aspects keeping a reasonable time response from simulation, an efficient system-level model has been designed, which main features are:

- Dynamic and Stochastic;
- Discrete events with a continuous time reference;
- Event driven and process oriented simulation.

The model events set definition and implementation details are given in (Cota, 2004).

5 SYSTEM PERFORMANCE ANALYSIS

In this section we describe the analysis features included on simulator. The analysis is the post-simulation phase in which all data collected along the simulation can be displayed to the tool user. The analysis information can be divided in coverage, users, base station and services analysis.

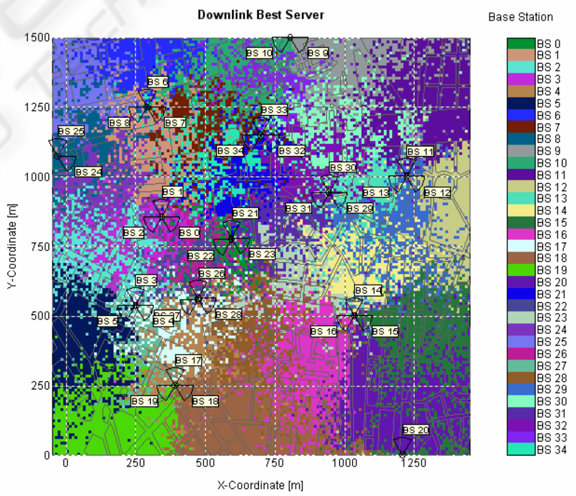

Figure 5: Downlink best server plot example.

The coverage analysis contains several information about radio coverage which is plotted as maps. To this analysis belongs the plots of link losses, CPICH channel receive power and E_c/I_0, best server, active set size and service coverage prediction. In Figure 5, a plot of downlink best server of an example scenario is depicted.

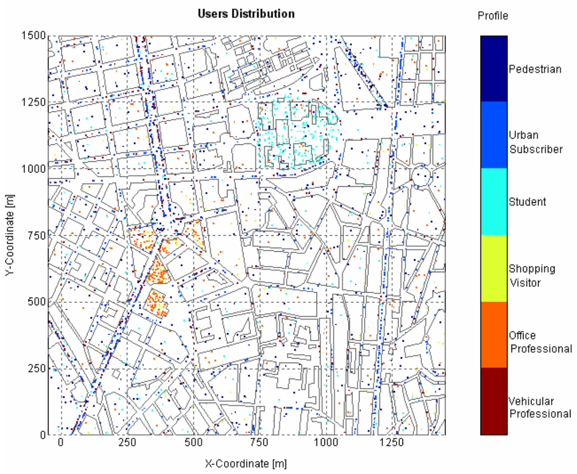

Figure 6: Users distribution plot.

The users analysis includes all user and related mobile equipment informatio. This information is often plotted on maps, allowing that users services performance could be related with their locations. Also belonging to this group are the mobile distribution, average transmission power, satisfaction and outage, circuit and packet services performance. In Figure 6 an example of users distribution is displayed. In this scenario, six user profiles had been defined (Cota, 2004). In the presented plot we can see that users hotspot locations correspond to users density area definition. Another example of users analysis is the UL transmit power. This analysis can be done for a single service only or to all services. Transmit power distribution can be analysed through its distribution histogram or a CDF graph. An example is shown in Figure 7.

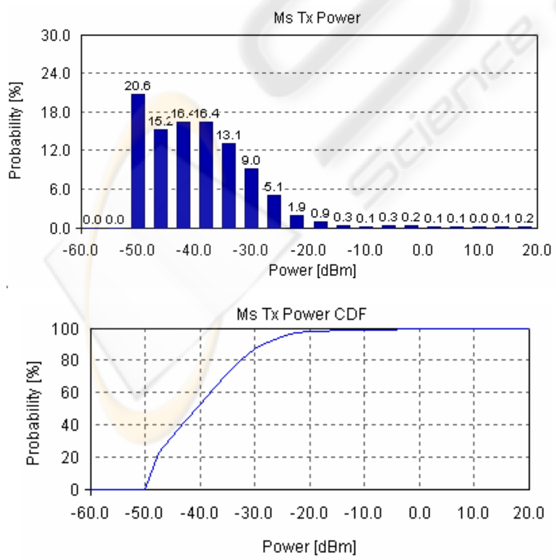

Figure 7: Terminal transmit power histogram and CDF.

Base stations analysis allows the identification of each base station concerning its performance. The information can be plotted as a histogram or a XY graph. Examples of this analysis type are the base station load, interference, transmission power and circuit services satisfaction, outage and performance. Figure 8 presents the downlink average packet delay of each cell, for the scenario in Figure 5.

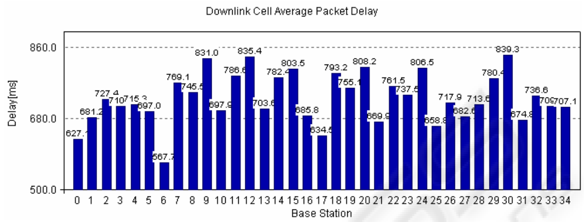

Figure 8: Terminal transmit power histogram and CDF.

Finally, on services analysis group, we can visualize all information about global performance. This includes transmission power, satisfaction and outage level, circuit and packet services performance. Figure 9 shows the downlink transmit power for an example scenario.

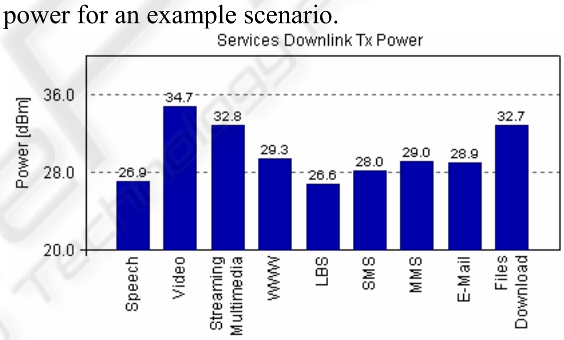

Figure 9: Services downlink transmit power.

6 CONCLUSIONS

This work concentrates in presenting a dynamic and system-level simulation tool for UMTS FDD. It integrates several simulation phases in one single Windows™ based application. A flexible simulation scenario was adopted allowing the creation of new services and users profiles, and all simulation parameters are fully interchangeable. The obtained results allow the service, base stations and system performance analysis. The final results confirm the developed tool validity and its good functionality in relation to simulation scenario definition, simulation and analysis phase.

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