Dynamic simulation planning of mobile WiMAX networks

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***Abstract*— This paper presents a tool for dynamic simulation of radio resources in WiMAX IEEE802.16e-2005 networks. The developed tool provides an integrated environment for defining user scenario characteristics, BS planning, simulation and analysis. For implementing the different mechanisms of WiMAX radio technology, the simulation tool kernel is defined on a system-level, dynamic, stochastic and a discrete event driven simulation model. With the purpose of validating the simulation model, two phases of testing were considered: coverage and capacity. The results confirm the developed tool validity and its good functionality in what scenario definition, simulation and analysis are concerned.**

Keywords: **WiMAX, Planning, Capacity, Coverage, Scheduling**.

I. INTRODUCTION

Broadband wireless access has been serving enterprises and operators for some years, to the great satisfaction of its users. However, the new IP-based standard developed by the IEEE802.16 and the WiMAX Forum is likely to accelerate its adoption. WiMAX will boost today's fragmented broadband wireless access market thanks to standardization and interoperability [1] [2].

Operators who wish to offer this technology will have to plan from scratch, a new access network with new technological assumptions that are totally different from previous systems. Mobile WiMAX has several differences from the traditional CDMA based 3G systems, so the 3G planning tools in the market may not be used for WiMAX planning. Moreover, new systems to simulate and plan a WiMAX network need to be developed.

Simulation tools are used in the two most important phases of cellular planning. The first phase is before the equipment is installed, where such tools can estimate the best place for the BS deployment and their parameterization. In the later phase, with the system in operation, the tool is an important aid in optimizing the network, especially when it has information on the operation of the network. In this case it is possible to estimate the impact of changes in parameterization or even the placement of new BS in the network.

In WiMAX, in order to estimate radio coverage, it is necessary to assess the quality of the radio channel used for communication. The quality of a channel depends on the interference caused by neighbouring cells which although excluding an examination at cell level, makes using planning tools on several cells necessary so as to estimate the performance of the network in certain situations. Besides the physical issues, it is essential that the simulator receives information on the type of system utilization. Thus, different Traffic Models that describe the user behaviour are used. Another factor to be taken into account, is the fulfilment of Quality of Service (QoS) of each service and different User Profiles of each subscriber.

The inclusion of the above-mentioned aspects in a simulation tool can be done in two ways. Using static models which provide averages for characterizing the occupation of the system's resources, or resorting to dynamic models which reflect the users' behaviour in a more realistic way. The tools available are usually static because they are less complex and mainly produce results at short term, an important factor in the planning process. However, the use of a static simulator has some limitations, particularly on user mobility that has a high impact on the performance of the network.

Similarly, the mechanisms of admission control, power control and handover such as algorithms for the deployment of packets, are omitted from static simulation. Taking into account all these factors we may come to the conclusion that, for analysing radio resources in a WiMAX network, it is important to use a dynamic simulator.

In Section II the Simulator is described. The default scenario, as well as the results are presented and analyzed in Section III. In Section IV the main conclusions are drawn.

II. SIMULATOR DESCRIPTION

A. *Overview*

The main aim of the present work has been to develop a simulator to study WiMAX 802.16e performance. The use of simulation tools in the planning of resources in radio systems for mobile communications in general, and in particular in WiMAX, is essential if it is to act as a way of predicting and analyzing the performance of effective planning. Evaluating the performance simulation of these systems has a key role in the process of scaling at various planning stages.

The simulation tool developed can be characterized by three successive stages, as illustrated in Figure II-1: Configuration, Simulation and Analysis.

This simulator is based upon and greatly extends an existing UMTS simulator [3]. The main changes made in the structure of the simulator may be found in the Radio Prediction Module and System Simulation Model. They have all been changed owing to the fact that a different kind of technology is involved. The Analysis Modules have been adapted so as to assess the performance of WiMAX technology and a new module has also been added to apply different algorithms to the resource allocation, called the Scheduling Algorithms module.

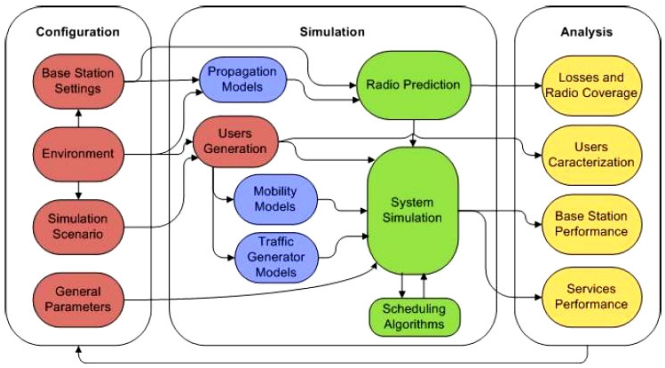

Figure II-1 - Characterization of the simulation tool.

B. Model Characterization

The simulation model is an abstraction of the system to be studied, allowing the examination of its behaviour without having to implement it in reality. The construction of a simulation model requires a number of characteristics in order to ensure that the conduct and results of the model does not deviate from the real system. The model implements the following characteristics: dynamic, discrete events, continue time reference, stochastic and simulation led by events and process guided.

There are four main model entities that have an active role in the simulation and are responsible for the events generation: Mobile Station, Base Station, Packet Traffic Generator and Simulation Manager, presented in Figure II-2.

The actions performed by entities in the model responsible for changes in the status of the system are carried out by the events. Another function of the algorithms triggered by events is the deployment of new events.

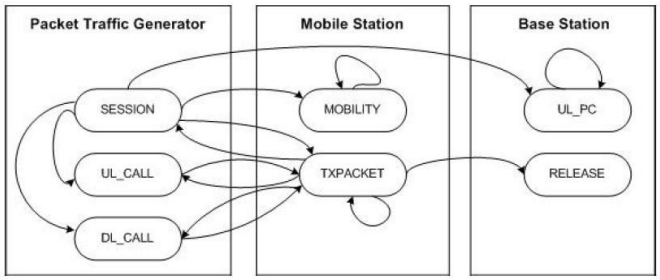

Figure II-2 - Relationship between the events of the simulation model.

In Figure II-2 the relationship is shown between events of the simulation model and their correspondence with the entities that implement them. This sequence of events is the simulation. The Simulation Manager, which isn't present in the Figure II-2, is related to the functioning of the simulation itself. In addition to these aspects, this entity has the important job of forwarding the events for each of the entities according to a chronology associated with the staging of these actions.

It is therefore necessary to define the aspects of the system under consideration in order to achieve this goal, since their choice influences the design and development of the simulation tool. The inclusion of the functional aspects of the real system in the simulation model took into account the proposed objectives for the simulation tool as well as the constraints imposed by computer resources available. The main aspects related to the system, considered in the simulator are: DL and UL directions, Adaptive Modulation and Coding (AMC), Power Control in UL, Scheduling Algorithms, Handover and Admission Control. Regarding the behaviour of the user, the following aspects should be considered: mobility, packet switch services and multiple services simultaneously.

C. Modules Description

In this section, more detailed descriptions of the simulator models are presented. The Radio Prediction module is presented in the first sub-section, followed by a description of the Scheduling Algorithms module. Finally, the Simulator main module is described.

1) Radio Prediction

The prediction of radio coverage aims to make the necessary pre-processing of the System Simulation module by conducting an estimation of loss of connection to the whole area of simulation, since these values do not change during the simulation.

The estimation of the CINR is the parameter that evaluates the quality of the channel which allows the definition of what is the best BS for the whole area of simulation, which is necessary for the subsequent simulation network.

In this way, it is possible to detect the BSs that allow a better channel quality, to have a direct access to information during the simulation in terms of which is the best BSs at each place, without involving serious computational complexity.

2) Scheduling Algorithms

The idea of scheduling algorithms is determining which users to schedule and how to allocate the available resources to them.

In the present study, three different algorithms are implemented in order to treat the co-existence of a service mix differently and the different radio conditions experienced by each user. These algorithms are: Weighted AMC Round Robin (WARR), Weighted AMC and QoS Round Robin (WAQRR) and Maximum Sum Rate (MSR) [4]. The tool is totally flexible to add new algorithms.

3) Simulator Description

The simulation is driven by events, which means that it is important to have a description of the simulation events, incorporating them into entities that implement them, as is shown in Figure II-2. The Packet Traffic Generator plays the leading role in the establishment of packet traffic.

This entity is responsible for the event SESSION, which is responsible for triggering a series of actions related to the establishment of the UL and DL. The events DL/UL_CALL are responsible for the beginnings of calls on the DL and UL respectively.

The simulation is focused on the user, implying that the Mobile Station is the most important entity in the simulation. This entity is responsible for processing the MOBILITY event that triggers all actions related to the mobility of the user and the event TXPACKET which is responsible for sending the packets and all related development.

At last, The Base Station is responsible for the event PC_UL which performs the Power Control in the UL direction and for RELEASE which is corresponds to the release of resources used to send data at the end of each frame.

4) Analysis Module

The features included in the process of results analysis will directly influence the usefulness of the application which is developed, since only after correct viewing and measurement of the final results, will it be possible to draw conclusions about the system's performance and the simulator itself.

The results analysis is usually made on the basis of information collected during the simulation and compiled in order to obtain performance measurements of the simulated system. The information concerning the results analysis are grouped into four distinct sets:

- Coverage Analysis - This analysis includes different information on the prediction of the system's radio coverage, which allows for sizing and system planning before performing the complete simulation, thus leading to a more efficient use of the simulation tool.
- Users' Analysis - The users' analysis offers a set of information to enable performance analysis at terminal level. The information is presented geographically, allowing for the measures of the users' performance with their geographic location to be recorded.
- Base Stations Analysis - The introduction of the BS individual performance results makes it possible to compare different BS performances happening in one scenario. This analysis provides access to performance measures at BS level in order to help the BS scaling processes and the BS locations.
- Service Analysis - This allows the performance analysis of the system and the planning accomplished in terms of different services.

III. RESULTS ANALYSIS

The aim of this work was to develop a dynamic simulator to analyse the overall performance of a converged multi-service, by mainly focussing on aspects that were concerned with radio interface coverage and capacity.

The environment under consideration consists of an area measuring 1,5km^2 near the Instituto Superior Técnico (the Lisbon Technical University), and is composed of real urban morphology: buildings, roads and crossroads. Several user profiles are included and 7400 users were distributed throughout the map area. The initial station's location has been based on real data from some UMTS operators. The locations have been subsequently adjusted in order to improve some performance measures and they have been adapt to the users' distribution as defined in the scenario described in [4]. The reference [4] has also a detailed description of the models used in the tool.

A. Coverage Analysis

The simulator makes possible to do this coverage analysis before performing the complete simulation allowing more efficient use of simulation tool to the sizing and advance planning of the system.

Figure III-1 presents the simulator coverage result for the studied scenario, which has a covered area of 99.6%. The BS settings uses four sectors and four frequencies, which allows to place more BSs in studied place thanks to the interference isolation achieved [4].

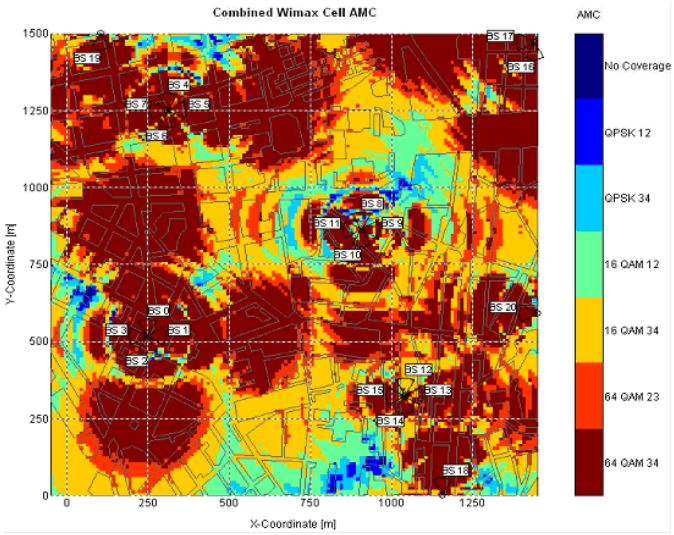

Figure III-1 - Combined WiMAX Cell AMC for the studied scenario.

B. Capacity Analysis

The capacity analysis is designed to exploit the capabilities of simulation and analysis of the tool developed regarding the performance measures in terms of the equipment and services of a mobile telecommunications network.

1) Base Stations Analysis

The Base Station Analysis allows access to performance measures in terms of basic equipment, thus helping the scaling process and the BS location. Only then is it possible to identify not only the overloaded BS and low satisfaction levels in demand for resources, but also the oversized BS with low efficiency usage of their radio resources.

The dissertation [4] has a complete example of this simulator usage in a planning project phase. In this paper it is important to analyze the performance of the chosen scenario in an environment with an acceptable number of people in the area, with a typical call density from 3G users and with a source rate considered normal for the different services.

This analysis allows inferring the usefulness of the tool in the BS optimization at a mobile network. For example the situation presented in Figure III-2, shows results of 5% average drop session rate, where it is the Saldanha area, Fontes Pereira de Melo Avenue and Republic Avenue that deserve greater attention in terms of BS design for a scenario containing high traffic volumes.

As shown in the above analysis, using the simulator developed, WiMAX can serve an optimized distribution of 7400 users in an area of 1.5 km^2, with a traffic volume and rates typical of UMTS technology. Now the aim should be to

study the impact of changes in some parameters in the same scenarios. With significant parameters increases that directly influence the traffic volume requested by the network, it is expected that the radio resources will be exhausted, allowing to assess the strengths and weaknesses of the different network BS distribution, like is explained in [4].

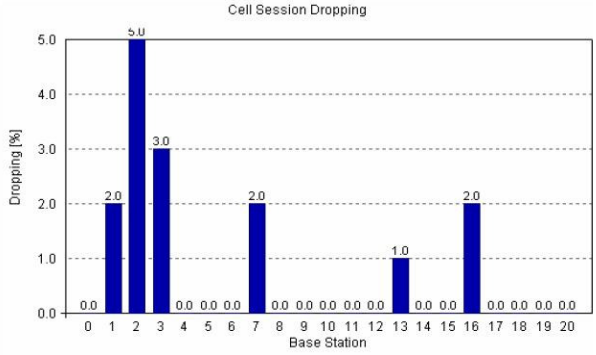

Figure III-2 - Cell Session Dropping for the studied scenario.

2) Service Analysis

This section aims at making a complete and comprehensive analysis of the system, using the tool developed. In this way, information is made available about the performance level of each service considered in the scenario used.

This kind of analysis considers the information as a whole, regardless of the terminal or the BS, where the tool provides information that portrays the performance of the various services under study.

This is done performing an analysis to the system services with the parameters regarded as typical of a UMTS network [3]. It is observed that a WiMAX network guarantees high performance, managed to serve users at the desired rates and without any relevant delays [4].

Another example of possible output of the simulator is the Packet Services DL User Throughput which is presented in the Figure III-3. As expected, a WiMAX network in these conditions can drain the traffic without relevant delay traffic obtaining the established maximum throughput for each service [4], like illustrated in Figure III-3.

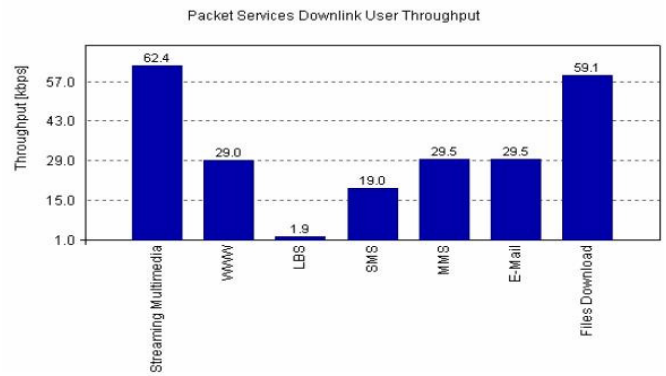

Figure III-3 - Packet Services DL User Throughput for the considered scenario.

IV. CONCLUSIONS

The main motivation of this work was the construction of a tool for planning WiMAX 802.16e networks with multi-services. The work presented in this paper was developed to respond directly to the initial objectives, using a platform for dynamic simulation of a tool for planning UMTS access networks developed in a previous work [3].

In order to demonstrate the tool functionality, it was set up a baseline scenario. In this scenario various services and different users' profiles have been identified with a genuine geographic distribution and characterized by mobility models to enable the usage of implemented tool and test the functioning and performance of the developed model. A city urban area respecting the environment, with micro-cell characteristics, representative of the defined types of services and profiles was taken into consideration. At the level of BS distribution, it was adjusted the location based on real data from some UMTS operators.

The analysis was divided into two consecutive phases: coverage analysis and capacity analysis. The coverage analysis allowed exploiting the simulator capabilities in pre-processing information on the signal quality over the whole simulation scenario, before actually performing the simulation.

In turn, it was achieved a capacity analysis divided into two stages: a BS analysis and a service analysis. The capacity analysis at the BS level, made possible to identify the BSs overloaded and with low satisfaction levels in demand for resources, but also the BSs oversized and with low efficiency in the use of their radio resources. The tool allows the clarification of BS either overcrowded or under-utilized by which a performance analysis of the global system would not be possible to be mode and conclusions achieved. The capacity analysis also allows for a complete analysis of the overall system, obtaining information from the performance level of each service considered in the use scenario.

The characteristics mentioned above allow the use of the developed tool in the whole planning process and optimization of mobile communication systems. In addition to this implementation, the work shows that the use could be made also in the field of scientific research, to study the system behaviour in certain scenarios, and linking this behaviour with the various parameters that define the scene, as well as educational field, constituting an important resource in the analysis and demonstration systems based on WiMAX technology.

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