Modelling and Simulation for Real Scenarios of 4G Mobile Communications Using Google Maps

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***Abstract* — The 4G Planning Tool is a simulation tool for 4G wireless communications. This tool is a mobile traffic simulator (MTS) based on multiagent systems, developed using Google Maps and JavaScript programming languages. The simulator uses a multi-agent model and it is used in this research work with updated data to analyse base stations in cellular networks for proper capacity and coverage planning in real scenarios. Nevertheless, it can be used in many other applications, for instance, to model and study the evolution of social events. The planning can be carried out anywhere in the world where Google Maps is available Results from simulations are obtained and analysed, allowing to check whether there is a need to upgrade the cellular network.**

Keywords – Simulation; Modeling; Cellular Planning Tool; 4G; Google Maps; Cellular networks; Multi-agent systems.

I. INTRODUCTION

The emergence of new services and the improved Quality of Service (QoS) of mobile telecommunications systems results on the increasing volume of data transmission. In addition to this change, the increasing variation of the distribution of the population, owing to the greater ease of mobility, and the existence of more and more social events, brings in new implications, which include the characteristics and topology of cellular networks.

Given this dynamic of constant change, it becomes necessary to plan existing and new networks of base stations (BS) for covering and providing useful services to the people and to the events that they attend, in a defined geographic space and for a very short time. To this end, the development of a system based on maps for analysing the ability of BSs for cellular mobile communications is critical.

However, in most cases, the use of maps is carried out by importing small and restricted geographic information systems to simulation tools. The design and implementation of a basic tool for the simulation of social systems with more realistic data, updated and geographically scalable, makes the analysis more competitive.

This paper describes a planning tool for 4G wireless communications, based on multi-agent-based simulation and Google Maps. The coverage and capacity models are described in section II. The simulation tool is described in section III. The agent model is specified in section IV. Results for a case study are presented in section V. Conclusions are described in section VI.

II. PLANNING MODELS

For the developing of wireless simulation tools is essential to obtain the right propagation and capacity models. The propagation models are primarily aimed to predict the power of the transmitted signal as it propagates to the point of receipt. These models provide an average value and its variation at a particular point or receiver, which could be useful to define goals and objectives in building wireless systems.

With the large variety of scenarios existing on our planet, there is several propagation models, each one optimized for a particular type of scenario. The wireless networks could be performed in two main environments: outdoor, where the signal propagates in an open space, usually with a cell radius of the order of kilometers (macrocells) or hundreds of meters (microcells) or tens of meters (fentocells); and indoor, where the propagation takes place in a closed space and is usually associated with cell radius of the order of tens of meters (picocells).

Nowadays there are innumerous propagation models for outdoor as well as for indoor environments, however, each one was developed for the environment where the experimental tests were carried out.

In general, all propagation models have limitations on its use, but the principal limitation is frequency. In the Figure 1 can be observed the frequency operation range of several known and most often used outdoor and indoor propagation models.

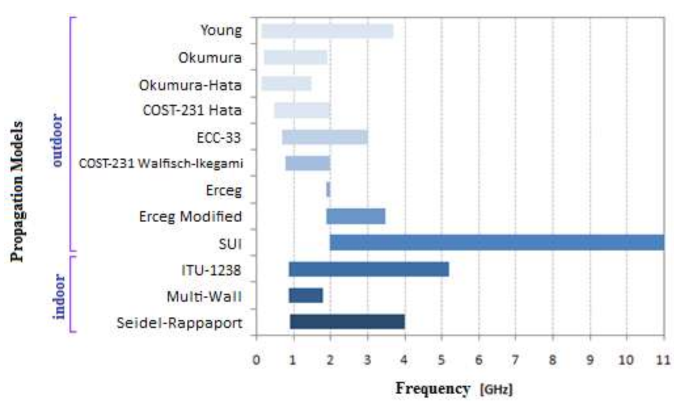

Fig. 1. Propagation models [1].

In addition to frequency, particularly for outdoor propagation models, there are other limitations that may significantly influence the prediction signal such as the height of the BS or the terminal antenna height. Some of the outdoor models were developed by varying the BS and terminal heights in their experimental trials. This led to propagation models that own correction factors in order to correct the result of the path loss prediction, depending on the nature of the scenario [1] and [2].

Concerning to the capacity models the total capacity required for each BS is defined by using experimental measurements for the application's transmission throughputs for VoIP (Voice over IP), Video over IP, FTP, E-mail, WWW (World Wide Web), and FT (File Transfer). The total capacity supported by each BS is obtained as a function of the number of users assigned to it, and of the average duration of the applications.

The planning of 4G mobile networks is mainly focused in the coverage of all terminals. However, sometimes, this strategy is not enough to produce the most profitable planning, and the evaluation of the user's traffic is also important to define the number of BS (macrocells/fentocells) and their positions. As an example, the average transmission throughput corresponding to a group of applications is presented in [3], [4] and [5].

For MTS defines the total number of BSs and their positions by assuming a given user simultaneous factor (USF) for each application and a correspondence between the received power threshold and the maximum transmission throughput [5].

For a given usage scenario the choice of the USF for each application depends on the percentage of simultaneous users. A placement algorithm is used to choose the fentocells positions [5]. In the automatic mode, the algorithm guarantees the fulfillment of a given throughput (in Mbps). The distribution of fentocells is made by applying one of two different methods: either dynamic or static. If no value is defined for the throughput threshold the algorithm uses the default value of the standard. The purpose of the dynamic algorithm is to properly choose fentocells positions in the coverage area defined by the network designer. As mobile terminals are either portable or nomadic, and their position is random, the algorithm sets the optimized number (and location) of fentocells to cover a given area.

The static algorithm is the best approach when the spots are fixed, i.e., there are several users associated to one zone. In this context, the required throughput can be obtained for each zone. Thus, for the cellular planning procedures considering the coverage and throughput requirements for users of each cell.

III. SIMULATION TOOL

The mobile traffic simulator (MTS), [6], is characterized by implementing an easy and intuitive interface, in order to facilitate its use, providing easy configuration of variables and options, presenting graphics data of the evolution over time. This reflects the options taken by the user before the start of the simulation.

In order to make simulation as accurate and realistic as possible, the MTS implements the calculation and representation of the coverage of BSs (Figure 2) according to the calculation of losses in the free space, in conjunction with the calculation of the recursive major obstacle method.

To improve the outcomes of planning, i.e., creating a more efficient network in order to meet the needs required, we make multi-agent-based simulations, where agents can represent sets of mobile users. Given the results of the simulations, and if the requirements are not met, the topology of the network can then be changed to reach an optimal network.

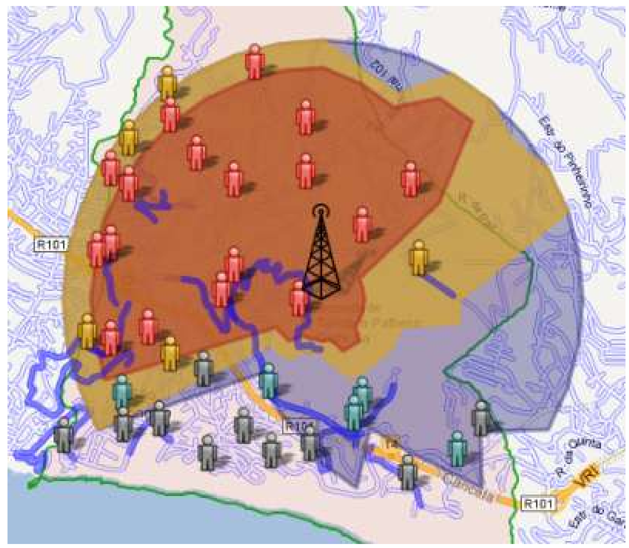

Fig. 2. Graphical representation by Google Maps of the simulation, showing agents (mobile users) and BS coverage levels. Each agent marker can represent more than one agent.

The tool is built entirely in JavaScript programming language, based on object oriented programming over HTML and CSS. The basic API used is Google Maps JavaScript API V3 [7], with several tools, which were used, such as: Map, Controls, Overlays, Services (*DirectionsService*, *ElevationService*, *Distance*), Map Types, Events, Base, Drawing Library.

Apart from the extensive used of these APIs, others are used for the clustering of objects (markers on map) [8], such as representing various agents as a single one, thereby enhancing visualization in the map. Features to show the path travelled by the agents at every time-step were also implemented. Auxiliary tools, like Google Maps API Styled Map Wizard [9], based on Section Map Types, were also used, which helped building new types of maps interactively and quickly. A type of maps called "Blue Roads" was used, as shown in Figure 4.

To bring reality to the simulation, data from Census 2011 held in Portugal was loaded to the tool, [10]. The proper use of the data involves the representation in the map of administrative boundaries for the smallest regions. The spatial data for the administrative regions was downloaded from the Website Administrative Areas [11], in *kmz* format. Initially, a number of agents is affected to a given region, according to census data, and later distributed within the administrative region according to urban density.

The operation of the tool involves three main phases, and that is reflected in the user interface comprised by three blocks, *inputs*, *processing* and *outputs*.

A. Inputs

Early in the planning, through a setup menu, the user enters various parameters using inputs and sliders, such as simulation time, social events times and positions, BS parameters and positions, and BS coverage resolution.

B. Processing

The second block of the MTS controls the processing of the simulation, including decisions made by agents, which take into account the characteristics that differentiate them. Agents are thus heterogeneous, and may have different behaviors. When the simulation starts, the simulator runs through each element of the list of agents, previously scrambled [12], and processes the agent's next actions, such as communication and movement. This is performed repeatedly until the limit of iterations defined by the user is reached,

C. *Outputs*

Outputs of the simulation are presented in the form of graphs and tables, allowing the user to analyse the progress of the simulation at any time-interval.

The coverage of the BS is computed and represented in the map, as can be shown in Figure 2. The BS has three different levels of coverage (low, medium and high) and different geometries, depending on the received power at each point, which is calculated as a function of distance and obstructions due to terrain elevation.

During the simulation three gauge charts are presented (Figure 3), showing the current capacity throughput of coverage levels along the simulation.

Fig. 3. Gauge charts of users charge for each level of BS coverage

IV. AGENT MODEL

Agents are distributed and moved through a road map. The initial position of each one is calculated by an Agent Distribution Algorithm (ADA) created for these propose, as described below.

Figure 2 shows paths highlighted in blue; agents are distributed along these pathways, assuming that the higher density of roads corresponds to a higher population density residing in the neighborhoods. With this new map representation we can easily predict the actual distribution of the population.

The agent model has three main blocks: inputs, processing and outputs.

A. Inputs

The simulator has a setup menu for the distribution of agents. This menu present a few parameters to define the grid of points used for the calculation of the agent's positions.

Fig. 4. Blue roads and red administrative boundary representation of "São Gonçalo" region.

B. Processing

The ADA algorithm was established based on pathways density data, in order to obtain a distribution of agents closer to reality, as compared to a uniform spatial distribution. The agents position is calculated from a grid of points and via the Google Directions service. This algorithm allows agents to be placed along the pathways, thus excluding the "green zones" (areas where there are no roads), approximating the distribution of the agents to the distribution of the actual population.

The distance from a grid point to a point in the nearest pathway, as calculated by the Google Directions service, determines the insertion of an agent (represented by a marker) on the map. This distance must be less than a threshold, depending on the distance between two points in the grid. If the calculated distance is less than the threshold, then an agent is created in that geographic point, as calculated by the Google service described above. This limitation on distance prevents placing markers around "green areas" such as those observed in the northern part of the administrative region (Figure 4), when there are no pathways.

After the initial distribution of agents in the map, agents move around, on foot or by car. The speed of travelling depends if the agent walks or move by car, presently set to 5 and 50 km/h, respectively.

C. Outputs

Agents have the ability to move through the pathways of the map with different routes and speeds, so everyone can move different paths and distances. The outputs show several graphs illustrating the percentage and number of agents in motion as well as the traveled distance for each one.

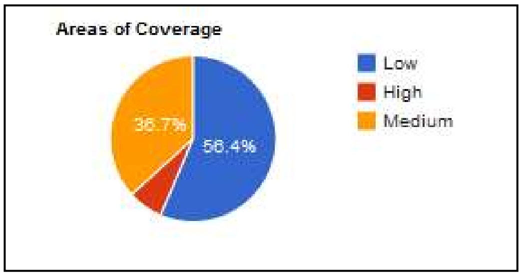

Fig. 5. Relative coverage areas form one BS

V. RESULTS

This section presents the graphical results of simulation and the analysis performed, using various scalable parameters. They are accompanied by illustrative figures of this simulation.

As can be observed in Figure 7, we can verify that the three coverage levels (low, medium and high) have different averages and variances. This is due to differences in geographical size of each level. As shown in Figure 5, "Areas of Coverage", levels are ordered in ascending order of size: high, medium, and low.

As such, the larger the coverage area of the level, the greater the number of agents. However, agents do not always have a homogeneous distribution in the pathways. Moreover, during the existence of an event, for example a football game, the movement of the agents which decide to go to the event can change, moving towards the target when the event starts (Figure 6).

We can see that the output on medium level increases at the beginning of the event and then decreases. The reason for this behavior is that agents walk through the medium level area before arriving at the event. During the event, the flow of medium level decreases and the low level increases because the event is located in the blue coverage area, corresponding to the low level of coverage.

During most of the event duration, the low level remains stable at the value of 40 kbps, which is the maximum level supported. Each level has a threshold defined. Because there are many users using the mobile service, the limit can be reached and there is packet loss information. In this case there are many losses at this coverage level, as shown in Figure 8, corresponding to the lower limit.

Fig. 6. Simulation with agents on the occurrence of an event

When the event is over, there is an increase of throughput in medium level, because agents come out almost simultaneously. At the beginning of the event, the increase in this level is slower, which simulates the lag arrival of agents to the event. These two moments of the simulation, input and output of the event, are very close to real scenarios, e.g., the beginning and the end of a football game.

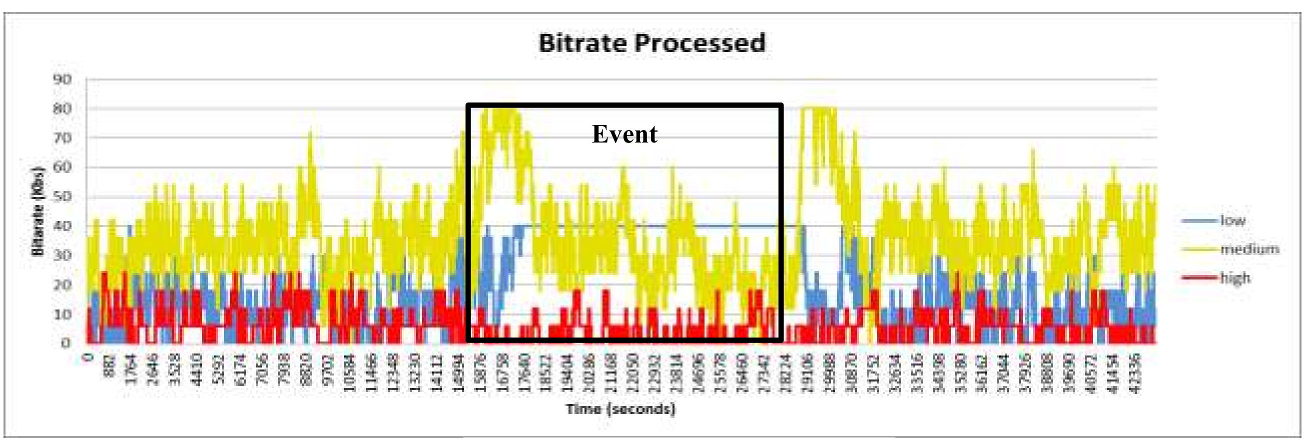

Fig. 7. Bitrate Processed

VI. Conclusions

The 4G planning developed and presented in this paper considered the needs of the user; it is very user friendly. It can be used by academic students and by industrial professionals.

The planning can be carried out anywhere in the world where Google Maps is available. The distribution of agents is efficient and very close to the real world. The tool allows manipulating different variables of the simulation in a flexible way.

Results have showed that the presence of an event inside the coverage area of one BS can saturate the traffic and does not satisfy all requests for long periods of time, due to the concentration of users.

Acknowledgment

This work was partially supported by the FCT - *Fundação para a Ciência e Tecnologia* (project LTE-Advanced Enhancements using Femtocells PTDC/EEA-TEL/120666/2010).

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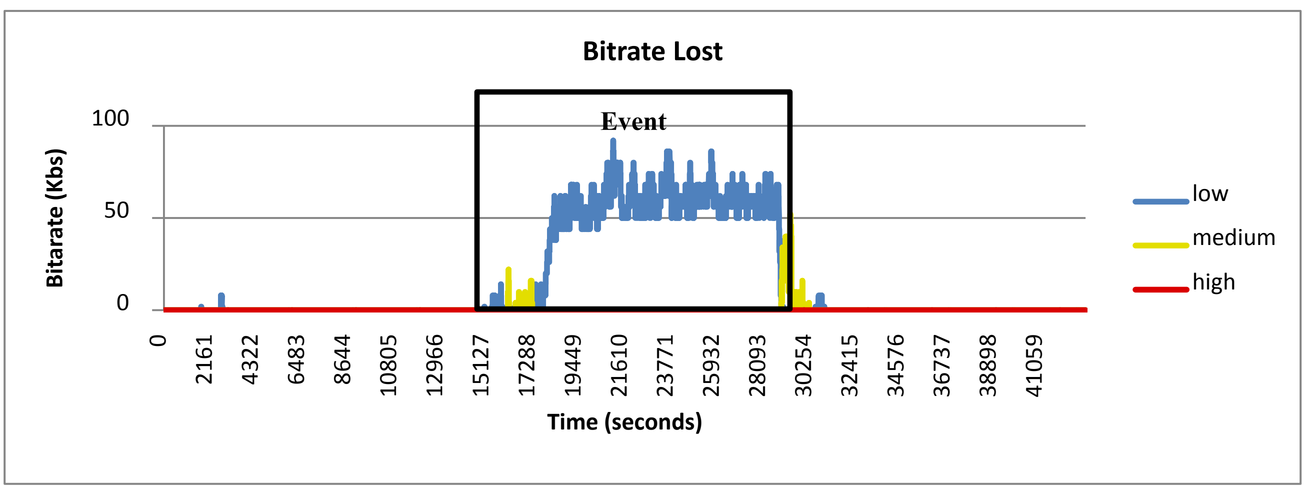

Fig. 8. Bitrate lost