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A MODIFIED LTE SIMULATOR FOR 3D FEMTOCELL NETWORKS

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ABSTRACT

Using simulation tools save the construction cost of the wireless system. It is not necessary to establish the system and test whether it is working properly or not. Therefore, simulation tools are required to be accurate, simple and with the minimum time. From the accuracy perspective, the stacked femtocells built in most available simulators in the literature are widely deployed horizontally. However, this is not the case in the indoor environment where femtocells have to be arranged vertically; such as, in residential towers where apartments are on the top of each other. In this paper, the state of the art of link and system level simulators is introduced. In addition, a three-dimensional (3D) system level simulator is developed in order to help the researcher in the Long Term Evolution (LTE) femtocell field to analyze and investigate more real scenarios of femtocell deployment. The developed simulator allows the researcher to locate a multi-story building in the region of interest, choose the number of floors, determine the ceiling height, and allocate the position of the femtocell inside the house.

Keywords: system level simulators, femtocell networks, indoor propagation models, three dimensional environments.

1. INTRODUCTION

Simulation tools are necessary and play an important role in the wireless system configuration. It helps the mobile operators to adjust the optimal configuration of their systems and evaluate the network performance. In addition planning tools aid the operators to test the impact of new installation equipment such as new femtocell deployment or new base station. Furthermore, simulation tools make the improvement of available algorithms an easy process. Moreover, using these tools will reduce the cost and the complexity of wireless system deployment. Therefore, developing a simulation tool is important and worth spending time on.

It is not a practical process to simulate all the channels between all base stations and all user equipment's in the wireless system in one simulation scheme. Hence, the simulation process in wireless system networks is divided into two main parts, link level and system level as shown in Figure-1. In the link level, the channel characteristics between single transmitter and single receiver are evaluated. Then, these characteristics used as an input to the system level simulator. These characteristics are mapped using look up tables and Link to System (L2S) models that work as an interface between the two levels of simulation process [1, 2]. In the system level simulator, the network performance is evaluated as a whole. In addition, the media access control layer aspects are considered in this level such as resource management, network capacity, network coverage, packet scheduling, handover algorithms, and mobility management [3].

All previous system level simulators that will be presented in the next section are two dimensional however; their limitations are clearly observed in the indoor environment where femtocell device is deployed.

A femtocell is a small home base station that is installed in an indoor environment to compensate the attenuation in the signal strength inside the building [4]. Since femtocell installed indoor, the vertical distance between two femtocells in the dense indoor environment could be much less than the horizontal one. Thus, studying vertically stacked femtocells are important. Therefore, this paper reviews the available system level simulators and discusses their characteristics and effectiveness. In addition, a 3D simulator is proposed where the researcher is able to add an apartment in a specific or random location with a different number of floors to investigate the effect of vertical stacked of femtocells. The rest of this paper is organized as follows: next section review the available simulators in the literature. The scope of this paper is the LTE system level simulators. Section 3 presents the proposed 3D simulator. Finally, the paper is concluded in Section 4.

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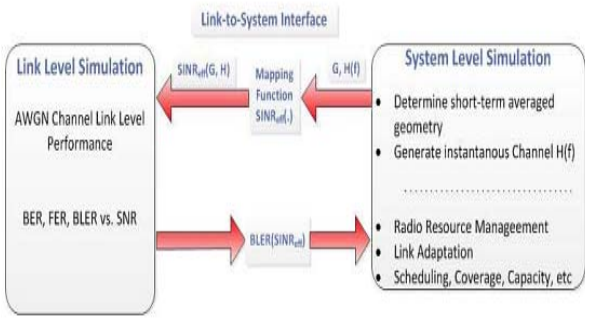

Figure-1. Wireless system simulation process [2].

2. SIMULATION TOOLS

In this section, the previous works regarding the simulation process are presented. This section is divided to three subsections that cover link level simulators, L2S mapping models and system level simulators.

a) Link level simulators

Also known as physical level simulators, they are used to evaluate the properties of the physical layer. The output of such simulators is normally block error ratios. Link level simulators that are available in the literature are based on different platforms and could be divided to uplink and downlink communication. Single-carrier Frequency Division Multiple Access (SC-FDMA) is employed as the air-interface in the LTE uplink channel, while Orthogonal Frequency Division Multiple Access (OFDMA) is employed in the downlink.

Matlab based uplink link level simulators were presented in [5] and [6], which were based on an open source models. A free open source Matlab based downlink link level simulator was presented in [7]. The simulator supports the parallel computing that significantly reduce the execution time. Another downlink direction simulator was introduced in [8] but based on the C++ WM-SIM platform. Although the later simulator has higher performance than previous ones, Matlab based simulators were more flexible and reliable.

b) L2S models

To match between the link and system level simulators, L2S models are important and necessary. Some interface solutions are evaluated for OFDMA, MIMO and LTE systems in [2, 9, 10]. In addition, the performance of interface models such as Exponential Effective SINR Mapping (EESM) model and Mutual Information Effective SINR Mapping (MIESM) model were presented in [1] and [2].

c) System level simulators

In the previous simulators, the channel characteristics between one or few transceiver are targeted. However, in system level simulators, several cell aspects are evaluated. The work in [11] used OPNET software in order to study the indoor deployment of a femtocell. However the OPNET does not yet support the femtocell deployment, authors assumed that UMTS macrocell base station behaves like femtocell. Therefore, OPNET is not recommended yet for studying of femtocell networks.

Another simulation tool was proposed in [12] based on LTE-sim simulator which is written in C++ programming language. The LTE-sim was modified to include the femtocell and its related aspects such as propagation model, access mode, buildings and streets. The simulation environment considered two types of indoor layouts as shown in Figure-2. Even though, the researcher is able to choose the number of floors, only one femtocell can be applied for each apartment. Similarly, a 3D scenario was considered in [13] for a five storey building where only one femtocell was fixed as well at the ground floor and the signal strength was measured in all of the five floors. This scenario is simple enough comparing to the real environment, where probably more than one femtocell in the same building. Moreover, in most of the cases the vertically stacked femtocell is much closer than the horizontally stacked one.

A basic module for LTE network simulator was presented in [14] and improved in [15] using Network Simulator (NS-3) platform. The code is free for researchers and supports many aspects of the LTE networks such as resource management, spectrum access, packet scheduling and interference coordination. The most popular simulator for LTE networks that available in the literature is the one presented in [16] and known as Vienna LTE simulator. This simulator is based on MATLAB programming language. The simulator supports both Single Input Single Output (SISO) and Multiple Input Multiple Output (MIMO) technologies. Moreover, different scheduling algorithms and spatial distribution techniques were applied. In addition, interference mitigation technique such as fractional frequency reuse was tested. Furthermore, the simulator supports reproducibility where the researcher is able to compare his results with the previous results of the developer. However, the vertically stacked femtocells are not implemented in this simulator. Therefore, it has been developed in order to evaluate the 3D deployment of femtocell networks.

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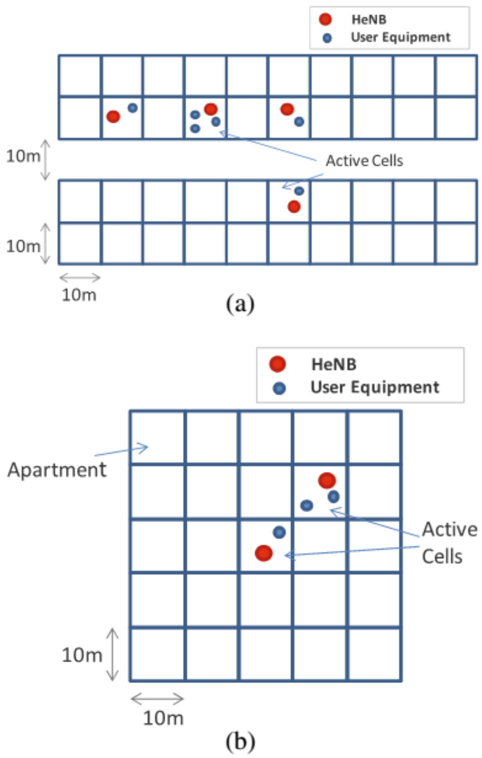

Figure-2. Building configuration (a) dual stripe blocks and (b) 5 X 5 apartment grid [5].

3. PROPOSED 3D SIMULATOR

Based on the work presented in [16], a 3D simulator has been proposed in this section. To include the third dimension, many aspects should be considered. The first step was to change the layout of the generated network from 2D to 3D. Therefore, the network layout code in the model that presented in Figure-3 needs to be modified in order to generate a 3D region of interest. In this stage, the number of floors, the ceiling height, and the femtocell height above the floor should be specified. So, based on the previous parameters a multi-storey building has been generated. Then according to the number of floors a 3D map has been generated. The vertically resolution level was the ceiling height in this case. Subsequently, the distance from each base station to every point in the region of interest was calculated for each level. Next, the received power at each distance was calculated based on the path loss model described in the next stage of the modification model. In the generated building, the worst scenario has been considered where the femtocell was stacked vertically above each other as shown in Figure-4. In the

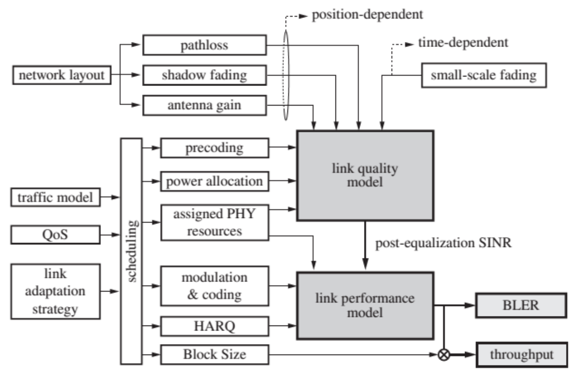

Figure-3. LTE Link-to-System model [1].

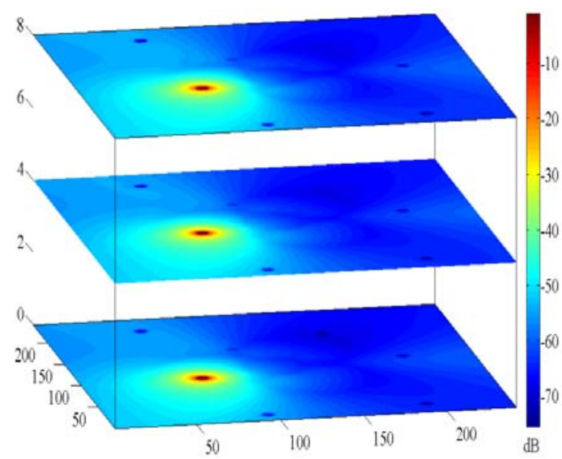

Figure-4. SINR map for vertically stacked femtocell over the region of interest.

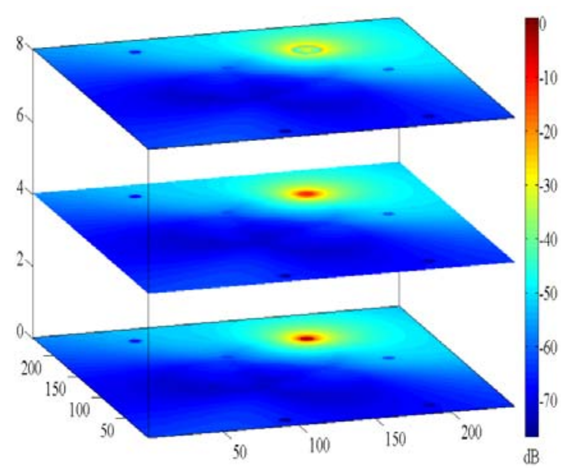

Figure-5. Effect of femtocell deployed in level 1 on other user equipments at another levels.

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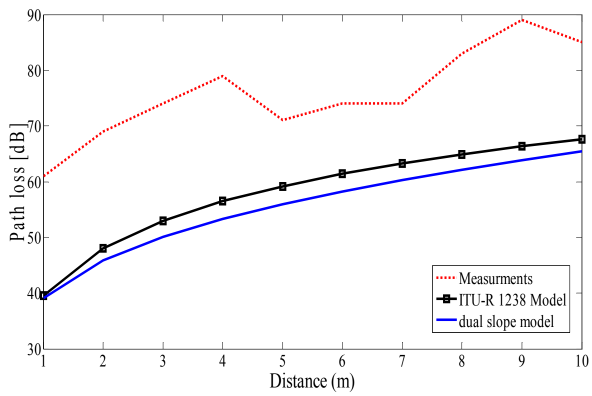

Figure-6. Comparison between measurements and some indoor models at 2.6 GHz [17].

figure, the SINR for 3 open access femtocells has been presented. The figure shows the effect of each femtocell on its own level but not on other levels. The effect of femtocell on other femtocells and other user equipment's is investigated as shown in Figure 5. By adding the floor penetration losses, it clear from the figure that there is still interferer signal from the femtocell in level one on other users in different floors.

The researcher has the choice to change the number of floors in the building and the position of the building whether the position is specific or random. In the case of 3D, the map resolution of the vertical dimension will be lower in value than the resolution of horizontal dimension. The reason is that the height of apartments or units is below 5 meters or otherwise some floors may not be represented on the map.

The second stage is to develop the path loss model since it is the most important parameter to calculate the SINR. Based on real measurements conducted in [17-19], it has been shown that most of the well-known models in the literature underestimate the real measurements of the indoor deployment as shown in Figure-6 for horizontal distance. The path loss model in [16] was modified to include the floor loss based on the ITUR recommendations. Based on positions of the macrocells, macrocells users, femtocells and femtocells users, the path loss will be calculated, then the SINR map could be determined for each location in the region of interest. After that, these calculations will be used later to evaluate the spectral efficiency and the throughput of the network. SINR for a building constructed of three different levels is presented in Figure-4. One femtocell was deployed in each floor. In the figure the map is coloured according the SINR level in the network as shown on the colour bar on the right of the figure.

Moreover, the path loss models that were used in the modified simulator were validated and compared with measured data at 2.6 GHz for a femtocell fixed 1 meter above the ground on the second floor. The measurements conducted vertically above the femtocell on the second and the third floor with 1 meter separation distance. The 4^{th} meter measurement is in the third floor on the ground. The comparison is presented in Table-1.

The path loss model that was applied is the ITUR- P1238-7 model as in Eq. (1) [20] where it is shown in Figure-5 that it is closest to measured data.

$$PL = 20\log(f) + N\log(d) + L_f(n) - 28 \qquad (1)$$

where PL is the path loss, f is the frequency (MHz), N is the distance power loss coefficient, d is the distance in meter between the femtocell and the user (d >1 m), L_f is the floor penetration loss factor (dB), and n is the number of floors separate between the femtocell and users. N in the ITU-R model is 28, and Lf is 20 dB. In addition, the dual slope model is applied as in Equation (2) below:

$$PL = 38.46 + 20\log(d) + 0.7d + 18.3n^{((n+2)/(n+1)-0.46)} \qquad (2)$$

where d is the distance and n is the number of penetrated floors. As a result, it is very crucial to have an accurate indoor propagation model. A path loss model from the measurement conducted in different indoor scenarios and different floor levels will be proposed as a future work.

Table-1. path loss as a function of distance and floor penetration loss.

Distance (Vertically) [m]	**Path loss** [dB]		
	Measured	**ITU-R model**	**Dual slope model**
1	61.44	40.30	39.16
2	79.18	48.73	45.8
3	72.23	53.66	50.1
4	97.66	77.15	71.6
5	100.52	79.87	74.24
6	103.77	82.09	76.52
7	102.83	83.96	78.56
8	115.63	85.59	80.42

4. CONCLUSIONS

In this paper an LTE 3D system level simulator has been developed and has been presented for femtocell networks. The presented simulator helps the researcher to investigate the effect of vertically stacked femtocell. As a future works an indoor propagation model need to be developed for 3D indoor environment. Moreover, interference mitigation techniques still an open research trend.

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