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Impact of Interferences in Co-Operative Femtocell Networks

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Abstract: With the advent of newer cellular standards like LTE, users expect not only good quality of voice but also many other features such as uninterrupted voice calls, clear video images at much faster data speed. More than 50% of voice calls and more than 70% of data traffic are in indoor environment. Femtocell provides a good solution to overcome inadequate indoor environment where user spend most of their time. Existing studies have focused on outage detection, while the major challenge is the interference between macro cell and femto base station has not been addressed. In this project, different femtocell deployment and the interference scenarios that the femtocell faces with macro cell is considered and analyzed. The aim of the paper is the motivation to move towards small cells and to analyze the cross-tier interference. In order to maintain stability in the networks, reconfiguration is kept as local as possible, hence co-operative architecture is considered. The analysis is carried out in mat lab using femto-macro simulator in LTE system.

Key words: LTE · Femtocell · Cross-tier interference

INTRODUCTION

Femtocell technology emerged to meet the demands of cellular services like voice calls and data within a home or an enterprise. Femtocell is a small base station [1] that can be used within home or building enterprises to provide seamless cellular services. Femto base station are installed based on the subscriber's need in their homes and typically connected to an operator's core network via public Internet connections, such as DSL and cable modems. Benefit both subscribers and operators; better voice coverage and higher indoor data throughput for subscribers and Macro cell offloading and indoor coverage improvement at low [1] capital and operational costs for operators. The main issue associated with this technology is the interference with the macro cell base station. This interference is due to the licensed spectrum that is being shared by both femto base station and macro base station. This interference has major [1, 2] impact since 70 % of the traffic occurs indoor due to this femto macro signal interaction. Femto are smaller cell structures and are found as a promising approach to address these issues. In the recent years, the femtocell has obtained significant success in deployments, [1] consumer acceptance and technological maturity. Commercial femtocell have been deployed by operators worldwide, including Sprint and AT&T in the US, [2] Europe and Japan. Besides, more than 50 other operators are currently performing field trials. A femtocell, is connected to the core network through cable or digital subscriber line (DSL) backhaul [1,2], is a low-power small access point designed for indoor purpose and uses the same spectrum and technology as macro cells.

Femtocell Technology: Based on the operator's need femtocell may use dedicated carrier or shared one with the macro user. Femtocell can support up to 10 users [3] within the range of 20-30m coverage area. These are mainly used for high speed mobile communication which is deployed by operator or customer. There are two configurations possible: Closed Subscriber Loop (CSG), Open Subscribed Loop (OSG) [4]. CSG femtocell has a fixed set of subscribed home users that are licensed to use the femtocell. OSG femtocell, on the other hand, [5, 6] provide service to macro cell users if they move nearby them.

Femtocell Architecture: Basic femtocell network architecture, as shown in Figure 1, is generally comprised of three elements: a femtocell Access Point (FAP), a security gateway and a femtocell management system. The femtocell base station also requires a means of connecting to the internet, typically through a broadband internet connection (DSL). The Femtocell Access point is

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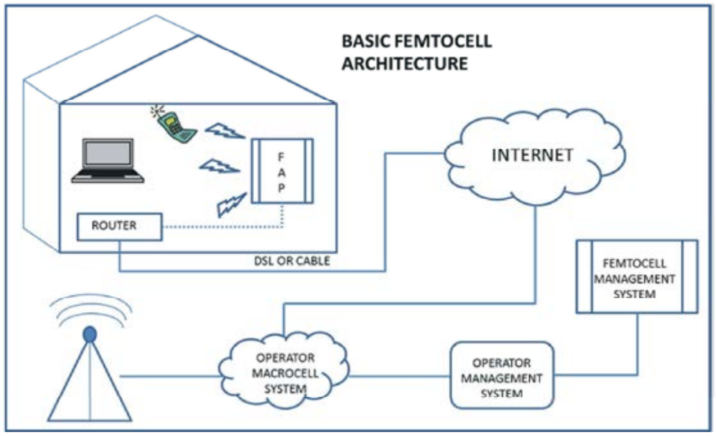

Fig. 1: Basic Femtocell Architecture [9,10]

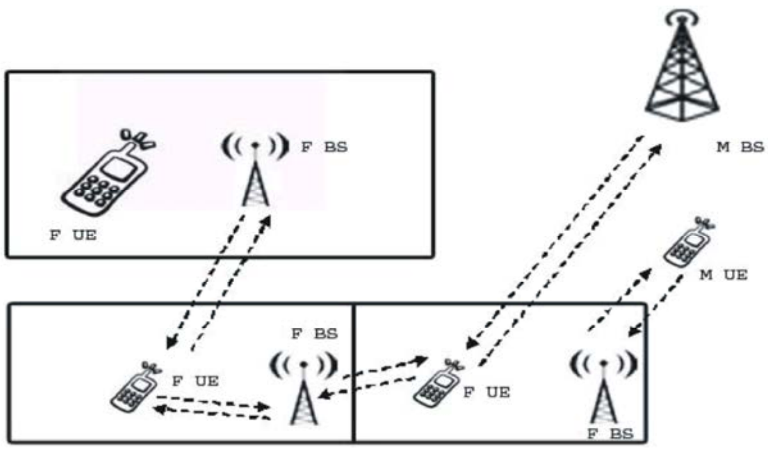

Fig. 2: Urban interference scenarios

basically a small scale cellular base station. It is the primary node in the network that connects the user to the user to the network [7, 8].

Interference Scenarios: In Figure 1 the main different interference scenarios are shown. There, two simplified buildings divided by a street are depicted. One has two apartments and the other has one single apartment. Each femtocell User Equipment (UE), which may be a mobile phone, is connected to its home femtocell Base Station (femtocell BS), which is represented by a little antenna indoors.

In the case of the macro UE, this is represented by the mobile phone. The macro cell BS is given as the big antenna. Femtocell UE is called F UE in the Fig. 1, while Macro cell UE is denominated M UE. The same scheme is followed by the BS (F BS and M BS). The interference is represented by dashed lines [11, 12].

To analyze different interference, an easy and intuitive idea would be to estimate the interference knowing the interferer path loss model.

In this paper, a simulation framework that estimates the interference in every point of a custom integrated femtocell/macro cell LTE, with related information provided by the user. This framework can be used for studying its interference behavior. In order to estimate the adjacent macro cell interference, the SINR by using an analytical model that takes into account the path and penetration loss due to external or internal walls and also due to signal propagation is calculated. The simulation framework is implemented in Matlab.

Interference Management: One of the major concerns for the mobile operators considering the deployment of femtocell is the interference to their existing networks [1, 4]. Management of this has become part of planning and coordinating the macro networks. Femto cell management techniques used by the femtocell forum allow much more efficient reuse of spectrum.

The frequency and bandwidth issues are very important in femtocell technology. Femtocell operates on the same licensed spectrum that is allowed to cellular service providers [3, 5]. To deal with issues two methods have been used: the co-channel frequency deployment and Orthogonal channel deployment.

OFDMA Access Technique: In LTE OFDMA access technique [13-17] is used. In this the whole bandwidth is divided into small subscribers or parallel channels which is then used for the transmission with reduced signalling rate. These subcarriers are orthogonal which means that they do not correlate with each other. Subcarrier is first modulated with a data symbol of either 0 or 1 [5], the resulting OFDMA symbol is then formed by simply adding the modulated carrier signal [5, 6]. This OFDMA symbol has larger magnitude than individual subcarrier and thus having high peak value which is the characteristics of OFDMA technique [6].

Indoor to Outdoor Interference Scenarios: Here two cases are considered; in the first case interference from femto base station to the macro user equipment is taken. In the second case, [3, 4] interference between femto user equipment to the macro base station is considered. The first case may be dangerous when the macro user receiving signal strength becomes low at the cell's edge, where it tends to receive signal from the nearby femto base station. The second case will appear if the femtocell UE were quite near the macro cell BS that is unrealistic. Indoor-to-Outdoor path loss Model which is expected to be useful to estimate the real [4, 6] interference impact from femtocell to macro cells.

In this paper femtocell application especially for LTE is taken into consideration [7], hence some of the important features of the LTE are given below [8] and are used for the simulation [7, 8].

Pathloss Estimation: In order to analyze the various interferences incurred between femtocell and macro cell, it's important to know the SINR.Path loss relates the loss of signal strength to distance between two terminals [6].

Path loss between femto cell base station and UE is given by [9].

$$PL(dB) = 38.46 + 20\log_{10} R + 0.7 d_{2D,indoor} + 18.3 n^{((n+2)/(n+1)-0.46)} + 9 * L_{iw} \quad (1)$$

where n is the number of penetrated doors, q is the number of walls separating apartments between the femto BS and the UE and L_{iw} is the penetration loss of the wall separating apartments [9]. Also, the term $0.7d_{2D,\ indoor}$ takes account of penetration loss due to walls inside an apartment and is expressed in meter.

Table 1: Lte System Parameters

LTE system Features	
Bandwidth	1.25-20MHz
Duplexing	FDD,TDD,Half-duplex FDD
Mobility access	Downlink OFDMA
	Uplink SC-FDMA
MIMO	Downlink 2x2,4x2,4x4
	Uplink 1x2,1x4
Modulation	QPSK,16,64QAM

Table 2: Simulation Parameters

PARAMETER	VALUE					
Macro cell Radius (R_m)	250m					
Femtocell Radius(R_f)	20 m					
Frequency	2 GHz					
Macro BS power	46 dBm					
Femto BS power	20 dBm					
Outdoor Walls loss (L_{ow})	20 dB					
Indoor Walls loss(L_{iw})	5 dB					
Bandwidth(MHz)	20	15	10	5	3	1.4
Modulation Scheme	64QAM		16QAM		QPSK	
Subcarrier Spacing	15 KHz					
White noise power density	-174 dBm/Hz					

SINR is calculated from the given equation:

$$SINR_{m,k} = \frac{P_{M,k} G_{m,M,k}}{N_0 \Delta f + \sum_{M'} P_{M',k} G_{m,M',k} + \sum_{f} P_{F,k} G_{m,F,k}} \quad (2)$$

$$SINR_{m,k} = \frac{P_{F,k} G_{f,Fk}}{N_0 \Delta f + \sum_{M'} P_{M',K} G_{f,M',k} + \sum_{f} P_{F,K} G_{f,F,k}} \quad (3)$$

$$G = 10^{\frac{-PL}{10}} \quad (4)$$

Simulation: The simulator is written in MATLAB version. First, the number of macro users, the number of femto users associated to each femtocell, the number of femto BSs located within the macro-cell area and the preferred channel bandwidth, according to the current LTE-A standards (1.4, 3, 5, 10, 15 or 20 MHz) [17] can be set by the end users [9]. Also, urban environment is considered hence the end-user has to select the width of the map's streets, in meters. All base stations operate at 20 MHz/64QAM. By selecting a deployed BS or a user, the corresponding properties are displayed.

In this example (Figure 4) since single macro user is deployed the macro user MU1 is selected and the interference of femto/macro users MU1, FU1 in the second building is considered.

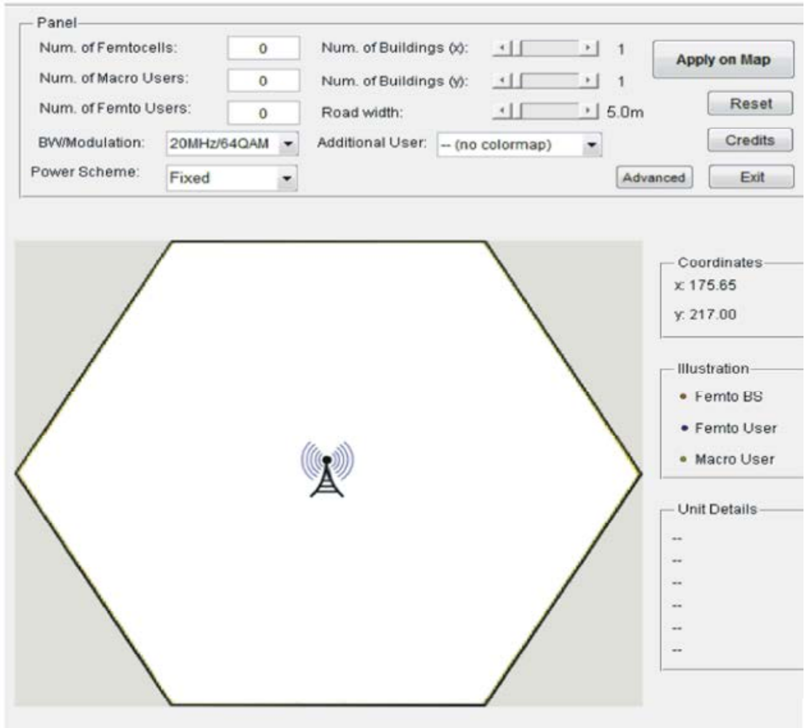

Fig. 3: Simulation Frame

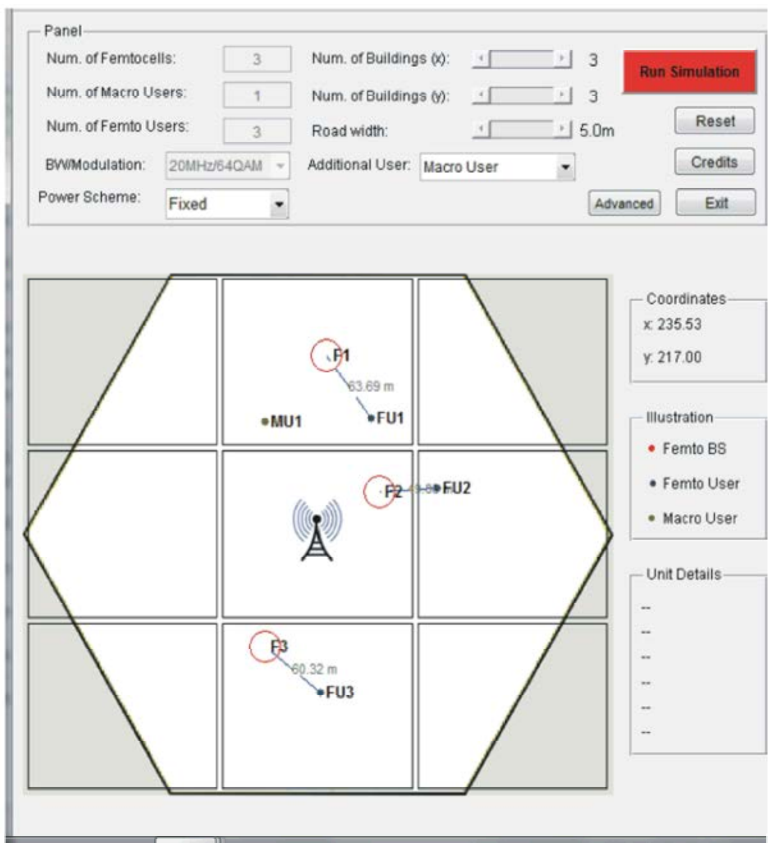

Fig. 4: Placements of Femtocell and Femto Users

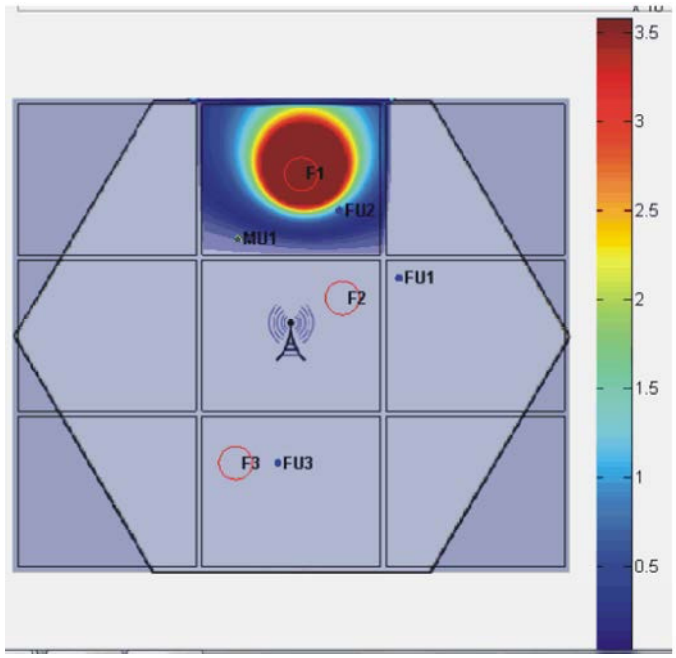

Fig. 5: Interference of Femtocell

The parameters for the analysis of femto-macro interference are summarized in the Table 2:

Figure 5 illustrates the map colored accordingly. It reveals that the throughput of the femto user is highly decreased at the building's surrounding environment, due to cross-tier interference and path loss [18, 19].

Here the radius of the macro cell and femtocell are considered in meter (m).

CONCLUSION

In this paper, a simulation framework for femto-macro interference is used and their various interferences have been analyzed using LTE simulator. Furthermore, possible indoor interferences between the macro base station users and the femto base station users were analyzed and the corresponding SINR and pathless incurred were estimated. From the simulation results users can deploy their femtocell in their indoor environment and the simulations can be used to prevent much of interferences with the neighboring femto users and macro users. Future research can be done on a self-organizing and self healing femtocell network where the femtocell can heal themselves from the various types of interferences. Self healing coordination of femtocell involves detection, diagnosis and self repair; these can be concentrated in the future.

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