PERFORMANCE EVALUATION OF LTE FEMTOCELL IN AN INDOOR CELLULAR NETWORK

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Abstract— Long-term evolution (LTE) femtocells represent a very promising answer to the ever growing bandwidth demand of mobile applications. They can be easily deployed without requiring a centralized planning, to provide high data rate connectivity with a limited coverage. In this way, the overall capacity of the cellular network can be greatly improved. This paper investigates the use of femtocell as a solution to improve indoor coverage and off-load mobile data indoors on the macro cellular networks. Specifically, the article deals with a performance analysis of femtocell in an indoor cellular network. This is achieved by designing and modeling femtocell network in an indoor cellular network using an open source LTE-Sim Simulator. The performance metrics of the femtocell were obtained by measuring the SINR and the throughput. These performance metrics were discussed and compared to the macro cellular networks. The results demonstrate that femtocell assures improved indoor coverage, provides better network capacity than the 3G macro cellular networks.

Keywords—LTE femtocell, LTE sim, indoor networks

I. INTRODUCTION

LTE is being standardized by 3GPP to provide multi-megabit bandwidth, more efficient use of the radio network, latency reduction, improved mobility, and potentially lower cost per bit. The 3GPP introduced a new low-power and small range radio based station, i.e., the HeNB, for providing broadband services in indoor and outdoor environments. Such a device is connected to the operator network through a DSL line available at consumers' houses or offices, like a common Wi-Fi access point. The very limited geographical area it covers is called femtocell [2]. In conventional cellular networks, indoor users experience low Signal to Interference plus Noise Ratio (SINR) due to high penetration loss of radio signals thus leading to low throughput. However, it is found that most high bit rate demand is from indoor users [1]. As per traffic statistics given by Huawei and Nokia-Siemens [7], 60% of the voice and video traffic in cellular networks come from indoor environments. Further, poor throughput is also experienced by users at cell edge due to high pathloss and heavy co-channel interference from neighboring base stations in Orthogonal Frequency Division Multiple Access (OFDMA)-Single Frequency Network (SFN). To improve the situation link budget needs to be improved. A fundamental parameter is the desired received signal strength. Femtocell is one of the important approaches to address this issue.

This article investigates the use of Femtocell as an effective alternative to off-load traffic on the macro network and improve cellular coverage in indoor environment. Specifically, the article will consist of simulation of indoor network in a commercial area using Femtocell as an access point, with LTE-Sim open source simulator. Simulations will then be carried out to measure signal to-interference plus noise ratio (SINR) and throughput of Femtocell and also comparison will be made with LTE macrocell to evaluate the network performances in an indoor environment.

Rest of the paper is organized as follows: Section II describes the resource allocation in LTE femtocell, simulation parameters and scenarios are presented in Section III. Then, Section IV provides the simulation results and discussion. At last, conclusion is provided in Section V.

II. RESORCE ALLOCATION IN LTE FEMTOCELLS

The LTE system is mainly composed by two parts: the air interface, i.e., the evolved-universal terrestrial radio access network (E-UTRAN), and the packet switched core net work, known as Evolved Packet Core. From the network side, the evolved NodeB (eNB) is the only node of the E-UTRAN and it is in charge of providing network connectivity through the air interface to all user equipments (UEs) in the cell, according to the classic cellular network paradigm.

At the physical layer, the radio interface supports both frequency and time division duplexing. Channel access, According to [2], radio resources are allocated in a time/frequency domain. In the time domain, they are distributed every transmission time interval (TTI), each one lasting 1ms. Furthermore, each TTI is composed by two time slots of 0.5 ms, corresponding to seven OFDM symbols in the default configuration with short cyclic prefix; 10 consecutive TTIs form the LTE Frame lasting 10ms. In the frequency domain, instead, the whole band width is divided into 180 kHz sub-channels, corresponding to 12 consecutive and equally spaced sub-carriers. At time/frequency radio resource, spanning over one time slot lasting 0.5 ms in the time domain and over one sub channel in the frequency domain, is called resource block (RB) and corresponds to the smallest radio resource that can be assigned to an UE for data transmission. At the physical layer, LTE allows variable bandwidth from 1.4 MHz up to 20 MHz and provides radio spectrum access based on the Orthogonal Freq. Division Multiplexing (OFDM) scheme. The air interface uses OFDMA and Single Carrier Frequency Division Multiple Access (SC-FDMA) for the down link and up link respectively.

The scheduler in the MAC layer of the eNodeB allocates the available radio resources among different UEs in a cell through proper handling of priority. The scheduling method used largely impacts the throughput of individual users as well as throughput of the cell. Following resource scheduling algorithms are used to in these simulations. *Proportional Fair, Frame Level Scheduler [4], Logarithmic Rule Algorithm [5], Exponential Rule Algorithm*.

III. SIMULATION PARAMETERS

To investigate the performance of femtocell in an indoor network, a realistic cell scenario of 500 m layout overlapped with 25 femtocells and shown in fig. 1 and fig .2. A Down link BW of 5 MHz is used. For channel model, a propagation loss model for an urban cell has been considered for macrocell structure according to [5]. It takes into account all phenomena influencing channel conditions: (i) the path loss, (ii) the shadowing, (iii) the loss due to penetration and (iv) the fast fading effect due to the multi path propagation. In particular, the path loss, PL, is given by the expression PL = 128:1 + 37:6 log d, where d is the distance between the eNodeB and the UE, in kilometers.

The large scale shadowing fading has been modeled through a log-normal distribution with 0 mean and 8 dB of standard deviation. The penetration loss has been set to 10 dB. Finally, the time frequency correlated signal multipath is modeled by using the Rayleigh fading channel model. Moreover, in order to cope with the peculiar features of femtocells, the path loss model i.e. Femtocell Urban Area Model has been considered which also takes into account an additional attenuation factor while calculating the path loss i.e. external wall attenuation with default value of 20 dB.

An indoor structure composed by 25 apartments, each one delimiting the area of a given femtocell located over a 5 × 5 grid has been developed. Femtocells operate in open access mode. Main simulation parameters are summarized in Table 1.

Table 1 Simulation Parameters

Parameter	Assumption
Carrier Frequency	2GHz
Downlink Bandwidth	5MHz
eNB Transmission Power	43dBm
Propagation Model	Macro-cell and Femtocell Urban scenario
Path loss Model	128.1+37.6log 10 R
Macrocell radius	500 meters
Indoor Structure	Building Type : (5 x5) Grid type Apartment Size :100 m 2 No. of Femtocell :25 Access policy :Open Access
Traffic	Real time traffic type :Video (242 kbps), VOIP

A *Simulation scenario without femtocells*

Traditional urban environment without femtocells where only one macro cell and buildings are used as reference case, this scenario is to investigate the performance of network without femto cells.

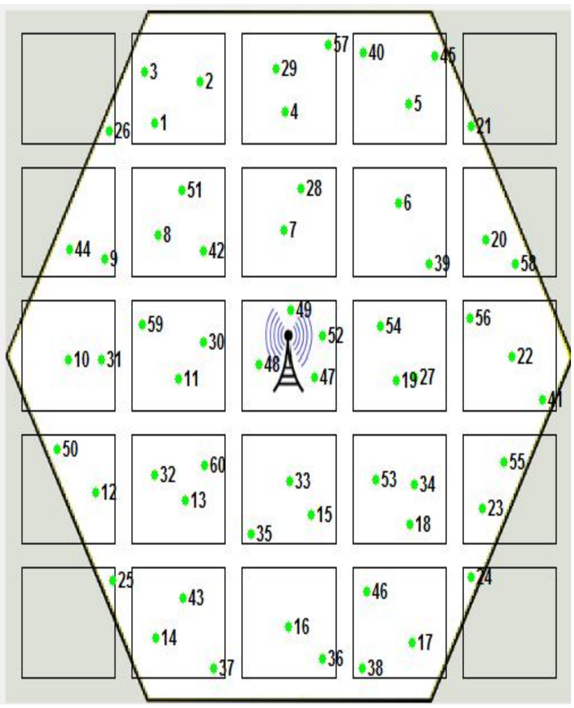

Fig. 1 5X5 apartment grid with one macrocell and 60 users

Macro cell provides the coverage for all indoor users is considered and deployment is shown in fig. 1 with one macro cell and 60 users (shown in green colour, scenario is created using LTE-Advanced simulator for more understanding purpose)

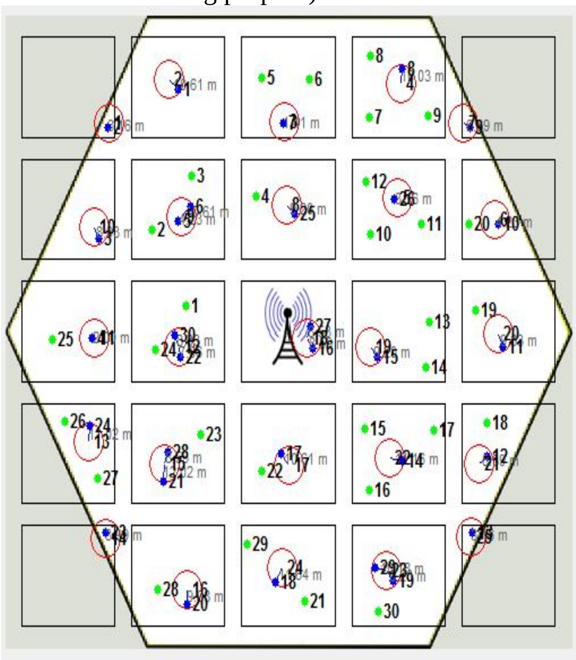

Fig.2 5X5 apartment grid with one macrocell, 25 femto cells and 60 users

B Simulation scenario with femtocells

Urban environment with femtocells where one femtocell per apartment is assumed to be active and working on the same operative bandwidth of the macrocell. This scenario is to investigate the performance of indoor network with femto cells. One Macro cell and 25 femto cells provides the coverage for all indoor users is considered, red colour circles are coverage range of femtocells shown in fig. 2. Macro users are shown in green and femto users are shown in blue color.

IV. PERFORMANCE EVALUATION

To analyze the performance several simulation scenarios has been considered, as network without femtocells, with femto cells, with streets and with reuse schemes. Power distribution of different scenarios is depicted in fig. 3. Cdf of SINR of different scenarios is presented in fig. 4, it is observed from the Fig. 4 macro with femtocell is having higher SINR strength than the remaining scenarios and also from Fig. 4, it is evident that the adoption of a frequency reuse scheme improves the channel quality perceived by users.

Throughput comparison of only macro and macro with femtocell with 60 users and 40 users is shown in fig. 5 and it is found that offloading macro cell traffic to femtocells helps in increasing sum–cell–throughput significantly.

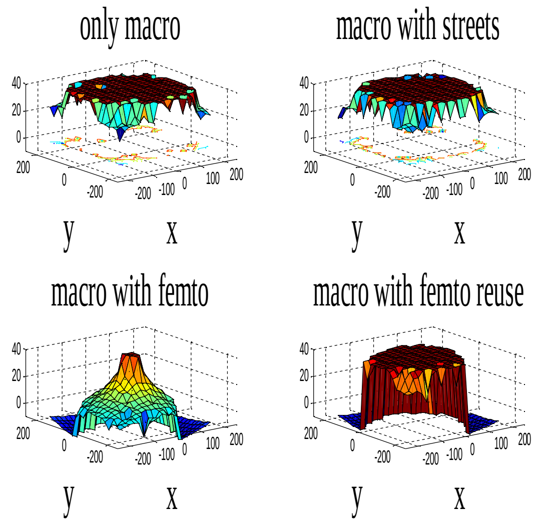

Fig. 3 Distribution of power for different scenarios

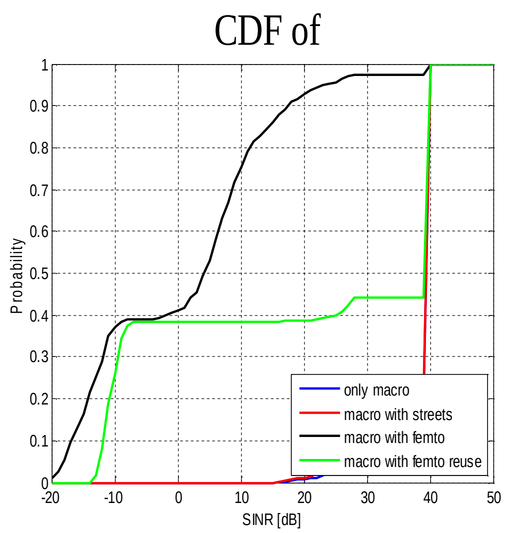

Fig. 4 Cdf of SINR for different scenarios

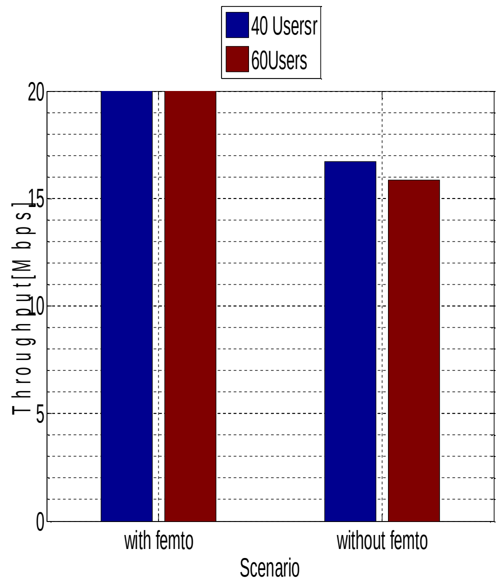

Fig. 5 Throughput of an indoor network

CONCLUSION

In this paper, the performance evaluation of femtocells in an indoor environment was simulated and measured SINR and throughput with different scenarios while varying number of users. It is found that offloading macro cell traffic to femtocells helps in increasing sum–cell–throughput significantly.

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