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Analysis of Propagation Pathloss Models and Throughput for Femto Cells

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Abstract–

This work studies about the propagation path loss models for femto cells by considering different cases for user equipment position with respect to femto cell position and estimating about throughput in each case. Different types of small cells have been used to enhance the coverage capacity of networks and femtocell is one of them.A femtocell is a wireless access point that improves cellular reception inside a home or office building. The device, which resembles a wireless router, essentially acts as a repeater. The device communicates with the mobile phone and converts voice calls into voice over IP (VoIP) packets. The packets are then transmitted over a broadband connection to the mobile operator's servers. Femto cell is the solution to improve the coverage for heterogeneous based networks in wireless communication. This paper considers an urban scenario for femto cells deployment and studies throughput by analysing various pathloss models. The simulation framework for analysis of propagation path loss models for femto cells in heterogeneous in urban environment is introduced in this work.

Keywords - small cell; femto cell; pathloss models; throughput; simulation framework.

I. INTRODUCTION

With high mobile communication rates, there is a need to provide high coverage to users. For the same reasons, femto cell access point (FAP) has received considerable attention both in commercial applications and in the literature [1]. Macro cells based coverage is not enough to satisfy user's demand. The topology and architecture of cellular networks areundergoing a major paradigm shift from voice-centric, circuit switched and centrally optimized for coverage towards data centric, packet switched and organically deployed for capacity. The principle drivers for this shift are intense consumer demand for mobile data. For example, in 2010 the amount of global mobile data traffic nearly tripled for the third year in a row, and exceeded the traffic on the entire global Internet in 2000 [2]. By 2015, nearly 1 billion people are expected to access the Internet exclusively through a mobile wireless device [2].Specifically, scenarios where indoor FAP networks are implemented in a presence of existing network of macro-cell base stations (MBS) are of great practical interest.

Path Loss is the attenuation that occurs as the voice travel over a distance or through obstacles. For example, if a speaker is loud enough that the attenuation of the sound allows the listener to hear and understand, then, communication is successful. Path Loss occurs naturally with distance and obstacle between the transmitter and receiver also attenuate signal. The application of femtocell provides a good quality of service (QoS) and high performance. Figure 1 shows the path loss within the transmitter andreceiver channel. Generally, whenever the received signalstrength is poor, it is required to use the femtocell as signal booster's receiver. Since most of the calls mainly originatefrom the indoor environment, this makes femtocell more important for indoor uses. A study by ABI showed that 50%of voice calls and more than 70% of data traffic is projectedto originate from the indoor environment in the near future. [3]

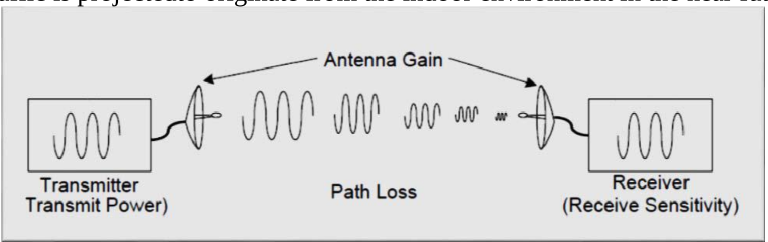

Fig 1: Show the direction of path loss between the transmitter and receiver. [3]

Interference is the major challenge when it comes to deployment of femtocells as the network topology is disturbed by the femtocell network. Interferences in femtocell network can be of the following types Macrocell to Femtocell, Femtocell to Femtocell, Femtocell to Macrocell.[4] Due to various losses, the throughput of femtocell varies with many parameters such as location and distance. Throughput is a measure of how many units of information a system can process in a given amount of time.This work investigates the throughput considering pathloss as a major parameter when macro user equipment (MUE) and femto user equipment (FUE) are at a distance from femto cell. This pathloss is analysed for three cases: 1)UE is inside the same house as femto BS. 2) UE is outside 3) UE is inside a different house.

II. DIFFERENT TYPES OF SMALL CELLS

Small cells encompass microcells, picocells, and femtocells.
Small-cell networks can also be realized by means of distributed radio technology consisting of centralized baseband units and remote radio heads. Beamforming technology (focusing a radio signal on a very specific area) can be utilized to further enhance or focus small cell coverage. A common factor in all these approaches to small cells is that they are centrally managed by mobile network operators.Small cells provide a small radio footprint, which can range from 10 meters within urban and in-building locations to 2 km for a rural location [3]. Picocells and microcells can also have a range of a few hundred meters to a few kilometers, but they differ from femtocells in that they do not always have self-organising and self-management capabilities[5].

A. Picocells

A picocell is a small mobile base station that improves in-building cellular coverage. Picocells have a range of up to 30,000 square feet and can support up to 100 users.[6]

B. Microcells

A microcell is a cell in a mobile phone network served by a low power cellular base station (tower), covering a limited area such as a mall, a hotel, or a transportation hub. A microcell is usually larger than a picocell, though the distinction is not always clear. A microcell uses power control to limit the radius of its coverage area. The range of a microcell is less than two kilometers wide.[7]

C. Femtocells

A femtocell is a wireless access point that improves cellular reception inside a home or office building. The device, which resembles a wireless router, essentially acts as a VOIP repeater.[8]

III. FEMTO CELL ARCHITECTURE

Femto cells present mobile operators with an opportunity to reduce the total cost of ownership of their voice and data services while improving customer loyalty and unlocking new revenue opportunities. The cost benefits include reducing macro RAN expansion needs for voice and 3G data capacity and lowering backhaul costs by using the subscriber broadband connection. At the same time, mobile operators will improve indoor radio coverage at the subscriber home or business and could enhance their average revenue per user (ARPU) and profitability with new tariffs, pricing plans or Femto zone services. Applicable to CDMA, GSM/UMTS, LTE and Wi MAX, Femto cells can leverage existing mobile switching centers or Session Initiation Protocol (SIP) core networks, including IP Multimedia Subsystem (IMS) networks. All Femto cell architectures use IPsec tunnels to deliver voice, messaging and packet data services to 2G, 3G or 4G handsets connected via a fixed broadband access connection to the Internet or a managed IP network. The figure 1 shows about the general backhaul connection of Femto cell network where the voice/data traffic is routed to the internet. [9]

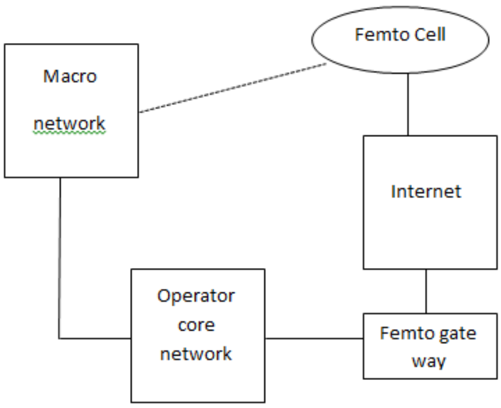

Fig 2 GFemto cell general Network Architecture [9]

To provide services to the end users having a femtocell base station, it is necessary for theoperators to define the architecture for a femtocell based on the type of cellular network. Generally, amobile phone user can switch itself to the corenetwork either by connecting itself to the femtocell or macrocell.[10]
Initially femtocells were designed just for residential use, but by observing its competency and consistency, its self-optimization and coverage principles, can be extended further to include enterprises, campus, and even metropolitan zones.[11]

IV. PROPAGATION PATH LOSS MODELS

In this work, urban scenario is considered for femto cell deployment and to calculate the path losses. Figure 4 shows Macro Base Station providing coverage to all user equipments and Femto Base Staion deployed in houses providing coverage to their respective user equipments. Propagation pathloss(PL) models are the reference formulas used to describe the propagation loss encountered in the downlink between Transmitter (femto base station) and Receiver which may be Macro User equipment (MUE) or Femto User Equipment (FUE) in this case. Pathloss formulas are valid for Transmitter-Reciever separation larger than 1 m. Here, three Pathloss (PL) model formulas canbe summarized as follows:

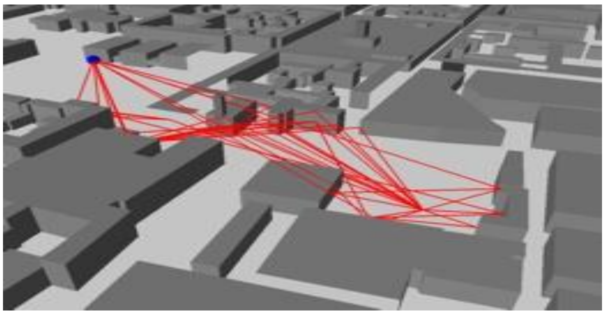

Fig 3.Urban Scenario [1]

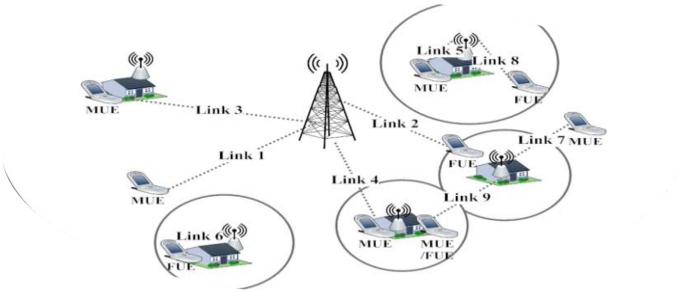

Fig4. Different Connection Links of Hybrid Macro-Femto Network [12]

1. UE is inside the same house as femto BS:

In this case, femto BS and user equipment is in the same house and assumed that there is no wall between the positions of two. The following PL model expressed in equation (1) is used when the transmitter is a femto BS and the receiver is either indoor MUE or a FUE located inside the housesuch as link 5 and 6 respectively in figure 4.

$PL(db) = 38.46 + 20logR_1 + 0.7d_{2D,indoor}$ (1)

Where,

- PL --- Path loss
- R1 --- Distance between Transmitter and Receiver
- d2D, indoor --- distance inside the house

2. UE is outside:

Here, user equipment is positioned outside the house where femto BS has been deployed. So, there will be wall between the two positions and hence wall loss has taken into consideration. The following PL model expressed in equation (2) is used when the transmitter is a femto BS and the receiver is either outdoor MUE or a FUE located outside the house such as link 7 and 8 respectively in figure 4.

$PL(db) = \max(15.3 + 37.6logR_2, 38.46 + 20logR_2) + 0.7d_{2D,indoor} + L_{ow}$ (2)

Where,

- R2 --- Distance between Transmitter and Receiver
- d2D, indoor --- distance inside the house
- Low --- Penetration loss of outdoor wall which is 10 dB.

3. UE is inside a different house:

The following PL model expressed in equation (3) is used when the transmitter is afemto BS and the receiver is either MUE or FUE located inside a different house other than that of femto BS such as link 9 in figure 4.

$PL(db) = \max(15.3 + 37.6logR_3, 38.46 + 20logR_3) + 0.7d_{2D.indoor} + L_{ow,1} + L_{ow,2}$(3)

Where,

- R3 is the distance between Transmitter and Receiver.
- Low, Low; 1 and Low;2 are the penetration losses of outdoor walls, which are 10dB.
- d2D; indoor is the total distance inside two houses as it is located in a different house. [12]

V. SIMULATION RESULTS

In this section the equation in section IV for pathloss models were used for simulation results in MATLAB and other parameters such as femto cell power, signal interference ratio were put into consideration. The throughput estimation was

calculated for all the three cases specified in section III where in one case we assumed that both Femto user and Femto Access Point (FAP) have been placed in the same house, hence avoiding outdoor walls losses. In other two cases, outdoor walls losses are present and hence throughput varies in all cases. This experiment evaluation will help us understand the behaviour of the whole Femto cell network with respect to user's position. [3]
Simulation result has been shown in figure 5, 6 and 7 for respective cases.

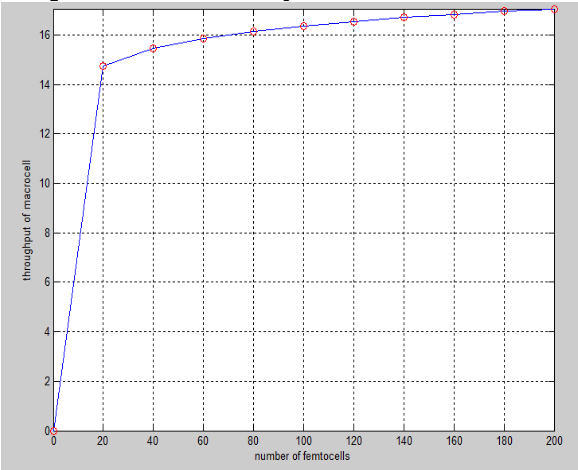

Fig 5.Throughput when UE is inside the same house as femtoBS

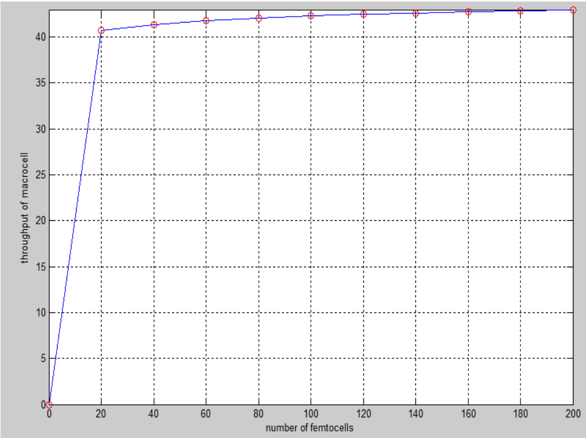

Fig 6.Throughput when UE to Femto BS is outside

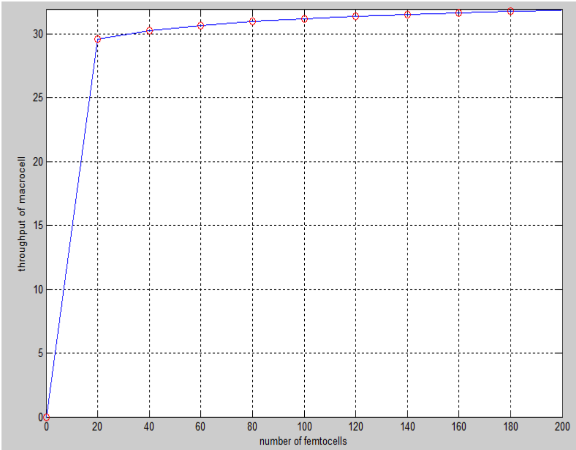

Fig 7.Throughput when UE is inside a different house

VI. CONCLUSION

In this paper, we examined femtocell throughput considering pathloss models for each case. When femto BS and UE are in the same house, there is no outdoor wall loss and hence it gives better throughput than other two cases. The case, when UE is outside the house where femto BS has been deployed shows better throughput than last case in which UE was inside the different house.
The capacity performance is achieved due tothe closeness of the base station to the end users (i.e. in case 1) within the indoor environment for quality and data coverage. It is observed that for smooth and quality service from the service provider, the base station must be closer to the end users. This will cut off expenditures from the service provider, such as

electricity bills, maintenance cost etc. so as to enable them to concentrate on quality of service for the end users of the network.

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