Indoor Communication: Femtocell Behavior in an Indoor Environment

O.A Akinlabi, B.S. Paul, M. K. Joseph and H.C. Ferreira

Abstract ---- **The indoor Telecom coverage suffers poor reception, call distortion and low voice calling quality, by signal distortions and interference. In order to improve the quality and performance of voice calls service in the indoor environment, a number of base stations are required. Therefore, femtocells were introduced in the indoor environment for signal booster and other services for end users. Femtocells are deployed in the existing macrocell network coverage to enhance network coverage in an indoor environment. In this paper, we present the simulation base on the signal and the path loss model in the indoor environment, to show that femtocell enhanced indoor communication with improved signal strength without interference.**

Index Terms— **Femtocell, Interference Management, Path loss, Macrocell**

I. INTRODUCTION

Recently, a femtocell is accepted into the mobile network for utilized as a sustainable solution that allow broadband connectivity into the telecom networks, in order to enjoy voice calling in both homes and offices. It serves in the indoor environment in which the transmitter and the base station are closer to the end user of the device. However, the prediction of path loss and wall loss are major characteristics for planning a cellular system. The unpredictability of the building material causes the variable of attenuation and difficult to support data or measurement. 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.

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Generally, whenever the received signal strength is poor, it required the use of femtocell as signal booster's receiver. Since most of the calls mainly originate from the indoor environment, this makes femtocell more important for indoor use. A study by ABI showed that 50% of voice calls and more than 70% of data traffic is projected to originate from the indoor environment in the near future [1].

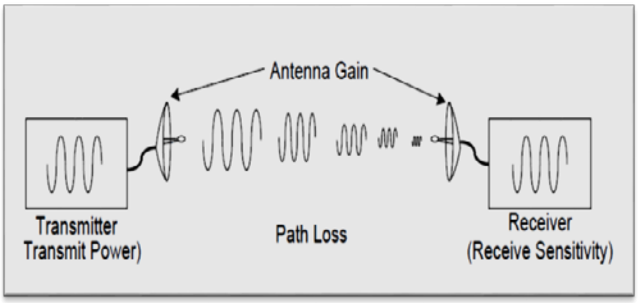

Fig. 1. Show the direction of path loss between the transmitter and receiver.

It is widely believed that, by providing a good quality of service for an indoor user, there will be an increase in revenue for the telecom operators. Femtocells are low cost, short range, which are usually installed by the subscriber [2]. It's work within the license frequency band. The access point known as Femtocell Access Point (FAP) serves as a Base Station (BSs) that allows high quality voice calls, data and multimedia service to be delivered to mobile devices in the indoor setting.

Apart from the communication enhancement of the femtocell, it can also be used to interact with smart home appliances and personal computers in the house [3] such as:

- Control TV from their mobile device
- Control home appliance such as air condition
- Synchronize music collection on their mobile device with their home PC when return home
- Leave virtual fridge note to be delivered when the recipient returns home

The FAP is used as a point to link the user's optical fiber or broadband internet connection to the mobile core network.

Another important function of the femtocells is that, it operates in a closed subscriber group (CSG), which enables limited access by registered user equipment, while other user equipment cannot access the connection.

In this paper, we consider a femtocell as a signal booster at the indoor environment and their path loss. We provide simulation results to demonstrate the performance of a femtocell at the indoor environment.

The rest of this paper is organized as follows: the benefits of deploying femtocell in section II. In section III, the health and safety of femtocell in the indoor environment. Section IV, gives an overview of interference mitigation techniques. While section V, explains the notation representation for the modelling. Section VI, presents the experimental results. Finally, section VII gives the conclusions.

II. Benefits of Deployment Of Femtocell

The application of new technology known as a femtocell reduces the building of macro cell site and churn in the network, (where the operators spend millions of dollars to reduce churn in the network and built macro cell site). Femtocell improves quality of coverage to the end users of the network at the indoor and more additional revenue for the mobile network such as internet service, video, and data service. However, femtocell maximizes the operator's revenue and increases network capacity performance. The worry of electricity bills is no more an issue for the operators. A typical femtocell network with appliances connected to a FAP is shown in figure 2. The entire smart home appliances are linked to FAP, for the purpose of voice call and security of homes or offices.

Due to poor coverage in the indoor environment, femtocell enhances the quality of the network coverage performance to be enjoyed along with additional services such as multimedia, internet, video, voice call and high speed data services with effective cost.

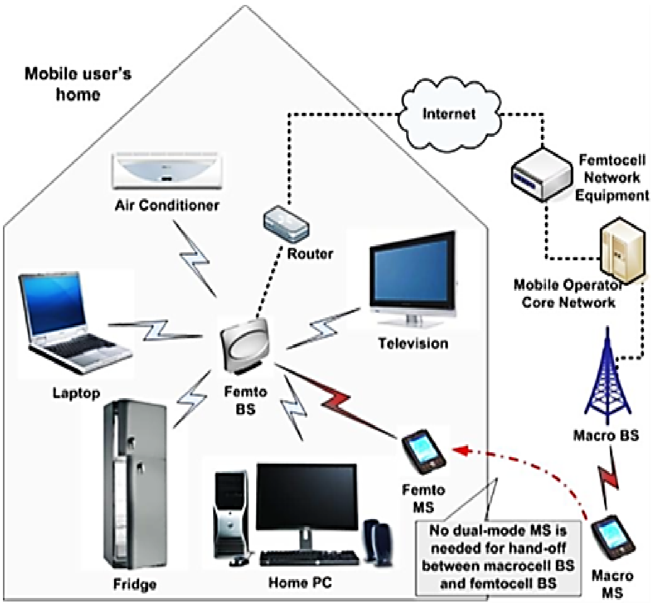

Fig. 2. Application of a femtocell in an indoor environment

III. Health and Safety of Femtocell AT THE INDOOR Environment

The use of Femtocell in an indoor environment raises some health and safety concerns that relate to the perceived association of some health problems with the use of radio radiation. Much work has been done by researchers on radio equipment. Although direct links have not been found between radiation and cancer, the general counsel is that of caution in the undue exposure to radio radiation. Moreover, the manufacturer of Femtocell has not indicated that no health threat had been reported during the usage of Femtocell in an indoor environment. Presently, the principle of radio frequency radiation is set to ranking, which allow radio transmission of several forms to be used, but at a level where current scientific research shows that there are no unreasonable risk in regard to the usage of Femtocell at the indoor environment. Femtocell fulfills all the safety limits that are applied to other wireless device such as mobile phones, Wi-Fi access points, Bluetooth devices, etc. Thus, these safety limits have been recognized by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and also authorized by the World Health Organization (WHO) and widely approved by governments around the world.

IV. Overview of interference Mitigation techniques

In this section, we describe the interference among the femtocell network in cellular network coverage where a Base Station is located at the center of the cell with a number of Femtocells randomly positioned around the cellular network. The base station, which is located in the center of the cell is known as the primary base station and that of the Femtocell is known as the secondary base station in a spectrum overlay network. The Figure 3 depicts a centralized base station with a number of femtocell base stations randomly positioned within the cellular network. However, some related work on mitigating interference management in femtocell networks for voice communication and other purpose, which is the main problem, due to their self-behavior of each user of femtocell at each region of the cellular network, completing for a common license spectrum resource. Several works of researchers have indicated their interest on mitigation techniques, in order to utilize femtocell at the indoor (for high quality of voice and other purposes). The introduction of price policy to mitigate interference management in femtocell network was proposed by Akinlabi et al [4]. Under this concept, the price was used to control the power transmission of each Femto user in the cell coverage, in order to mitigate interference and ensure the quality of the network in the cell network coverage. This concept enhances quality performance of the cell network coverage whereby as power increase, the price is updated. Dynamic frequency planning [5] is another method employed to avoid interference, and hence capacity and the throughput of the network at its optimal level. The scheme estimate sub-channels, considering each user's bandwidth in each sector. The interference is calculated when all the sectors transmit at the same frequency.

Another method of mitigating interference in femtocell network is by use of Power control scheme. In this method, power control algorithm was proposed to address the issues of interference and ensure the quality of service of the network users. The use of the fractional frequency reuse scheme with a pilot sensing approach for the purpose of reducing co-channel interference in the network [6] is also another method of mitigating interference. This scheme applied a factor of 3 for macrocell user and the reuse factor of 1 for Femtocell users. Spectrum partition and the frequency ALOHA scheme were applied here [7]. This scheme removes interference between the macrocell and femtocell by applying orthogonal spectrum.

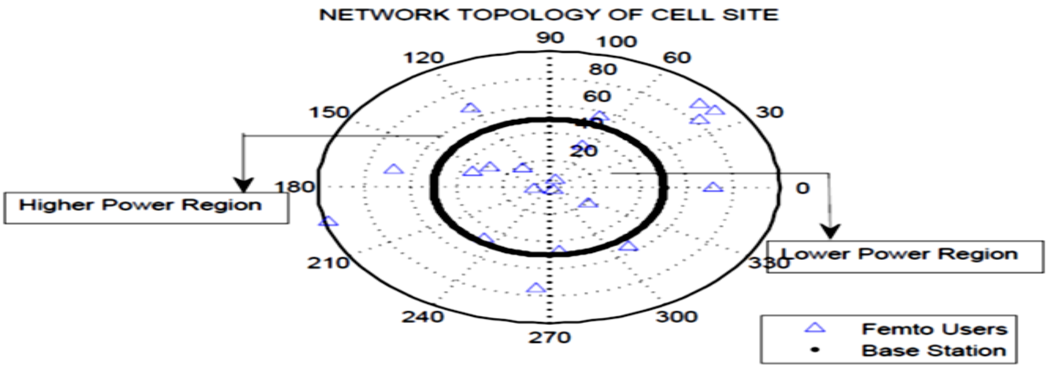

Fig. 3. A centralized base station with multiple femtocell base station

Due to high interference that exists between the macrocell and femtocell network, Ji-Hoon et al. [8], also recommend a distributed self-organized femtocell management architecture, which is known as CTRI (complementary Tri- control). This consists of three loops that determine the maximum transmission power of femtocell user, and target SINR of femtocell user, in order to protect the femtocell user from the macrocell interference. The effect of interference to neighboring macrocell users was addressed by this highly technical scheme. However, this paper addresses the indoor communication whereby femtocell is used as a signal booster, and the behavior of the femtocell performance evaluated in the indoor environment.

V. Notation System for Modelling

In this section we evaluate, and present the notation system for the modelling and the parameters for the experimental result. The primary focus is to understand the path loss model which is associated with femtocell in an indoor environment.

A. Path loss model within an indoor environment

The path loss model [9] that is used in this paper is ITU-R type of path loss model that approximates the fluctuation of a signal in an indoor environment. Thus, the path loss between the users and Femto base station in the indoor is expressed in equation (1):

$$PL(dB) = \max(15.3 + 37.6Log_{10}(d)), 38.4 + 20Log_{10}(d) + 0.7d_{2D,indoor} + 18.3n^{\left(\frac{n+2}{n+1}\right)-0.46} + qL_{iw} + L_{ow1} + qL_{ow2} \quad (1)$$

Where,
PL is the path loss model
n ---- Number of penetration floors
q ---- Number of walls separating apartments between Femto and user equipment
L_{iw} ------ Penetration loss of the wall separating rooms within an indoor
$0.7d_{2D,indoor}$ ------ Account of penetration loss due to walls inside an apartment, this is expressed in meter
d ----- Distance between transmitter and receiver in meter

L_{ow} and L_{iw} are assuming to be set to 20dB and 5dB respectively.

B. Estimation of SINR at both indoor and outdoor

In order to evaluate the performance of the network, the estimation of SINR is highly important. We estimate the SINR [10-12] for each user and each sub-carrier n. The SINR of the user K with the power P is expressed in equation (2):

$$SINR_{k,m} = \frac{P_{m,k}G_{m,k}}{N_o + \sum_M P_{k,m}G_{k,m} + \sum_F P_{F,k}G_{F,k}} \quad (2)$$

$P_{m,k}$ --------- Power transmission from the base station
$G_{m,k}$ --------- Gain channel
N_o ----------- White noise power
$P_{F,k}$ ----------- Power transmission from the FAP
$G_{F,k}$ ------------ Gain Channel from the FAP

C. Bit Error Rate

The transmission model is depended mostly on the bit error rate (BER) due to the pathloss associate to the channel. The BER of a Shannon channel capacity is mathematically expressed as shown in equation (3):

$$BER = 0.2\exp\left(\frac{1.5SINR}{2^k - 1}\right) \quad (3)$$

$$\alpha = \frac{-1.5}{\ln(5BER)} \quad (4)$$

D. Throughput estimation

To calculate the throughput [13], the capacity of Femto user on the same sub-carrier *n*, is expressed as (5):

$$C_{i,n} = W.\log_{10}\left(1 + \alpha SINR_{i,n}\right) \quad (5)$$

Where
$C_{i,n}$ ----- denote the capacity of the networks
W ----- Bandwidth for subcarrier n
$SINR_{i,n}$ -----denote our signal to interference plus noise ratio

VI. EXPERIMENTAL RESULTS

In this section, the equations in section III were used for the simulation results in MATLAB and other parameters. The transmission power of femtocell base station, and path loss were put into consideration. The throughput estimation was calculated for the Femto user in the indoor to integrate the mobile core networks. However, the simulation provides here show the behavior of femtocell signal in the indoor environment, over the existing macrocell base station at the outdoor. We assumed that both the user and FAP are placed in the same room where they experience less cross-tier interference from macrocell transmission. This experiment evaluation will help us to understand fully the merit of femtocell in the indoor environment.

Based on the simulation result, figure 4 shows the results of bit error rate against signal, where the path loss within the indoor environment is considered. The bit error rate is the key parameter in data transmission of any system that transmits a data over the network where interference and path loss causes degradation of the digital signal. From the simulation result in figure 4, show that if the bit error rate is low the signal will be high and this will improve voice calls. In reducing the bit error rate, the throughput will be achieved in the system.

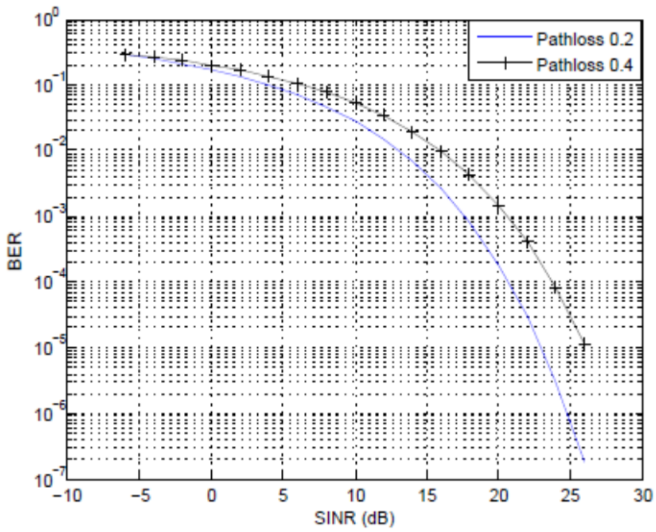

Fig. 4. illustrate the function of BER versus signal to interference ratio.

In figure 5, depicts signal behavior in both the indoor and outdoor environment. The signal at the indoor increase along with capacity, this shows the quality of FAP in the indoor environment. However, the users experience no interference rather than quality of voice calling and other service from the telecom network. More so, it used for multiple purposes for end users

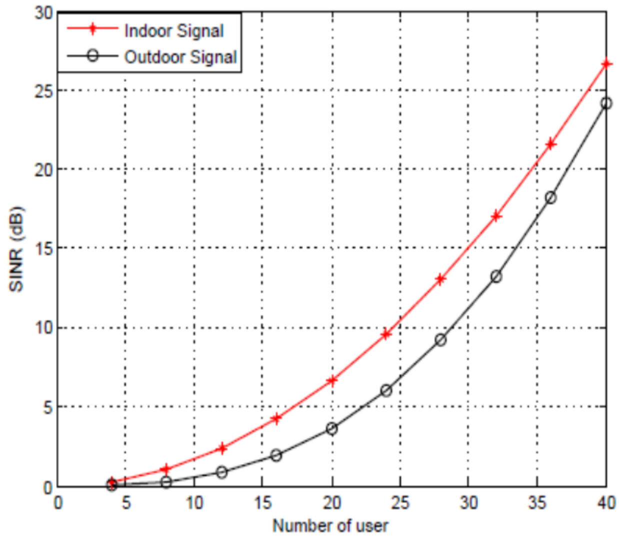

Fig. 5. Demonstrate the signal at both indoor and outdoor behavior

VII. CONCLUSION

In this paper, we examined femtocell in an indoor environment to enhance good quality service and high performance to the mobile network, where the path loss was analyzed within the indoor environment. We discovered that femtocell in the indoor environment experience no interference, whereby the end users enjoy good quality and smooth voice calls within the mobile network from the service providers.

In addition, the capacity performance is achieved due to the closeness of the base station to the end users (.i.e. FAP) within the indoor environment for quality and data coverage. We hereby 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. This allowed them to focus on quality of service for the end users of the network.

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