The Effect of Path Loss Compensation Factor to SINR Performance in Two-Tier LTE Network

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***Abstract*— In order to enhance indoor coverage, Long Term Evolution (LTE) has developed new technology called femtocells or called as Home Evolved Node B (HeNB). This low power device is a home base station that is installed by home or business user themselves. Also, this high-performance device operates in licensed spectrum and provide low cost coverage and capacity for small areas over public Internet backhaul. However, femtocell deployment in existing network caused interference between femtocells itself and interference to the existing macrocells. By having these types of interference, overall femtocell performance definitely will be affected. This paper will investigate the effect of path loss compensation factor, α in a mobile cellular system and proposed the best value of α. The values is then used in simulation to analyze UE's Signal to Interference and Noise Ratio (SINR) performance. The simulation is done using Matlab software and based on several interference scenarios that possibly occur in hierarchical mobile cellular network. Based on the simulation result obtained, higher value of α gives better SINR for UE.**

***Index Terms*—Femtocell, LTE, SINR performance, interference, path loss compensation factor**

I. INTRODUCTION

One of major challenges in our radio network nowadays is to improve indoor coverage and to provide higher data rate services demand in a cost-effective way. In order to fulfill said requirements, mobile operators need to come out with some suitable solutions and approaches. One of the traditional solutions is to have more outdoor base stations and in-building base stations. However, this approaches is not economic due to its high implementation cost.

3GPP formulated LTE to make mobile communication a more satisfying experience for users, driving demand for streaming, gaming, social networking, and other multimedia services. The LTE femtocell is a key ingredient. HeNB usually deployed in homes and businesses where it can also cover hotspots indoors and outdoors. Radio waves fade faster at higher carrier frequencies, making it hard to serve indoor subscribers with outdoor macro base transceiver stations (BTS). This requires deployment of smaller cells, such as femtocells to assure to figure prominently in LTE's future [2].

Femtocells are low power base stations that have coverage 10-50 meters, placed indoor by the end user just like Wi Fi router and provide cellular functionalities such as data and voice services. Femto Access Point (FAP) is then connected to operator's core network through user's internet connection [4]. The cells with different sizes can be deployed as in a hierarchical cell structure (HCS) to provide multi-tier network connectivity. Macrocells are deployed as one radio tier to cover wide areas, and femtocells are embedded inside macrocell as another radio tier to supply sporadic coverage. The benefits for this arrangement are increased capacity gain, better coverage, and reduced battery consumption of handset. In this paper, we consider a two-tier 3GPP LTE network that consists of overlaying macrocell and femtocell. In LTE network, an UE can access a macrocell base station (BS), i.e., eNodeB (eNB), or a femtocell BS, i.e., Home eNodeB (HeNB). An UE accessed to a macrocell BS is called an MUE, and an UE accessed to a femtocell BS is called a HUE.

Femtocells can provide a better solution for the indoor coverage problem since it have small cell radius. With such small radius, it can reduce the distance between transmitter and receiver and get a good Received Signal Strength (RSS) and the receiver end. The quality of a signal is actually measure in terms of SINR. The SINR is calculated based on transmitted power from the desired BS, transmitted power from interfering transmitters which also considering shadowing, fading and path losses [4]. Targeted SINR can be achieved by having an optimum value of α since it is important parameter that determines cell-edge performance.

The rest of this paper can be described as follows: Section II provides the researches and works that related to path loss compensation factor. Section III give brief descriptions on optimal path loss compensation factor. Then, Section IV explains the system model and assumption during simulation. Follow by evaluation on simulation result in Section V. Finally, Section VI concludes this paper and propose potential scope for future works.

II. RELATED WORKS

The path loss compensation factor will determine the fairness within the cell. The value of α will take from the following set, α ∈ {0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1}. As described in [7], with full compensation, α=1, network will enables the cell edge users that have higher path loss value to transmit at high power levels. When the compensation factor decrease and approaching 0, the fairness of the system will also decrease as the path loss of cell-edge users is not compensated. Consequently, this improves the rates for the cell center and median users due to less interference compared to the full path loss compensation case.

In [9], it stated that path loss can be compensated depends on the targeted SINR and the transmission bandwidth. The path loss compensation factor α can be seen as a tool to trade off the fairness of the uplink scheduling against the total cell capacity. Full path loss compensation surely can maximize the fairness of cell-edge users, but when considering multiple cells in a system partial path loss is better solution. In this situation, less resources are spent ensuring the transmission success from cell-edge's UE as well as less inter-cell interference caused by neighboring cell. The value of α is around 0.7-0.8 typically to give a maximum uplink system capacity without causing degradation to the cell-edge users data rate.

The path loss compensation factor was investigated in [8] based on novel fractional closed-loop power control algorithm using α range 0.7 to 1 as proposed by the standards. Simulation results have shown that system performance is improved in terms of the mean and cell-edge bit rate with α=0.8. In the ideal case, α=0.8 has shown performance gain by improving the mean bit rate by 68% and simultaneously providing the same cell-edge bit rate for a given target SINR.

In [10], the author presents two different types of power control to tackle interference problem that might occur in two-tier LTE network that consists of macrocell and femtocell. The first described method is fractional open loop power control. Using this method, HUE will calculate transmit power for uplink to serving HeNB. HeNB will receive the same SINR from all served HUEs. Transmit power of HUE is given by:

$$Tx\_PSD = \min\{Tx_{max}, 10\log(M) + \Gamma + I + \alpha PL\} \quad (1)$$

Where:

- M = Number of the assigned resource clusters
- TxPSD = Transmit Power Spectral Density (Power per Resource Cluster)
- Γ = Target SINR (dB)
- I = Average uplink interference per resource cluster (dB)
- PL = Path Loss (including shadow fading) (dB)
- Tx_max = UE's max transmit power in dBm
- α = Path loss compensation factor

With this power control scheme, HUEs will get different target SINR according to its path loss and at the same time allows cell-edge HUE to degrade the inter-cell interference to its neighbor HeNB. Path loss is compensated at the HUE uplink depends on α parameter. As mentioned in [10], the value of α can be between 0 and 1 (0 < α <1), the exact values are: [0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1]. Based on simulation result in this research paper, in the case of α=0 where there is no path loss compensation, transmit power will remain minimum. In other hand, when value of α=1 where there is full path loss compensation, the transmit power will be as maximum.

Additionally, the calculation of SINR is shown in this paper by author. From Equation 1, interference can be illustrated as below:

$$I\_HUE = Tx\_PSD\_HeNB - PL\_HUE\_HeNB \quad (2)$$

Interference at HUE is the difference of transmitted power of HeNB and path loss between HUE and HeNB. From this calculation, the SINR at HUE can be determine.

$$SINR\_HUE = Rx\_PSD\_HUE - I\_HUE \quad (3)$$

HUE's SINR is the difference between received power of HUE and interference experience by HUE. The received power of HUE is the difference of HUE's transmitted power and path loss between HUE and HeNB. Received power can be express as below:

$$Rx\_PSD = Tx\_PSD\_HUE - PL\_HUE\_HeNB \quad (4)$$

In this paper, the optimal value of path loss compensation factor will be determine from Received Signal Strength (RSS) that will be explain in detail in Section 3. The optimal values will be apply in simulation to get SINR performance of HUE.

III. OPTIMAL PATH LOSS COMPENSATION FACTOR

As mentioned in previous section, the optimal value of path loss factor will be determine based on Received Signal Strength (RSS). For h RSS can be express as:

$$RSS\_HUE = Tx\_HeNB - PL\_HUE\_HeNB - LNS \quad (5)$$

Received signal strength of HUE is the difference of HeNB's transmitted power and path loss between HUE and HeNB including log normal shadowing (LNS). For macrocell, LNS value is 8 dB while for femtocell, LNS is 4 dB [6]. The transmitted power has been fixed in this case. For macrocell, the transmitted power is fixed to 46 dBm and for femtocell the power is fixed at 20 dBm.

Figure 1 and Figure 2 show the correlation between RSS and distance between UE and eNB. The RSS value is illustrated for different α, ranged from 0 to 1. It is clearly shown as the distance between UE and eNB is increase, the RSS will decrease. In femtocell case in Figure 1, the RSS is decrease as the distance between HUE and HeNB is increase. In other hand, the RSS for macrocell is slowly decrease as the distance between MUE and MeNB keep increasing.

From both figures, the higher value of α will give better RSS. When α is set to minimum which is 0, there is no path loss compensation and the received power will keep at minimum value. As for maximum value of α=1 where is full path loss compensation is applied here, the received power is higher compared to no path loss compensation case.

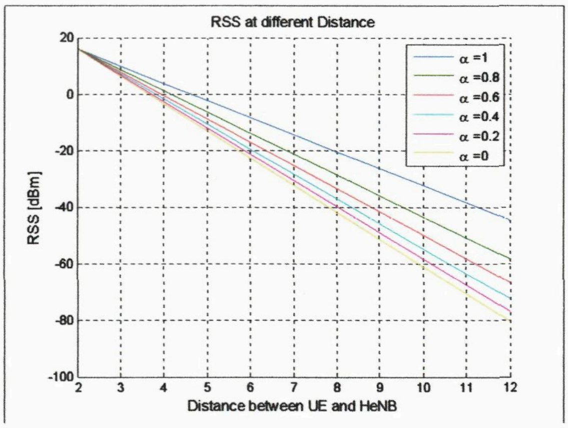

Fig. 1. Correlation between Received Signal Strength and Distance (HUE and HeNB)

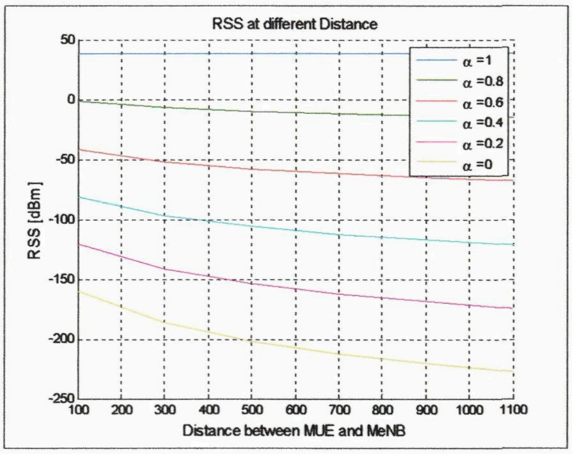

Fig. 2. Correlation between Received Signal Strength and Distance (MUE and MeNB)

Now, we will see how α value affect SINR performance of femtocell as well as macrocell. For SINR calculation, we will use Equation 3 from previous section. We will make use the received power value from Figure 1 and Figure 2. Here, we need to consider interference using Equation 2 in our calculation to get SINR value.

Figure 3 shows the SINR value for different α for femtocell while Figure 4 shows the same for macrocell. In Figure 3, the SINR is increasing as the distance between HUE and HeNB increase. SINR is maximum when α=1 where the path loss is fully compensated. As in Figure 4, the SINR is decrease as the distance is increase which is different from femtocell case. But still highest value of α will give higher SINR value.

Fig. 3. Graph of SINR of HUE vs Distance between HUE and HeNB (Different α)

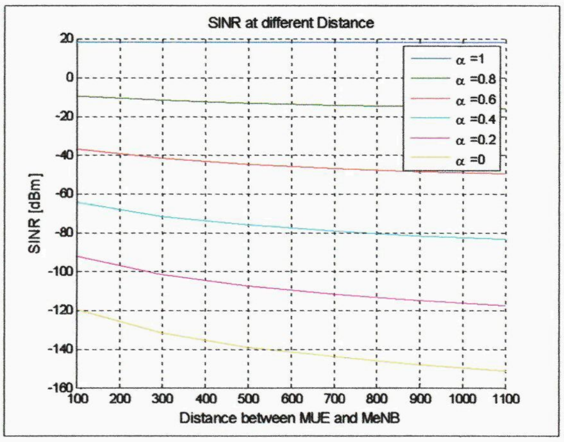

Fig. 4. Graph of SINR of MUE vs Distance between MUE and MeNB (Different α)

From above study, we will consider α value from 1 to 0.6 as this value will fulfill our requirement to meet target SINR which is 20 dBm for both femtocell and macrocell. However, since we would like to consider multiple cells in a system, we will go for α=0.8 and 0.6. As explained in Section 2 previously, partial path loss is better solution to give maximum uplink system capacity without degrading data rate at cell-edge.

IV. SIMULATION MODEL AND ASSUMPTIONS

A. Deployment Model

The simulation is done based on suburban HeNB model deployment [5] as illustrated in Figure 5. HeNB are dropped within macro coverage area with fixed position, subject to minimum separation between HeNB and MeNB. Number of HeNB in macrocell is also fixed to 2 HeNB, where each HeNB is placed in a house. Within each house, there are HUEs with specified distance of the centre point of the house. A macro UE (MUE) may be within a HeNB house as well [5].

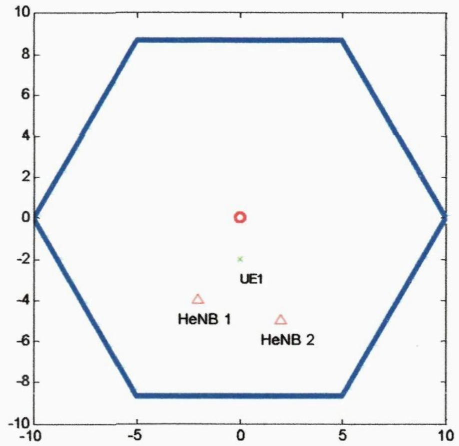

Fig. 5. Deployment Model

Note that HUE and MUE position are initially fixed in the house. The simulation will consider these 2 scenarios as shown in Figure 6 and Figure 7:

1. HUE2 attached to HeNB1, interfere with HeNB2 in the other house
2. Indoor MUE1 in House 1 attached to MeNB, interfere with HeNB1 in the same house

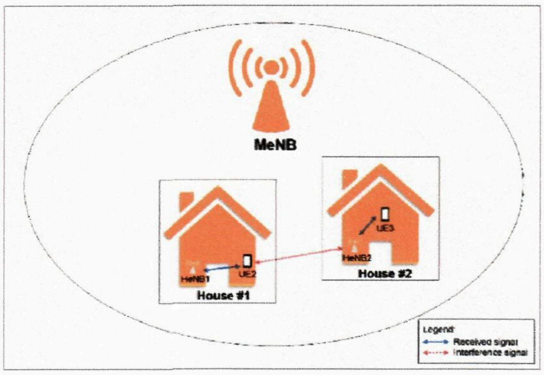

Fig. 6. Scenario 1-HUE attached to HeNB

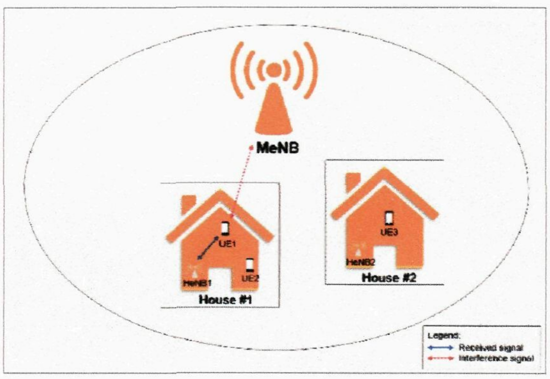

Fig. 7. Scenario 2-MUE attached to MeNB

B. Path Loss Model

In order to get SINR, we need to calculate the path loss for each scenario. We will use path loss models for suburban deployment as expressed in [5] developed by 3GPP in our simulation. The path loss in Scenario 1 for indoor HUE that in the same house as HeNB can be determine as follows:

$$PL(dB) = 38.46 + 20\log R + 0.7d \quad (6)$$

In Scenario 1, HUE also interfered by HeNB from other house. The path loss is given by:

$$PL(dB) = 15.3 + 37.6\log R + 0.7d + L_{ow1} + L_{ow2} \quad (7)$$

Whereas, for Scenario 2 which indoor MUE is connected to MeNB, the path loss is expressed as below:

$$PL(dB) = 15.3 + 37.6\log R + 0.7d + L_{ow} \quad (8)$$

In Scenario 2, indoor MUE is also interfered with HeNB in the house. Thus, the path loss is given as in Equation 6.

Where R is the separation between Tx-Rx in meter, d is distance inside house in meter and L_{ow} is the penetration loss of an outdoor wall, which is 10dB. In both scenarios, we assume that HeNB is in single-floor house and there are no barriers between HeNB and HUE.

V. SIMULATION RESULT

In this section, we present the simulation result using MATLAB software based on deployment model and assumptions as discussed in previous section. A structure framework is designed as in Figure 8 and Figure 9. Referring to Figure 8, the simulation is done when UE is moving to certain direction in a straight line. Also, the simulation will be done when UE is randomly moving to certain direction as shown in Figure 9. The result will show the SINR performance of UE when it is moving in straight line and random for each of the scenario mentioned in Section 4.

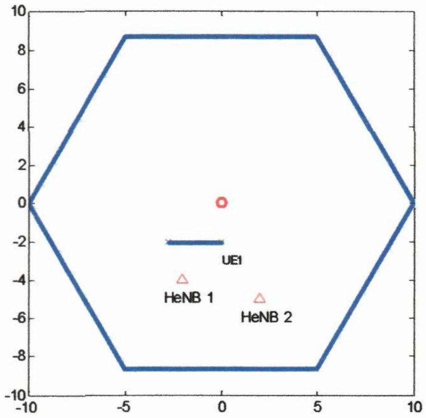

Fig. 8. UE is moving in a Straight Line

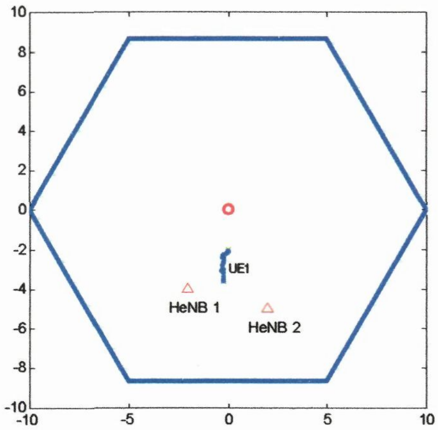

Fig. 9. UE is Randomly Moving

The selection of parameters value that will be used in simulation is based on [5]. Table 1 provides the required parameters along with the selected values.

Table I. System Level Simulation Parameters

Parameter	Value
Cellular layout	Hexagonal grid
Carrier frequency	2000 MHz
No of MeNB	1
No of HeNB	2
MeNB Power	46 dBm
HeNB Power	20 dBm
Minimum distance between UE and MeNB	>= 35m
Minimum separation UE to HeNB	20 cm
Macrocell log normal shadowing	8 dB
Femtocell log normal shadowing	4 dB
Penetration loss	10 dB

The remainder of this section presents the conducted simulation along with their results.

A. SINR Performance for Scenario 1

Figure 10 shows the SINR performance of HUE when it is moving to West in a straight line. The SINR is increasing along with HUE and HeNB distance. As describes in theory, the higher value of α=0.8 will give better SINR compared to α=0.6. Referring to the resulting reading of α=0.8, the SINR reading is better compared to α=0.6 readings. Both value of α still give increasing SINR, but higher value of α give better performance than lower value of α.

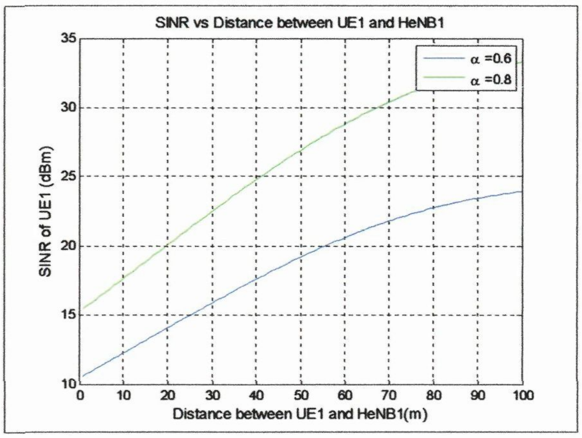

Fig. 10. Graph of SINR vs Distance When HUE is moving in Straight Line

In other hand, Figure 11 shows the SINR of HUE when it is randomly moving away from HeNB. The SINR value is fluctuated where it is increasing at the beginning but slowly decreasing at the end of the simulation. Here, the SINR is depends on the distance between HUE and HeNB. Since HUE is moving in random, the distance is not uniform as in previous result. Non-uniform distance give non-uniform SINR and make the performance graph fluctuated. Comparing results from both α value, higher value give better performance than the lower value of α. However, both SINR reading did is still in acceptable value.

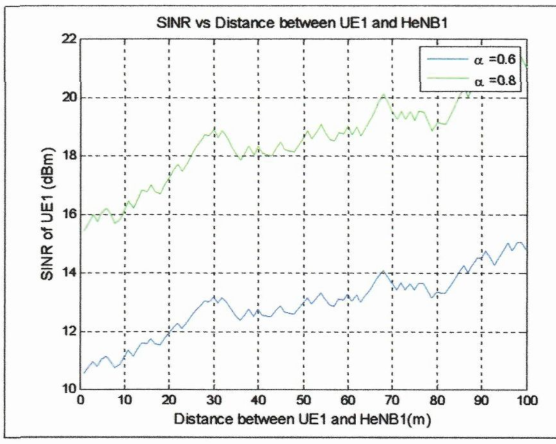

Fig. 11. Graph of SINR vs Distance When HUE is randomly moving

B. SINR Performance for Scenario 2

Graph in Figure 12 shows SINR performance of MUE when it is moving in a straight line as in Figure 8. The readings is increasing as the distance of MUE and MeNB is increasing. The SINR performance getting better as MUE travel in a straight line. In terms of α, same as Scenario 1, higher value of α will give better SINR reading compared to lower value. The SINR keep increasing and nearly reach 26 dBm for α=0.8 and nearly reach 24 dBm for α=0.6.

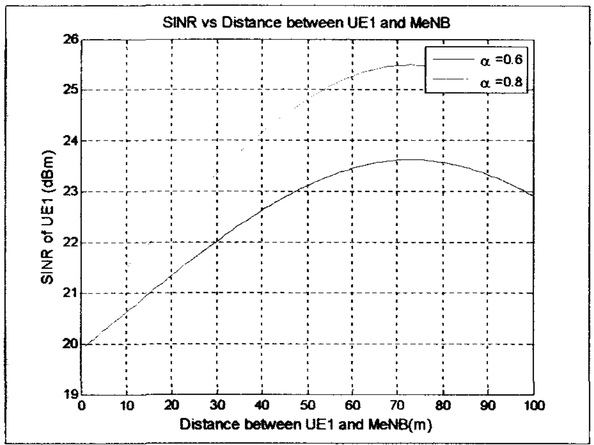

Fig. 12. Graph of SINR vs Distance When MUE is moving in Straight Line

As for Figure 13 below, the graph shows the SINR when MUE is randomly moving away from MeNB. Even the reading is not uniform, it is clearly shows that SINR is increase as the distance keep increasing. In terms of α, the higher value still give better SINR compared to lower α value.

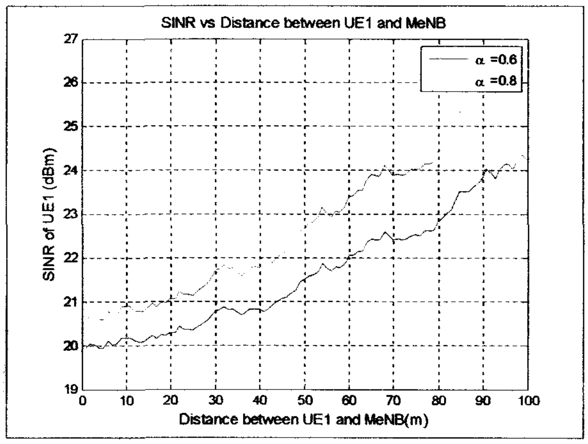

Fig. 13. Graph of SINR vs Distance When MUE is randomly moving

VI. CONCLUSION & FUTURE WORK

In this paper, we have examine the two-tier network interference of LTE network that consists of macrocell and femtocell. The investigation includes cross-tier and co-tier interference. We have evaluated SINR performance of UE that experiences interference from other BS to see the effect of interference to network performance. To evaluate the SINR performance, we also investigate correlation between path loss compensation factor and SINR performance of femtocell and macrocell in LTE network. In can be concluded that higher value of α will give better SINR, here we can say the optimal value is 0.8.

Additionally, we have evaluated the SINR performance from simulation in case where the MeNB and HeNB are in fixed location. In this simulation, UE is firstly move in straight line and then randomly move. The UE's performance is evaluated based on received SINR from simulation. The result shows that for femtocell case in Scenario 1, the target SINR can be achieved with higher value of α. However, in macrocell case in Scenario 2, the SINR is exceeded its target value where SINR can go up to 28 dB.

An interesting future work that can be done is the other method to reduce the interference and therefore increase the SINR of the system. These method could include fractional frequency reuse or self-organizing methods for the frequency allocation in the femtocell overlay.

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