# An Adaptive Power Control Mechanism for Femtocell LTE Network

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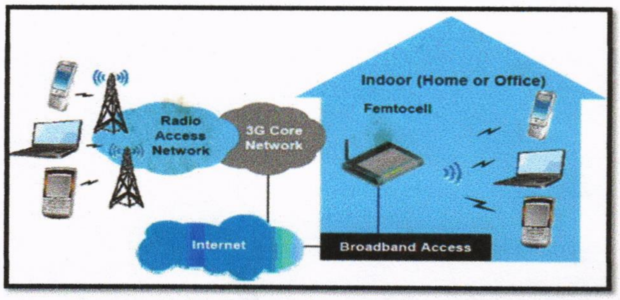
***Abstract*—The increase in capacity and system data rate may lead to capacity problems and hence become one of the crucial issues of any Mobile Communications Networks. Although the Long Term Evolution (LTE) is called as the 4th generation of the Mobile Cellular Communication Network, it can no longer solve the problem regarding the capacity of the cell. Deployed femtocells in macrocell are is one of the efficient technologies to improve the performance of mobile services in high traffic congested areas. Femtocells, also known as home base station, are cellular network access points that connect standard mobile devices to a mobile operator's network using residential Digital Subscriber Line (DSL), optical fibres, cable broadband connections or wireless last-mile technologies. It is fully user deployed and can set it by themselves thereby reduce infrastructure, maintenance and operating costs of the operator and at the same time providing better Quality of Service (QoS) to end users and high network capacity gain. This paper present the 3rd Generation Partnership Project (3GPP) LTE Power Control mechanism applying to the LTE femtocells for maximising system performance by adapting LTE Fractional Power Control (FPC) scheme on the environment and propose new Open Loop Uplink Power Control (OLUPC) techniques for LTE femtocells environment. A Simulation-based PC program is made to analyse the performance of the LTE femtocell power control schemes. The simulation results indicate the propose scheme is advantageous and can control the transmit power of the UE in femtocell along with the SINR (Signal to Interference plus Noise Ratio) as compared to the conventional open loop power control.**

***Keyword*- LTE, Femtocell, Uplink, Power Control, SINR (Signal to Interference plus Noise Ratio)**

## I. *INTRODUCTION*

In telecommunications, LTE is a wireless data communications technology and an evolution of the GSM/UMTS standards. LTE is being developed by the 3GPP standards body that is also responsible for GSM and W-CDMA. The 3GPP unites 6 telecommunications standards bodies, ARIB Japan, ATIS USA, CCSA China, TTA Korea, ETSI Europe and TTC Japan known as Organizational Partners and provides their members with a stable environment to produce the highly successful Reports and Specifications that define 3GPP technologies. Mobile networks have evolved through a series of innovations to meet the ever-growing demand for wireless services, beginning with the analog cellular networks introduced almost 30 years ago. The main goal of LTE was to increase the capacity and speed of the wireless data networks using new Digital Signal Processing (DSP) techniques and modulations. Besides, the further goal was to redesign and simplification of the network architecture to an IP-based system with significantly reduced transfer latency and reduced delay. The LTE specification provides uplink peak rates of 75 Mbit/s , the downlink peak rates of 300 Mbit/s and QoS provisions allowing the transfer latency of less than 5 ms in the radio access network [17]. LTE supports scalable carrier bandwidth, from 1.4 MHz to 20 MHz and supports both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD). In addition, LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink, which is better suited than W-CDMA for achieving high peak data rates in high spectrum bandwidth. Besides the downlink, the uplink LTE uses SC-FDMA (Single Carrier Frequency Division Multiple Access), a technology that provides advantages in power efficiency and hence resulting terminal battery life versus a pure OFDM approach.

Femtocells are low-power cellular base access points and short range, typically designed for use in homes or small businesses. It can combine mobile and internet technologies within the homes or building. The femtocell unit generates a personal mobile phone signals in the home and connects to the service provider's network via broadband (such as DSL or cable). By doing this, it will allow the users to improve the coverage and capacity within their home for better data and indoor voice reception. As a user, you can just buy and install your femtocell access point in your premise and feel free having own independent mobile network in the premise.




Source: Pakistan's Telecom & Technology [5]
Figure 1. Femtocell Network

To summarize, the key attributes in favour of femtocells are the following:

i. **Better coverage and capacity** - Due to their short range of transmit-receive distance, femtocells can greatly lower the User Equipment's transmit power, prolong handset battery life and achieve a higher signal-to- interference-plus-noise ratio (SINR). These may improve signal reception and higher capacity. Because of the reduced in interference, there are more users can be packed into a given area in the same region of spectrum, thus can increase total number of active users per unit area.

ii. **Simplification of maintenance** – The subscribers can set up the femtocells by themselves and hence simplify the operation and maintenance issues for mobile network operators.

iii. Femtocells can give a larger section of their resources (transmit power & bandwidth) to each subscriber as femtocells serve only around 1-4 users at one time. But, on the other hand, macrocell has a larger coverage area (500m -1km radius); with a larger number of users thus providing Quality of Service (QoS) for data users is more difficult [3].

The paper is structured as follows - Section II provides a brief description of Interference in LTE. Section III discusses the Open loop power control component. Section IV gives the details of simulation and results of the findings. Lastly, conclusions followed by future work are in section V.

## II. INTERFERENCE IN LTE

In OFDMA, the User Equipment (UE) assigned to different sub-carriers and they are orthogonal in frequency in one cell. In the case of Frequency Reuse Factor (FRF) is equal to 1 and to improve spectral efficiency of the system, neighbouring cells use the same frequency. If the UE sends the data in the same sub-carrier with the other UE in the neighbouring cells, it will lead to inter-cell interference (frequency collision), which will degrade or lower the bit rate, especially for the UE located at the edge of the cell. Based on the condition, it can be said that the inter-cell interference between neighbouring cells can dominate or control the system performance.

There are 3 types of Uplink interferences cases are illustrated as in Figure 2:

i. *FemtoUE to FemtoBS* – Uplink interference from Femto User Equipment (FemtoUE2) which serving by Femto Base Station (FemtoBS2) which is working also in the Macro Base Station. FemtoUE2 is in the edge of the FemtoBS premise could interfere to neighbouring FemtoBS link.

ii. *MacroUE to FemtoBS* – Uplink Interference from Macro User Equipment (MacroUE1) which serving by Macro Base Station to Femto Base Station which is working in the Macro Base Station premise.

iii. *FemtoUE to MacroBS* – Uplink Interference from Femto User Equipment (FemtoUE1) which serving by Femto Base Station near the Macro Base Station to Macro Base Station. The FemtoUE which is very near to the Macro Base Station Uplink. The Macro Base Station is the normal base station that managed by the service providers (In LTE it is called as enhanced Node B (eNB)).

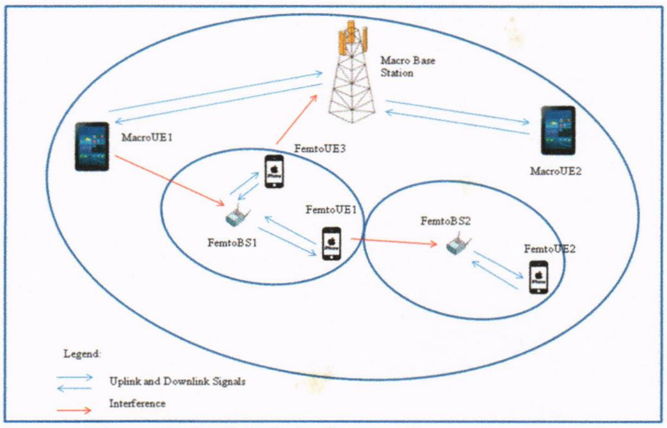



Figure 2. Uplink Interference Scenarios

From the above interference cases of the LTE femtocell system, we will further discuss the interference case from FemtoUE to FemtoBS in simulation analysis.

## III. FRACTIONAL POWER CONTROL ALGORITHM

Power control is a crucial radio network function in cellular systems environment and plays an important role on the uplink of LTE cellular networks. Implementation of LTE is based on new multiple access schemes on the air interface: OFDMA in downlink and SC-FDMA in uplink. Usage of SC-FDMA in uplink eliminates intra- cell interference. In LTE, the Power Control methods for LTE Uplink is divide into many types depends on the different schemes and processing on the parameter values. Based on different channel variations, two different power control categories have been define:

a) *Slow Power Control*: compensates for slow channel variations (path loss, shadow fading);

b) *Fast Power Control*: compensates for fast channel variations, like fast fading.

Besides above categories, there is another classification for power control algorithm depending on the cooperation to the Base Station, it is called:

a) *Open Loop Power Control*: the power is set at mobile terminal using parameters and measures obtained from signals sent by the Femto Base Station (FemtoBS). In this case no feedback related to the power being used for transmission by the user equipment is sent to the Base Station (One-way communication)

b) *Closed Loop Power Control*: The mobile terminal or User Equipment (UE) sends its feedback to the FBS, which is used afterwards to correct the user Transmit Power so as to optimize the system performance. (Two-ways communication)

### A. *The Power Control (PC) Scheme in LTE Uplink*

In this section, the LTE Uplink Power Control standardized method for macrocell and femtocell are calculated and illustrated. Besides, some analysis on the correlation of the parameters is done for further improvement and adaptation for the femtocell environment in mobile network.

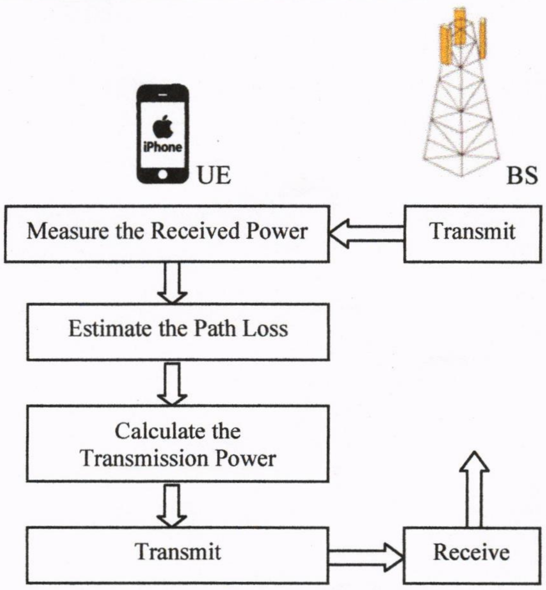



Figure 3. Block diagram of steps involved in setting the uplink power using the open-loop control

#### *1. LTE Fractional Open Loop Power Control*

The setting of the UE transmits power (in femtocell), $PSD_{TX}$, for the uplink transmission is defined in Equation (1) in dB scale. We will name this equation as Fractional Open Loop (FPC) equation in the next section.

$$Power_{TX} = \min\{P_{max}, Po + 10*\log_{10}(M) + I_{serving} + \alpha*PLoss\} \quad [dB] \qquad (1)$$

Where:

- $Power_{TX}$: Transmit Power of the UE (per Resource Cluster)
- $P_{max}$: Maximum transmit power of FemtoUE allowed in uplink and it depends on UE - in dBm.
- Po: The power to be contained in one PRB measured in dBm/PRB.
- M: The number of the assigned resource cluster
- $I_{serving}$ :Uplink interference per resource cluster
- PLoss: Uplink Path Loss between user and serving BS (including shadow fading)
- $\alpha$ (alpha): slope parameters (the path loss compensation factor in the range [0 1])

Refer to Equation (1), the meaning of the equation is the UE choose the transmit power as minimum of the maximum power and path loss compensated power.

In order to understand the Fractional Open Loop Power Control, some simplifications and assumptions are needed and the parameters as as follows:

- $P_{max}$ : fixed at 100mW (20dBm)
- $\alpha$ (alpha) : Equal to all cells in the system

Refer to interference cases as mentioned previously, for next discussion we will focus on the *Interference Case1 – FemtoUE to FemtoBS* as illustrated in Figure 4 which is only focused the interference within femtocell environment.

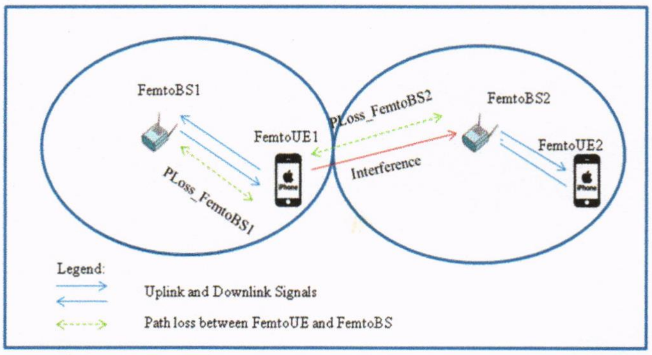



Figure 4. Interference Case 1 (FemtoUE to FemtoBS)

According to 3GPP specifications [4], the slope parameter $\alpha$ can take the value between 0 and 1 i.e. [$0<\alpha<1$] (the values are confirmed by 3GPP in release 8 in 2007). By using Equation (1), we can develop a graph showing the correlation of the Transmit Power of FemtoUE with the different $\alpha$ value as shown in Figure 5.

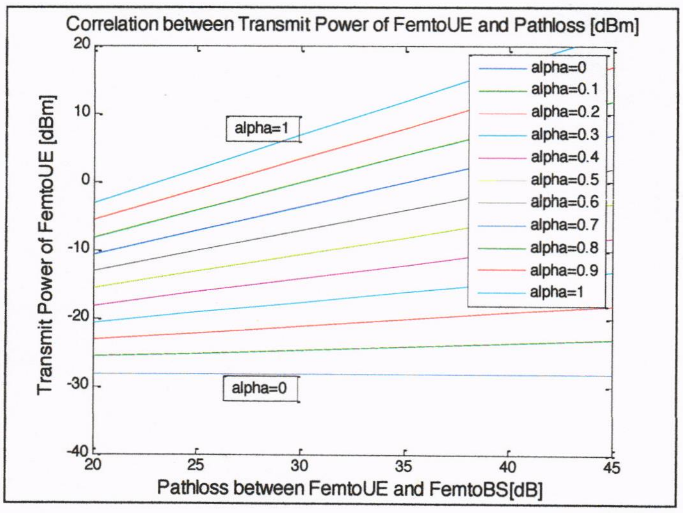



Figure 5. Correlation between Transmit Power and Path Loss (for different values of alpha, $\alpha$)

As in Figure 5, when $\alpha$=0, which means no path loss compensation, hence transmit power will be constant as minimum. Besides, we can say no power control mechanism is implemented and all mobile terminals use the same transmit power. The case when α=1, it corresponds to full path loss compensation and transmit power will be at maximum value. For α in the interval 0 and 1, a compromise is being done in between full compensation and no power control mechanism. Hence, in this case, a fractional compensation of path loss is used and it is also depending on the condition of the particular cells either cell edge users or cell centre users. Also, in this case, the transmit power is limited to 20dBm as maximum transmit power of the FemtoBS. Terms SINR, Signal to Interference plus noise ratio, is a function of a power used at the transmitters to measure the quality of wireless connections. The energy of a signal fades with distance and measured in dB.

From Equation (1), we can calculate the Interference, I at the FemtoBS2 is as below:

$$I\_FemtoBS2 = (Power_{TX}\_FemtoUE1) - (PLoss\_FemtoUE1\_FemtoBS2) \quad (2)$$

The interference at FemtoBS2 is the difference of transmission Power of FemtoUE1 and path loss between FemtoUE1 and FemtoBS2. From this calculation, the SINR at FemtoBS2 as below:

$$SINR\_FemtoBS2 = (Power_{RX}\_FemtoUE2) - (I\_FemtoBS2) \quad [dB] \quad (3)$$

SINR at the FemtoBS2 is the difference between received power of FemtoUE2 and interference at FemtoBS2. The received power of Femto_UE2 is the difference of transmit power of Femto_UE2 and path loss between Femto_UE2 and Femto_BS2 as follows:

$$Power_{RX} = (Power_{TX}\_FemtoUE2) - (PLoss\_FemtoUE2\_FemtoBS2) \quad [dBm] \quad (4)$$

Using equation (2), (3) and (4), The SINR value at FemtoBS2 is as below equation:

$$SINR\_FemtoBS2 = [(Power_{TX}\_FemtoUE2)-(PLoss\_FemtoUE2\_FemtoBS2)] - [(Power_{TX}\_FemtoUE1)-(PLoss\_FemtoUE1\_FemtoBS2) \quad [dB] \quad (5)$$

Path Loss between FemtoUEs and FemtoBSs are calculated according to the ITU-R P.1238 path loss model [18] when distance power loss coefficient N=28 is assumed as below:

$$PLoss = (20*\log(F)) + (N*\log_{10}(D)) + Lf(n) - 28 \quad [dB] \quad (6)$$

Where:

- N: distance power loss coefficient
- F: frequency in MHz
- D: separation distance in meter between the base station and portable terminal (where d> 1m)
- L: floor penetration loss factor in dB
    - 20dB between FemtoBS1 and Femto UE2
    - 0 dB between FemtoBS1 and FemtoUE1
- n: number of floors between base station and portable terminal ($n \geq 1$)

Path loss equation is propagation data and prediction methods for the planning of the indoor radio communication systems and radio local area networks in the frequency range 900MHz to 100GHz.

Based on the path loss equation and using higher α values (α=0.6, 0.7, 0.8, 0.9, 1), we simulate a program using Matlab to generate SINR graph by varying the distance from FemtoUE to FemtoBS.

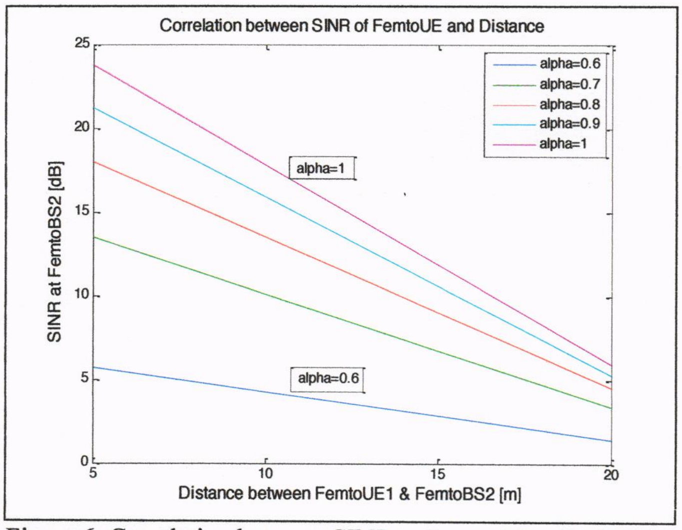



Figure 6. Correlation between SINR at FemtoBS and Distance from FemtoUE to FemtoBS

From Figure 6, we can see that higher α value will give higher value of SINR. In terms of FemtoUE location, the FemtoUE near FemtoBS will have a higher SINR as compared to UE located at edge cell. When α is less than 1, the SINR decreases with path loss. The FPC of LTE is Open Loop which compensates for the Path Loss for the selection of optimal power of UEs. The analysis is completed for the correlation of the Transmit Power to Path Loss and SINR of different α parameters and distance. From the analysis, we will choose higher α value for further simulation and comparison in the next section.

2. *Adaptive Open Loop Power Control*

The objective of Open Loop Power Control technique is to compensate the path loss of the FemtoUE only to the serving FemtoBS, but not the neighbouring FemtoBS. This means that it can improve the efficiency of the spectrum, but does not take into account the interference generated FUE to neighbouring cells. It means the FemtoUE can improve the spectral efficiency but does not take into account the interference value that FemtoUE generate to the neighbour cell. From Equation (3), the only way to decrease the SINR level at FemtoBS is the degradation of $Power_{RX}$_FemtoUE2, or in other words to degrade the transmit power of aggressor FemtoUE2. In this section, we will consider the interference value of the neighbour cell and hence the propose equation or known as Adaptive Power Control (APC) can be written as follows:

$$Power_{TX} = \min \{P_{max}, Po + 10*\log_{10}(M) + I_{serving} + \alpha*DELTAPLoss\} \quad [dBm] \quad (7)$$

In this situation, the FemtoUE use the difference of serving and neighbouring path losses:

DELTAPLoss = (PLoss_FemtoBS1) – (PLoss_FemtoBS2)

The path losses to the neighbour Femto Base Station are known from the 3GPP specification as in [6], [7].The difference of two path losses DELTAPLoss should not be equal to zero.

## IV. SIMULATION AND RESULTS

In this section, the simulation and results for the LTE FPC technique and Adaptive Power Control Technique are calculated and graph of SINR are plotted. As we know, for the Femtocell users, they will require more high speed for different data services and this is why a different SINR needed for different Femtocell users.

Refer to Figure 7, the graph showing the correlation between SINR, Path Loss and Distance between FemtoUE to FemtoBS. But, when we compare the SINR value when α=0.6 and α=0.8, we can see that the value of SINR is increasing with the increase in α value. This was calculated and simulates using FPC equation (1).

On the other hand, by using propose equation (7) as in Figure 8, we can see that the value of SINR also increases at the same path loss value. So, different values of α will contribute the different values of transmit power of the UE. In Femtocell, the selection of transmit power of UE is important due to the in-building location, FemtoUE and FemtoBS located near to each other as compare to the macrocell. With that reason, the Path Loss compensation is very sensitive for the selection of the transmit power for FemtoUEs. The standard macrocell LTE Fractional Open Loop Power Control could not implement directly in femtocell environment. That is why Adaptive Power Control scheme is introduce in this project. In order to show the difference between FPC and propose equation, we simulated using Mathlab with the simulation parameters as in Table 1.

Table 1: Simulation Parameters [11]

| Parameter | Values |
|---|---|
| Carrier Frequency in MHz | F=2000 |
| Penetration Loss | 20dB for external walls |
| Number of assigned Resource Cluster | M=40 |
| Maximum target SINR of UE | 25dB |
| Maximum transmit power | 20dBm |
| Average Uplink Interference per resource clusters | α=0.6; 15dB<br>α=0.8; 20dB |
| Floor penetration loss in dB | Lout=20; external walls<br>Lin=0 ; no wall |
| Path loss between FemtoUE2 and FemtoBS1 in dB | PLoss = 20*log(F)+N*log(D2)+Lout-28 |
| Distance power loss coefficient for Residential | N=28 |
| The slope parameter values | α=[0.6 0.8] |
| Distance between FemtoUE1 and FemtoBS2 in meter | D1=5 to 25 meters (varies) |
| Distance between FemtoUE2 and FemtoBS2 in meter | D2=2 meter |

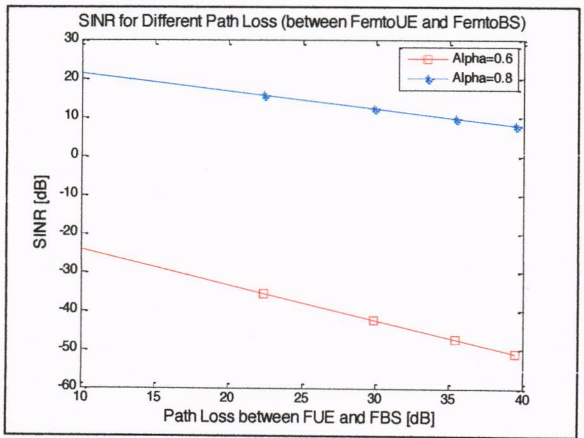



Figure 7. Correlation between SINR and Path Loss with varies of distance, d (alpha, α = 0.6 & 0.8) – using FPC equation

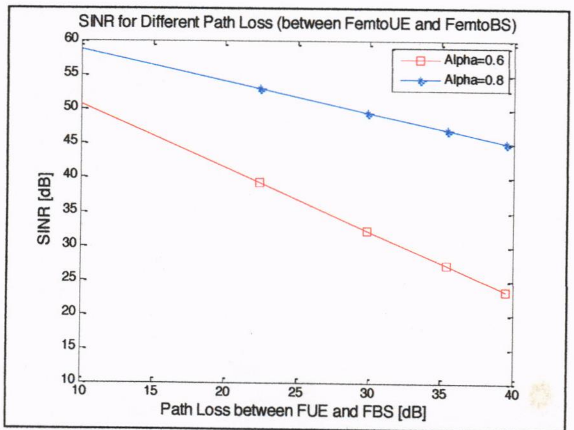



Figure 8. Correlation between SINR and Path Loss with varies of distance, d (alpha, α = 0.6 & 0.8) - using Propose/APC equation

For further simulation, as in Figure 9, a structure framework has been designed and simulated using Mathlab to compare the finding between numerical/theory and also the real situation. Refer to Figure 9, there are 2 cells with 2 Macro Base Station, 2 Femto Base Station and also 1 Femtocell User Equipment. We will simulate the program in order to generate the graph showing the correlation of SINR and Pathloss. In Figure 10, when the Femto UE moves away from FemtoBS2 (refer: blue colour line will move heading North), the distance and pathloss will increase. Due to these, SINR decreases as the FemtoUE moves away from FemtoBS.

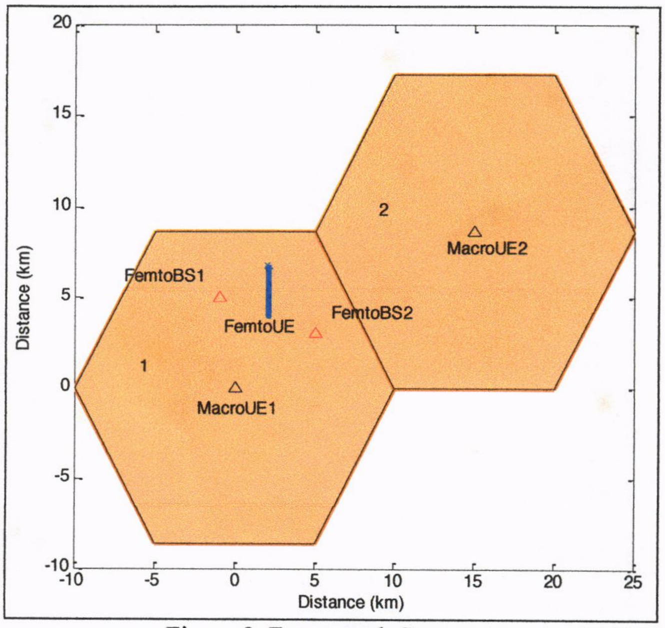



Figure 9. Framework Structure

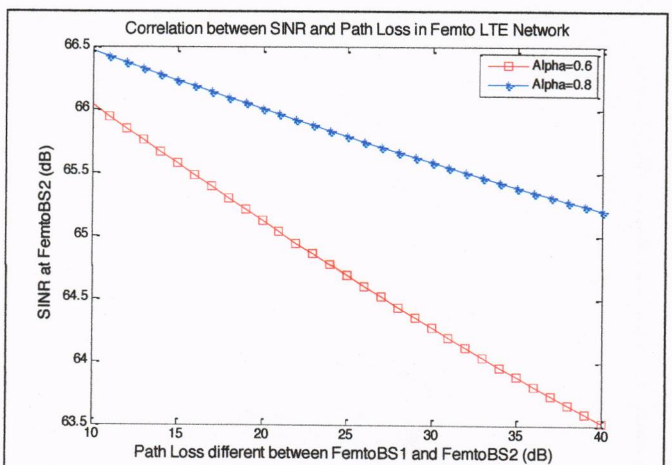



Figure 10.Correlation between SINR and Pathloss in Femto LTE Network (real situation)

It is shown that the SINR value varies with path loss of FemtoUE from FemtoBS. The values of path loss increase as we move the FemtoUE away from FemtoBS. The SINR of FemtoUE located near FemtoBS has high value as compared to the FemtoUE located away from FemtoBS or near cell edge.

On the other hand, the value of transmit power of the FemtoUE is decreases when we consider interference from neighbour FemtoBS as in propose equation. But, even we reduce the transmit power of the FemtoUE, the value of SINR still increase as in Figure 9. By using APC equation, we can control the transmit power of the FemtoUE especially for FemtoUE located near to each other, hence we can say that the propose technique suitable to use in femtocell environment.

## V. Conclusion

In this paper, we are focusing on the adaptation of the standardized LTE FPC technique for the femtocell environment by proposing an Adaptive Power Control technique.

The LTE FPC scheme compensates the Pathloss between UE and BS as the open loop approach of the Power Control which is intended for the different received SINR for FemtoUE of different locations. In other words, to allow users near the FemtoBS to have better receive SINR as compare to users far from the BS. According to the analysis, it can be concluded that the uplink Adaptive Power Control mechanism is suitable to use in femtocell for controlling the transmit power of the UE and also minimize the interference in femtocell. For future study an enhancement in power control for femtocell environment, the Closed Loop approach for LTE power control will be studied for minimizing interference thus improve the signal reception level of the UEs.

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