Performance Analysis Of Power Control For Minimizing Interference on LTE-A Femtocell

Mohammad Nasrul Hafiz Bin Shah Room
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia
40450 Shah Alam, Selangor, Malaysia
e-mail: mohdnasrulhafiz@ymail.com

Abstract—**The increases of user network today may lead to the capacity degradation and problems hence become the major issue that must be concerned in Mobile Communication Networks. Even though the Long Term Evolution - Advanced (LTE-A) well known as the 4th generation of the Mobile Cellular Communication Network, it could not longer to solve the problems regarding capacity of the cell network. In fact that networking is an important thing to the world today. Femtocell deployment is considered to be the most efficient way to improve the capacity of cell and performance of mobile service especially in high traffic user at urban area. However, the radio signal interferences were occurs in macrocell that cause the capacity degradation in LTE-A femtocell. Therefore, minimizing the interference in LTE-A femtocell power control technology is necessary. The objective of the research is to analyze power control for minimizing the interferences applying on LTE-A Femtocell. The method is by adapting the LTE-A Fractional Power Control (FPC) scheme to the LTE-A environment and proposing new Open Loop Uplink Power Control (OLUPC) technique for LTE-A Femtocell. The program is based on MATLAB simulation. From the compared simulation results the stable Signal to Interference plus Noise Ratio (SINR) performance is recommended for the proposed scheme.**

Keywords-LTE-A, Femtocell, Power Control, SINR, Interference.

I. Introduction

In telecommunications, LTE-A is a term for Long Term Evolution – Advanced. It is most familiar to known as wireless data communications technology and an evolution of the GSM/UMTS standards. LTE-A was being developed by the 3rd Generation Partnership Project (3GPP) standards organization Release 10 that was responsible for GSM and W-CDMA standards [5]. The 3GPP standards were standardize 6 telecommunications standards organizations such as CCSA China, TTA Korea, ARIB Japan, TTC Japan, ETSI Europe and ATIS USA. They are also known as Organizational Telecommunications Standard Partners and provide their members with the safety environment to produce the highly successful Reports and Specifications for 3GPP technologies. Telecommunication Industries nowadays are involved a lot of innovations to meets the demand for wireless services started with the analog cellular network that was introduced almost 30 years ago until the latest technology todays. The main goal of LTE-A was to improve the network coverage, capacity user and speed of the wireless data to ensure the user fairness.

LTE-A was designed to provide up to 10 times the speeds of 3G networks for mobile devices such as wireless hotspot, smartphone and broadband. One of the important LTE-A benefits was their ability to take advantage of improvement topology network, whereas optimized heterogeneous network with a mix of Macrocell to more lower power nodes such as Picocell, Femtocell and news Relays nodes. It introduces multicarrier to be able to use ultra wide bandwidth, up to 100MHz of spectrum supporting very high data rates [6]. LTE-A can supports carrier bandwidth between 1.4MHz to 20MHz which were supports both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD). In addition, LTE-A also used Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink, which more better suited than W-CDMA for achieving the high peak data rates in high spectrum bandwidth. Besides the downlink, the uplink LTE-A used Single Carrier Frequency Division Multiple Access (SC-CDMA), a technology that provides an advantage in efficiency resulting terminal battery life and power consumption.

Femtocells concepts are low power base access points that have coverage 10 – 50 meters, typically use within the houses or building as shown in Figure 1. It can combine mobile and internet network access then placed indoor by end user like Wi Fi router to provide data and generates mobile phone signal. By doing these techniques, it will improve the capacity and coverage for each user within their home for better data transmission, power consumption and indoor voice reception [1]. So that as user, they can buy and install itself their Femtocell devices and feel free having their own independent access network inside the building. The most important tasks of the Femtocell in network are to increase the capacity and improve signal of the entire network within their home.

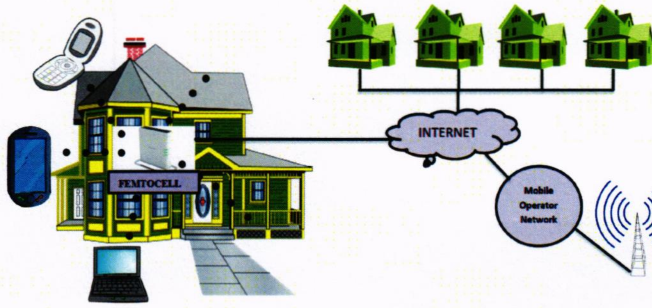

Figure 1: Femtocell Network

To summarize, the key attributes in favor of Femtocell are as the following:

I. **Flexibility of Femtocell -** Not only residential user can set up the Femtocell in their home, but mobile network provider also could set up Femtocell devices especially in the congested areas or suburban areas.

II. **Connection to the operator network –**Referred Figure 1, Femtocells can be connected to the operator network by using standard broadband devices for residential, included cable fiber and DSL. The internet connection can be connected and subscribes from any network broadband line provider as long they offered mobile data network to the residential.

III. **Increasing capacity and independent coverage -** Femtocell concept are not only increase the capacity of the network, but also improve the coverage to the residential users which can allow them to have an independent coverage at high speed data. Compare to the repeaters operations which are used to increase and longer the coverage, Femtocell can provide a high data rate for limited number of users [3].

IV. **Better coverage and Capacity** – Due to their short range of transmit and receive distance, Femtocell can produces lower User Equipment Transmit Power, enhanced duration of battery life and achieved the higher Signal-to-Interference Noise Ratio (SINR). These may improve signal reception and higher data capacity. When the interference was reduced, it can increase the total numbers of active users per unit area.

The paper is structured as follows – Section II provides a brief description of Interferences Model in LTE-A Power Control. Section III discusses the Power Control. Section IV gives the details findings of simulation results. Lastly, the conclusion followed by the future work in Section V.

II. INTERFERENCE MODEL IN LTE-A

According to the model of Femtocell operation on Figure 2, it shown two neighboring Femtocell are operating inside the Macrocell. Actually, the OFDMA System is different compared to Wideband Code Division Multiple Access (WCDMA) because Frequency bandwidth was split into orthogonal frequency channels and they are many frequency channels could be used by residential user. In case of frequency reuse factor (FRF) equals to 1, neighboring cells use the same frequency. Therefore, there is no near-far effect in OFDMA system, but the interference by users which are using the same orthogonal frequency would be occurred.

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

i. **MacroUE to FemtoBS** – Uplink Interference from Macro User Equipment (MacroUE-1) which serving by Macro Base Station to Femto Base Station (FemtoBS-1) which is working inside the Macro Base Station premise.

ii. **FemtoUE to FemtoBS** - Uplink Interference from Femto User Equipment (FemtoUE-1) which serving by Femto Base Station (FemtoBS-1) which is working also inside the Macro Base Station. However, Femto User Equipment (FemtoUE-1) was located to the edge of the Femto Base Station (FemtoBS-2) cell that could be interfering to neighbouring link.

iii. **FemtoUE to MacroBS** - Uplink Interference from Femto User Equipment (FemtoUE-3) which serving by Femto Base Station (FemtoBS-1) near to the Macro Base station (MBS). The FemtoUE-3 which is closed to the Macro Base Station Uplink. The Macro Base Station is the normal base station that conducts by the services provider which is called enhanced Node B (eNB).

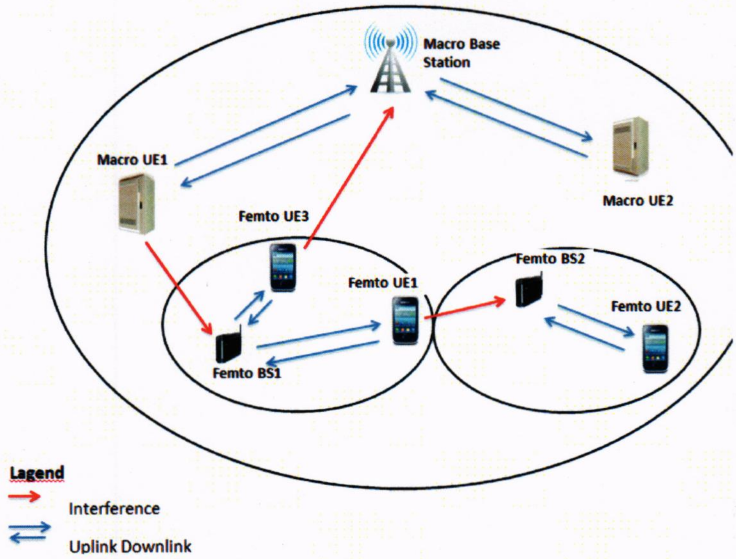

Figure 2 : Uplink Interference Scenarios

III. POWER CONTROL

Power control plays an important role in view of the facts that every receiver gets the signals transmitted by all the transmitters. To ensure maximum efficiency, the power received at the Base Station from Macrocell must be nearly equal. If the received power is too low, there is a high probability of bits error would occurs, and if the received power is too high, interference will be increases. Power control is applied at both the Macro Base Stations as well as the Base Station. There are several different techniques that are used in power control started either by the Macro Station or the Base Station, and the control can be based on the signal strength receives by the Base Station or can depend on other parameters.

In open –loop power control at the Macro Station, the Macro Station detects the strength of the signal and can adjust its power based on that. If the signal is very strong, it can be assumed that the Macro Station is too closed to the Base Station and the power level should be dropped. In closed-loop power control at the Macro Station, power control information is transmitting to the Macro Station from the Base Station. This message states either a transition up or transition down in power. In open-loop power control at the Base Station, the Base Station decreases its power level gradually and waits to hear the Frame Error Rate (FER) from the Macro Station. If the FER is high, it increases its power level [8].The Power Control methods are divided into many types depends on the different schemes and processing on the parameter values. Based on different channel variations, there are two different power control categories which are Fast Power Control and Slow Power Control. From the categories, there is another detail classification of power control algorithm depending on the operation to the Base Station which is Open Loop Power Control or Closed Loop Power Control [9].

1. *Open Loop Power Control*

The power is set at the mobile terminal using parameters and measures obtained from signals sent by the Femtocells Base Station (FemtoBS). In this case, there is no feedback related to the power was used for transmission by the User to the Base Station. This is also known as one-way communication.

2. *Closed Loop Power Control*

This case occurs when the mobile user or User Equipment sends feedback to the FemtoBS, which is used later to correct the user Transmitted power to optimized the system performance. This is known as two-way communication.

A. *Fractional Open Loop Control*

In this section, the uplink power control was standardized the method for femtocell being calculated and illustrated. Beside thats, some of analysis on the colleration of the paramater values is attached for futher adaptation and improvement in the femtocell environment of network. The User Equipment transmit power in femtocell ,$Power_{TX}$ for the uplink transmission as shown on equation (1) derived in dB. This equation was stated as Fractional Open Loop (FPC) which is the propose equation use in this simulation [13].

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

Where:

- $Power_{TX}$: Transmit Power of the UE
- P_{max}: Maximum transmits power of FemtoUE allowed in uplink and it depends on UE - in dBm.
- P_o: The power to be contained in one PRB measured in dBm.
- 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)
- α (alpha): slope parameters (the path loss compensation factor in the range [0 to 1])

Referred to equation (1), the equation states that the User Equipment chooses the minimum transmit power value from the maximum transmit power and path loss compensated factor. In order to more understand the Fractional Open Loop Power Control, some of the simplifications and assumptions are as follows:

- P_{max} : fixed at 20dBm (Femto) and 46dBm (Macro)
- α (alpha) : Equal to all cells in the system

According to interference cases as mentioned before, the next discussion will be focus on the *Case 2 – FemtoUE – FemtoBS* as illustrated in Figure 3 which is only focus on the interferences occurs within femtocell environment.

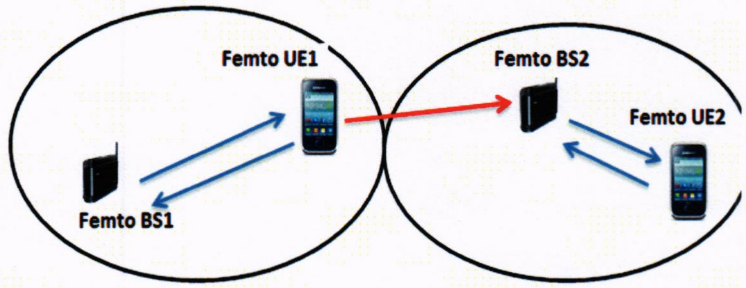

Figure 3: Case 2 – FemtoUE – FemtoBS

Referring to 3GPP specifications, slope of the parameter α can be referred between the value of 0 until 1 i.e $(0 < \alpha < 1)$[14]. By using the equation (1), Figure 4 showing the correlation of the Transmit Power of FemtoUE with their different value of α.

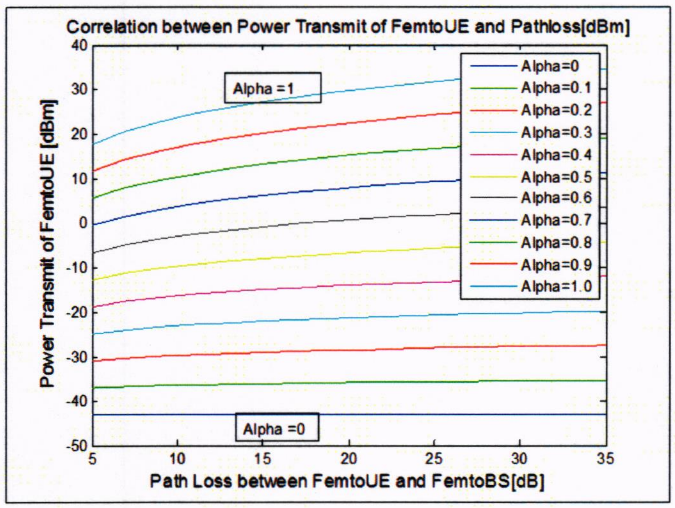

Figure 4: Correlation between Power Transmit and Path Loss (Different value of alpha α)

As in Figure 4, it shown that when α=0, which means there is no path loss compensation occurs, hence the transmit power will be constant as minimum condition. Other that, it can be assumed that no power control mechanism is implemented and all mobile terminals use the same transmits power. However, when case α=1, it corresponds to full path loss compensation and the transmit power will occurs at maximum condition. For α in the interval 0 and 1, a comparison is being done in between full compensation and no power control mechanism. In this case, a fractional compensation of path loss is used and it is also depending on the condition of the certain cells either cell edge users or cell center users. In this case, the transmit power was fixed to 20dBm as maximum transmit power of the FemtoBS. The term of SINR, is a function of a power indicator at the transmitter to measure the quality of wireless connections. The energy of a signal with distance is measured in dB.

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

$$I\_FemtoBS\text{-}2 = (Power_{TX}\_FemtoUE\text{-}1) - (PLoss\_FemtoUE\text{-}1\_FemtoBS\text{-}2) \quad (2)$$

The interference at FemtoBS-2 is the differences of transmission Power of FemtoUE-1 and path loss between FemtoUE-1 and FemtoBS-2. From this calculation, the SINR at FemtoBS-2 as below:

$$SINR\_FemtoBS\text{-}2 = (Power_{RX}\_FemtoUE\text{-}2) - (I\_FemtoBS\text{-}2) \quad [dB] \quad (3)$$

SINR at the FemtoBS-2 is the differences between received power of FemtoUE-2 and interference at FemtoBS-2. The received power of FemtoUE-2 is the difference of transmit power of FemtoUE-2 and path loss between FemtoUE-2 and Femto_BS2 as follows:

$$Power_{RX} = (Power_{TX}\_FemtoUE\text{-}2) - (PLoss\_FemtoUE\text{-}2\_FemtoBS\text{-}2) \quad [dBm] \quad (4)$$

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

$$SINR\_FemtoBS\text{-}2 = [(Power_{TX}\_FemtoUE\text{-}2)\text{-}(PLoss\_FemtoUE\text{-}2\_FemtoBS\text{-}2)] - [(Power_{TX}\_FemtoUE\text{-}1)\text{-}(PLoss\_FemtoUE\text{-}1\_FemtoBS\text{-}2) \quad [dB] \quad (5)$$

In order to get SINR, Path Loss calculation between FemtoUE and FemtoBS for path loss suburban deployment model as expressed in [15]. The path loss for indoor FemtoUE1 is shown as follows:

$$PLoss = 38.46 + 20\log_{10}R + 0.7d \quad [dB] \quad (6)$$

FemtoUE1 also interfered by FemtoBS2 from other house. The path loss is expressed as below:

$$PLoss = \max(15.3 + 37.6\log_{10}R,\ 38.46 + 20\log_{10}R) + 0.7d + L_{ow1} + L_{ow2} \quad [dB] \quad (7)$$

Where:

- R: distance between Tx - Rx
- n: no of penetrated floors
- d: Total distance inside the houses
- L_{ow}: floor penetration losses of outdoor walls in dB which is 10dB between FemtoBS2 and FemtoUE1

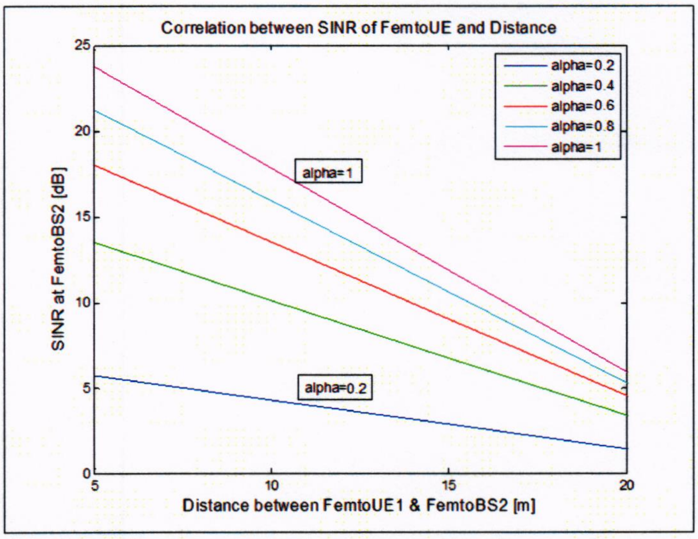

Figure 5: Correlation between SINR at FemtoBS and Distance from FemtoUE to FemtoBS

From Figure 5, it states that higher α value will give the higher value of SINR. In terms of FemtoUE location, the FemtoUE near FemtoBS will get a higher SINR as compared to UE located at edge of the cell. When α is less than 1, the SINR will decreases with path loss. The Fractional Power Control (FPC) 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 Power Transmit to Path Loss and SINR of different α parameters and distance. From the analysis, criteria to choose higher α value are important for doing simulation and to make comparison in the next section.

B. Adaptive Open Loop Power Control

The main objective of Open Loop Power Control technique is to compensate the path loss of the FemtoUE to the serving FemtoBS only, but not the neighbouring FemtoBS. This means that it can be use to improve the efficiency of the signal, but do not take the interference generated FemtoUE to neighbouring cells. It means the FemtoUE can improve the signal efficiency but does not take into account the interference value that FemtoUE generate to the neighbor 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 FemtoUE-2. In this section, the interference value of the neighbor cell and hence the propose equation or known as Adaptive Power Control (APC) can be written as follows:

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

In this condition, the FemtoUE use differences of serving and neighbouring path losses:

$$DELTAP_{Loss} = (PLoss\_FemtoBS\text{-}1) - (PLoss\_FemtoBS\text{-}2)$$

The path losses to the neighbour Femto Base Station are known from the 3GPP specification as in [14], [15].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-A FPC technique and Adaptive Power Control Technique are calculated and graph of SINR are plotted. Besides that, for the Femtocell users, it requires more high speed for different transmission data services and this is why a different SINR are needed for different Femtocell users.

Referring to Figure 6, the graph showing the correlation between SINR and Path Loss between FemtoUE to FemtoBS. When α=0.4, α=0.6 and α=0.8, it shown that the value of SINR is decreasing with the increase of path loss values with the different value of α. This was calculated and simulates using APC equation (7).

On the Figure 7, by using FPC equation (1), it shown that the value of SINR also decreases when the path loss value increase. The different values of α will contribute to the different values of power transmit of the User Equipment. Theoretically, in Femtocell, choosing the efficient value of power transmit is important due to the in-building location. FemtoUE and FemtoBS must be located near to each other within 10 – 50 meters. For that reason, the Path Loss compensation is very important when choosing the power transmit for FemtoUE. According to the standard of OLPC, Macrocell cannot be implemented directly to the Femtocell operating, so that Adaptive Power Control methods was propose in this research. In order to show the differences between APC and FPC equation, a simulation by using Matlab with the parameters as shown in Table 1 is configured.

Table 1: Simulation Parameter

Parameter	Values
Carrier Frequency in MHz	F=2000MHz (Fixed)
Penetration Loss	10dB for external wall
Number of assigned Resource Cluster	M=40
Maximum transmit power(Femto)	20dBm
Average Uplink Interference per resource clusters	α = 0.4; 10dB α = 0.6; 15dB α = 0.8; 20dB
Minimum Distance between FemtoUE to MacroBS	>=35m
Path Loss between FemtoUE to FemtoBS (outside)	PLoss =max ($38.46+37.6\log_{10}R$, $38.46 +20\log_{10}R$) $+ 0.7d + 18.3n + L_{ow1} + L_{ow2}$
The slope parameter values	α = [0.4 0.6 0.8]

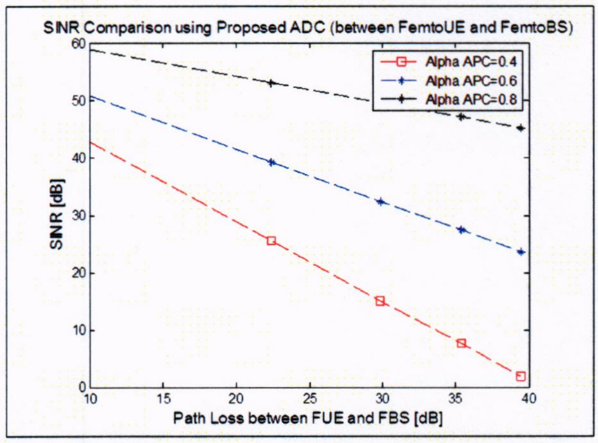

Figure 6: Correlation between SINR and Path Loss with varies of distance, d (alpha, α = 0.4, 0.6 & 0.8) - using Propose/APC equation

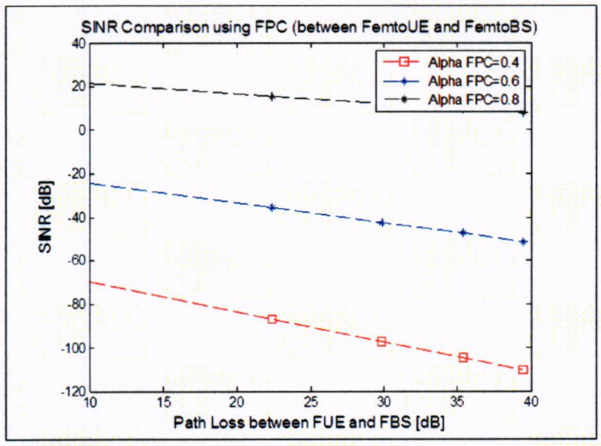

Figure 7: Correlation between SINR and Path Loss with varies of distance, d (alpha, α = 0.4, 0.6 & 0.8) - using FPC equation

On the simulation part, as shown in Figure 8 and Figure 11, the deployment model of cell structure had been designed and simulated using Matlab to make comparison between theoretical parts and based on the real situation. According to Figure 8 (Directed) and Figure 11 (Random), there are single cell with single Macro Base Station, 2 Femto Base Station and 1 Femtocell User Equipment. The simulation program was design in order to generate the graph to showing the correlation of SINR and distances.

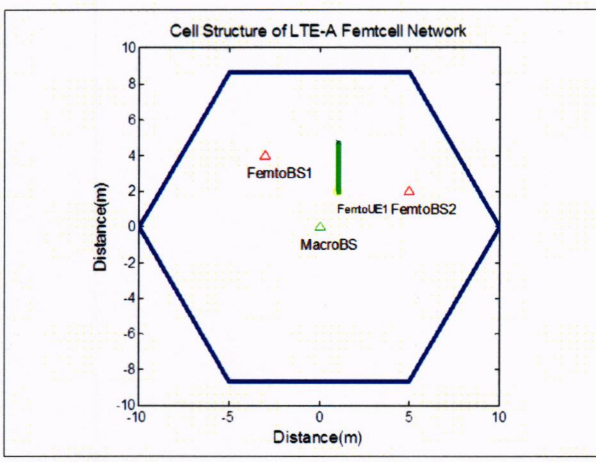

Figure 8: Cell Structure of LTE-A Femtocell (Directed)

In Figure 9, when the FemtoUE1 moves away in straight lines from FemtoBS, the distance increases while SINR performance was decreased. Due to these, SINR decreases as the FemtoUE moves away from FemtoBS. As discuss on theory, the higher value of α will give better SINR compared to 0.4 and 0.6 reading. Both shown the decreases value but higher value of α will give more better performance than lower value.

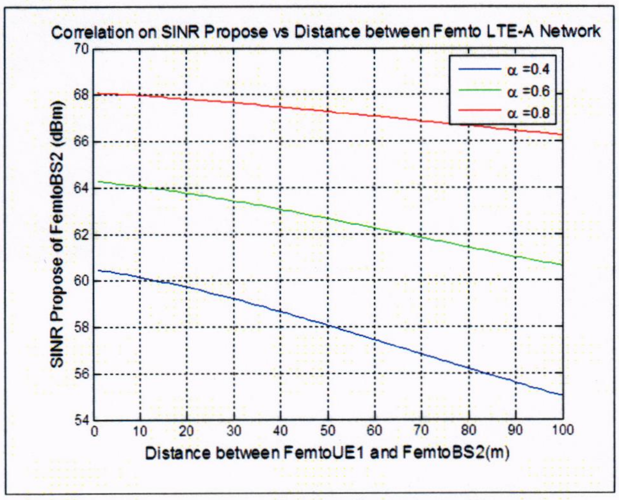

Figure 9 : SINR Propose vs Distance (Directed)

In Figure 10, it shown the path loss performance was increases due to increases of distance. Due to these, the value of path loss increases due to distance because when FemtoUE move away from FemtoBS, interference and low signal strength should be considered that affected the performance of path loss itself.

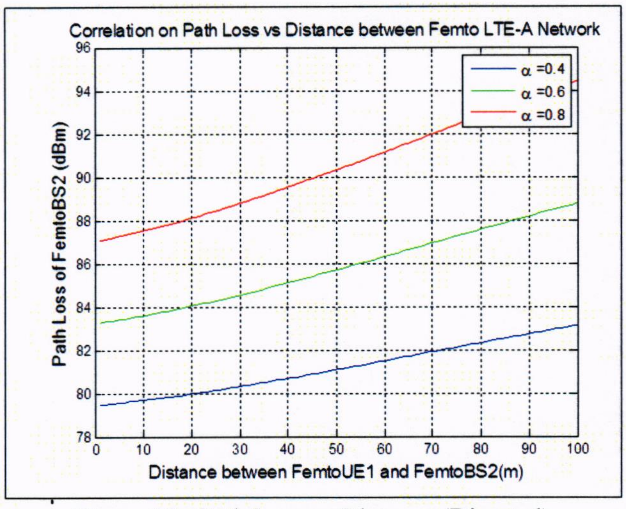

Figure 10 : Path Loss vs Distance (Directed)

Figure 12 shows based on the randomly movement, the SINR also shown decreases as the distance increases. This is because the movement is not uniform as directed and show the performance graph fluctuated.

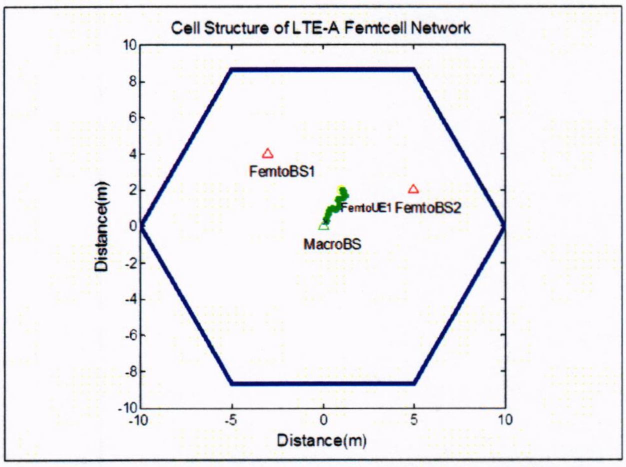

Figure 11 : Cell Structure of LTE-A Femtocell (Random)

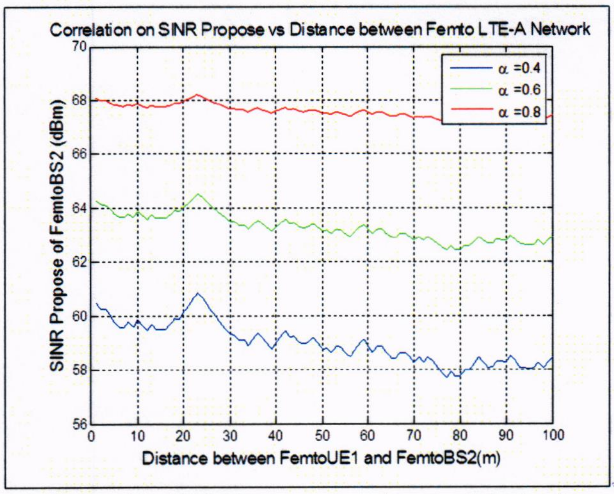

Figure 12 : SINR Propose vs Distance (Random)

In Figure 13, it shows the path loss also shown increases as the distance increases. Since the FemtoUE is moving in random, the movement is not uniform as in previous result. Non-uniform movement also affected to the non-uniform path loss then make the performance graph fluctuated.

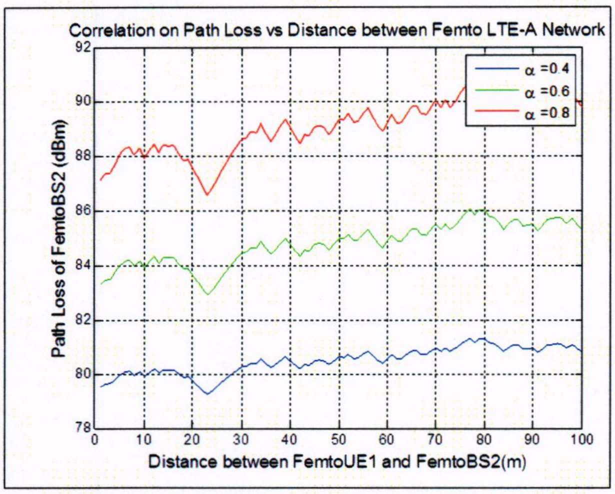

Figure 13 : Path Loss vs Distance (Random)

From that result, it is shown that the SINR and Path Loss performance value varies with distance of FemtoUE from

FemtoBS. The values of SINR decrease as the FemtoUE move away from FemtoBS. The SINR of FemtoUE located near FemtoBS has high value as compared to the FemtoUE located move away from FemtoBS or near cell edge. Besides that, the value of SINR FemtoUE was decreases when interference from neighbor FemtoBS as in proposes equation was considered. By using APC equation, the transmit power signal of the FemtoUE especially when FemtoUE are located near to each other can be controlled, hence it can states that the propose technique is suitable method in femtocell environment.

V. CONCLUSION

In this paper, focusing on analysis of the interference of LTE-A network that consist of Macrocell and Femtocell by using LTE-A Propose technique had been done successfully. The FPC scheme compensates the path loss between FemtoUE and FemtoBS as the open loop approach of the power control which are intended for the different received SINR of FemtoUE in different locations. In other words, users that nearly to FemtoBS get better receive SINR compared to far away from FemtoBS. The SINR performance of FemtoUE that occurred from FemtoBS2 to see their effect of interference to the network performance had been evaluated. Based on that analysis also, the correlation between path loss compensation factor and SINR performance of Femtocell in LTE-A network can be concluded that higher value of α will give better SINR. From that comparison, it can say the optimal value of α is 0.8. Besides that, the SINR performance where the FemtoUE is moving in straight and then randomly move had been evaluated based on received SINR. 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 work, an enhancement in power control for LTE-A environment, the Closed Loop approach for LTE-A power control will be studied for improvement the signal reception level of the FemtoUEs. Other that, Hybrid Power Control (HPC) technique which is combination between an Adaptive Open Loop Power Control (AOLPC) and Adaptive Closed Loop Power Control (ACLPC) technique for future improvement of user capacity as minimizing the interferences will be studied. Lastly, for the improvement of the analysis, the system based on simulation approach could be better solution as a future studies.

REFERENCES

[1] Vikram Chandrasekhar, Jeffrey G. Andrews, Tarik Muharemovic, Zukang Shen, " Power Control in Two-Tier Femtocell Networks", IEEE Transactions on Wireless Comm, Vol 8, No 8, August 2009.

[2] http://en.wikipedia.org/wiki/Femtocell

[3] Alan Barbieri, Aleksandar Damnjanovic, Tingfang Ji, Juan Montojo, Yongbin Wei, Durga Malladi,Osok Song, and Gavin Horn, " LTE Femtocells : System Design and Performance Analysis" , IEEE Journal on selected areas in comm,Vol 30,N0 3,April 2012.

[4] http://www.skmm.gov.my/Resources/Guidelines/Guidelines-%28Spectrum%29/Guideline-For-Usage-Of-Femtocell-Access-Point-Devi.aspx

[5] http://en.wikipedia.org/wiki/LTE_Advanced

[6] http://www.3gpp.org/lte-advanced

[7] http://wirelesstelecom.wordpress.com/2013/05/28/lte-advanced-key-features-and-differentiators/

[8] D.P Agrawal & Qing-An Zeng,Introduction to Wireless & Mobiles System,3rd Edition,2011

[9] Theodore S. Rappaport, " Wireless Communication Principles and Practice", Second Editionn,Prentice Hall,2002

[10] Thomas Keiser, Zhao Zhao. Power Control for interference management in LTE femtocell. s.l. : University of Hannover, 2010

[11] Arne Simonsson and Anders Furuskar. Uplink Power Control in LTE – Overview and Performance. s.l. : IEEE, 2008.978-1-4244-1722-3

[12] http://www.smallcellforum.org/aboutsmallcells-small-cells-consumer-faqs

[13] Ichinnorov Sanjaasuren, Study on Adaptive Uplink Power Control Applying to Minimize Interference on LTE Femtocells, 2010.

[14] 3GPP.TS 36.213 V8.8.0 (2009-09)

[15] 3GPP.TS 36.331 V8.10.0 (2010-06)