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Analyzing of power control technique in LTE-advanced Femtocell network

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Abstract: Nowadays, users demand for higher data rates and good quality of services. Thus, to supply better coverage, more capacity, higher throughput, and reduced latency with less complexity, Long Term Evolution – Advanced (LTE-A) has been created by 3rd Generation Partnership Project (3GPP). The use of small cells is becoming increasingly important due to their ability to provide increased system capacity compared to a homogeneous network of macrocells. However, many users may enter femtocells coverage, lead to major interference challenges. Radio signal interference is the main factor causing the capacity degradation in LTE-A Femtocells. Inter cell interference is causing a problem when frequency reuse factor is equals to one. Therefore, this paper presents power control technique by applying femtocells using better Signal Noise to Interference Ratio (SINR) to overcome the performance of handover in LTE-A femtocell network. In addition, comparisons between Fractional Uplink Power Control (FPC) and Adaptive Uplink Power Control (APC) technique also being done in this research. Both of two power control techniques are simulated by using Mathlab software to analyse the correlation between SINR and path loss. SINR values have been chosen from this two power control techniques to apply in LTE-A femtocell network to observe the performance of user equipment (UE) handover. From the result, it can be observed that the proposed power control technique shows better result in enhancing the performance of handover.

Key words: LTE, LTE-A; Macrocell; Femtocell; Uplink power control; SINR; Handover

1. Introduction

The Third-generation Partnership Project (3GPP) started working on solutions to fulfil the need for high data rates and came up with high speed packet access(HSPA) which is currently used in 3G phones for the before mentioned applications. In order to ensure the competitiveness of its standards in the future, 3GPP developed the Long Term Evolution (LTE) to be the 4th generation of mobile telephony [13]. LTE as defined by the 3GPP is the evolution of the 3rd generation of mobile communications (UMTS). The main goal of LTE is to introduce a new radio access technology with a focus on high data rates, low latency and packet optimized radio access technology. LTE is also referred to as Evolved UMTS Terrestrial Radio Access Networks (E-UTRAN) (3rd generation partnership project, 2008). Fig. 1 shows the 3GPP femtocell architecture in detail which has similarities to connections in the eNodeB architecture. LTE-Advanced is a 3GPP standard that describes technological advancements to a highly flexible radio interface that aims at bridging the gap between 3rd generation and 4th generation (4G) standards – described in International Mobile Telecommunications (IMT-Advanced). LTE does not meet most of the standards for 4G deployment, though it is often described as 3.9G or pre-4G. LTE-Advanced is capable of peak download data rates of 1 Gbps, with a wide transmission bandwidth, low C-plane latency, backwards compatibility, and increased user throughput and spectrum flexibility.

Femtocells has been proposed in LTE-A which are small, low power, low cost, short ranged and plug and play cellular base stations that can be placed inside homes and can be directly connected to the backhaul network through Internet Protocol (IP). From the user's point of view these are plug and play devices and no prior technical knowledge about the installation is required. However these devices have to be purchased from the mobile network operator by anyone wishing to have it in their residences. The advantages of having a femtocell are that the indoor coverage can be enhanced, coverage holes can be eliminated and also the operators can provide a better service at the cell edge (Bangalore, 2013). Femtocells will provide higher spectral efficiency, spatial frequency reuse and better coverage in areas not fully covered by macrocells. However, if interference cancellation or avoidance techniques are not applied, dead zones can appear within the macrocell, disrupting its service in the proximity of afemtocell (David et al., 2014). Among the various technical challenges facing Heterogeneous networks (HetNets), interference unarguably poses the major challenge. This is because the backhaul network that supports different kinds of cells may have different bandwidth and delay constraints, handover problems occasioned by the restricted access control

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associated with picocells and femtocells (3rd generation partnership project, 2008).

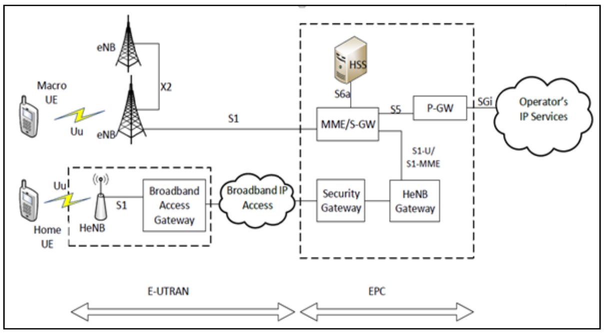

Fig. 1: 3GPP femtocell architecture overview (3rd generation partnership project, 2008)

2. Interference in LTE

In Orthogonal Frequency-Division Multiple Access (OFDMA), User Equipment's (UEs) are assigned the different sub-carriers and they are orthogonal on the frequency in one cell. In case of frequency reuse factor (FRF) equals to 1, in order to make the system spectral efficiency better, neighbouring cells use the same frequency. If UE transmits data in the same sub-carrier along with another UE of the neighbour cell, it will result to inter-cell interference (frequency collision), which will degrade the bit rate, especially for the UE in the cell edge. According to that situation it could be said that inter-cell interference between neighbour cells could dominate the system performance (Ankti and Pravesh, 2013). The Uplink interference cases are as illustrated in the Fig. 2.

- FUE to FBS: FUE (Femto User Equipment) in the edge of the FBS (Femto Base Station) premise could interfere to neighbouring FBS uplink.
- MUE to FBS: MUE (Macro User Equipment) near the premise of FBS could strongly interfere to FBS Uplink.
- FUE to MBS: The FUE which is very near to the MBS (Macro Base Station) could interfere to MBS uplink.

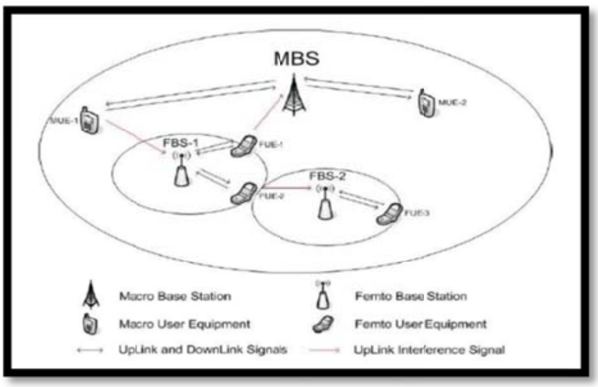

Fig. 2: Interference cases (Ankti and Pravesh, 2013)

3. Literature review

The authors in (Ankti and Pravesh, 2013) had been proposed the conventional power control and UMTS LTE uplink power control. For conventional power control technique, it compensates path loss between UE and Base Station (BS). UMTS LTE supports a power control scheme that allows for Macro User Equipment (MUE) to get different target Signal to Interference and Noise Ratio (SINR) alternately of the same target SINR according to its path loss to MBS.

Other published reference such as author in (Elena-Roxana et al., 2011) has studied the impacts on the system performance by using LTE uplink power control. Based on this author, the purpose of this technique are to increase capacity and improve service performance. Two power control categories have been defined, there are slow power control and fast power control. From these methods, it can be stated that uplink power control mechanism has a key role in optimizing uplink system capacity. Another way to increase uplink system performance is to implement the closed loop power control adaptive mechanism to correct errors generated by the open loop power control algorithm.

Besides, authors in (Ichinnorov, 2010) focused on the adaptation of the standardized LTE Fractional Power Control (FPC) technique for femtocell by proposing new APC technique. The FPC is the open loop scheme which satisfies the path loss for choosing of optimal power of UEs. Based on this paper, the analysis on the standardized formula of FPC is done for the relationship of the transmit power spectral density (PSD) to path loss and SINR values of different α parameters. FPC technique is to satisfy path loss of the FUE only to serving FBS, not to the neighbouring FBS. As the result, for the SINR at the Femto Base Station (FBS), it is seen that performances of the different power control methods are almost the same. From that, the APC had been proposed in this paper because it is stable in case of SINR.

4. Methodology

At the beginning of this research, the correlation between SINR and path loss between FemtoUE to FemtoBS and FemtoUE to MacroBS has been observed by using FPC and APC techniques. For FPC technique, we varies the value of path loss compensation factor, α (0.2, 0.4, 0.6, 0.8 and 1.0) while for APC we used α equal to 0.6 and 0.8. Based on previous research, by using FPC technique Home Users Equipment (HUE) will calculate transmit power for uplink to serving HeNB while APC technique will consider the interference experiences by UE from neighbouring cell. In this project, we used path loss model for urban deployment between FemtoUEs to FemtoBSs and between FemtoUEs to MacroBSs according to the 3GPP TSG RAN #51 path loss as depicted in Table 1.

4.1. Fractional uplink power control (FPC)

By using this power control scheme, the different UE gets different target SINR instead of the same target of SINR based to its path loss. FPC admits the UEs in the edge of the femtocell to reduce the inter-cell interference to neighbour femtocell. Based on this power control scheme, transmit power of FUE is given by:

TxPSD = min {Txmax, 10*log10 (M) + Γ + I + α*PL} [dBm] (1)

Table 1: Path loss models for urban deployment

Cases	Path Loss (dB)
UE to MacroBS	PL(dB)=15.3+(37.6*(log(R))) R –distance between FemtoUE and BS in meter
UE to HeNB	PL(dB)=max((38.46+(20*log(R))))+(0.7*(d2))+(18.3*(n)^((n+2)/(n+1)-0.46))+(q*Liw)+Low Low - the penetration loss of an outdoor wall which is 10dB or 20dB Liw - the penetration loss of the wall separating apartments which is 5dB q - the number of walls separating apartments between UE and HeNB d2 - penetration loss due to walls inside an apartment n – The number of penetrated floors.

where M is the number of the assigned resource clusters, TxPSD is the transmit Power Spectral Density (Power per Resource Cluster), Γ for Target SINR, I for average uplink interference per resource cluster, PL for Path Loss (including shadow fading), Tx_max for UE's max transmit power in dBm and α for path loss compensation factor. The value of α can be between 0 and 1 (0< α<1).

From equation (1), the interference, I can be calculating by using this formula:

1. Interference between FemtoUE1 to FemtoBS2:

I_FemtoBS2= (PowerTX_FemtoUE1) – (Path Loss FemtoUE1_FemtoBS2) (2)

2. Interference between FemtoUE1 to MacroBS1:

I _MacroBS1 = (PowerTX_FemtoUE1) – [(Path Loss FemtoUE1_FemtoBS2) – (Path Loss FemtoUE1_MacroBS1)] (3)

The interference at FemtoBS2 (FBS2) and MacroBS1 (MBS1) is the difference of power transmits FemtoUE1 (FUE1) and path loss between FUE1 to FBS2 and path loss between powers transmit FUE1 to MBS1. From this calculation, the SINR at FemtoBS2 and MacroBS1 as below:

SINR_FBS2 = (PowerRX_FUE2) – (I _FemtoBS2) [dB] (4)

SINR_MBS1 = (PowerRX_MUE1) – (I_MacroBS1) [dB] (5)

SINR at the FBS2 is the difference between received powers of FUE2 and interference at FBS2 and SINR at MBS1 the difference between received power of MacroUE1 (MUE1) and interference at MBS1. The received power of FUE2 is the difference of transmit power of FUE2 and path loss between FUE2 to FBS2 and for received power of MUE1 is the difference of transmit power of MUE1 and path loss between MUE1 to MBS1 as follows:

PowerRX_FUE2 =PowerTx_FUE2 - (Path Loss FemtoUE2_FemtoBS2) [dBm] (6)

PowerRX_MUE1 =PowerTx_MUE1 - (Path Loss MacroUE1_MacroBS1) [dBm] (7)

From equation (2), (3) and (4), the value of SINR at FemtoBS2 is as below equation:

SINR_FBS2 = [PowerTx_FUE2 - (Path Loss FemtoUE2_FemtoBS2)] - (PowerTX_FemtoUE1) – (Path Loss FemtoUE1_FemtoBS2)] [dB] (8)

From equation (5), (6) and (7), the value of SINR at MacroBS1 is as below equation:

SINR_MBS1 = [PowerTx_MUE1 - (Path LossMacroUE1_MacroBS1)]- [[(PowerTX_FemtoUE1) – [(PathLoss FemtoUE1_FemtoBS2) – (Path LossFemtoUE1_MacroBS1)]]][dB] (9)

4.2. Adaptive uplink power control (APC)

The second power control scheme introduced is APC that is derived from fractional uplink power control equation. With this power control scheme, it will consider the interference experiences by UE from neighbouring cell. Based on this power control scheme, transmit power of FUE is given by:

TxPSD = min {Tx_max, 10*log10 (M) + Γ + I + α*ΔPL}; [dBm] (10)

FUE will use the different of serving and neighbouring path losses instead of path loss to serving HeNB only. Delta path loss is given by:

ΔPL = PL_FBS2 – PL_FBS1 (11)

ΔPL = PL_MBS1 – PL_FBS1 (12)

4.3. Proposed power control in handover scheme

Fig. 3 shows the workflow of handover strategy for handover scheme by applying the proposed power control and path loss model for urban deployment. The objective is to observe the performances of handover in femtocells and macrocells. At the beginning, the UE is connected to the nearest macrocell or femtocell base station. When the signal strength of macro base station is lower than femto base station, and signal strength of femto base station is greater than propose SINR for femtoUE with speed of UE is set lower than 30km/h, femtocell handover will take place to appropriate target femtocell. For macrocell, handover will take place when signal strength up to propose SINR for macroUE and speed of UE greater than 30km/h.

5. Simulation and Result

In this section, graphs of SINR are plotted by using the LTE Fractional Power Control and Adaptive Power Control Technique. From equation of APC and FPC, we simulated both equation by using

Mathlab with the simulation parameters as in Table 2 to observe the different of SINR value.

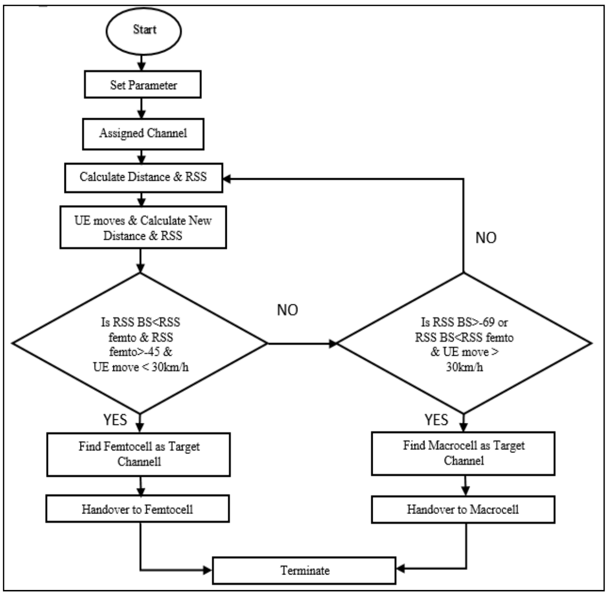

Fig. 3: The workflow of handover scheme

Table 2: Simulation parameter

Parameter	Values
Distance between FUE1 and FBS2 in meter	R1= 10 to 30 (varies)
Distance between FUE1 and FBS1 in meter	R2= 5
Distance between FUE1 and MBS1 in meter	R1= 100 to 500 (varies)
Maximum transmit power HeNB	20dBm
Maximum transmit power MacroBS	46dBm
Number of assigned Resource Cluster	M=33
Penetration loss of an outdoor wall	10dB
Penetration loss of the wall separating	5dB
Number of walls separating apartments between UE and HeNB	5 (assume)
Penetration loss due to walls inside an apartment	5 (assume)
Number of penetrated floors	10 (assume)
The slope parameter values	0.2, 0.4, 0.6, 0.8, 1.0

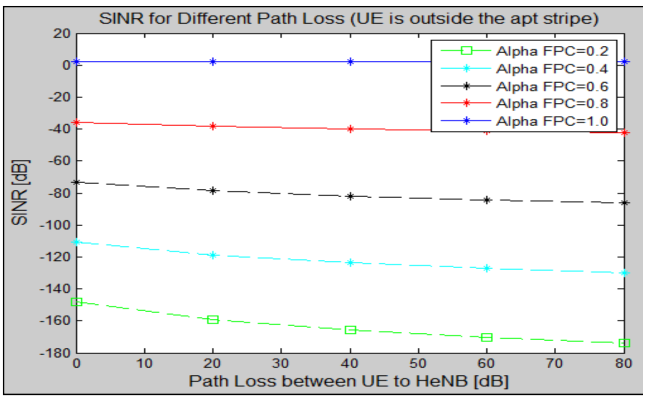

Fig. 4: Graph SINR versus path loss between FUE to FBS by using FPC equation

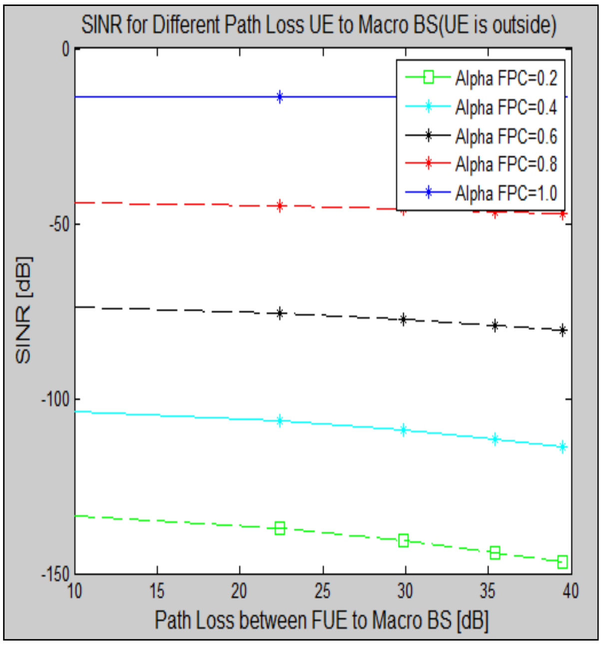

Fig. 5: Graph SINR versus path loss between FUE to MBS by using FPC equation

Fig. 4 and Fig. 5 show the correlation between SINR, Path Loss and Distance between FemtoUE to FemtoBS and between FemtoUE to MacroBS by using FPC equation (1). For this FPC equation, we vary the value of α (0.2, 0.4, 0.6, 0.8 and 1.0) and we can see that the value of SINR is increasing with the increase in α value. When the FemtoUE moves away from FemtoBS and MacroBS, the distance and path loss will increase. Due to these, SINR decreases as the FemtoUE moves away from FemtoBS and MacroBS. On the other hand, by using APC (2) as in Fig. 6 and Fig. 7, we can see that the value of SINR also increases at the same path loss value. For this APC equation, we use value of α is equal to 0.6 and 0.8. So, different values of α will assign the different values of transmit power of the UE. By using FPC equation, the value of SINR at α of 0.8 for femtocell is around -38dB while SINR for macrocell is around -40dB. Compare to APC equation, the value of SINR at α of 0.8 for both femtocell and macrocell are higher than SINR by using FPC equation which are -45dB and -69dB. In conclusion, at α of 0.8, APC shows better SINR than FPC. When the value of SINR is lower, the number of handover initiation is higher.

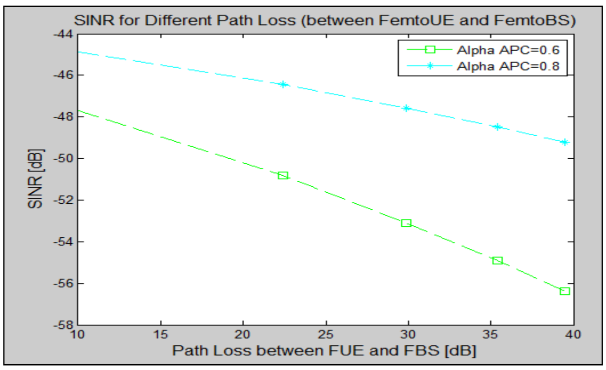

Fig. 6: Graph SINR versus path loss between FUE to FBS by using APC equation

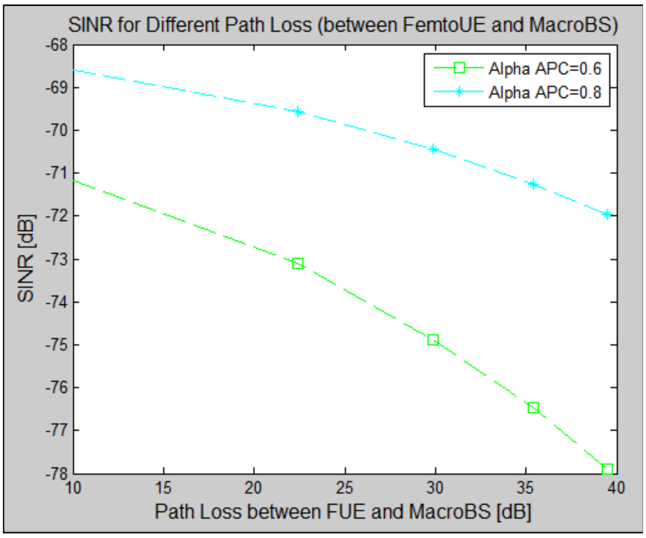

Fig. 7: Graph SINR and path loss between FUE to MBS by using APC equation

For further simulation, by APC for macro and femto with α 0.8, we propose the maximum SINR value for femtocell to initiate handover which is -45dBm and for macrocell is -69dBm. Based on this, a structure framework has been designed and simulated using Mathlab to observe the number of handovers for the system model when the movements of UE (black colour) are random and UE (green color) shows the initial position of UE as shown in Fig. 8. The simulation setup consists of an LTE macrocell and femtocell network, where the LTE network was designed with 33 clusters with equal to 231 hexagon cell with 231 macrocell base stations (blue and redcolour) and radius for macrocell is set 1km. For femtocell, there are 435 base stations (yellow colour) and randomly deployed inside the networks. The simulation time was set to 1500s and resources for every base station were allocated. Channel will be released by a UE after call finished. The simulation parameter based on recommendations has been summarized in Table 3.

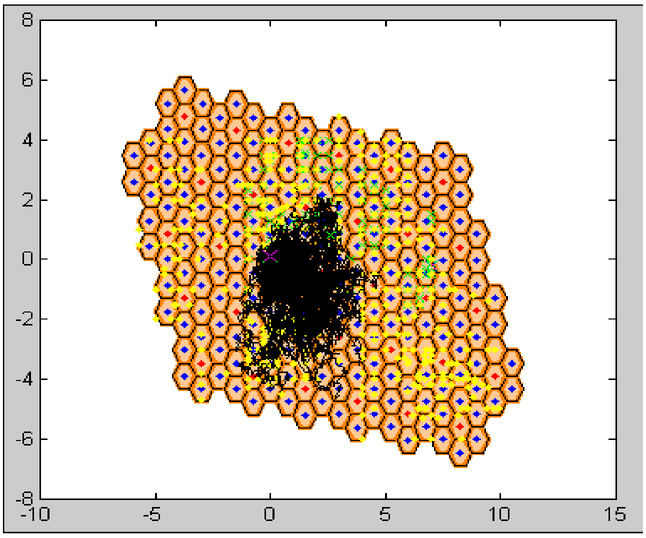

Fig. 8: The movement of UE is Random & UE in Hotspot Position

Table 3: Simulation parameter

Parameter	Explanation
Radius of femtocell coverage area	10m
Radius of macrocell	1km
Velocity of UE's	5 to 30km/h and above 30km/h
No. of UE	20 to 100 UE (black line colour)
Power transmit Macro	-94dBm
Power transmit Femto	-60dBm
Proposed SINR for MacroUE	-69dBm
Proposed SINR for FemtoUE	-45dBm

Fig. 9 and 10 show the simulation result for number of handover versus low speed and high speed of UE for femtocell handover (FemtoHO) and macrocell handover (MacroHO) respectively. For this simulation, the numbers of UE are set equal to 100 users for both low and high speed. In low speed, the speed of UE are set from 5km/h to 25km/h while for high speed are set from 30km/h to 110km/h. Both powers transmit for macro base station (MacroBS) and femto base station (FemtoBS) are set at -94dBm and -60dBm while the channel that can support for MacroBS and FemtoBS are 1000 and 20 respectively. For low speed, the graph shows that the number of UE's connected to FemtoBS is higher than the number of UE's that connected to MacroBS. Even the number handover for both macro and femto are fluctuated, the number of FemtoHO is constantly higher than the number of MacroHO. This is due to the postion UE that move randomly whereby when the UE position is nearer to femtocell it will connect to FemtoBS due to high power and vice versa. Differently for Fig. 10 that simulate the high speed movement of UE. Although 30km/h is consider as high speed, the UE are connected to FemtoBS because of the UE are randomly generated. When the simulation start the position of UE are nearer to FemtoBS so that it will connected to it. Only 24 FemtoHO handle by FemtoBS and the rest are connected to MacroBS that is higher signal strength. As the speed increased, the number of handover also increased.

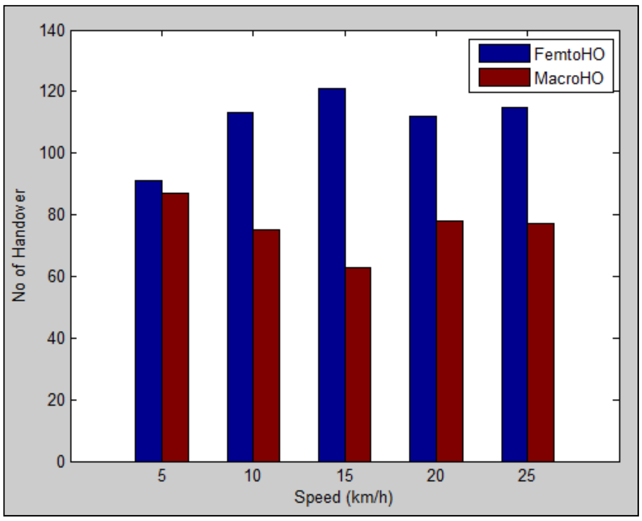

Fig. 9: Number of handovers versus low speed of UE

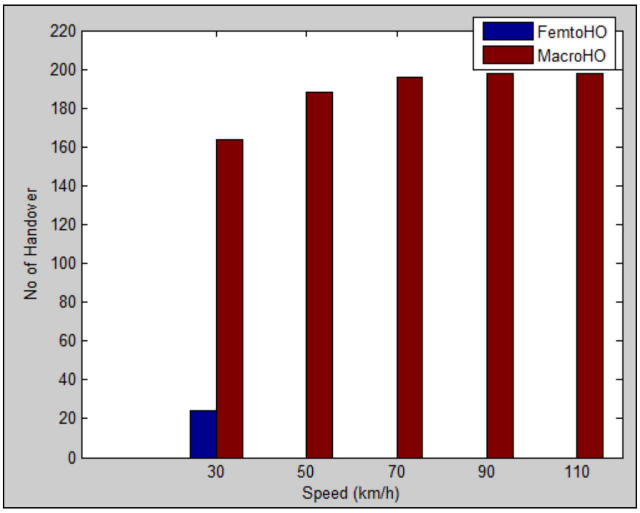

Fig. 10: Number of handovers versus high speed of UE

Fig. 11 and 12 shows the simulation result for number of handovers versus the number of users for low speed and high speed of UE respectively. In this simulation, the movement of UE are set to move at 20km/h for low speed and 100km/h for high speed. The number of users is place randomly from 20 to 100 users while the simulation time is set for 1500s. At 20 users, the number of handover for both femto and macro are equal. This is because the UE are generated randomly. When the number of users increase from 40 to 100 users, the number of handover for FemtoHO and MacroHO also increase and the number of FemtoHO are higher than MacroHO. FemtoHO induced more handovers for low speed and hence reduced the probability of drop call to happen. Differently for high speed, there is no FemtoHO occur during this simulation. The result shows the number of MacroHO increase when the number of users increase. This handover scheme is designed where only slow speed user below than 30km/h will be connected to FemtoBS and hence reduced the number of handover which can increase overload to the system.

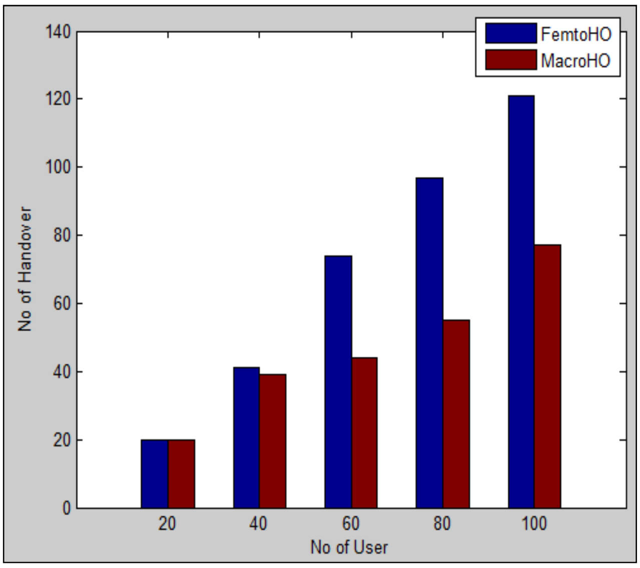

Fig. 11: Number of handovers versus number of users with speed of 20km/h

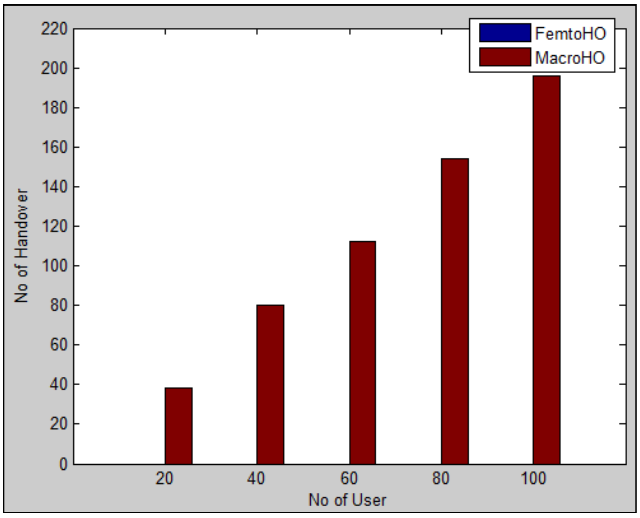

Fig. 12: Number of handovers versus number of users with speed of 100km/h

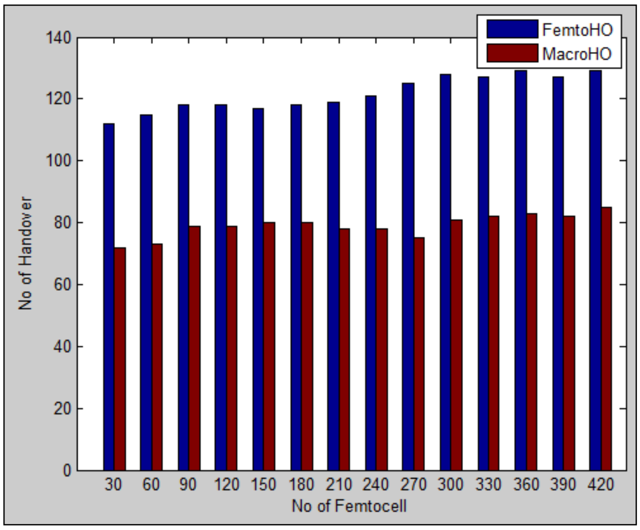

Fig. 13: Number of handovers versus number of deployed femtocells

Fig. 13 shows the number of handovers versus number of deployed femtocells. In this simulation, the numbers of femtocell are randomly deployed while the speed and the number of UE are set to 20km/h and 100 users respectively. Simulation time taken for this simulation is 1500s. Based on the result obtained, the number of handover for femto and macro fluctuated throughout the simulation time. However, the number of FemtoHO is constantly higher than MacroHO. The reason for the fluctuated result is because the femtocells are generated randomly and the movement of UE are in low velocity. The UE are more likely to connect to FemtoBS in low speed because it produce high signal strength and hence, reduced the probability of drop call to happen.

6. Conclusion and recommendation

In this research, two power control techniques have been studied which are FPC and APC to observe which techniques are given better SINR. Based on both techniques, we evaluate the SINR performance for femtocell and macrocell. We also consider path loss according to 3GPP standard and choose α of 0.8 that give better SINR for femto and macro equal to -45dBm and -69dBm respectively. Based on this SINR, we used this value in this simulation as a maximum SINR value for femtocell and macrocell to initiate handover. When the value of SINR is lower, UE are tending to generate more handover process. The proposed scheme can reduce number of handover by set maximum level of handoff threshold value during a call connection. To avoid probability of handover failures for lower speed, the proposed handover scheme hands over these users to femtocell. Simulation results showed that the proposed handover with better SINR can minimize number of handover as compared to traditional handover (MacroHO). According to the analysis, it can be concluded APC mechanism is suitable to use in femtocell for controlling the transmit power of the UE and also minimize the interference in LTE-A network. For future work that can be done is the other method with that can increase the SINR of the system? With this method, more femtocell and macrocell users with new scheme designed should be considered to reduce the interference in LTE-A femtocell. Another suggestion that can be made is combination of this technique with other power control technique that considers different path loss. Thus, it can enhance the performance of the network.

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