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THE PERFORMANCE OF POWER CONTROL METHOD ON MACROCELL-FEMTOCELL LTE HETEROGENEOUS NETWORKS

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ABSTRACT

In telecommunications, femtocell technology has been introduced to improve indoor coverage and capacity. Femtocell is a small, low-power cellular base station deployed to offer better good services with low cost as it reduces the transmitted power. It is also designed to offload the traffic in macrocell to the femtocell network. However, the unplanned deployment of femtocells and their uncoordinated operations may result severe interference conditions among the femtocells and between macrocells and femtocells. In this paper, power control techniques has been proposed at the base stations to mitigate interference and increase the network capacity. Power control equation is applied at the base stations for both outdoor macrocell users and indoor femtocell users, and a framework is developed by using the MATLAB software to analyze the signal performance. From the results obtained, this proposed technique has increased number of successful handover and hence, can effectively eliminates co-channel interferences between macrocells and femtocells in urban and busy area.

Keywords: femtocells, heterogeneous network, interference, power control, handover.

1. INTRODUCTION

Long Term Evolution (LTE) networks provide high data rates and better coverage to the rapid growth of traffics in wireless technology. In order to cope with the growing traffic, femtocell was proposed by the 3rd Generation Partnership Project (3GPP) standard. Femtocell, which also known as HeNB is a small range (10-30m) base station and has less than 20 dBm femtocell transmitting power as shown in Figure-1. Deploying these femtocells in the existing macrocell layer forms a two tier hierarchical cell network or called as a heterogeneous network.

Femtocells have many advantages to offer like improve the system capacity and coverage because the transmission is short so that a higher signal-to-interference-plus-noise-ratio (SINR) can be attained. Moreover, by improved the coverage it enables for the mobile phones to operate at the peak with the high call quality system. The amount of traffic in the macrocell also can be offloaded by the femtocell as it improved the macrocell reliability. Femtocells also can reduce the cost operation by reducing the cost installation as well as reducing the additional time for installation. However, this heterogeneous network has become denser and causes interferences at the base station between indoors and outdoors users. Interferences inside the buildings of cellular signal decrease the signal strength.

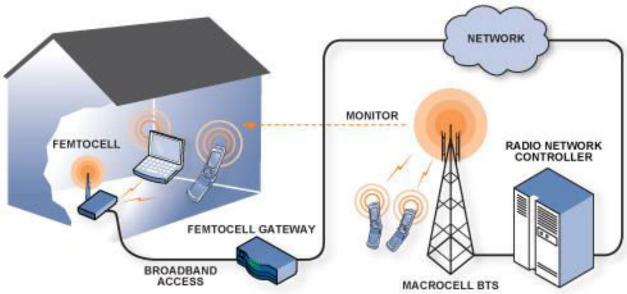

Figure-1. Femtocell architecture [1].

The interference problem in femtocell can be categorized into macro-femto (cross-tier) interference and femto-femto (co-tier) interference. Macro-femto interference can be described in a situation where macro users used the same sub-band with any femto-user in the same time. Femto-femto interference is caused due to apparent low transmit power and penetration losses due to walls inside the house which is the type of co-layer interference. Therefore, it is important to mitigate interference between indoor and outdoor user for both macrocell and femtocell in order to improve overall performance.

To solve this issue, a method called power control is used in this research to reduce interference in macrocell and femtocell networks. Power control equation is adopted on SINR. There are two types of power control technique [2] which are the Conventional Power Control and LTE Uplink Power Control. The Conventional Power Control technique reduces the path loss between user equipment (UE) and base station (BS) and in the BSs all the target of SINR are the same level. LTE Uplink Power is a power control technique that allows UE to have different target SINR instead of the same target of SINR based on the path loss to base station. In this paper, power control technique is derived to reduce interference of co channel for outdoor macrocell users and indoor femtocell users, and hence improve the system capacity. A framework is developed by using the MATLAB software in order to examine the signal performance based on the method that has been proposed. The significant of this study is to mitigate the interference in the macrocell-femtocell LTE heterogeneous networks.

This paper can be categorized as follows: Section II explains the literature reviews from previous studies on power control techniques. Section III explains the methodology of this project. For Section IV, the results for numerical and simulation are shown with analysis included. Finally, section V presented conclusion and the future work recommendations.

2. LITERATURE REVIEW

Many studies have been proposed to investigate the performance of femtocell LTE Heterogeneous network. The literature review will focused on the power control technique, heterogeneous network and the effect of femtocell position in the network. To improve the signal in the femtocell and reduce the interference between femtocell and macrocell, a power control technique is introduced to enhance the system performance and increase capacity of the network in urban and busy area.

The authors in [3] had identified open access and closed access mode to access control mechanism handover process between macrocells and femtocells. In open-access femtocells, macro user can handed over to the corresponding HeNb (Home eNodeB) while in close-access HeNb only allow to a set of authorized users. The author in [4] proposed an Adaptive Smart Power Control Algorithm (ASPCA) to avoid cross tier interference issues to determine range for femtocell without requiring a changing or complicated agreement between cells. The femtocell is offloading the network traffic from LTE macrocells, deployed in the overlapped area of macrocell and share the same spectrum with the macrocell, thus leading to the co-channel interference problem. By using ASPCA, it can reduce co-channel interference by separating cell center users and cell edge user. The authors had considered their own different scenario to demonstrate the simulation but no coordination; handoff and frequency reuse being applied.

In [5] the authors explained about a power management for outdoor macrocells and indoor femtocells users in a heterogeneous network. Stimulated annealing optimization algorithm is deployed to change the power transmission of the base station in femtocell to decrease the co-channel interference. It is for requirement to get higher data rates to solve the coverage problem that happens in the indoor environment. However, due to different of transmission power in base stations, to control the interference in heterogeneous networks is much more complex than that of the homogeneous deployment of macrocells. The author proposed the power control algorithm which can reducing femtocell base station transmission power while maintaining a minimum threshold value of SINR.

Other published references as in [6] had studied to reduce the interference due to cross-tier interference which shared spectrum among macrocell and femtocell. It is expected that femtocell users and macrocell users find different SINR and higher data rates at femtocells. The author used a Closed Access (CA) femtocell operation that each femtocell AP communicates only with its subscribed users. Moreover the method of cellular protection is also used which distributed algorithm to reduce transmission power of strongest femtocell interference. However, this method requires a few of repetition that does not increase the difficulty of the network.

In [7] the author proposed the method to mitigate interference which can be divided to centralized and distributed schemes. The macrocell controls the femtocell and assign frequency band, clustering or grouping, dynamic sub-channel allocation and self- organization. The author divides the distributed schemes into two parts. The first part is channel identify where there is cooperation between the macrocell and femtocell like cognitive radio, spectrum arrangement aware and frequency scheduling. While the second part is non-aware schemes like frequency reuse, distributed spectrum allocation schemes, directional antenna and power control. The disadvantages of centralized schemes is they are more unpredictable to actualize than the disseminated one event ought there is concurrence between the macrocell and femtocell. However, the developed model only considering a single tier of one macrocell and its related femtocells. Hence, this finding is not accurate as macrocells do exist in any network and each one is corresponding with femtocells and users.

In [8] author proposed interference control method where the macrocell bandwidth is divided into sub bands and the short range femtocell allocates their power across the sub bands based on a load-spillage power control method. In addition, authors proposed method for femtocell and macrocell interference control based on sub band scheduling and power control that available cancellation interference. In this proposed method, both uplink (UL) and downlink (DL) bands of macrocell overlay network are first divided into sub bands. This method also need a minimal cross-tier information for coordination between the femtocell and macrocell. However, the author did not explicity modelled the overhead for the signals to estimate the path losses. Hence, in this project, power control method with several parameters is further extended to reduce interference in two tier macrocell-femtocell networks.

3. RESEARCH METHODOLOGY

In this research, the urban environment with femtocell and macrocell LTE networks is considered. A number of distributed indoor and outdoor user with macrocells, femtocells and mobile station are defined. A cell layout consists of seven hexagonal macrocell environments. The macrocell are located in the residential area and femtocell base stations are located randomly within macrocell range. At the beginning of the project, the correlation between Transmit Power Spectral Density (TxPSD) and distance is investigated and followed by the correlation between Signal to Interference Noise Ratio (SINR) and distance. For the LTE Uplink Power Control the parameter value of path loss compensation factor, α varies from 0, 0.2, 0.4, 0.6, 0.8 and 1.0. Path loss (PL) is determined by the distance between the transmitter and receiver. Different path loss model are used to present indoor, outdoor and also indoor to outdoor channel and it is suit for urban femtocell deployment. The models for the macrocell and femtocell path loss are described respectively as in Table-1 and Table-2.

Table-1. Path loss model of macrocell.

Scenario	**Path loss** (dB)
UE is outside	PL(dB) = 15.3 + 37.6$\log_{10}$R R = transmit and receive distance
UE is inside	PL(dB) = PL (dB) = 15.3 + 37.6$\log_{10}$R R = transmit and receive distance

Table-2. Path loss model of femtocell.

Scenario	**Path loss** (dB)
UE is inside the house as HeNB	PL(dB) = 38.46 + 20 $\log_{10}$R + 0.7 + 18.3 + q*L_{iw} R= transmit and receive distance q= the number of walls separating between UE and HeNB L_{iw} = penetration loss of wall separating between UE and HeNB
UE is outside the house	PL (dB) = max(15.3 + 37.6$\log_{10}$R, 38.46 + 20$\log_{10}$R) + 0.7 + 18.3 + q*L_{iw} + L_{ow} R = transmit and receive distance q= the number of walls separating between UE and HeNB L_{iw} = penetration loss of wall separating between UE and HeNB L_{ow} = Outdoor wall loss
UE is inside a different house	PL(dB) = max(15.3 + 37.6$\log_{10}$R, 38.46 + 20$\log_{10}$R) + 0 + 18.3 + q*L_{iw} + $L_{ow,1}$ + $L_{ow,2}$ R = transmit and receive distance q= the number of walls separating between UE and HeNB L_{iw} = penetration loss of wall separating between UE and HeNB L_{ow} = outdoor wall loss

A. LTE uplink power control

The LTE uplink supports power control that allows for macro user equipment to get different target of SINR instead of the same target SINR depend on the path loss to macro base station. Accordingly, the Transmit Power Spectral (TxPSD) is given in dBm [9]:

$$TxPSD = \min \{Tx_{max}, 10*\log10 (M) + \Gamma + I + \alpha*PL\} \quad (1)$$

From this equation, Tx_{max} is the maximum power allowed for base station, M is the number of physical resources block located by node, Γ is target RSSI, I is average uplink interference per resource cluster, PL is Path Loss (including shadow fading), and α is a path loss compensation factor. The value of α can be varies between 0 and 1 ($0<\alpha<1$). In this research, the parameter value of α is varies from 0, 0.2, 0.4, 0.6, 0.8 and 1.0 to find the best optimum value and hence, get the highest value of SINR. All the values are tabulated as in Table 3.

From the equation (1) the value of SINR of macrocell and femtocell can be written as in equation (2) and (3):

$$SINR\_macrocell = TxPSD - Pathloss\_macrocelltoUE \quad (2)$$

$$SINR\_femtocell = TxPSD - Pathloss\_femtocelltoUE \quad (3)$$

Once the optimum value of α has been chosen in TxPSD equation and then adopted in the SINR equation, these SINR equation will be applied in simulation framework in order to identify the handover performance as shown in Figures 2, 3 and 4.

Table-3. Simulation parameter.

Parameter	**Value**
Radius of base station (BS)	1 km
Power transmit, Pt (dBm)	HeNB= 20 BS = 60
Maximum no. of user (UE)	100
Maximum UE velocity (km/h)	100
Number of macrocell user	100
Number of femtocell user	14
Cell layout	7 cell/cluster

B. Power control and handover in femtocell and macrocell network

In this study simulation is done by MATLAB software and represented by hexagonal cell cellular layout framework as shown in Figure-2. It contains 20 clusters with 7 cell per cluster and total cells is 140 cells. The location of BS is located at the center of the cluster of hexagonal cell with 1km of radius. The yellow dotted line represents the femtocell deployed indoor randomly at the cell and it contains 224 femtocells with 14 channel per cell as shown in Figure-3. The 100 UEs with black labelled are distributed uniformly with velocity can be varies from 0km/h to 100km/h at the hotspot position and random movement. The simulation time was setup for 500s. The channel was released by UE after call finish and terminated when reached the simulation time.

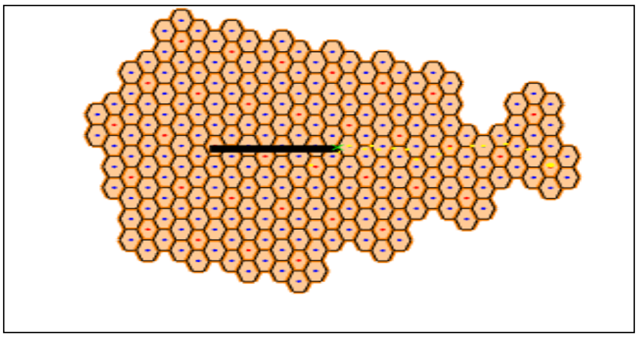

Figure-2. Simulation framework of macrocell and femtocell heterogeneous network.

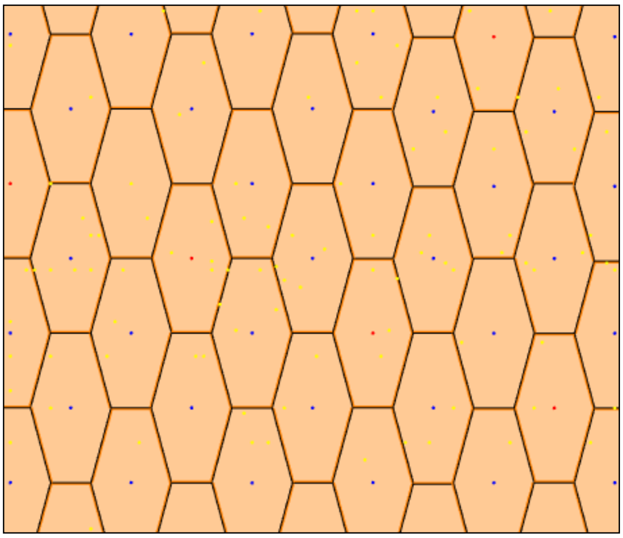

Figure-3. Cell layout in cell architecture of random femtocell.

The flowchart in Figure-4 shows the handover of macrocell and femtocell with power control method used. The process begins when UE enters the networks by selected on the minimum distance of macrocell or femtocell BS. If the UE is nearer to femtocell BS, the speed of UE is measured. In this proposed method, femtocell handover only occurred if the speed below than 30 km/h. If this condition is not satisfied, the macrocell handover will occurred. The femtocell handover process initiated if the proposed SINR as in equation (1) and (3) is satisfied and has enough available bandwidth. The call will be terminated once it is finished. The same process happens for the macrocell handover.

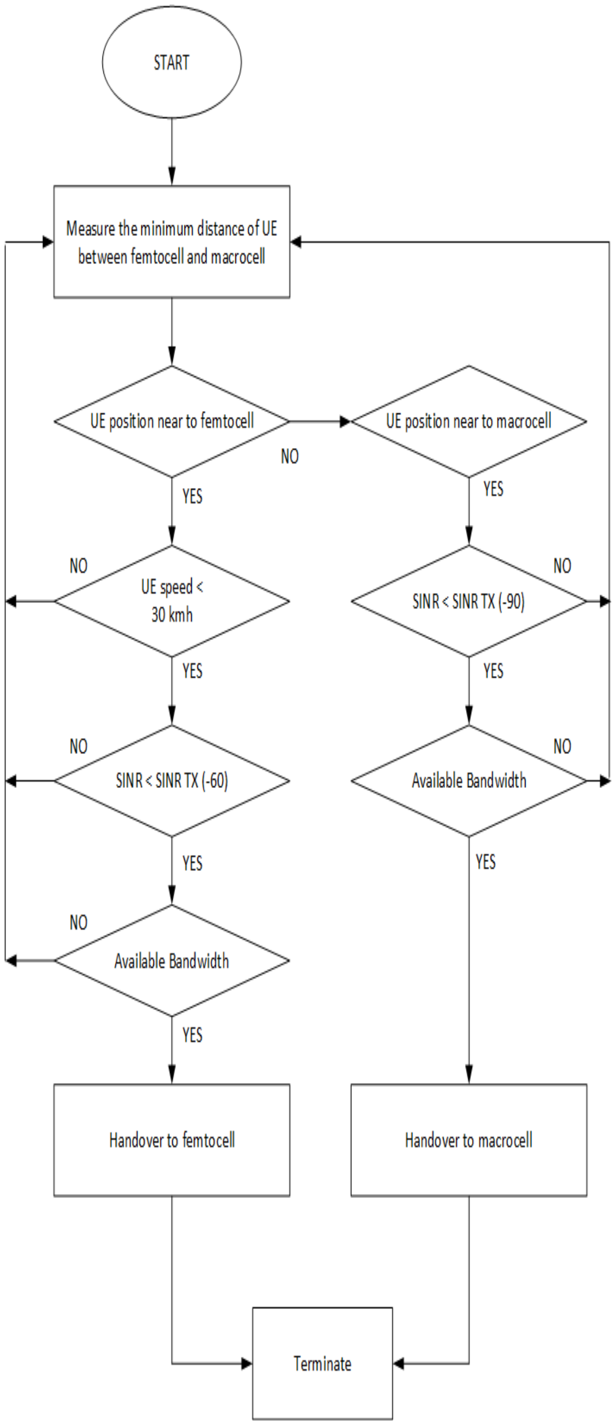

Figure-4. Handover flowchart of macrocell and femtocell with power control method.

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4. RESULTS, ANALYSIS AND DISCUSSIONS

A. Numerical results

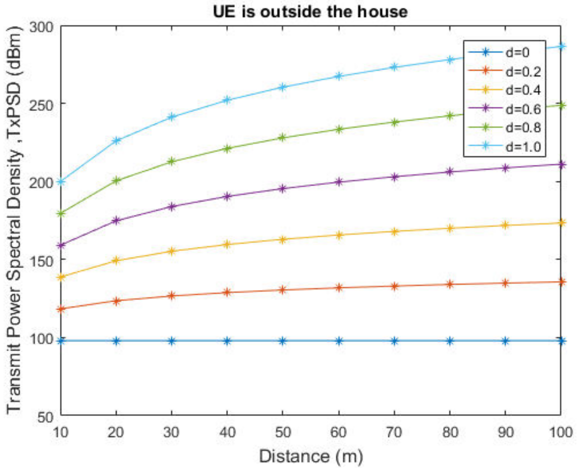

Figure-5. Correlation between transmit power spectral density (TxPSD) and Distance of UE is outside the house to macro BS.

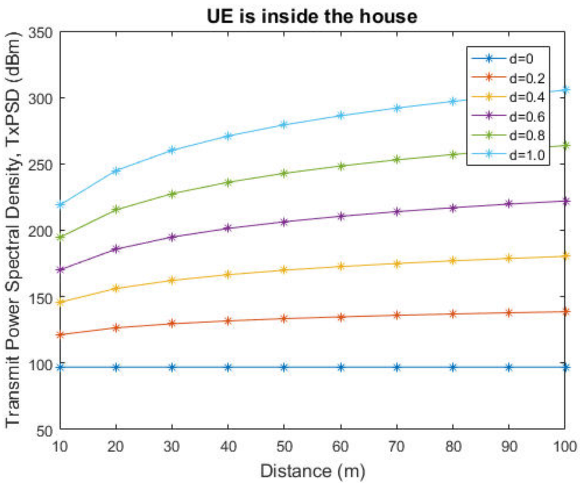

Figure-6. Correlation between transmit power spectral density (TxPSD) and distance of UE is inside the house to macro BS.

Figures 5 and 6 show the numerical result for correlation of Transmit Power Spectral Density (TxPSD) and Distance of UE is inside and outside the house to macro BS with different value of α starting from 0, 0.2, 0.4, 0.6, 0.8 and 1. Based on the graphs, TxPSD is increases as the distance is increases. This is due to the interference and several wall penetration losses as the distance increases. The graphs also show as α higher it gives better TxPSD because path loss is partly reduced by the power control. When α is at 0, the TxPSD remain constant at 100dBm because the TxPSD does not depend on the path loss and fixed where there is no applied of power control at all. The power control achieves better TxPSD when UE is inside to provide satisfactory services for indoors users due to penetrating of the walls.

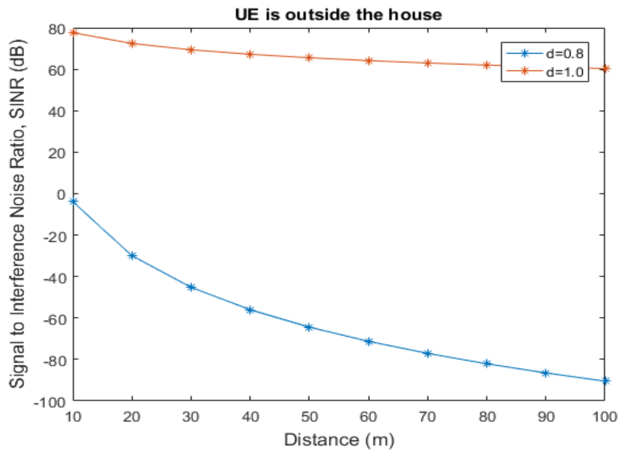

Figure-7. Correlation between signals to interference noise ratio (SINR) and distance of UE is outside the house to macro BS using power control equation.

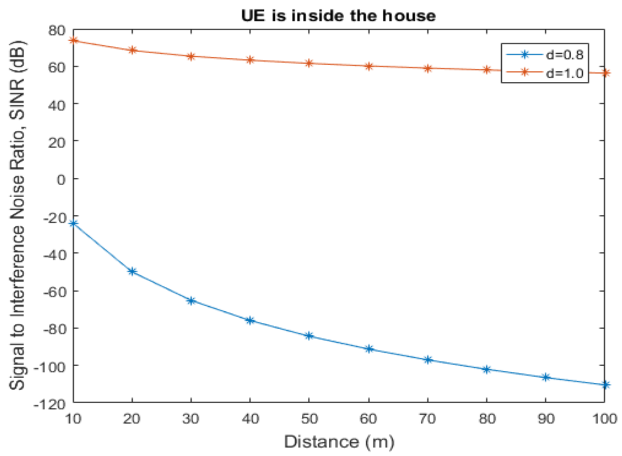

Figure-8. Correlation between signals to interference noise ratio (SINR) and distance of UE is inside the house to macro BS using power control equation.

Figures 7 and 8 shows the correlation between SINR and Distance of UE when it is outside and inside the apartment to macro BS by using power control equation. Based on the result from Figure 5 and 6, the higher value of α is chosen in the graph which is 0.8 and 1.0 to increase the TxPSD value. From the graph, the value of SINR is decreases as the distance increases. The SINR value is lower when UE is inside the house as the exterior walls effect the indoor signal. The value of α equal to 1 gives better SINR which it compensates the path loss more than alpha 0.8.

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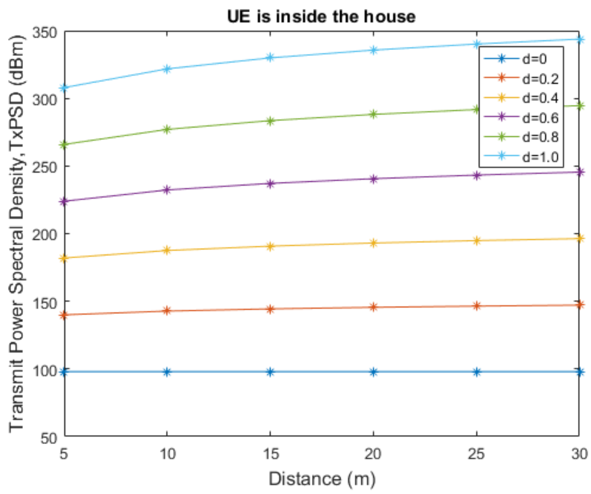

Figure-9. Correlation between transmit power spectral density (TxPSD) and distance of UE is inside the house to HeNB using power control equation.

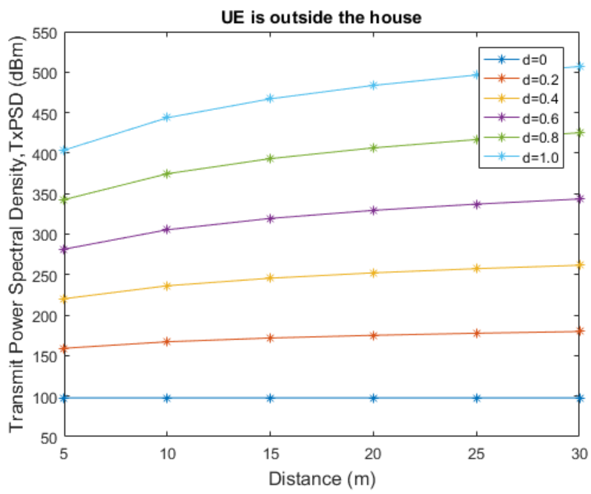

Figure-10. Correlation between transmit power spectral density (TxPSD) and distance of UE is outside the house to HeNB using power control equation.

Figures 9 and 10 show the correlation between TxPSD and Distance of UE is inside and outside the house by using power control equation. Based on the graph, the value of TxPSD is increases as the distance increases. This is due to the interference and several wall penetration losses as the distance increases. The graph also shows the higher α gives better TxPSD because path loss is partly reduced by the power control. When α is at 0, the TxPSD remain constant at 100dBm because the TxPSD is fixed and does not depend on the path loss where there is no power control at all. Moreover the value of TxPSD increases when UE is outside the house stripe due to the number of walls separating house between UE and HeNB and penetration loss of the wall separating house.

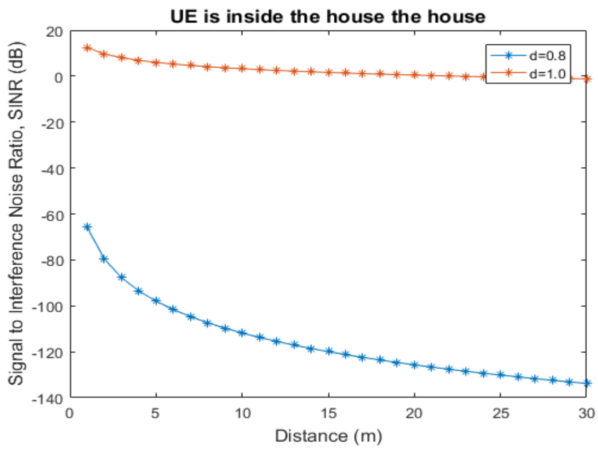

Figure-11. Correlation between signals to interference noise ratio (SINR) and distance of UE is inside the house to HeNB using power control equation.

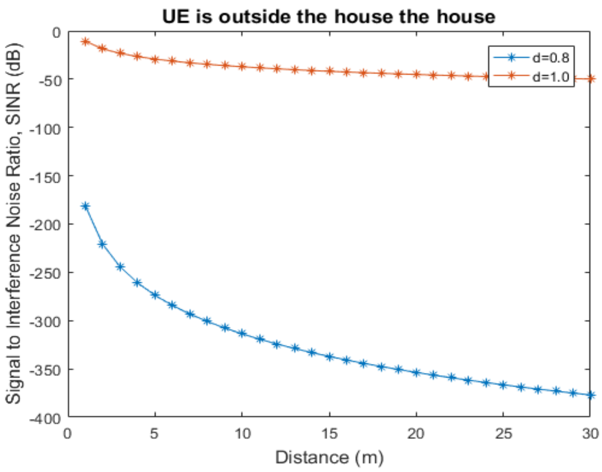

Figure-12. Correlation between signals to interference noise ratio (SINR)-and distance of UE is outside the house to HeNB using power control equation.

Figures 11 and 12 show the correlation between SINR and Distance of UE is inside and outside the house to HeNB by using power control equation. The higher value of α αwhich is 0.8 and 1.0 is used in the graph to increase the TxPSD value. From the graph, the value of SINR is decreases when the UE is far from the HeNB as it effected by the exterior wall and the value of α equal to 1 is better which it compensate the path loss more than α of 0.8.

B. Simulation results

Figure-13 shows the number of handover versus the number of UE by using power control and without power control. The speed of UE is maintained at 100km/h and the simulation time is set at 500s. The number of UE was set from 100, 80, 60, 40 and 20 respectively. The number of successful handover by using the power control is higher compare to without using power control when the number of UE are 100, 80 and 60 respectively. The value of α by using the power control is set to 1.

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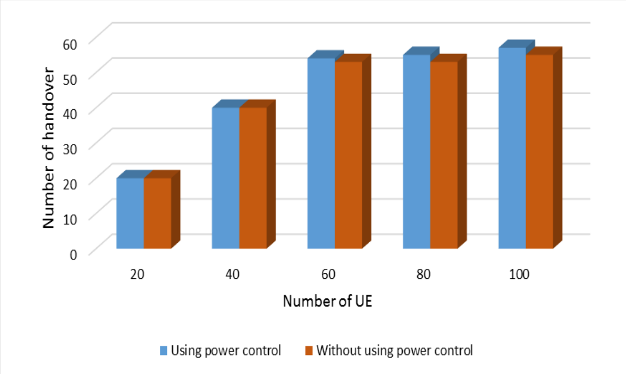

Figure-13. Number of handover versus number of UE using power control and without power control.

As proven from the previous graph, the value of 1 is chosen to receive full compensation of power control to achieved target received power as it is reduces the path loss. The value α without using the power control is 0 as the transmission power is fixed and does not depend on path loss. The fact that there is no power control at all and the received power at cell edge are weak. The value is not so much difference due to limited simulation time. However as can be seen from the figure, it does increase number of successful handover by using the proposed power control method as compared to without using power control.

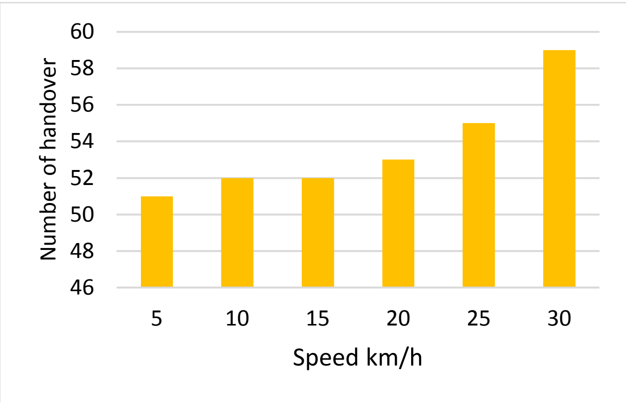

Figure-14. The number of femtocell handover versus the UE speed.

Figure-14 shows the number of femtocell handover versus the UE speed in km/h for low speed. The speed is set from 5, 10, 15, 20, 25 and 30 respectively. The number of UE is maintained at 100 and the simulation time is 500s. According to 3GPP standard, 5km/h to 30 km/h is considered as low speed [10]. The power transmits for the macrocell and femtocell are set at 60dBm and 20dBm, respectively. As can be seen from the figure, the number of successful handover increases as the speed increases. This situation occurred because the UE will initiate the femtocell handover when the UE speed is below than 30 km/h as stated in the handoff flow chart as shown in Figure-4. From this result, it shows that by applying the power control method, the interference has been reduced as SINR is better and hence the number of successful handover increased. Moreover, by the higher handover initiated to the femtocell, the macrocell traffic can be offloaded to the femtocell and hence higher network capacity can be achieved.

5. CONCLUSION AND RECOMMENDATIONS

The performance of power control technique on macrocell-femtocell LTE networks based on theoretical and simulation has been studied on this paper. From the numerical results, LTE uplink supports power control that allows for UE to get different target of SINR instead of the same target SINR depend on the path loss to base station. The used of compensation factor, α equal to 1 totally reduces the path loss in order to extend the targeted received power and give full compensation of power control. It is proven as simulation results show the number of successful handover increases when power control is adopted in the macrocell-femtocell networks. So by applying the power control technique in macrocell-femtocell LTE networks, the SINR value is better as it can mitigate the interference in the macrocell-femtocell networks and hence, increased network capacity.

There are some recommendations may be proposed for the future research. First recommendation is by combining this technique with other power control technique that considered different path loss so that it can optimize the network performance. To further investigate on femtocell deployment, it is suggested that the research also includes the other type of access modes which are closed and hybrid modes.

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REFERENCES

[1] O. Akinlabi and M. Joseph. 2016. Signal behaviour in an indoor environment: Femtocell over macrocell. in Environment and Electrical Engineering (EEEIC), 2016 IEEE 16th International Conference on. pp. 1-5: IEEE.

[2] A. Agarwal and P. Dahal. 2013. Adaptive Power Control Applying to Femtocell. 2013.

[3] M. Iturralde, T. A. Yahiya, A. Wei, and A.-L. Beylot. 2012. Interference mitigation by dynamic self-power control in femtocell scenarios in LTE networks. in Global Communications Conference (GLOBECOM), 2012 IEEE, pp. 4810-4815: IEEE.

[4] Y.-W. Kuo, L.-D. Chou and Y.-M. Chen. 2015. Adaptive Smart Power Control Algorithm for LTE downlink cross-tier interference avoidance. in

Heterogeneous Networking for Quality, Reliability, Security and Robustness (QSHINE), 2015 11th International Conference on, pp. 24-30: IEEE.

[5] A. Kalaycıoğlu and A. Akbulut. 2017. Simulated Annealing Based Femtocell Power Control in Heterogeneous LTE Networks.

[6] V. Chandrasekhar, J. G. Andrews, Z. Shen, T. Muharemovic and A. Gatherer. 2009. Distributed power control in femtocell-underlay cellular networks. in Global Telecommunications Conference, 2009. GLOBECOM 2009. IEEE, pp. 1-6: IEEE.

[7] A.-H. Zyoud, M. H. Habaebi, J. Chebil, and M. R. Islam. 2012. Femtocell interference mitigation. in Control and System Graduate Research Colloquium (ICSGRC), 2012 IEEE, pp. 94-99: IEEE.

[8] D. C. Shah and A. Malhotra. 2016. Coordinated Inter Cell Interference Avoidance Techniques and Performance Parameters for Cross Layer Interference in LTE-A Network. in Advanced Computing (IACC), 2016 IEEE 6th International Conference on, pp. 661-666: IEEE.

[9] Agarwal Ankit and Pravesh Dahal. 2013. Adaptive Power Control Applying to Femtocell. Diss.

[10] H. Zhang, X. Wen, B. Wang, W. Zheng, and Y. Sun. 2010. A novel handover mechanism between femtocell and macrocell for LTE based networks. Presented at the Second International Conference on Communication Software and Networks.