

SINR Performance of Macro and Femto LTE-A Network by Fractional Frequency Reuse Jointly Dynamic Power Control Method

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Abstract—This paper studies a two-tier macrocell/ femtocell covered heterogeneous network based on Orthogonal Frequency Division Multiple Access (OFDMA) technology. In order to survive the surge in demand for stable and high data rates among mobile users, femtocell has been developed to increase indoor capacity and coverage. However, arrangement of femtocells has a challenge which is interference between femtocells itself as well to the present macrocells due to the femtocells sharing the similar frequency band assigning as macrocells. This will deteriorate the SINR user's performance. Therefore, the Fractional Frequency Reuse (FFR) of six jointly a Dynamic Power Control (DPC) is proposed for mitigating the interference experienced between macro and femto users. This paper studied the effect of path loss compensation factor, α on the value of Signal to Interference Noise ratio (SINR) and proposed the best value of α . The simulation results indicate the proposed method is advantageous and can control the transmit power of the UE in femtocell along with the SINR (Signal to Interference plus Noise Ratio).

Index Terms—About DPC; Femtocell; FFR; Interference; Macrocell; OFDMA; SINR.

I. INTRODUCTION

Femtocell Base Station (FBS) are deployed within macrocell coverage area to increase performance of indoor user. In order to protect all indoor users, FBS make a network recognized as femtocell network. Since, FBS use same spectrum, they are causing interference on both Macro Users (MUE) and among Femto Users (FUE). The performance of the femtocell network depends on the SINR of FUEs of respective FBS which eventually depends on the interference produced on it. 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.

The cause of FBS using the same spectrum is because of the inadequate of radio spectrum which is the serious problem in mobile communication network nowadays. So that one competent way of spectrum resource consumption is applying the Fractional Frequency Reuse (FFR). The inadequate of

radio spectrum leads of Co-Channel Interference (CCI) problem cause of the frequency and time resources are allocated to users in orthogonal manner. The CCI problem will occurs if the same sub-carriers are used by different users among adjacent cells particularly for cell edge users. Proper inter-cell interference coordination technique should be essential to boost the system capacity and system throughput [1-3].

The underlay idea named a heterogeneous network that is involving of macrocell and Low Power Nodes (LPNs). The LPNs has three features that make it easy and further flexible to deploy such as the LPNs are smaller in size, cost less and have a lower transmission power. The types of LPNs that has deployed in heterogeneous network are Picocell, Femtocell and Relay Station [4].

The remaining part of this paper is organized as follows. The following section is an overview of the related works. After that, methodology of this research work is presented. Results and discussion in the next section are conducted to analysed the performance of the SINR for both macro and femto networks. The conclusion is concluding in last section.

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II. LITERATURE REVIEW

Interference management issues for the femtocell systems have been aggressively discussed in the LTE network nowadays. As the technologies growths from 1G to 4G, there are frequent readings obligate tried to describe as well as study the interference mitigation in a network through analysis of SINR performance. Refer to technical paper [5] "Comparison of SINR in femtocell and macrocell network in macrocell environment" written by Kanak Raj Chaudhary and Rachna Arya, the paper evaluates the SINR performance of femtocells in presence of macrocell. In this study, the author minimizes the interference between macro and femto in order to improve the performance. Besides, the author also analyzes the outage probability in femtocell network. Finally, consider the power consumption of femtocell network. The simulation results have presented an optimum combination of

ranges for lowest interference for femtocell users. In the finding, we had seen that that deployment of femtocell reduces the power consumption and improve the coverage. However, this technique need to deployed efficiency first then the performance in term of power and coverage can be improves later.

The authors of [6] studied the different frequency reuse schemes in OFDMA network such as the LTE in order to prevail over the CCI problem. The total frequency band is separated into several sub-bands and each cell is allocated with the dissimilar sub-band as the way to lessen the interferences. However, the authors have presented expressions of SINR as well as cell data rate for integer frequency reuse (IFR), FFR and two level power control (TLPC) schemes where is offered an analytical approach based on the fluid model. The conclusion of this authors work is intra-cell interference is removed and the inter-cell interference is significantly reduced.

The author of [7], investigated a coverage radius based adaptive power control scheme to mitigate interference for blindly placed LTE femtocells. The author was analysed by using system level simulation where is for single and multi-cell scenario. The simulation results have shown that the proposed scheme has an improved value of cross-tier SINR, throughput and lower co-tier SINR while compared to baseline and existing adaptive interference mitigation schemes. However, the proposed scheme does not require FAPs to be relocated on optimal locations for effective interference mitigation.

In [8], a femtocell power adjustment method whose main objective is to surge the average throughput of non-CSG MUEs by preventive the amount of interference caused by femtocells is proposed. However, the proposed priority weights used in the femtocells' Score Functions provide an efficient means for achieving the desired level of macrocell/femtocell throughput trade-off.

In [9], a method for optimal FFR scheme selection based on the mean user throughput or user satisfaction is proposed. This lesson is shown in a cellular network that does not bring the presence of femtocells. In [10], instant channel allocation technique is proposed under FFR method in order to improve the system throughput. In this research work, the Physical Resource Blocks (PRBs) is allocated to femtocells user through sectored FFR method to mitigate the interference between macrocell and femtocell. However, this research work only adopted three sectored FFR to analyze the performance of the implemented scheduling algorithms. In [11], FFR based resource allocation for device to device (D2D) is proposed. D2D communication consents two cellular devices to connect with each other without a base station, Another research work regarding on D2D communication in cellular networks with adopted the FFR method to mitigate interference is proposed in [12]. However, this research work also adopted three sectored of FFR same applied in [11].

The FFR is one of the answers to lessen the inter-cell interference in macrocell particularly for the cell edge users. Below this circumstance, the interference from the femtocell deployment ought to be lessened for the macro users. Motivated by the accomplishment of C.Y.Oh [13], A.S.Afolabi [14], Z.H.A.Hassan [15] and the limitation of the author's work, the researcher goes advance towards study the SINR performance of the user's.

III. METHODOLOGY

A. System Model

The main objective of this research work is to study the SINR performance for both macro and femto users by using the propose method which is the FFR of six sectors jointly with a DPC method. In order to accomplish this objective, the FFR method needs to be used in order to lessen the interference and then the DPC method is to study the effect of path loss compensation factor, α on the value of SINR. Hence, a good SINR performance will be achieved.

FFR is some of the interference mitigation method where is splits the band into certain sub-band then allocates that one toward dissimilar areas of a cell. Figure 1 showed how the radio resources are dividers for macrocell also femtocell networks in this research work. It demonstrate the network resources in this work are divided created on FFR method through propose of six sectorizations where enhancement and modification from [14].

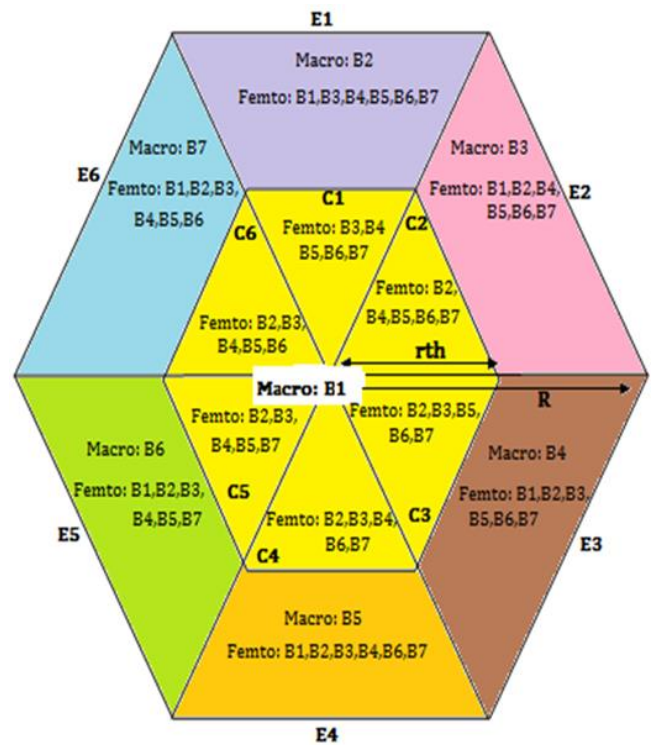


Figure 1: The Cell Structure of FFR

One partition of the available frequency band is devoted to the cell center users with reuse factor of 1, while the rest of the spectrum is respectively divided in six sub-bands and allotted to the cell edge users with reuse factor of 6. Figure 2 demonstrate the framework structure of the propose Dynamic Power Control Method (DPC) used in this research work.

The method focusses on the derivation of a mathematical formulation of SINR value which is the first propose method, FFR of 6 sectors is highlight the significance of the fraction of radius in center region (r_{th}) as well as the fraction of the system bandwidth (β) allocated for center area based on FFR method and for second propose method which is DPC, it is highlight the path loss compensation factor (α). The SINR performance of macro and femto network is analyzed based on four analyses. First, study the macro SINR performance for different distance of MUE and MBS. After that, the femto SINR performance for different distance of FUE and FBS is

studied. Next is the analysis of the comparison femto SINR between proposed method (FFR of 6) and the conventional method. Last analysis is the SINR performance of FFR 6 jointly a dynamic power control method (DPC). Several mathematical formulations elaborate in this research work in this manner.

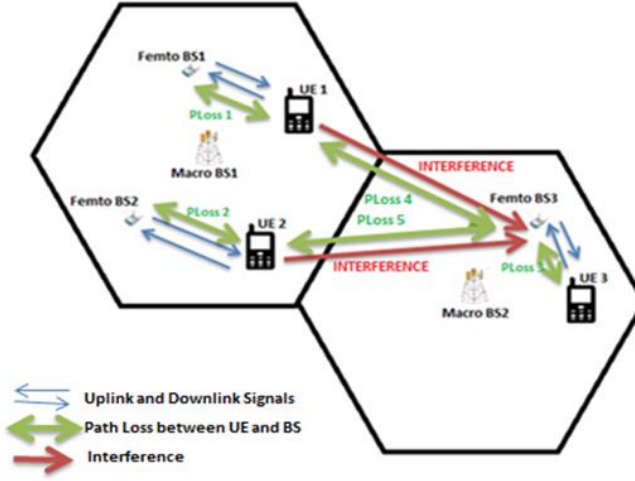


Figure 2: Framework Structure of Propose DPC

B. Mathematical Formulation

Since the work is implementing the hexagonal network model, so that the area of the hexagon can be calculated from the following equation:

$$\text{Area of hexagon} = \frac{\sqrt{3}}{4} R^2 \times 6 = 2.598076211R^2 \quad (1)$$

Next, the capacity for macro user center region and edge region is calculated as shown in our previous work [16].

$$C_{mcu} = \frac{\beta W R m^2}{(2.418399153)(N_m) \int_0^{1000rth} \frac{1+CINR_{center}}{r} dr} \quad (2)$$

$$C_{meu} = \frac{(1-\beta) \left(\frac{W}{6}\right) R m^2}{(2.418399153)(N_m) \int_{1000rth}^{1000} \frac{1+CINR_{edge}}{r} dr} \quad (3)$$

The SINR for macro and femto user can be calculated as follow:

$$SINR_{mcu} = (-35.49774998)(N_m)(rth)^2 / \beta W R m^2 (-3.024565) \quad (4)$$

$$SINR_{meu} = [(-3.119891493 \times 10^{-3})(N_m)(rth)^2 + (3.119891493 \times 10^{-3})(N_m)] / (-3.024565)(1-\beta)(W/6)(Rm^2) \quad (5)$$

$$SINR_{fu} = (-6.896551784 \times 10^{-7}) / (-3.024565)[30.08137381N_f W + 30.08137381N_f W \beta - 36.09764857N_f W (rth^2) \beta] \quad (6)$$

where: R = Radius of the hexagon cell
 SINR_{mcu} = SINR for macro center user
 SINR_{meu} = SINR for macro edge user
 SINR_{fu} = SINR for femto user
 β = fraction of the system bandwidth for center region
 rth = fraction of the center region radius

W = The system bandwidth
 N_m = The number of macrocell
 N_f = The number of femtocell

C. Software Description

The simulation results are conducted by using MATLAB software. Assume that the work takes the restriction which definitely not multi access channel and no fading for simplicity. Table I denoting the numerous simulation parameters that have been used in the simulation part in order to achieved the results presented in the next section

Table 1
The Simulation Parameters [9][14][17][18][19]

Parameter	Settings
Bandwidth (W)	10MHz
Macro Radius (R _m)	1000m
Femto Radius (R _f)	500m
Distance between macro user and neighboring macro base station (D)	1732m
Number of macrocell (N _m)	100
Number of femtocell (N _f)	100
Outdoor path loss exponent (α)	4
Indoor path loss exponent (α')	6
Macro Center User Transmit Power (P _{mc})	15W
Macro Edge User Transmit Power (P _{me})	22W
Femto Transmit Power (P _f)	20mW
Noise Power (N ₀)	-174dBm
Number of occupied sub-carrier (k)	25
Sub-carrier assignment (B _{mk} , B _{fk})	1

The overall network is composed of two-tier of macrocells and femtocells and the femtocells are randomly deployed over the macrocells. All the base stations are operated by the OFDMA technology. An Omni-directional antenna and the six sector antennas are installed at a macro base station. The transmit power for center and edge region are 15W and 22W respectively. While the transmit power for all femto base station is 20mW.

IV. RESULTS AND DISCUSSION

Figure 3 shows the correlation between SINR and distance between Macro User (MUE) and Macro Base Station (MBS). The SINR value is illustrated for different value of β , range from 0.1 to 0.9 where is β denoted as fraction of system bandwidth. It is clearly shown as the distance between MUE and MBS increase, the SINR will be increased. In this analysis, the Fractional Frequency Reuse of six (FFR of 6) is proposed with every cell is divided into two regions where are center region and edge region. Hence, we can say that as MUE move away from the MBS, the SINR of MUE will be also increasing. Which mean the proposed method (FFR of 6) has been reduced the interference in cell so that the user can maintain the SINR when they move away from MBS. From the figure below, the higher value of β will give better SINR. When β is set to minimum which is 0.1, meaning that lower resources is assigned to that, lower the capacity of user and the SINR of MUE will keep at minimum value. As for maximum value of $\beta=0.9$ applied here, the SINR of MUE is higher compared to the lower β assigned.

Figure 4 shows the correlation between SINR and distance between Femto User (FUE) and Femto Base Station (FBS). The SINR value is illustrated for different value of β , range from 0.1 to 0.9. Terms SINR, Signal to Interference plus Noise Ratio is a function of a power used at the transmitter to measure the quality of wireless connections. The energy of a

signal fades with distance and measured in dB. As seen in figure below, a higher β will give higher value of SINR. In terms of FUE location, the FUE near FBS will give a higher SINR as compared to FUE located at edge region cell. Also in this case, the distance of the FUE and FBS is limited to 0.5km as maximum distance for femtocell cases. In this analysis, the size bandwidth used by each FUE located at the center region and edge region is divided into six. So, as the FUE not connected to the nearest base station, the user will have the decrease of SINR value. As we had seen in our analysis that deployment of femtocell reduces the power consumption and improve the coverage.

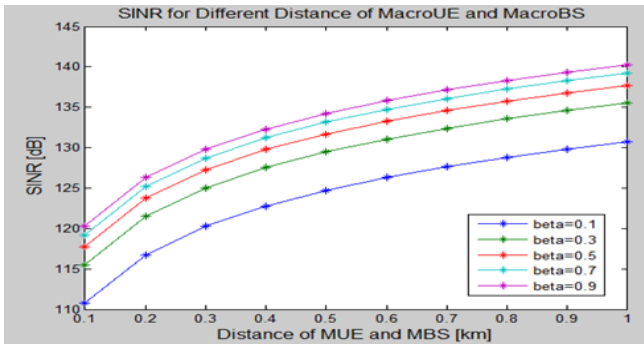


Figure 3: SINR for Different Distance of MacroUE and MacroBS

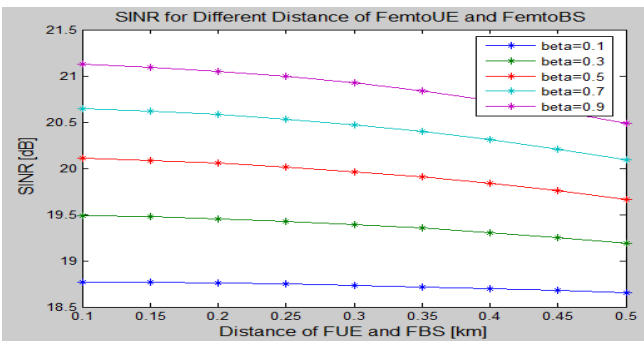


Figure 4: SINR for Different Distance of FemtoUE and FemtoBS

The simulation results for the LTE FFR of 6 and FFR of 3 are calculated and graph of femto SINR are plotted as shown in Figure 5. As we know, for the FUE, they will require more high speed for different data services and this is why a different SINR needed for different FUE. Refer to Figure 5, the graph showing the correlation between SINR and distance between FUE to FBS. But, when we compare the SINR value when $\beta=0.5$, $\beta=0.7$ and $\beta=0.9$, we can see that the value of SINR is increasing with the increase in β value. From the figure below, we were observed that the SINR for FFR of 6 is much higher and improved rather than FFR of 3. It is meaning that the FFR of 6 is helping much in reducing the interference for mobile communication network. This was calculated and simulates using FFR of 6 and FFR of 3 equations. So from here, we can conclude that the best choose of β value is 0.9.

Next, we compare the femto SINR for two different value r_{th} which $r_{th} = 0.8$ and $r_{th} = 0.9$. As mention previously, r_{th} is denoted as the fraction of radius for center region in hexagon cell. Figure 6 and Figure 7 shows the femto SINR for varies of transmit power for $r_{th} = 0.8$ and $r_{th}=0.9$ respectively. The femto transmit power is varies from 10dBm to 20dBm as the maximum of femtocell transmit power is 20dBm as state in 3GPP specification [20]. From this

analysis, we can say that as the power transmit of FemtoUE increase, the SINR will be increased. Also, the higher value of path loss compensation factor, α will give better SINR because path loss is higher compensated. As seen in Figure 6, the value of SINR higher rather than value of SINR in Figure 7. It is occur because of the higher the value of r_{th} in cell means that the distance of user from serving base station is become far away. Hence, the value of SINR will be decreased.

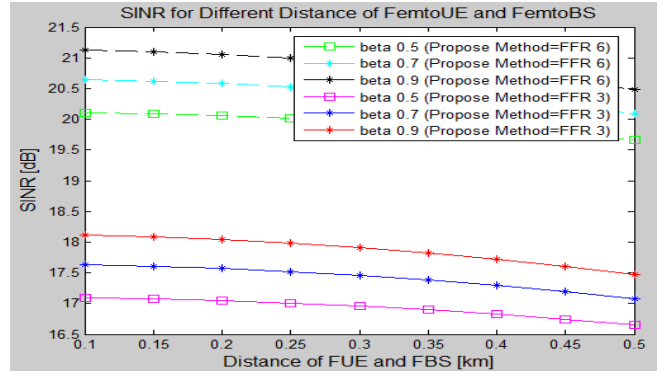


Figure 5: The Comparison of SINR Between FFR 6 and FFR 3

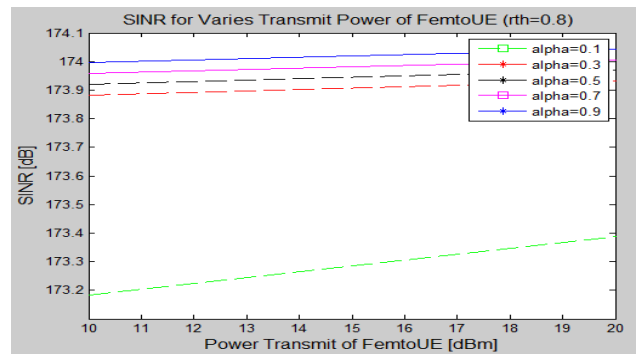


Figure 6: The SINR for Varies Transmit Power of FemtoUE ($r_{th}=0.8$)

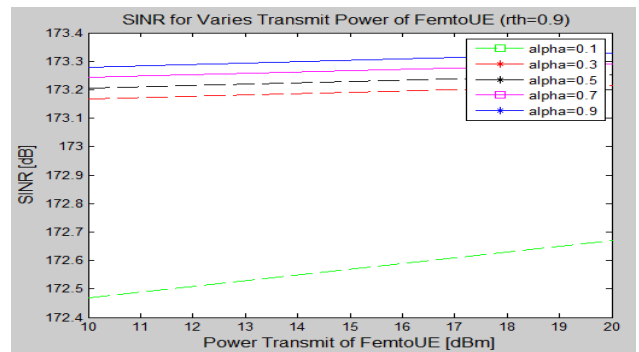


Figure 7: The SINR for Varies Transmit Power of FemtoUE ($r_{th}=0.9$)

V. CONCLUSION

In this study, the two-tier network interference of LTE network that consists of macrocell and femtocell has been observed. The SINR performance of UE that involvements interference from other BS has been evaluated to realize the effect of interference to network performance. The parameters r_{th} , α and β is studied in order to see the effect all these parameters on the value of SINR performance. In can be concluded that higher value of α will give better SINR, here it can say the optimal value of α and β are 0.9. The

technique proposed is based on the idea of fractional frequency reuses of 6 sectors that jointly with dynamic power control method (DPC) in order to reduces interference in network and achieves higher SINR performance. The proposed method enhances the SINR performance LTE network. It is also beneficial for the OFDMA network such as the LTE network where the FFR is applied.

This study will be continues through observing on the development an algorithm that can offload macrocells traffic to femtocells and the inter-cell interferences can be reduces in a network in the future work.

ACKNOWLEDGMENT

This paper is part of research work that supported by the REI grant no. 600-RMI/DANA 5/3/REI (1/2015) and the Faculty of Electrical Engineering, UiTM Shah Alam.

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