A NOVEL RESOURCE ALLOCATION METHODOLOGY TO IMPROVE OVERALL NETWORK EFFICIENCY IN LTE HETEROGENEOUS FEMTOCELL NETWORKS

MEGHANA ADUSUMILLI

M.Tech Student (wireless and mobile communications), Department of ETM, GNITS, Hyderabad, Telangana, India. ***adusumillimeghana@gmail.com***

---***---

Abstract - *Long-term evolution (LTE) has become one of the fastest wireless technologies. LTE Femtocells represent a very promising answer to the ever growing bandwidth demand of mobile applications .It is a low-power cellular base station basically designed for providing better in-building coverage in residential and small business offices from the Macro layer by their placement in the end-users' homes. The Macrocell and Femtocell in LTE cellular network use same frequency band which leads to co-channel interference. OFDMA is used for the downlink transmission in LTE. Using this, different physical resource blocks (PRBs) are assigned on request for Femtocell users through Femtocell base station in two tier Macro Femto cellular system. In this paper, an efficient method to improve system capacity through improved cell edge capacity in the existing Femto-Macro two tier networks has been proposed. In the proposed scheme, power controlling technique is used where Macro base stations limit power of Macrocell user's resource blocks using a power control factor to decrease Inter-cell interference between cell edge users and improve cell edge capacity.*

***Key Words*: Long term evolution (LTE), Inter cell interference, Femtocell, power ratio, PRB, Soft frequency reuse (SFR), Fractional frequency reuse (FFR) .**

1. INTRODUCTION

Fourth generation (4G) wireless systems (and beyond) are currently being developed to meet the explosive growth in demand for higher data rates by wireless devices. Due to the appealing characteristics of OFDMA, the major 4G standardization bodies such as IEEE and 3GPP/3GPP2 have adopted OFDMA as the main radio access technology for 4G standards such as Wi-MAX (worldwide interoperability for microwave access) and LTE (long term evolution) .Long Term Evolution (L TE) system is designed to achieve high spectral efficiency using Orthogonal Frequency Division Multiple Access (OFDMA). OFDMA and Single Carrier Frequency Division Multiple Access (SC-FDMA) are used for Downlink and uplink transmission respectively. However, indoor cell phone signal is one of the concerning issues in LTE technology. It has been found that a significant percentage of voice calls and data traffic are originated from the indoor environment. In fact indoor environments contribute for more than 50% of voice calls and more than 70% of data traffic services. Nowadays, the main base station (BS), known as Macro BS (M-BS), has the problem of maintaining strong signals after penetrating through the walls in order to provide satisfactory services for indoor users.

A Femtocell is a type of cell for use in the home, or in an office or some other smaller location. A cell is a part of the wireless network that makes up all of the coverage for mobile phones, including smart phones. A Femtocell is a very useful piece of technology that improves the coverage of mobile phone networks in areas where cell signal can be weak. A Femtocell is a very low-range, low-power base station, able to be deployed in a home, home office or office. It is usually provided by a mobile network operator, and operates in licensed frequency bands. Femtocell is the most recent step towards increasing the network capacity of a wireless network and improving the quality of service for cellular users.

A conventional cellular network overlaid with Femtocells can provide better improved coverage, quality of service, and system capacity. Femtocell base stations are user-deployed which are low-power, low-cost home base stations that enhance the cellular network. A Femtocell BS (F-BS) is installed by end users at homes or offices which provides a wireless interface for subscribers and it connects a small number of cellular users and the core Telephony Network via wired internet. It is used for the purpose of indoor network access. The typical indoor coverage of a Femtocell is in the order of ten meters. A Macrocell covered by M-BS can contain hundreds of F-BSs.

Home base station or Femtocell is the solution to improve the indoor coverage [1]. The Co-Channel interferences occur between Femtocell and Macrocell because both of them use the same frequency band [2]-[3].Using OFDMA as a multiple-access technique, different physical resource blocks are assigned to Femto users and macro users who are interfering with each other. FFR and

SFR are two of the solutions to reduce co-channel interference between Macrocell and Femtocell. A cell with three sectors and virtual sectors is divided into center zone and edge zone. Macro-cell users in the edge zone suffer severe interference from the Femtocells due to complete co-channel operation and low power signal received from Macro-cell BS. The inter channel interference can be reduced by varied power distribution which provides better power and throughput to edge users simultaneously taking care of center user throughput.

The rest of this paper is structured as follows. The related works are described in Section 2. Section 3 presents the system model and Section 4 looks at the mathematical model. Section 5 explains the proposed approach and Section 6 shows the simulation results. Finally, a conclusion along with future scope draws in Section 7.

2. RELATED WORKS

Interference between Femtocell and Macrocell has been noticed by many alliances. The co-channel interference .To mitigate the interference, several adaptive approaches have been proposed. Some of these approaches are: fractional frequency reuse (FFR) method [4,5], soft frequency reuse (SFR) method [6],. Fractional frequency reuse (FFR) and soft frequency reuse (SFR) [7] methods have been proposed to achieve frequency reuse factor I and reduce ICI in LTE networks. In FFR, the system spectrum is divided into two non-overlapping bands, referred to as inner and outer bands. The inner band is reused in every inner cell region to serve users near the cell center while the outer band is shared by outer cells to serve users located in cell edge, with a reuse factor greater than 1. SFR differs from FFR in that the whole spectrum can be reused in every cell. In SFR the spectrum in each cell is divided into two groups, major and minor subcarriers. The major subcarriers can be used by users located in both inner and outer cell regions and they are orthogonal to each other in adjacent cells. The minor sub-carriers have lower transmit power than the major subcarrier's and are used only by inner cell users. The ratio between minor and major subcarrier transmit powers is referred to as power ratio. The spectrum and power allocation for major and minor subcarriers in the SFR schemes are fixed. In [8] a hybrid frequency assignment for Femtocells in co-channel operation system has been proposed. Co-channel operation is only allowed in the edge zone, while Femtocells in the center zone use a dedicated frequency band which is not used by Macrocell users. Even though this method can reduce interference between the Macrocell and Femtocells in the center zone, Macrocell users in the edge zone suffer severe interference from the Femtocells due to complete co-channel operation and low power signal received from Macrocell BS.

3. SYSTEM MODEL

A number of randomly distributed indoor and outdoor environments with Macrocells, Femtocells and mobile stations are defined. A cell layout consists of seven hexagonal Macrocells environment, each of them is divided by central zone and edge zone. Edge zone is divided into three sectors each sector with 10MHz bandwidth. Femtocell ranges are around 10meters. Only one Femtocell user for each Femtocell BS is considered in an indoor environment. All Femtocells users are located within Femtocell range and Macrocell users are normally located randomly throughout the cell. Also some Macrocells users are located within Femtocell range. Each Femtocell operates in a closed subscriber group (CSG). CSG is chosen because when a Macrocells user enters within Femtocell range and if the user receives stronger signal at the time from the Femtocell base station then interference occurs.

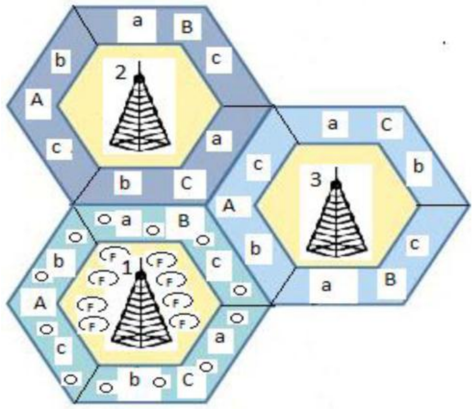

Fig -1: Femtocells deployment in Macrocells

The figure 1 shows a system model with Macrocell which is divided into center zone and edge zone. Edge zone has three sectors covers 120 degree each denoted by sub-area A, B, C. Each sub area has 60 degree virtual sub sectors denoted in small letters a, b and c which are allocated as the same frequency sub-band and power of A, B and C respectively. For Macrocell, different frequency sub-band (PRBs) is allocated to the each Macrocell sub-area according to the FFR. Consider the total number of PRBs is N which are allocated with equal power distribution (existing system). Number of PRB allocated for center zone is 2N/3 and for edge zone is N/3. Also consider N/3 is the sum of PRB allocated for sub-area A, B and C respectively.

In the existing scheme, PRBs for center zone is two third of total PRBs. The PRBs allocated by A can be used by the users of virtual sector 'a' and the PRBs allocated for B can be used by the user of virtual sector 'b' on-request basis. Femtocells and cell edge users can use only the PRBs 'a', 'b' or 'c'. Number of cells under consideration is seven. Cell radius is selected to be 500-600 meters.

Maximum transmission power allowed for a Macro Base Station is 43dBm or 20 Watts and maximum transmission power for Femtocell base station is 20mWatts. Total number of available Physical Resource Blocks (PRBs) is 25 for a bandwidth of 10MHz. When a Macrocell user or Femtocell user attempts to make a call, it then measures the signal strength receiving from nearer BSs. Say, T1 signal is received from its serving BS and T2, T3, T4 signals are received from other BSs. If T1» T2 or T3 or T4 in terms of signal strength then user is allocated PRBs from its serving BS. If T1 > T2 or T3 or T4 OR T1 < T2 or T3 or T4 in terms of signal strength then user is allocated PRBs from either virtual sub-sector a or virtual sub-sector b on request basis. Figure 2 shows existing method of equal distribution of power.

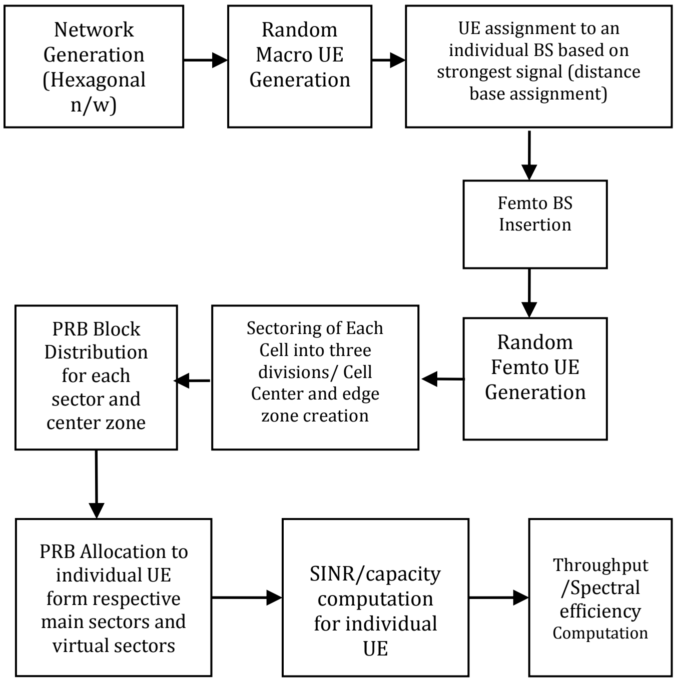

Fig-2: Equal distribution of power for improving system capacity through on request channel allocation

4. MATHEMATICAL MODEL

Inter-cell Interference for macro cell edge users is increased when using same power (existing method-equal power distribution) for both Macro users and Femto users PRBs ,as a result edge zone macro users do not get enough power to receive signal from the Macro base station . Thus, the objective of using power factor for user's PRB in a cell is how many users are classified into center zone and edge zone separately. For that each user's SINR is calculated individually after giving a power factor or power ratio which is defined as a ratio of center zone PRB power to edge zone PRB power.

A. Power ratio

Power ratio α= Center PRB power / Edge PRB power
Center power = α x edge power
Edge power +α edge power= total power

$$P_{edge} = \frac{nP_{total}}{N(1+\alpha(n-1))} \quad (1)$$

Where,
P_{edge} is edge PRB power, P_{total} is total transmit power of Macro base station, N is total PRBs, n is reuse factor.

B. SINR-Signal to interference plus noise ratio

$$SINR = \frac{P}{N+I} \quad (2)$$

Where,
P denotes transmit power of base stations, N is thermal noise, I is interference.

C. Path Loss

Path loss models are used to represent indoor, outdoor, and indoor-to-outdoor (and vice versa) channel environments. These are best suited for a dense urban Femtocell deployment. Path loss LS is determined by the distance between the transmitter and receiver for each subcarrier. Three models for the channel path loss are described here [9].

UE to Femto-BS: The path loss LS for interfering and non-interfering links between a Femto UE or a Macro UE and a Femto-BS is expressed as

$$\text{LS} = 127 + 30\log_{10}(d/1000) \quad (3)$$

Where, path loss LS is in dB, d (meters) is the distance between transmitter and receiver.

Outdoor UE to Macro-BS: Path loss for non-interfering link between outdoor M-UE and serving M-BS as well as interfering links between outdoor Macro-UE and neighboring Macro BS is calculated as

$$LS = 15.3 + 37.60\log_{10}(d) \quad (4)$$

Indoor UE to M-BS: This path loss model takes into account the wall penetration loss (L W) as the signal travels from indoor to outdoor and vice versa between an indoor located UE (Macro-UE or Femto-UE) and Macro-BS. This is calculated as

$$\text{LS} = 15.3 + 37.60\log_{10}(d) + Lw \quad (5)$$

D. Throughput Calculation

Throughput is calculated as follows using Shannon capacity formula.

$$C_{user} = \sum_{n=1}^{N} B_0 log_{10}(1 + SNIR) \quad (6)$$

The throughput of base station is the sum of its serving UEs and B_0 is the bandwidth of one PRB.

5. PROPOSED METHOD

The proposed method uses varied power distribution. The proposed idea is to mitigate Inter-cell interference which is caused due to complete co channel operation and low power signal received from Macrocell BS. By giving a power factor to the center users first and then the remaining power along with the already equally distributed PRB power to the edge zone users. Depending on the number of center users power factor is given to see whether cell edge capacity is improving or not. Power allocated is different to center users and edge users. [10]Depending on the frequency reuse scheme used, power allocated to each RB differs. For Reuse-I, all RBs share equal power, meaning

$$P_t = \frac{P_{total}}{N}$$

Where, N is the total number of PRBs, and P_{total} is total transmitting power of Macro base station. The power is evenly distributed among PRBs in a particular zone (center and edge). For Reuse-n, the total number of PRBs available in a cell is $N_c = N/n$, and the transmitted power on each RB is given as $P_t = P_{total}/N$.

For FFR, considering reuse -3 the total number of PRBs available in a cell is the sum of center PRBs and edge PRBs Center PRBs(2N/3) + Edge PRBs(N/3) = Total PRBs(N).

In SFR, edge or outer PRBs and center or inner PRBs transmit at different power levels. If the power on edge PRBs is denoted as P_{edge}, and the power on inner PRBs is denoted as P_{center}, then each can be calculated as

$$P_{center} = \alpha P_{edge}$$

and

$$P_{edge} = \frac{3P_{total}}{N(1+2\alpha)}$$

Where, n is the reuse factor, and α is defined as the power ratio. The power ratio α has a range 0 < α < 1. If α= 1, the scheme becomes a Reuse-I scheme where all the PRBs, inner and outer, transmit using the same power level.

After the power factor is given individual user equipment (UE) SINR is computed considering path loss equations (3-5) to obtain throughput using the equations (2),(6).Power on edge PRB and center PRB can be known from equation(1).Along with the existing system, proposed method of varied power distribution is shown in the block diagram with shaded blocks.

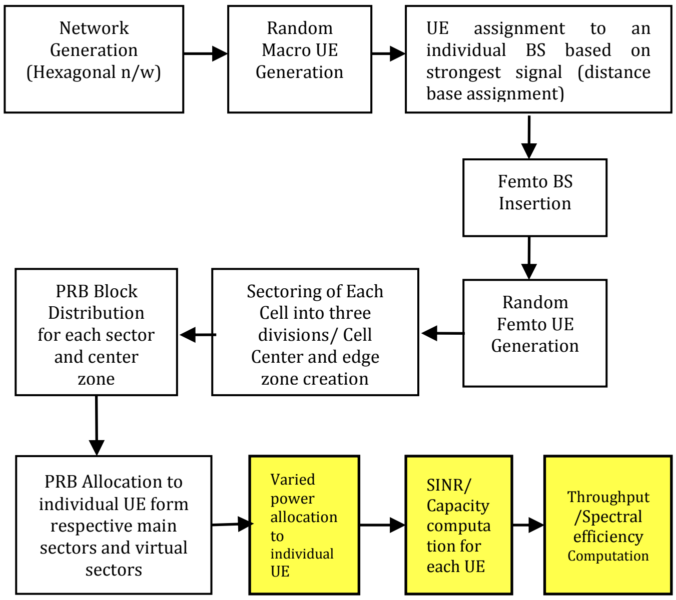

Fig- 3: Proposed method of varied power distribution

6. SIMULATION

6.1. Simulation Parameters

Table I shows the simulation parameters used for the experiment. The transmit power of the Femto BS is 20mW and the Macro BS transmits with 20W. Furthermore we consider a system with 10MHz divided into 25 sub carriers of 375kHz of bandwidth and 15 kHz of subcarrier spacing. A fixed number of 60 Femtocells randomly located in the network area in each cell are used for the calculation of the optimum parameters for the proposed scheme. According to the system model 16 PRBs are allotted to center zone and 9PRBs for edge zone. Upon request PRBs will be allocated to center users from 16PRBs and to edge users from 9PRBs.

Table-1: Simulation Parameters

Parameters	Values	
	Macro	Femto
Number of cells	7	420
Radius	600m	10m
BS transmitter power	20W	20mW
Topology	3 Sectored 7 hexagonal cell	Density 0f 60 per Macrocell
Number of UE	40 per Macro	1 per Femto
Bandwidth	10MHz	
Number of Total PRBs	24 PRBs , 1 PRB	
Subcarrier Bandwidth	375KHz	
Subcarrier spacing	15KHz	
Carrier frequency	2GHz	
Channel Model	3GPP Typical urban	
Power Factor	α=0.2	

6.2. Simulation Results

In the proposed scheme, PRBs for center zone is two third of total PRBs. The PRBs allocated by A can be used by the users of virtual sector 'a' and the PRBs allocated for B can be used by the user of virtual sector 'b' on-request basis. Femtocells and cell edge users can use only the PRBs 'a', 'b' or 'c'.

The proposed varied power distribution scheme for edge users' capacity with Femtocells and also average cell capacity along with PRB efficiency has been compared with the equal distribution method (existing method).

1. System model -network topology

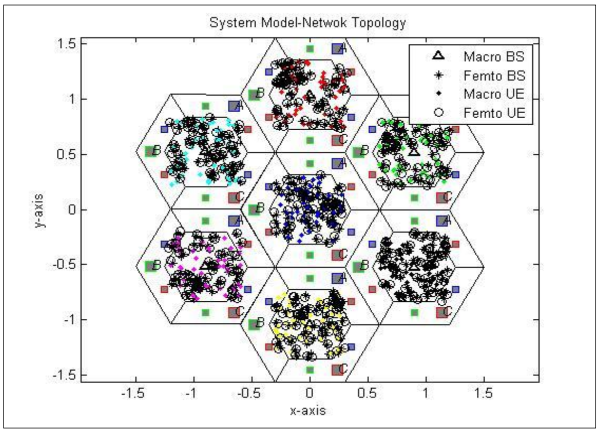

Chart-1: System model of 40 Femto users, 60 Macro users

Chart 1 is the system model that has been generated using mat lab. It shows seven hexagonal cells, each divided into center zone and edge zone. Each edge zone is further divided into three sectors. Macro users, Femtocells and its users are randomly distributed in each cell of the network.

2. Average Cell Capacity

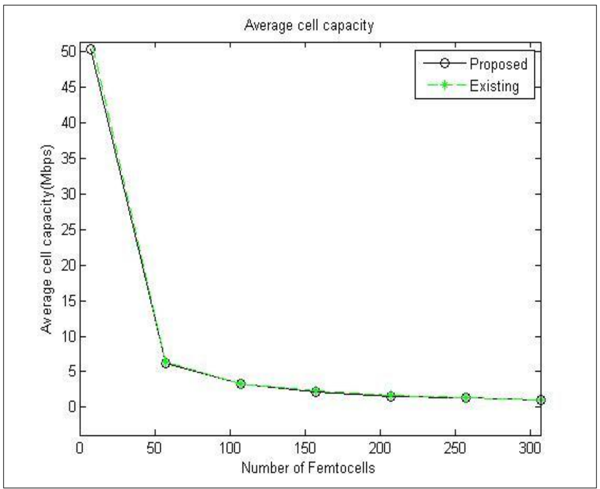

Chart-2: Average Cell capacity

Chart 2 shows the average cell capacity with respect to Femtocells. This is same as existing method which is not of serious concern. It is observed that power factor does not change or degrade the average cell capacity but definitely changes cell edge capacity which improves the overall network performance. The proposed method should improve cell edge capacity without degrading average cell capacity.

3. Average Cell Edge Capacity

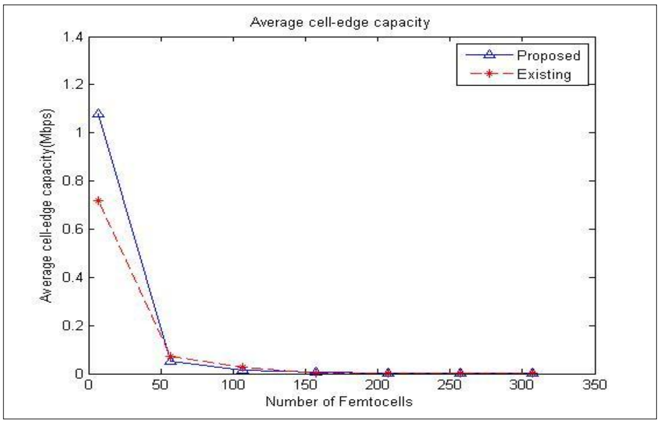

Chart-3: Average cell capacity

Chart 3 shows the average cell edge capacity with respect to Femtocells. The simulation result shows a significant improvement by proposed method. The proposed method has high capacity when the number of Femtocells is between 1 to 50 which is a considerate amount of improvement to deploy a network in reality. Improvement in average cell edge capacity with power factor $\alpha = 0.2$ increases the overall network performance.

The total power on PRBs in both the center zone and edge zone should not cross the maximum transmission power of Macro base station.

4. Average PRB Efficiency

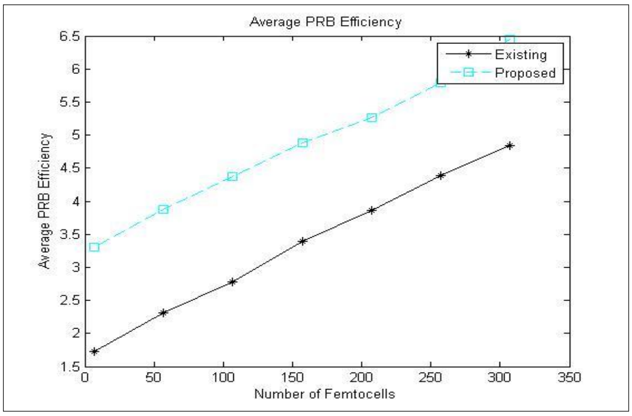

Chart-4: Average PRB efficiency

Chart 4 shows average PRB efficiency with respect to Femtocells. Proposed method has a lot of improvement over existing method. Usually when a system is being designed for deployment and cell edge capacity has improved than the existing method, with same average PRB efficiency as existing method without degrading overall network performance then that network can be deployed.

In summary, the proposed method reduces the interference and enhances the overall network performance by improving average cell edge capacity using power factor.

7. CONCLUSIONS AND FUTURE SCOPE

Femtocell technology can provide many advantages to the mobile subscribers and the service providers. Thus, Femtocells could be viewed as a promising option for next generation wireless communication networks such as OFDMA-based LTE networks. However, there is interference problem due to lack of proper frequency band allocation method. An interference mitigation technique based on channel allocation knowledge using FFR and SFR that allows the Femtocells or Macrocell edge users to access PRBs on request basis to satisfy the increasing demand on higher data rate was seen in the existing method which had the main advantage of saving more spectrum as it was on request based resource allocation.

But due to co channel operation and low power signal received from Macro base station ,cell edge users suffer heavy inter cell interference especially macro users in cell edge zone because signals from Femtocells nearby cause interference .Varied power distribution which is a proposed method is employed to give sufficient power to center users to receive signal and remaining power to edge users so that edge zone Macro users have more power to receive signal without any interference from Femtocells and its users.

Cell-edge performance is affected by the power ratio. From the results, proposed method shows better cell edge performance without decreasing the average cell capacity. Having a low power, low cost Femtocells that share load with Macrocell in a heterogeneous LTE network is a great solution to provide advantages to users and the service providers. Holding a limit for the number of Femtocells works good for this proposed method. As number of Femtocells increases, PRB efficiency increases but capacity decreases proportionally. To get better edge performance for more Femtocells we can increase the cell radius.

Power controlling has been done with respect to macro users in cell edge zone. Future work can be done from Femto base station and its Femtocells point of view in cell edge zone which would require an additional power along with remaining power left after giving to center users and power of PRB from equal power distribution that is Extra power+(1-α x center PRB power)+1W(PRB power, equal distributed power, existing method).

REFERENCES

[1] V. Chandrasekhar and J. G. Andrews, "Femtocell Networks: A Survey", IEEE Commun. Mag., vol. 46, no. 9, pp. S9-67, Sept. 2008.

[2] H. Claussen, "Performance of Macro- and co-channel Femtocells in a hierarchical cell structure," IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2007, September 2007.

[3] K. Cho, W. Lee, D. Yoon, K. Hyun, and Yun-Sung Choi, "Resource alloation for orthogonal and co-channel Femtocells in a hierarchical cell structure," 13th IEEE (lSCE2009), May 2009.

[4] M. Assaad, "Optimal Fractional Frequency Reuse (FFR) in Multicellular OFDMA System,"IEEE Vehicular Technology Conference (VTC),Sept,2008

[5] H. Lei, L. Zhang, X. Zhang, and D. Yang, "A Novel Multi-cell OFDMA System Structure Using Fractional Frequency Reuse," IEEE International Symposium on Mobile Radio Communications (PIMRC), Sept. 2007.

[6] T. Novlan, et al., "Comparison of FFR Approaches in the OFDMA Cellular Downlink ," in Proceedings of IEEE GLOBECOM Sep. 201O.

[7] 3GPP,Huawei,"Soft frequency reuse scheme for LTE," 2008.

[8] I.Guvenc, M.R Jeong, F. Watanabe, H.Inamura "A Hybrid Frequency Assignment for Femtocells and Coverage Area Analysis for Co-Channel Operation,"IEEE Comm.Letters, vol.12,no. 12,pp.880-882,Dec.20

[9] Femtoforum white paper, "Interference Management in UMTS Femtocells," December 2008

[10]Bereket MathewosHambebo, Marco M. Carvalho Fredric M.Ham "Performance Evaluation of Static Frequency Reuse Techniques for OFDMA cellular Networks"IEEE 2014