International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

An FFR Based Technique to Improve System Capacity through Femtocell Based Network

Mariam Shema Thomas[1], Jisha Anu Jose[2]

[1]M .Tech student, Department of Communication Engineering, Sree Buddha College of Engineering for Women, Elavumthitta, Kerala, India

[2]Assistant Professor, Department of Electronics and Communication Engineering, Sree Buddha College of Engineering for Women, Elavumthitta, Kerala, India

Abstract: ***Nowadays, Long Term Evolution (LTE) networks are becoming more and more popular. Femtocells have a strong potential for increasing the efficiency, cell coverage and network capacity of next-generation mobile networks. LTE femtocells represent a very promising answer to the ever growing bandwidth demand of mobile application. This system can be easily deployed without requiring a centralized planning to provide high data rate connectivity with a limited coverage. Femtocell is low power, very small and cost effective cellular base station used in indoor environment. But the impact of femtocell on the performance of the conventional Macrocell system leads interference problem between femtocell and pre-existing Macrocell as they share the same licensed frequency spectrum. Frequency Reuse is a technique to improve system capacity by manipulating the frequency resource allocation upon terminal's location. In this paper, an efficient method to improve system capacity through interference management in the existing Femto- Macro two tier networks has been proposed. In this scheme, a novel frequency planning for two tier cellular network using frequency reuse technique is used where Macro base station allocate frequency sub-bands for femtocell users on- request basis through femtocell base stations to cancel interference.***

Keywords: LTE, Resource allocation, Macrocell, Femtocell, Frequency reuse

1. Introduction

Long Term Evolution (LTE) represents the next step in a progression from GSM, a 2G standard to UTMS the 3G technology based upon GSM. LTE provides significantly increased peak data rates, scalable bandwidth capacity and backwards compatibility existing GSM and UTMS technology. LTE incorporates OFDMA air interface in the downlink and single carrier FDMA in the uplink. OFDMA was adopted as the main radio access technology for 4G standards such as WiMAX (Worldwide interoperability for microwave access) and LTE by the major standardization bodies like IEEE and 3GPP/3GPP2. This is due to the appealing characteristics of OFDMA. However, one of the concerning issue in LTE technology is indoor cell phone signal. 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.

Femtocell is the most recent step towards increasing the network capacity of a wireless network. Due to the large attenuation loss for indoor users in LTE networks, Femtocells are proposed to serve as small range indoor access points, which are installed by users and backhaul data through a broadband gateway over the Internet. Femtocells improve the quality of service for cellular users. The integrated femtocell/macrocell environments comprise of a conventional cellular network overlaid with a femtocell offer an efficient way to improve the capacity of a cellular system. Femtocell base stations are short range, self configurable, low power and low cost home base stations. It is used for the purpose of indoor network access. The typical indoor coverage is in the order of ten meters for a Femtocell.

One of the major problems in LTE system is inter-cell interference. In integrated Femtocell/Macrocell environments interference is caused by overlapping of frequency bands as a result of deploying Femtocells randomly in Macrocell area. This indicates that a different frequency channel should be used in the Femtocells than the one of the potentially nearby high power Macrocell users. The problem of co-channel interference can be eliminated by adopting the fractional frequency reuse technique. This work aims at the mitigation of interference between the Macrocell and the Femtocell by allocating on request PRBs to Femtocell users through femtocell base stations under sectored-FFR OFDMA Macro Femto cellular systems.

2. Parameters and Assumptions

2.1 Fractional Frequency Reuse

The main characteristic of a cellular network is the ability to reuse frequencies to increase both coverage and capacity. In frequency reuse technique the available bandwidth is reused in multiple cells. This approach is called Reuse-1 approach. But Reuse-1 causes considerable inter-cell interference. The simplest approach used to address this inter-cell interference problem that occurs when Reuse-l is applied is the frequency reusen (Reuse-n) approach. By increasing the reuse factor, interference can be reduced. But interference avoidance comes at the expense of bandwidth. So this scheme is not bandwidth efficient. Fractional frequency reuse technique partitions the whole spectrum into two parts; namely, one with reuse factor 1, and one with reuse factor n, usually n = 3. The main idea behind FFR is to employ a reuse factor of unity for cell-centre regions and a reuse factor of 3 for cell-edge regions. An example of FFR scheme is shown in figure 1.

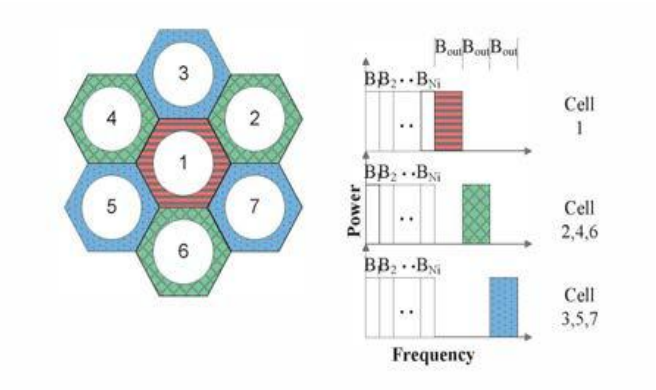

Figure 1: FFR scheme. In FFR, the reuse factor for interior users is 1 and the reuse factor for exterior users is 3.

In Resource Allocation Framework for Femtocell (RAFF), the resource blocks are assigned through greedy algorithm. Even though RAFF algorithm handles co-channel interference through alternate resource assignment, it is unaware about the co-tier interference experienced between neighboring femtocells. As inter-femto-base station distance and femtocells transmit power are not weighed by RAFF algorithm, a coverage overlapping femtocell may tend to operate at higher transmit power thereby causing co-tier interference to its neighbors.

Distributed Random Access (DRA) needs to iteratively hash resources of each femtocell. If there are more neighboring femtocells, hash collision occurs more often. When hash collision occurs, the DRA uses a iterations to find the reallocated resources. There are mainly 2 types of DRA, Low-Loading (LL) and High-Loading (HL). In Low Loading arrival rates are intended for home or office usage; so it is called low-loading (LL) scenario. Also, we assume HL scenario for crowded public environments, such as department stores or subway stations. The main idea of HL is to increase the arrival rate of each QCI to ten times the arrival rate in LL.

2.2 System Model

The proposed idea of this scheme is to mitigate downlink interference from Femtocell BS to MUEs and FUEs through on request channel allocation. The reuse method considered here is Soft Frequency Reuse (SFR). In the case of soft frequency reuse, usually the cell-center users are not affected by other cell-center users even though they share the same physical resource block because cell-center users are limited to a lower level power and the distance between a cell-center user and the adjacent eNodeBs is usually long enough to ensure large path loss, thus further reducing the received interfering power. So the mutual interference between serving cell-edge users and cell-edge users from different cells while simultaneously using the same PRB is considered here.

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 has 500 meters radius with 10 MHz bandwidth. The Macrocells are located in residential area where Femtocell base stations are installed in a random location within Macrocells range. Femtocell ranges are around 10 meters. Only one Femtocell user for each Femtocell base station is considered in an indoor environment. Each Macrocell contains a three floor building with a number of apartments. There is a street between the two stripes of these apartments. Assume that the Femtocell BSs from different blocks are not too close to each other. 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.

The Macrocell coverage is divided into centre 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. Number of PRB allocated for center zone is 2/3N and for edge zone is N/3. Also consider N/3 is the sum of PRB N_1, N_2 and N_3 allocated for sub-area A, B and C respectively. As mentioned above, only edge zone is considered and it is focused on only one sector, i.e. A for PRB allocation. The other two sectors are treated in a similar manner. The total number PRBs of N_1 can be used at Macro layer.

2.3 Power Allocation

In multicell OFDMA networks, cell edge users suffer from heavy inter-cell interference and relatively low performance. By providing better signal power on cell-edge user's carrier signal, the cell-edge user performance can be improved. But doing so would have an adverse effect on cell-center users. So an optimal power distribution design has to be developed which would provide better power and throughput to edge users simultaneously taking care of center cell user throughput.

This can be considered as constrained optimization problem where main objective would be maximizing cell-edge user throughput or rate equation subjected to few constrains like SNR/rate of center user maintained above certain threshold, total power distributed to the user of a cell is below or limited to serving base station maximum transmission power etc.. An optimal solution (weight factors) for power distribution will be determined and used for rate computation, with these constraints. The power optimization is formulated as an iterative barrier-constrained water-filling problem and solved by using the Lagrange method. Simulation results indicate that our proposed scheme can achieve significantly balanced performance improvement between cell-edge and cell-center users in multi-cell networks compared with other schemes, and therefore realize the goal of future wireless networks in terms of providing high performance to anyone from anywhere. The sum of the overall allocated power in each cell cannot exceed the maximum transmission power of the BS. Here it is assumed that all BSs in the network are given the same maximum transmission power. Also power is allocated according to SINR which is computed as a function of distance based path loss systems.

2.4 Calculation

For Femtocell user equipment, F received SINR is given as:

$$SINR_{F,K} = \frac{P_{F,k} \cdot P_{l,F,m,k} \cdot X_{F,k}}{N_0 + \sum_{F'} P_{F',k} \cdot P_{l,F',m,k} \cdot X_{F',k} + \sum_M P_{M,m,k} \cdot P_{l,M,m,k} \cdot X_{M,m,k}}$$

Where,

$P_{F,k}$, $P_{F'K}$ and $P_{M,m,k}$ denote the transmit powers from serving Femtocell Base Station (SFBS), neighbor Femtocell Base Stations (NFBS) and Macrocell Base Stations (MBS)respectively on PRB k. $P_{l,F,m,k}$ represents the path loss between FUE F and its serving BS . $P'_{l,F',m,k}$ represents path loss between FUE F and its neighbour Femtocell BS which is known as interfering signal on F. $P_{l,M,m,k}$ represents path loss between FUE and neighbour Macrocell BS. $X_{F,k}$ =1 when FUE F requests PRB k from Macro BS through Femto BS to occupy PRB k and then SINR will be calculated for FUE F on PRB k. When $X_{F,k}$=l, then $X_{F',k}$ =0 and $X_{M,m'}$, =0 because one PRB cannot be shared by more than one user at a time. If $X_{M,m,k}$=0, it means there is no PRB occupied by the user F and then SINR for the user F will be zero.

To represent indoor, outdoor, and indoor-to-outdoor (and vice versa) channel environments path loss models are used. 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.

- 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:

LS= 127 + 30[log10 (d/1000)

Where, path loss LS is in dB, d (meters) is the distance between transmitter and receiver. Assuming that the base station antenna height is fixed at 15 m above the rooftop, and a carrier frequency of 2 GHz is used, the path loss L can be expressed as above. (3GPP TR 136.931)

- 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 neighbouring Macro BS is calculated as

LS= 15.3+37.60 log_{10} (d)

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

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

3. Result

The transmission power is allowed to be independently allocated on each active PRB that has been assigned to users in the network. So, dynamic or fixed power allocation can be performed depending on different schemes. The sum of the overall allocated power in each cell cannot exceed the maximum transmission power of the BS. Here it is assumed that all BSs in the network are given the same maximum transmission power. Here power is allocated according to SINR which is computed as a function of distance based path loss systems.

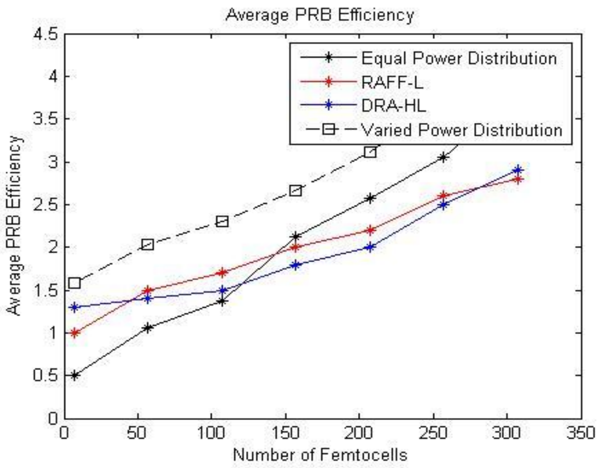

Figure 2: Average PRB Efficiency in Femto system.

Simulation Settings includes an LTE based cellular system. This system is simulated. A 1 tier (7-cell) system layout is simulated with users randomly distributed in each cell. Each cell is assumed to have a base station with a 3 sector antenna system at the center of a cell. The radius of each of the hexagonal cells is R = .6 km. The inner radius for FFR schemes is given as αR, where alpha takes values from 0 to 1. The cell radius ratio considered is 60%. The total bandwidth of the system is 10 MHz. The spectrum is divided into 25 RBs each having a bandwidth of 375 KHz. The total transmit power is set to 43 dBm / 20 W. There are 6 users in each cell and are randomly placed over the cell system. The total transmit power is set to 43 dBm / 20 W. There are 6 users in each cell and are randomly placed over the cell system. Two users are there with every Femto Access Points (FAP). The number of femto cells varies from 0 to 270. The scheduling method used is Round Robin (RR) scheduling algorithm, where users take turns using RBs over a period of time (frame).

Figure 2 shows the average PRB efficiency with respect to the number of femtocells. The simulation result shows a significant improvement by proposed method in the average PRB efficiency. Algorithm is not simple like DRA-HL and RAFF –LL but the throughput in terms of spectral efficiency is very high. This is because as the number of femto cells increases the allocation of PRBs in macro cells as well as femtocells becomes efficient and it is based on distance based power allocation which is needed for a user.

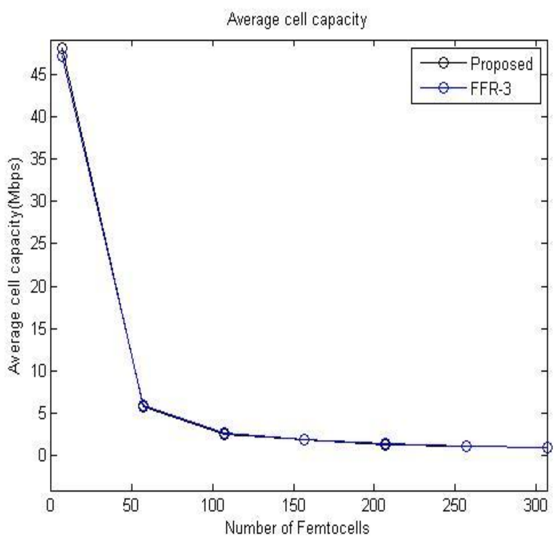

Figure 3: Average Cell Capacity for Proposed system

Figure 3 shows the average cell capacity of macro cell system with number of femto cells. When the number of femtocell users is reduced in the macro cell edge zone area, the average system capacity increased. Specifically the capacity of the femto user is satisfactory for the case of 50 to 100 femto users. Up to this number of femtocells is enough to share a specific number of frequency channels without any interference. Thus the average cell capacity of the proposed scheme is higher. The capacity decreases from 50 Mbps to 10 Mbps as the number of femto cells increases from 0 to 50. Almost 70% decrease in capacity. This is because as the number of femto cells increases the interference of signals in macro cells as well as femto cells increases due to inter and intra e Node Bs as well as FAPs.

Figure 4 shows the cell center capacity of macro cell system with number of femto cells. The cell radius ratio has a key role in cell-center and cell-edge capacity of macro as well as femto cells. As the number of inner RBs increase and the increase in resource could mitigate the resource shortage by the increase in inner cell area, which increases the number of inner cell users.

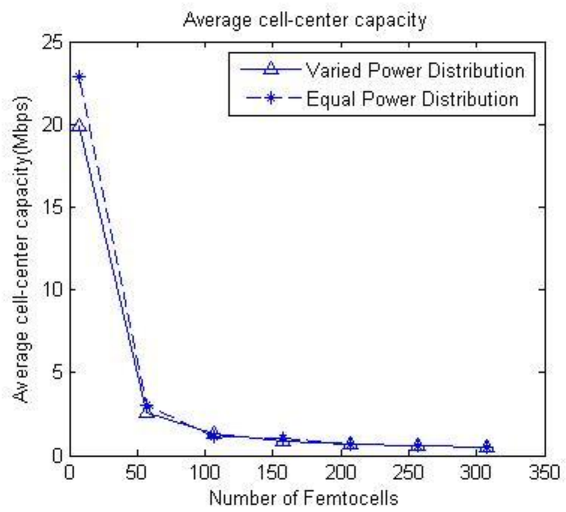

Figure 4: Cell Center Capacity for Proposed system

Form the figure it is clear that while the femto cell number increases from 0 to 50 the cell-center capacity get decreases from 26 Mbps to 4 Mbps. This is because as the number of femto cells increases the interference of signals in macro cells as well as femto cells increases due to inter and intra eNodeBs as well as FAPs. Here the decrease in capacity is 44% for the 50 FAPS. For the increment in next 50 femto cells the decay rate is lower.

4. Conclusion

LTE networks comprising Macrocells plus Femtocells are beginning to offer economically viable solutions to achieving high user capacity. Femtocell technology can provide many advantages to the mobile subscribers and the service providers. Thus, a femtocell is a promising option for next generation wireless communication networks such as OFDMA-based LTE networks. But, due to lack of proper frequency band allocation method, there is interference problem. In this work, an interference mitigation technique based on, On Request channel allocation with varied power basis is proposed. The main advantage of the proposed method is that it can save more spectrum as it is on request based PRB allocation. The simulation results show that this method can reduce the interferences through increasing the throughput.

5. Acknowledgment

I would like to express profound gratitude to our Head of the Department, Prof. Cherian Schariah, for his encouragement and for providing all facilities for my work. I express my highest regard and sincere thanks to my guide, Asst. Prof. Ms. Jisha Anu Jose., who provided the necessary guidance and serious advice for my work.

References

[1] Hambebo, B.M.; Carvalho, M.M.; Ham, F.M. "Performance evaluation of static frequency reuse techniques for OFDMA cellular networks," IEEE Trans., pp. 355-360, April 2014.
[2] S Srikanth, P. Murugesa Pandian and X.Fernando, “Orthogonal frequency divison multiple access in WiMAX and LTE: a comparison,” Communication Magazine IEEE vol. 50, pp.153-161.2012.
[3] R.Y Chang, Z. Tao, J Zhang and C-c J. Kuo, “Dynamic fractional frequency reuse (D-FFR) for multi cell ofdma networks using a graph framework,” Wireless Communications and Mobile Computing Vol.13, pp.12-27, 2013.
[4] V. Chandrasekhar and J.G Andrews, “Femtocell Networks: A Survey,” IEEE Commun. Mag. vol. 46, no.9 pp.9-67, Sept. 2008.
[5] R.Yan and G Zhang “An effective semi-static interference co-ordination scheme for wireless cellular networks,” IEEE Commun. Mag vol. 46 no. 9, pp.59-67, Sept 2008
[6] www.mathworks.in

Author Profile

Mariam Shema Thomas received the B-Tech degrees in Electronics and Communication Engineering from M.G University, Kerala at Sree Buddha college of Engineering for women in 2014. And now she is pursuing her M-Tech degree in Communication Engineering under the same university in Sree Buddha college of Engineering for women.

Jisha Anu Jose working as Assistant Professor in department of Electronics and Communication, Sree Buddha college of Engineering for women, Elavumthitta, Pathanamthitta.