FREQUENCY REUSE AND POWER CONTROL FOR INTERFERENCE MITIGATION IN FEMTOCELL LTE-A NETWORKS

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FACULTY OF ENGINEERING
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ABSTRACT

Currently, femto cells have become the best solution to further enhance services provided by the LTE cellular network, which offers high capacity and high data-rate. This is done by boosting the coverage area and the data rate at restricted areas. The combinations of LTE networks and femto-cells results to a heterogeneous environment, in which a two tier networks that try to fully utilize all the available spectrum. This, however introduces interference. One of the most common solution is investigating the locations of the newly installed femto base station (FBS) and use power control in order to avoid suffering from performance degradation caused by interference. Besides, it is also possible to deploy Inter-cell Interference Cancellation (ICIC) at the macro-cell, which utilizes the spectrum completely or partially to prevent co-channel interference. With the use of Matlab simulation, which is highly configurable, this report will study the interference mitigation techniques under various topologies. In details, the cellular networks have been analyzed and evaluated, as well as the cross-tier interference issues. Also, each interference mitigation technique is deployed and evaluated for various femto-cells. Lastly, the results that got from each method are compared in terms of overall throughput, spectral efficiency and cell-edge users' performance.

ABSTRAK

Pada masa ini, sel-sel femto telah menjadi penyelesaian terbaik untuk meningkatkan lagi perkhidmatan yang disediakan oleh rangkaian selular LTE, yang menawarkan kapasiti tinggi dan data kadar tinggi. Ini dilakukan dengan meningkatkan kawasan liputan dan kadar data di kawasan larangan. Kombinasi rangkaian LTE dan keputusan femto-sel untuk persekitaran yang heterogen, di mana dua rangkaian peringkat yang cuba untuk menggunakan sepenuhnya semua spektrum yang ada. Walau bagaimanapun, ini memperkenalkan gangguan. Salah satu penyelesaian yang paling biasa ialah dengan menyiasat lokasi pangkalan femto stesen yang baru dipasang (FBS) dan menggunakan kawalan kuasa untuk mengelakkan ia mengalami kemerosotan prestasi yang disebabkan oleh gangguan. Selain itu, ia juga tidak mustahil untuk menggunakan Pembatalan Gangguan Inter-sel (ICIC) di makro-sel, yang menggunakan spektrum sepenuhnya atau sebahagiannya untuk mengelakkan gangguan saluran yang sama. Dengan menggunakan simulasi Matlab, yang boleh dikonfigurasikan, laporan ini akan mengkaji teknik pengurangan gangguan di bawah pelbagai topologi. Secara terperinci, rangkaian selular telah dianalisis dan dinilai, serta isu-isu gangguan silang peringkat. Selain itu juga, setiap teknik mengurangkan gangguan dikerahkan dan dinilai untuk pelbagai femto-sel. Akhir sekali, hasil yang dapat dari setiap kaedah dibandingkan dari segi pemprosesan keseluruhan, kecekapan spektrum dan prestasi pengguna sel-edge.

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In the name of Allah, the most beneficent and the most merciful"

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LIST OF SYMBOLS AND ABBREVIATIONS

4G	:	Fourth generation
5G	:	Fifth generation
BS	:	Base Station
CSG	:	Closed Subscriber group
FBSs	:	Femto Base Stations
FFR	:	Fractional frequency reuse
HNBs	:	Home node-B
ICIC	:	Inter-cell interference cancellation ICIC
IFR	:	Integer frequency reuse
IFR-1	:	IFR of factor 1
IFR-3	:	IFR of factor 3
LTE-A	:	Long term evolution-advanced
MBS	:	Macro base station
OFDMA	:	Orthogonal frequency-division multiple access
PL	:	Path loss
RSRP	:	Reference signal received power
SFR	:	Soft frequency reuse
SINR	:	Signal to interference plus noise ratio
TPLC	:	Two Level Power Control
UBPC	:	Utility-based power control
UE	:	User equipment

CHAPTER 1: INTRODUCTION

1.1 General

The revaluation mobile network generation from 2G, 3G and 4G that happened previously changes our world and the concept of mobile devices usage. In 2G system becomes more efficient on the spectrum that allows to cover wider area, also data services introduced for mobile with SMS messaging. The first mobile broadband experience got by the emergence of 3G which consider as promising technology. The studies expected that by 2020 the mobile broadband network will cover around 90% of the world's population. The traffic of mobile data in Q1 2015 is higher by 55% than in Q1 2014. By 2020 most of the mobile data traffic will be from smartphones. During 2020 the technology of 5g will be predominant with around 3.6 billion clients (Noura & Nordin, 2016). The long term evolution-advanced (LTE-A) is the fourth generation (4G) cellular network which introduced for higher data rates in mobile communication. One of the features of LTE-A is the shore of heterogeneous networks which provide the wider coverage of macro site without the need of costly infrastructure. While the use of low nodes that enhance the coverage and capacity is preferable. Femtocells as femto or home Node-B or femto base station (FBSs) which deployed by user are short-range and inexpensive. By macro cell infrastructure LTE-A sets specifications of femtocells installation (Bouras, Diles, Kokkinos, Kontodimas, & Papazois, 2014).

Femtocells considers a promising technique which gained attention because of the inexpensive deployment and maintenance and it provides a high spectral efficiency. Furthermore, femtocells enhancing the overall performance of the mobile network by minimizing its load of working as they employ the cable or DSL backhaul connection of subscribers (Bouras et al., 2014).

1.2 Problem Statement

Interference is a significant barrier to achieve higher network performance in LTE-A Network, is it possible to use the proper frequency reuse and power control methods to reduce the effects of interference caused by femtocells and so increase the overall network performance?.

1.3 Motivation

Firstly, the Heterogeneous Networks (HetNets) incorporate all kinds of small cells such as femto, pica. micro, relay in addition to the macro cell. The employment of small cells can bring the network closer to the user and also cater the need of increasing data rate and channel capacity demand. Among the small cells, the residential femtocells are getting more attractive among operators as this indoor small cell is a new model which provides a network of low-cost, plug-and-play and strong connectivity to the internet. It is deployed wherever back haul and power is available. Based on the Figure 1.1, the number of small cell used shows an exponential growth, especially the femtocell. This gives us a mighty reason to drill it down on optimization the deployment of femto-base stations.

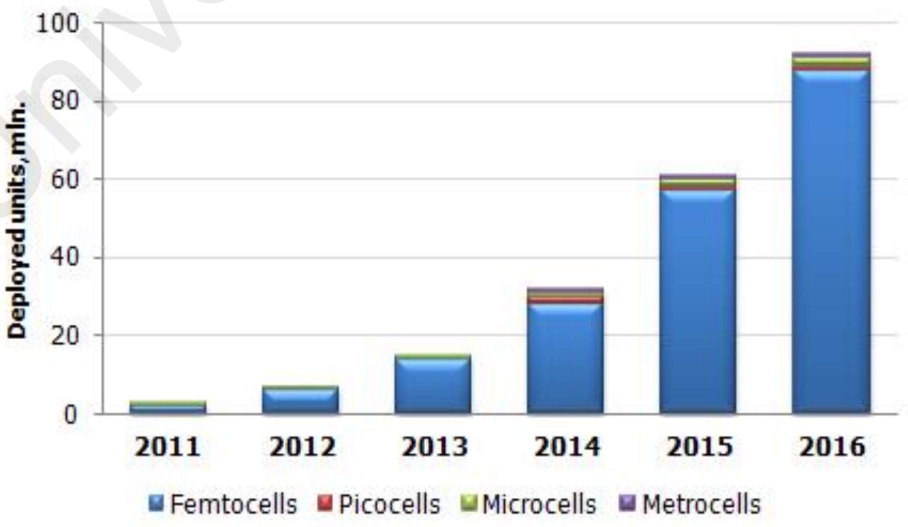

Figure 1.1 Number of small cells deployment in the world, 2011-2017 (Consulting, 2012)

secondly, in order to allow users to enjoy seamless mobile broadband services at any location without creating dead-zone, the technologies, managing power to mime the signal interference, is of utmost important especially the users are at cell-edge. Hence, from the view point of network operators to provide a good Quality of Internet, service in a hyper-dense and random deployment of small cells in mobile network and a reliable user experience at the cell-edge of a planned cell, we need effective and robust frequency reuse scheme , management of power and interference.

1.4 Objective

The main objective of this research is to compare various frequency reuse and power control methods to reduce the interference caused by femtocells.

1.5 Organization of Research Report

Chapter 1, outlines the background of LTE-A , femtocell , statement problem , objectives of study, and the structure of the research report. Chapter 2, discusses the related works comprehensively. Chapter 3, outlines the research methodology. Chapter 4, presents the results and discussion. Chapter 5, summarizes the research with direction for future developments.

CHAPTER 2: LITERATURE REVIEW

2.1 Background

In (Mhiri, Sethom, & Bouallegue, 2013), the main idea of femtocell is to enhance the indoor coverage , deploy the next generation of the wireless networks, , increase the overall capacity, and offload the overlay macrocell traffic.

Despite its advantages, femtocells may also prompt to significant local service degradation because of interference issues. As shown in Figure 2.1, sharing the same available bandwidth with the macro base station (MBS) may lead to severe interference phenomenon when there is co-channel operation, both between femto base stations (FBSs) and the MBS (also known as cross-tier interference), and between FBSs.

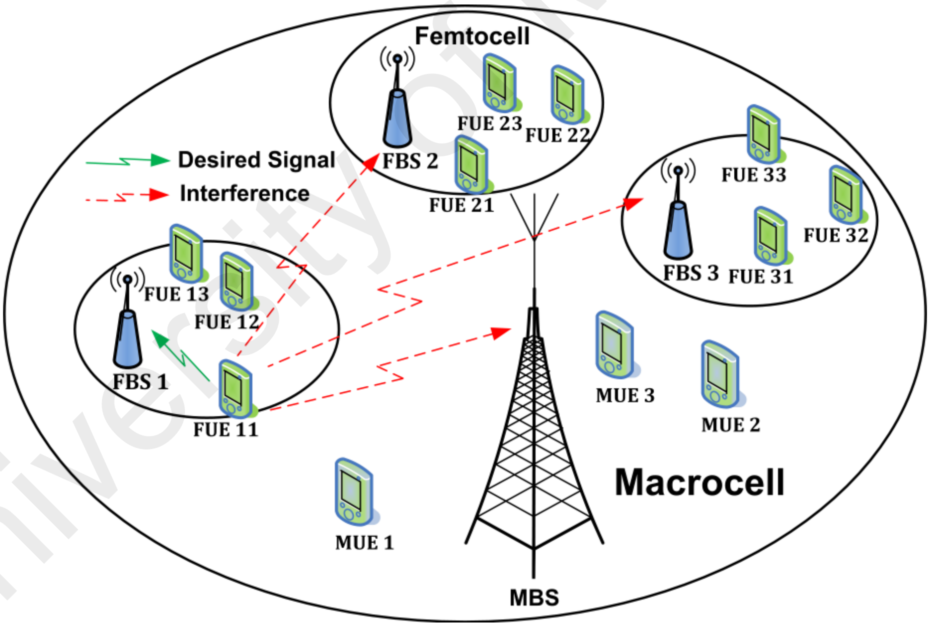

Figure 2.1 HetNet system model with multiple mobile users per cell showing an example of desired and interfering signals

A way to bypass this problem would be to allow free access to femtocell service for everyone in the proximity of its BS. This way, the service would be unproblematic, and a handover would happen, unperceivably to the user. Femtocells, however are commercially exploited using subscription system charges, a system called closed subscriber group (CSG), making such a solution impractical.

In this chapter the literature review will be presented. In the second section interference and its types will be discussed. In the third section the ways to mitigate interference will be presented as well.

2.2 Interference

In (Mhiri et al., 2013) and (Al-Omari, Ramli, Sali, & Azmir, 2016) , Interference is a serious issue with HetNet, the main two types of interference are:

a) Co-Tier Interference: Co-tier interference takes place between network elements of same tier. In terms of femtocell, co-tier interference relates to the interference between neighboring femtocells. Co-tier interference occurs in two different forms; uplink co-tier interference and downlink co-tier interference. The uplink co-tier interference occurs when femtocell user equipment cause interference in the uplink to its neighboring femtocell base stations which is illustrated in index 5 of Figure 2.2 and Table 2.1. Downlink co-tier interference occurs when a FBS may cause downlink interferences to a nearby FUEs. The downlink co-tier interference is illustrated in index 6 in both Figure 2.2 and Table 2.1. In OFDMA femtocell network, the occurrence of co- tier uplink/downlink interferences takes place only when both the neighboring femtocell attempts to communicate using the same sub-channels. Thus, for interference mitigation in such networks, an intelligent and efficient radio resource allocation mechanism is required.

b) Cross-Tier Interference: It is resulting from the occurrence of interference between network elements which belong to dissimilar tiers of the network; for example, between elements of the macrocell tier and those of the femtocell tier and vice versa. In Figure 2.2, the macrocell UEs and femtocell UEs are the sources of uplink cross-tier interferences towards the nearby Femtocell Base Stations (FBSs) as well as the serving Macrocell Base Station (MBS) as shown in indexes 1 and 3 of both Figure 2.2 and Table 2.1 respectively. Conversely, the serving MBS, together with the FBS results in forward link (downlink) cross-tier interferences to the FUEs as well as neighboring MUEs as illustrated with indexes 2 and 4, respectively. Figure 2.2 provides a summary of the various cross-tier scenarios. For OFDMA networks, cross-tier forward-link (downlink)/reverse-link (uplink) interferences occur only in cases where both the aggressor and the victim attempt to use the same sub-channels. Thus, efficient channel allocation is indeed crucial for interference avoidance is such systems. Figure 2.2, again, shows all the various possibilities of interferences scenarios in OFDMA- based femtocell networks. By adopting a suitable interference management technique, co-tier interferences can be effectively avoided, while cross-tier interferences can be considerably minimized in order to improve the overall system throughput.

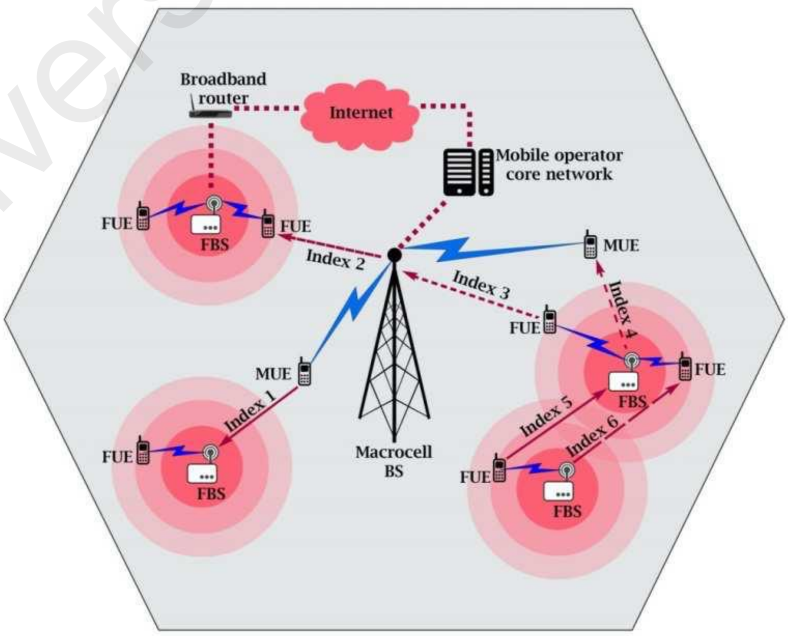

Figure 2.2 Interference Scenarios OFDMA-Based Femtocell Networks (Al-Omari et al., 2016)

Table 2.1 All Interference Scenarios for OFDMA-Based Femtocell Networks (Al-Omari et al., 2016)

Index	Interference type	Aggressor	Victim	Transmission mode
1	Cross-tier	MUE	FBS	Uplink
2	Cross-tier	MBS	FUE	Downlink
3	Cross-tier	FUE	MBS	Uplink
4	Cross-tier	FBS	MUE	Downlink
5	Co-tier	FUE	FBS	Uplink
6	Co-tier	FBS	FBS	Downlink

2.3 Interference Mitigation

To mitigate interference , (Mhiri et al., 2013) provide an overview on the different interference and resource management techniques in Self-Organizing Network as per specifics characterization criteria. These techniques derive from the following approaches: frequency reuse, power control, proper cell planning, OFDMA, self-configuration and self-optimization, conventional TDD, etc. These techniques can be applied separately and can be used as hybrid. In this research, I will focus on two approaches frequency reuse schemes and Power control.

2.3.1 Frequency Reuse schemes

The discussion on the frequency reuse (FR) schemes is of greater importance among researchers as an efficient and widely used mechanism for interference avoidance. In (Godlewski, Maqbool, Coupechoux, & Kélif, 2008), several FR schemes including IFR and FFR in OFDMA based cellular networks were discussed. They also discussed about the Two Level Power Control (TPLC) schemes and provided comparison with the FR schemes. They concluded their work stating that with proper settings of power ratio and the selection of the inner radius would lead to best performance of the network when an approach of fairness in throughput is considered. The optimization of fractional frequency reuse (FFR) for the purpose to achieve the best throughput performance and user satisfaction based on frequency partitioning and cluster sizing has been presented in (Bilios, Bouras, Kokkinos, Papazois, & Tseliou, 2012).

The concept of the soft frequency reuse (SFR) scheme was introduced in (Project, 2005) which is a efficient resource utilization scheme compared to FFR. The SFR scheme is an efficient FR scheme for inter-cell interference coordination as shown by (Yu, Dutkiewicz, Huang, Mueck, & Fang, 2010) in their paper. They made use of the traffic load conditions and configuration of different power ratio to develop their analysis. While an adaptive and decentralized SFR scheme for uplink spectrum has been introduced by (Mao, Maaref, & Teo, 2008). They adopted the approach of avoiding reuse of resource block and also implementation of efficient cell-edge bandwidth allocation at the cost of exchanging some insignificant information over the network to achieve the adaptive SFR model. In (Novlan, Andrews, Sohn, Ganti, & Ghosh, 2010), the authors have presented a comparison in between the SFR and the strict FFR schemes for interference mitigation. They have shown in their work that they get a better balance for the interference mitigation and the spectral efficiency while SFR has been used but the strict FFR scheme provided a better overall throughout performance for the users and also a higher SINR level at the cell-edge regions. Two modified FFR schemes have been proposed in (He et al., 2007) and they have also shown that the proposed schemes was able to achieve a higher throughput for the cell-edge users as well as for the whole system while compared to a standard FFR. The researchers in (Jia, Zhang, Yu, Cheng, & Li, 2007) have developed the performance metrics for network throughput and outage probability, thereafter obtained the optimal frequency planning schemes based on the subcarrier permutation and the frequency reuse pattern. The results for analysis was obtained using a system level simulator designed for the SINR evaluation in the 802.16 OFDMA network. Another type of FFR is suggested by (Giuliano, Monti, & Loreti, 2008), where they have shown that the resource allocation for the inner and outer regions of the cell can also be in terms of time slots rather than depending only on segmentation of subcarriers. This concept was further extended in the research work in (Hamouda, Yeh, Kim, Wooram, & Kwon, 2009). They have introduced a hard FFR scheme which would create cell sectors by dynamically adjusting the size based on the system load.

Similarly, the discussion on several different interference mitigation techniques for femtocell-based heterogeneous LTE-A networks are also found in literature. In the 3GPP technical report (Project, 2009) an overview is given for all the available interference management approaches found for LTE-A networks. A study of interference avoidance, based on system level simulation, for femtocell deployment in Wimax networks are presented in (López-Pérez, de la Roche, Valcarce, Juttner, & Zhang, 2008). They proposed a dynamic frequency planning (DFP) which they compared with other frequency allocation strategies. A study on the optimal power configuration for femtocells is found in (Lee, Bae, Kwon, & Chung, 2011), when FFR is the adopted frequency allocation scheme. In (Claussen, 2007), a power control mechanism for the femto base stations ensuring constant femtocell coverage has been studied which will also be incorporated in the simulation scenario of chapter 3. The authors of (Bouras, Diles, Kokkinos, & Papazois, 2012) have presented an overall quantitative comparison for several different power control methods. The advantages and disadvantages of those methods are also discussed in the paper based on the results obtained from simulation. There also some schemes which are designed to neglect the interference effects in heterogeneous networks. For example, the research work presented in (López-Pérez, Valcarce, De La Roche, & Zhang, 2009) gives an overview on the general approaches of interference avoidance by the power management of self-configurable femto devices which also can imply the self-optimization techniques. A utility-based power control scheme (UBPC) has been discussed in (Xiao, Shroff, &

Chong, 2001), where a power control algorithm has been selected that uses some constraints on target SINR values. The SINR values are estimated based on the traffic load in the network but are relaxed accordingly depending on the system feasibility.

2.3.2 Power Control schemes

(Bouras et al., 2014) and (Lopez-Perez et al., 2011) stated that power management is an attractive solution. Since FBSs will be installed in different locations, which means different impact and different demands on the overall network, a common value for power transmission would be inappropriate. Instead, adjusting the power transmission levels of FBSs according to the needs of the specific area, and evaluating their impact on neighbor femtocells and underlying macrocell, leads to a fairer and more efficient network, from an interference perspective. This configuration maintains that both femto and macro users will have access to service and achieve adequate throughput regardless of their position in the network. In (Chandrasekhar, Andrews, Muharemovic, Shen, & Gatherer, 2009), the simulation scenarios the comparison between the fixed power allocation and the power control ensuring constant coverage femtocell radius are presented. The fixed power scheme is the usual scheme where all the FBSs are radiating at a fixed level of power irrespective of their position within the macrocell region. Another power control scheme which is the SINR adaptation of the femtocells based on distributed utility from alleviating cross-tier interference is also found in literature as well as in the simulator tool that has been used for their paper.

CHAPTER 3: POWER CONTROL AND FREQUENCY REUSE IN HETNETS

3.1 Introduction

HetNets recently have attracted significant research interest which involves the deployment of small base stations (small cells) overlaid over the macrocell. It consists of mix of macrocells, remote radio heads, smaller and lower power nodes such as pico cells, femtocells and relays. This increase in proximity between the base stations and end users has the potential to provide the next significant leap in communication networks, enhance the indoor coverage, and boost spectral efficiency per unit area (Pradhan, 2014). It also improve throughput, coverage and user experience explicitly at indoors. Femtocell Access Points (FAPs), foreseen as a cost efficient indoor coverage solution, serve as low-power, short range base station that are overlaid on the macrocell networks. Since it connects users to the core service network by making use of high speed broadband connections such as DSL, cable modem, it can provide increased throughput and improved coverage for home users, while off-loading traffic from expensive macrocell radio access networks onto the low-cost public internet (Sivaraj & Palanisamy, 2016). But unlike traditional cellular networks HetNets are complex in natural in terms of coverage and interference management. This makes the handover mechanisms, the cell selection, and the frequency planning very challenging for the network. The HetNet infrastructure , unlike usual wireless network structure , is unplanned as the low power nodes (LPNs) are scattered within the macrocell randomly. The LPNs can be at times closed to the main macrocell base station and can have different value of transmission powers. The cell range expansion allows the nearest LPNs to be connected to the user equipment to get the benefit of performance gain although the power received from the designed macrocell base station can be higher. All these factors adds up to construct the most challenging task of HetNet compared to macro only cellular network, the severe interference characteristics, which will degrades the overall performance of the system. In order to have a clear picture on the interference scenarios that is generated because of the deployment of heterogeneous LTE-A network Figure 3.1 is represented. As shown in scenario 1 of the figure there is an effect on the femto users caused by the macro base station. In scenario 2 it is depicted that a macro user is also effected by interference arising from the nearby femto base station. And finally the femto users also have to deal with inter femtocell interference which is depicted in the third scenario. Moreover, the interference issues from the adjacent macrocells using the frequency channel also need to be considered. Hence it is essential to mitigate these additional and complex interference scenarios in heterogeneous networks using certain mitigation techniques, discussed later , before we can achieve the expected higher data rate performance in LTE-A networks .

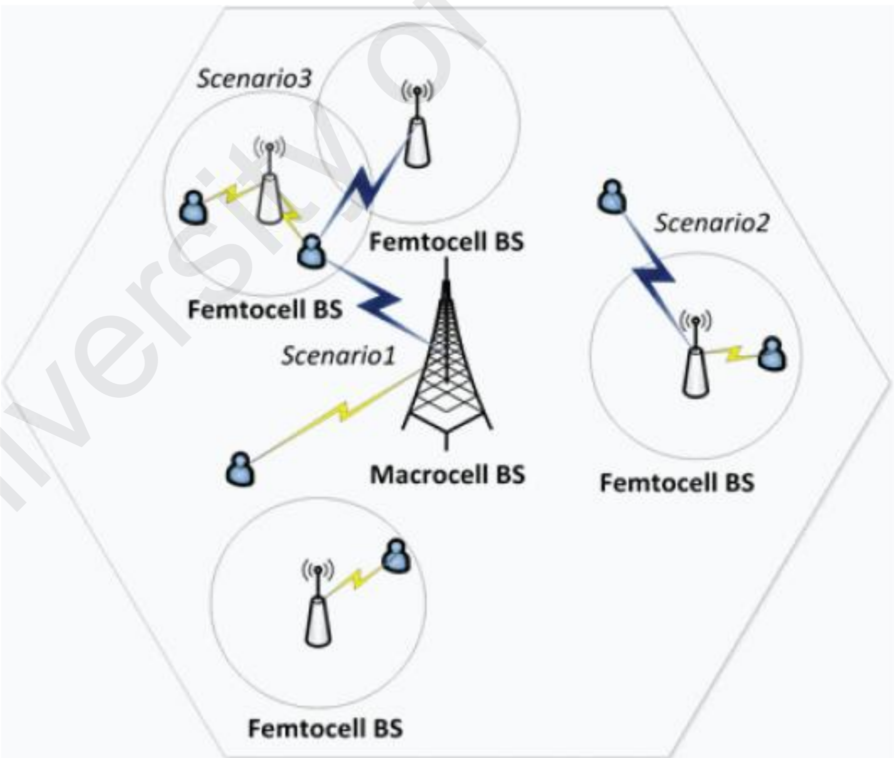

Figure 3.1 Interfernce scenarios in a two-tire femtocell/macrocell environment for downlink (Bilios et al., 2014)

In this chapter the research methodology will be presented. In the second and third sections interference mitigation in the basis of some frequency reuse-based schemes and power control schemes for the HetNets will be discussed briefly. In the fourth section, the simulation settings that used to get the result with introducing the system model and simulation framework.

3.2 Frequency Reuse-based Schemes

In this section an elaborate explanation one of the fundamental techniques to deal with the inter channel interference, which is to control the use of frequencies over the various channels in the network, will be presented. The most common frequency reuse schemes in the research community are Integer/Conventional Frequency planning schemes (Reuse-1 and Reuse-3), fractional frequency reuse (FFR) and soft frequency reuse (SFR). The objective of these frequency reuse planning algorithms is to increase the SINR, and hence, allow the system to support as many users as possible (Hamza, Khalifa, Hamza, & Elsayed, 2013). The discussion and the explanation for this section will also be confined within these frequency planning schemes since later in the simulation platform only these schemes will be available as a choice for the network interference performance evaluation. Despite their differences, all frequency reuse-based schemes need to comply and determine some certain specifications as follow: (1) the set of channels (sub-carriers) that will be used in each sector/cell, (2) the transmitted power at which each channel is operating within the cell, and (3) the region of the sector/cell in which this set of channels are used (for example, cell-centre or cell-edge). The discussed schemes are defined by different values and approaches of these aforementioned parameters.

3.2.1 Reuse-1 scheme

We study the Reuse-1 scheme in our research work for comparison purpose with other schemes. The universal reuse scheme (or Reuse-1) assigns the entire frequency resources to be reused by all macrocells and femtocells existing in the system. The main advantage of Reuse-1 scheme is the possibility of using all available frequency resources and hence increasing the spectral efficiency of scarce bandwidth. This usually comes at the expense of the amount of interference generated in the system. Since all macrocells and femtocells share the same bandwidth at the same time to provide service for their attached UEs, the amount of inter-cell interference ICI becomes very high especially for small-sized macrocells. The Reuse-1 scheme also results in a coverage problem due to poor SINR for those MUEs far from their serving BSs at the edge of macrocell due to the interfering transmission of nearby macrocells. Reuse-1 scheme also results in a severe problem for indoor MUEs that are very near to active transmitting femto BSs.

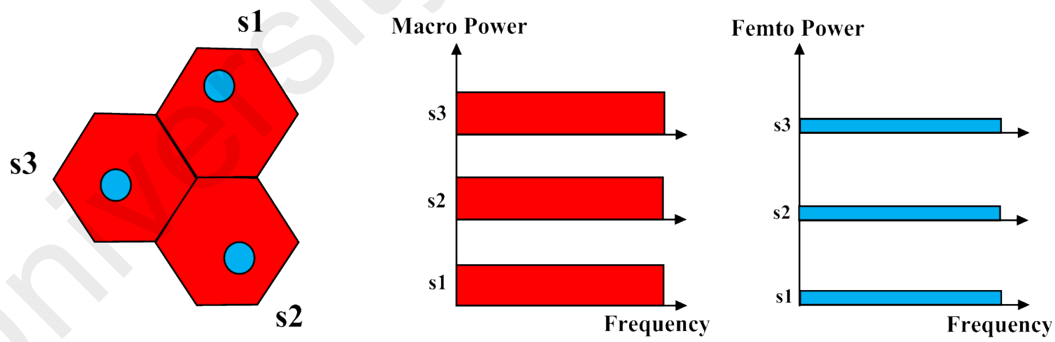

Figure 3.2 Reuse-1 Scheme

In Figure 3.2 we describe the operation of Reuse-1 scheme where all macrocells use the entire frequency bandwidth at the same time slots with reference transmission power P_M . The femtocells also applies the concept of Reuse-1 such that they use the same entire frequency bandwidth simultaneously with macrocells but with limited transmission power P_F (Selim, 2012).

3.2.2 Reuse-3 scheme

Higher reuse factors than Reuse-1 have been proposed in order to solve the problem of poor coverage at edge zone. Reuse-3 has proved that it can provide the best performance among different reuse factors. In Reuse-3 scheme the entire frequency band is divided equally into three sub-bands such that each cell is assigned only one of the available sub-bands and the frequency bandwidth is reused every three cells rather than every cell like Reuse-1 case. We can notice that the amount of inter-cell interference ICI has been highly decreased due to limiting most of dominant interferers by operating on a different sub-bands while at the same time the spectral efficiency of the limited frequency resources also decreased by wasting most of them to avoid interference.

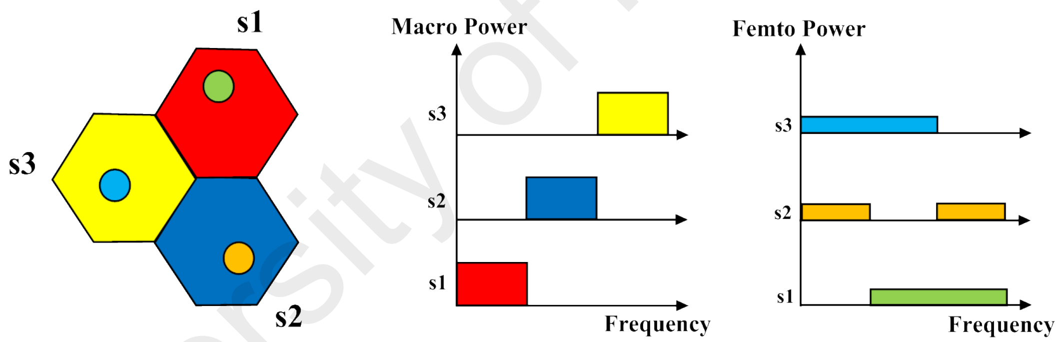

Figure 3.3 Reuse-3 Scheme

Figure 3.3 describes the operation of Reuse-3 scheme. Each macrocell is divided into three different sectors and each sector is served by a different directional antenna. The three sectors are assigned the three different sub-bands such that the interference is only limited to one sector (instead of 3 in Reuse-1 case) that operates on the same sub-bands in neighboring macrocells. The transmission power level in each sector is set as 3P where P is the reference power level used in Reuse-1 transmission. For femtocell operation we propose that femtocells at each sector operate on the two remaining sub-bands not used by macrocell. This procedure provides almost complete frequency separation between macrocell and femtocell networks but at the expense of spectral efficiency (Selim, 2012).

3.2.3 Fractional Frequency Reuse

It has been seen from the discussion of the integer frequency reuse that both the frequency planning schemes IFR1 and IFR3 have lower and upper limits of the interference experienced by users and on utilization of the network resources. So to overcome the limitations of the integer frequency reuse methods the fractional frequency reuse scheme is established where the frequency reuse factor stands between one and three. In this method the whole frequency spectrum is partitioned into two groups, the major group and minor group (Hamza et al., 2013). The area of a cell in this scheme is also divided into two regions, the inner region near the base station and the outer region at the edge of the cell. The minor group of frequencies are intended to serve the inner region whereas the cell-edge region users are being served by the major frequency group.

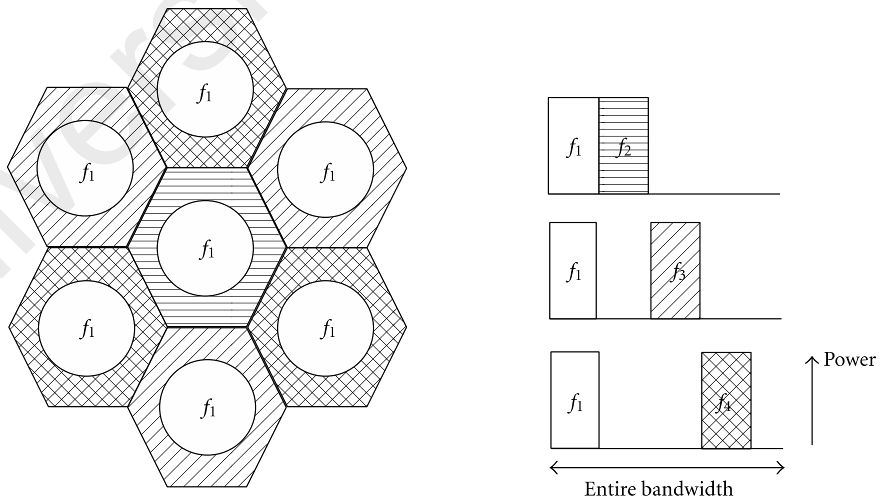

Figure 3.4 Illustration of FFR scheme (Kwan & Leung, 2010).

Figure 3.4 gives an illustration of the FFR frequency planning method. From the diagram we can see that the frequency set f1 forms the minor group and the frequency sets f2, f3 and it forms the major group. The minor group frequency has been used in all the cell center regions resulting in a frequency reuse factor of unity. Whereas the frequency sets f2, f3 and f3 non-uniformly distributed to the outer regions of the cells therefore the frequency reuse factor of 3 is observed in the cell edge region which is quite similar to the IFR3 frequency distribution scheme. This approach aids to greatly improve the SINR experienced by the cell-edge users which was a major concern in IFR1. The cell-center reuse factor of unity also helps to attain the higher bandwidth utilization similar to IFR1 at least for the central region of the cell. Also since the adjacent cell regions (inner and outer) are using different set of frequencies hence intra cell interference is eliminated. In overall the FFR schemes perform better compared to any of the integer frequency reuse schemes individually despite of the fact that the full utilization of the spectrum is yet not made in each cell .

3.2.4 Soft Frequency Reuse

In the FFR scheme mentioned in the earlier section we have seen that the whole frequency spectrum available for the communication network is still underutilized. The soft frequency reuse scheme try to address this issue of underutilization of the scarce frequency spectrum. The SFR frequency planning is identical to the FFR scheme apart from the fact that it allows the inner region of the cell to share the frequency channels that are being used in the cell-edge areas of the adjacent cells. So here again similar to IFR3 the whole spectrum is divided into three groups. Out of these three frequency sets two of them are alternatively Used within the center region of the adjacent cells and the remaining frequency sets are respectively used in the outer region of the corresponding cell.

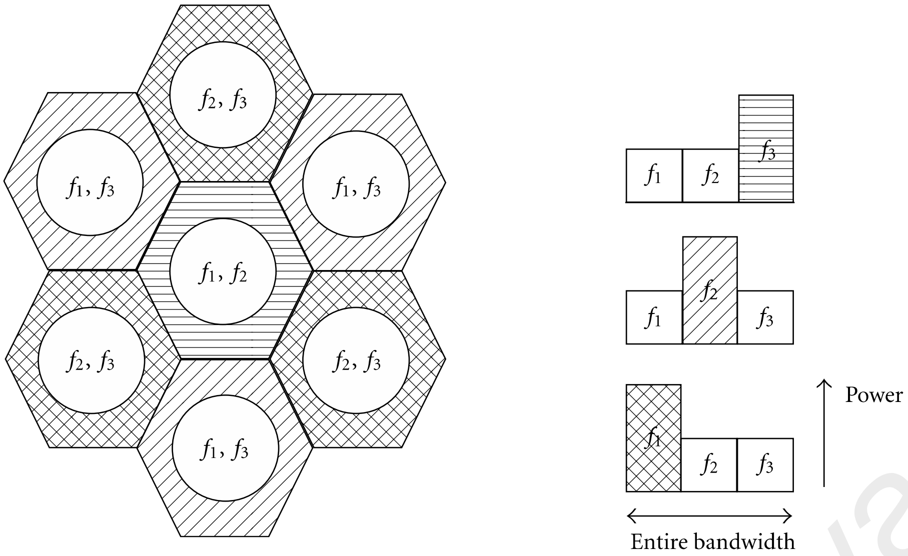

Figure 3.5 Illustration of SFR scheme (Kwan & Leung, 2010).

Figure 3.5 will give us a better understanding of the concept of soft frequency reuse scheme. We can see form the diagram that in a three cell cluster we are using the combinations of frequency sets f1 + f2, f1 + f3 and f2 + f3 in the center region of the cells whereas f3, f2 and f1 are respectively dedicated for the users in the outer region of the cells. in this manner we can use the whole frequency spectrum within each cell and hence achieve the highest spectral efficiency. Although the (sheet of co-channel interference would definitely be higher than that obtained in FFR frequency allocation. The choice of SFR over FFR is best suited when the spectrum utilization is of more significance tolerating a worse interference effect. A better performance is achieved while using SFR by using different transmission power levels for the cell-center and cell-edge users which also depicted in Figure 3.5. This is possible to implement because the users near the base station suffers horn less path loss and hence require lesser transmit power from the base station.

3.3 Power Control schemes

In this section, three power management schemes with different principles in this project are evaluated in LTE-A networks. The aim of any power management schemes is to enhance the overall system performance and increase the throughput and SINR for any user within the cell. The well-known power management schemes exploited in this work are fixed power scheme, constant radius scheme, and target-SINR scheme. All of these schemes are described as following:

3.3.1 Fixed power scheme (FPS)

The fixed power scheme tends to be the most basic scheme among these three that the system assigns a fixed value of power to each FBS regardless of their distance to the central MBS. The advantage of applying scheme is that the FBSs is capable to provide a significant throughput and SINR for the FUEs around due to the high power transmitted. However, the disadvantage is also apparent. The MUEs are likely to suffer from a dead zone when they are approaching FBS, especially for those who stay in the edge area. Er addition to this, the high power transmission by FBS could be redundant for FUEs, which is failed to be cost-effective.

3.3.2 Constant Radius

Compared with first power scheme, the power assigned to FBS in the second scheme may take distance into account. At th't downlink, from BS to UEs, the pilot power is determined based on the defaulted FBS coverage value, computed by radius r, the distance from FBS to MBS. and the antenna gain and it can be formulated as

$$P_f = \min\left(P_m + G_\theta - PL_m(d) + PL_f(r)\,, P_{max}\right)$$

Where: P_f is the power transmitted by FBS , P_m is the Power transmitted by MBS , G_θ is the antenna gain , $PL_m(d)$ is the path loss from FBS to MBS in terms of d in Macro cell and $PL_f(r)$ is the path loss at radius r in femtocell.

According to the formula, at anywhere within the macro cell, it ensures a constant coverage with respected to femtocell radius r, by setting FBSs power value equal to the power received from the MBS at a target femtocell radius r . This scheme in some extent may outweigh the first power scheme, especially in edge area, that the PBS may transmit power abstemiously to FUEs without generating much interference to MUEs around it.

3.3.3 Target-SINR

For both fixed power scheme and constant radius scheme, the power transmission in FBS is fixed all the time once the location of FBS is determined. On the other hand, the power in third is adaptive and a signal SNR threshold is proposed based on the bit error rate in QoS requirement. When applying the third scheme, it tends to readjusts FBSs transmission power level periodically in order to achieve the desired SINR value in a user-specified range, which is set up by system, when that is feasible. Generally, the power in next iteration could be expressed in terms of SINR:

$$P_{(k+1)} = \frac{SINR_t}{SINR_c} P_i(k)$$

Where $SINR_t$ is the target SINR and $SINR_c$ and $P_i(k)$ is the current SINR and power level respectively.

And the SINR with n users could be express as :

$$SINR_i = \frac{G_{ii}P_i}{\sum_{i \neq j} G_{ij}P_i + n_i}$$

Where P_i is the transmission power for user i , G_{ii} is the antenna gain for user i , $G_{ii}P_i$ is the interference power to user i from user j and n_i is the background noise received by user i.

Theoretically this algorithm enable FBS to either converge adequately as the number of FUEs Boating over each iteration or reach the maximum allowed values when the target SINR is achieved .

3.4 Simulation Settings

In this section the detailed steps that has been done in order to create the network topology for evaluating the interference mitigation performance of the HEtNets is presented. In the first section, the equations of the parameters used for the simulation tool is discussed on the basis of how they are developed and calculated and what are their significance. The second section I tried to explain about the simulator architecture about how does it perform step by step and what are the basics of the architecture working behind this simulation tool.

3.4.1 System Model

The path loss in between a macro user and the macro base station and the path loss between a femto user (FU) and the femto base station (FBS) should be calculated to develop the system model. Thereafter estimate the SINR of any position within the cell area using the path loss equation. Thus, (Project, 2010) gives the path loss of a warning outdoor MU in an urban area at a frequency of 2GHz:

$$\boldsymbol{PL(dB) = 15.3 + 37.6\ \log_{10} R}$$

where R is the distance in meters between macro user and macro base station.

For the case of indoor macro user , the equation is modified as given below:

$$\boldsymbol{PL(dB) = 15.3 + 37.6\ \log_{10} R + L_{ow}}$$

where the term L_{ow} represent the penetration loss of the external wall for the macro user. Similarly the path loss between a FU and FBS can be estimated by the below given equation:

$$\boldsymbol{PL(dB) = 38.64 + 20\ \log_{10} R + 0.7 d_{2D,indoor} + 18.3 n^{\left[\frac{n+2}{n+1} - 0.46\right]} + q^{*} L_{iw}}$$

Where q is the number of walls that separate apartments between the FBS and FU, n represents the number of floors been penetrated and L_{iw} is the penetration loss due to the Walls which separates the apartments. The term $0.7d_{2D,indoor}$ is used to estimate the path loss for the walls inside an apartment. The above given equation is for the path loss estimation of an indoor FU. The path loss calculation for an outdoor FU which is associated with an indoor FBS is represented by equation:

$$PL(dB) = \max(15.3 + 37.6\ \log_{10} R\ , 38.64 + 20\ \log_{10} R) + \ 0.7 d_{2D,indoor} + 18.3 n^{\left[\frac{n+2}{n+1} - 0.46\right]} + q^{*} L_{iw} + L_{ow}$$

The typical values for penetrations loss of internal and external loss can be assumed as 7dB and l5dB respectively (Ho & Claussen, 2007). This is the estimation which will also be carried out in the simulation tool which will be used here.

Now after calculating the values of the path loss the respective channel gain G can be calculated using the generic equation:

$$G = 10^{-\frac{PL}{10}}$$

Using the values of the channel gain the received SINR for a MU m operating at a subcarrier n can be estimated using the equation of $SINR_{m,n}$. It is considered that the interference on the macro user m is generating from the neighboring macrocells as well as from the adjacent femtocells that are deployed within the associated macrocell (Bouras, Kokkinos, Kontodimas, & Papazois, 2012).

$$SINR_{m,n} = \frac{G_{m,M,n} \times P_{M,n}}{N_0 \Delta f + \sum_{niegM} G_{m,niegM,n} \times P_{niegM,n} + \sum_F G_{m,F,n} \times P_{F,n}}$$

where $P_{M,n}$ is the power transmitted by the serving base station M for user m on subcarrier n, $P_{niegM,n}$ and $P_{F,n}$ represents the power transmitted by neighboring co-channel macrocells and adjacent femtocells respectively for user m on subcarrier n. $G_{m,M,n}$ represents the channel gain in between the serving base station M and the user m on subcarrier n. $G_{m,niegM,n}$ represents the channel gain in between any neighboring base station neigM and the user m on subcarrier n. Similarly $G_{m,F,n}$ is the channel gain in between any adjacent FBS F and the user m. The term N_0 represents the power spectral density of the Additive White Gaussian Noise (AWGN) and Δf is the spacing between the subcarriers.

We can also deduce a similar equation in order to calculate the SINR of any femto user f Operating on the subcarrier n and considering interference from all macrocells and adjacent femtocells by the below given equation (Claussen, 2007):

$$SINR_{f,n} = \frac{G_{f,F,n} \times P_{F,n}}{N_0 \Delta f + \sum_{niegF} G_{f,niegF,n} \times P_{niegF,n} + \sum_M G_{f,M,n} \times P_{M,n}}$$

Now, since we know how to calculate the respective SINR for a FU or MU we can proceed to calculate the practical capacity of a MU m with subcarrier n by the following equation:

$$C_{m,n} = \Delta f \times \log_2\left(1 + \alpha SINR_{m,n}\right)$$

where Δf represents the spacing between the subcarriers and α is a constant denoting the target bit error rate (BER) given as a = -l.5/ln(5BER). So using the value of the capacity obtained using the last equation for a single user the overall throughput provided by a macrocell M can be expressed as given below:

$$T_M = \sum_m \sum_n \beta_{m,n} \times C_{m,n}$$

where $\beta_{m,n}$ denotes the subcarrier assignment for the users in the cell. When $\beta_{m,n}$= 1 the subcarrier n is assigned to the user m and otherwise $\beta_{m,n}$ = 0. We know ii'om the characteristics of the OFDMA system, each sub-carrier is allocated for only one macro user per time slot within the cell. So this shows that $\sum_{m=1}^{N_m} \beta_{m,n} = 1$, where N_m denotes the total number of macro users within the macrocell.

Now we need to develop the parameters needed for the power control scheme to be used in the simulation tool. When a femtocell is deployed within a network a self configuration process takes place in order to adapt to some specific optimized network parameters. A very important parameter is to set the transmission power of the femto base station. The desired performance by the femto device, the type of femtocell deployment and also the network topology are the determinants of the choice to be made for the transmitted power scheme (Bouras et al., 2014). For the simulation two different power configurations of the femtocell device will be used. The first one is a simple fixed power assignment for all the femto devices within the network. The second power scheme is used to ensure a constant coverage femtocell radius (Claussen, 2007). The below given equation represents the power transmitted by a PBS f for the second power control scheme in decibels:

$$P_f = \min\left(P_m + G_\theta - PL_m(d) + PL_f(r)\,, P_{max}\right)$$

where PL_f (r) is representing the line of sight path loss for a cell radius r and the power transmitted by the macro base station in which the femtocell located is denoted by P_m. The parameter PL_m denoted the average path loss of the macrocell at the femtocell distance d within the cell. The power transmitted value on average is equal to the power received from the nearest MBS for a target femtocell radius of r and is subject to a maximum power of P_m. Finally, the parameter G_θ represents the antenna gain of the FBS in the direction of the FBS where θ being the angle of the femtocell position with respect to the sector angle and is calculated as given below for a 3-sector cell site:

$$G_\theta = G_{max} - \min\left(12\left(\frac{\theta}{\beta}\right)^2, G_s\right)$$

The value of θ ranges from negative π to β, where β = 70/180 the angle where gain pattern is 3dB lower from the peak value. G_s= 20dB and G_{max} =l6dB are the side lobe gain and the maximum gain respectively. So using the above power configuration makes it possible for the FBS to have a constant cell range irrespective of its distance to the macrocell.

3.4.2 Simulation Framework

This section comprises of an overview of the simulation software that is used for evaluating the interference mitigation performance of the heterogeneous LTE-A network based on the ICIC techniques as well as power control mechanism of FBS. The mathematical analysis done in the previous section is used to design the simulation framework. The complexity of the algorithm and simulation codes are hidden behind a simple user friendly interface. It can be easily understood that the simulation for a heterogeneous system is more complex compared to a homogeneous system due to their coincidental, unplanned and large scale nature. The first thing is that the number of users UE and base stations deployed in the network topology are huge in numbers and hence their interconnecting links, their coordination and relationships gradually becomes more complicated. Second thing is the random deployment of femtocells within the macrocell area makes the simulation difficult and scenario-dependent. The integration of all the scenarios for a specific network topology by the simulator is also a very difficult task. Still a wide range of possible scenarios of ICIC techniques as well as power control mechanism has been included in the simulator to have a clear picture of the performance evaluation. Modularity was the fundamental principal kept in mind while designing the simulation tool. So that a user or an interested researcher can easily modify or expand the design by either scaling existing parameters or adding new ones for future research work.

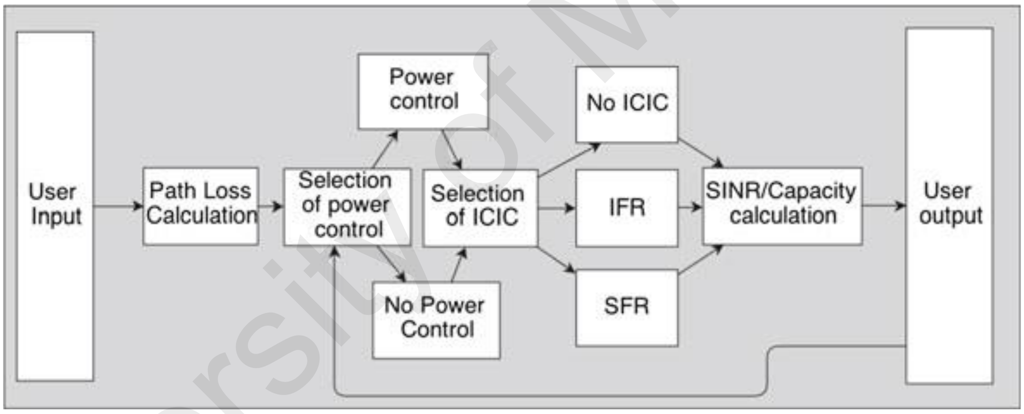

Figure 3.6 Simulation architecture overview

The simulation architecture overview is illustrated in Figure 3.6. As shown in the figure each of the step depicted represents a separate module which are allowed to expand in future while keeping the relationship with rest of the framework in phase. The core component of the framework evaluate the parameters as discussed in system model based on the input configuration chosen by the user, such as the number of femtocells and femto users, number of macro users, number of buildings, the interference mitigation technique to be applied and so on. The input given by the user triggers the mechanism and starts with calculating the path loss based on the equation discussed earlier. Thereafter, based on the user selection made for the power control mechanism and ICIC technique the network topology is designed. In this simulation a full buffer traffic model is considered since it is the worst possible interference scenario which cannot be handled even with scheduling techniques. The selected ICIC technique arrange for the frequency allocation among the femto users and macro users based on the input given at the beginning. Finally, the SINR, the capacity and the throughout is calculated based on the equations discussed in the last section. After the final calculation step a colored map is generated based on the throughout for any location within the cell service area. Also a colored bar is generated beside graphical cellular map to show the level of SINR been produced based on color intensity. This helps to get a comprehensive idea of the resulting performance which we would see in the results and discussion section. A complete information for the results obtained is available for any location within the cell area by just clicking on the graphical map. For a better understanding of these facts a typical instance for the graphical presentation of the simulation results is presented in Figure 3.8. In Figure 3.8 , the colors show the change of the throughput value as shown on the color bar in the right side of the graph.

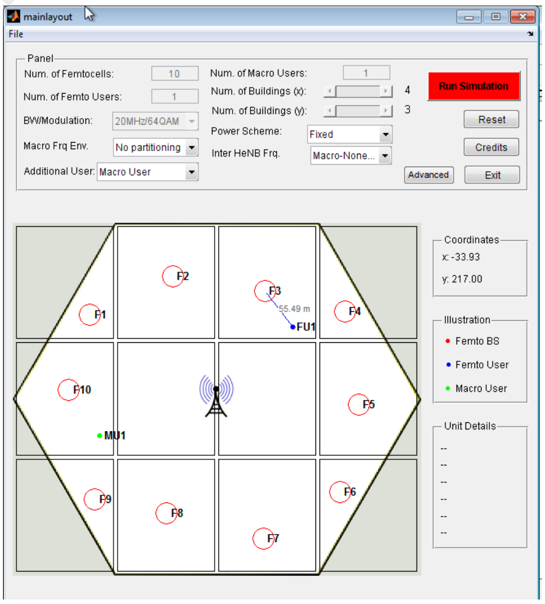

Figure 3.7 A typical instance of the interface during configuration stage.

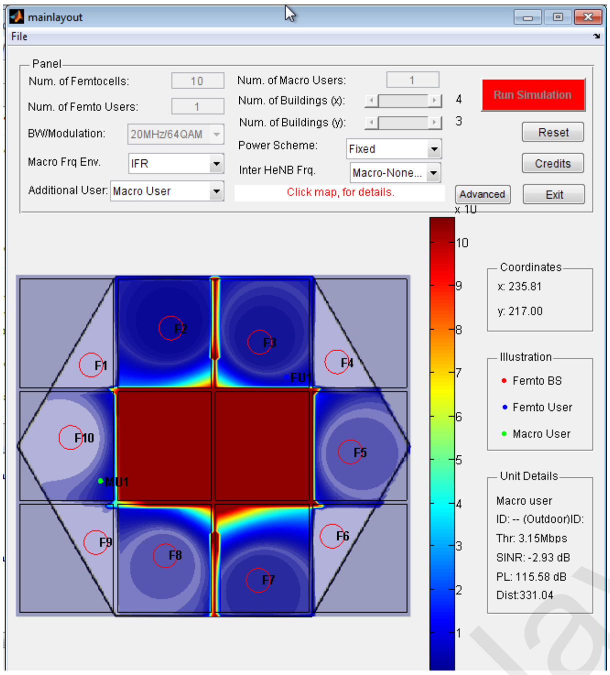

Figure 3.8 An overview of the graphical presentation for the simulation result.

The user initially need to interact with a simple customizable graphical interface in order to provide the custom input parameters to generate the heterogeneous LTE-A network topology. For a better understanding a typical instance for graphical interface is presented in Figure 3.7. As we can see in the diagram that a user can choose the number of femtocells, femto users and macro users that needed to be deployed within the service area. Also the user can determine the density of buildings within the macrocell coverage region to get a detailed analysis of indoor and outdoor user performance. In addition, to define the urban environment completely the user also need to mention the width of the streets (in meters) in the map. The user also got to choose the ICIC techniques (IFR/FFR/SFR) or the power configuration mechanisms discussed in the earlier section. Finally the user get to choose the amount of available bandwidth (1.4, 3 , 5 , 10, 15 or 20MHz) for the network and the type of modulation scheme (QPSK/lGQAM/MQAM) need to be implemented. The input need to be provided depends on the level of the user. In general, an average user are expected to provide basic input parameters like location of femtocells, the number of MU and FU, the number of buildings etc. Whereas an advanced user can work on choosing more advanced parameters like the channel bandwidth, the range desired for femtocell so as to obtain an extensive usage of the simulator tool.

A network topology based on 19 macrocells is a common choice in a lot of simulators. But in this simulator tool only one macrocell is used for the purpose of performance analysis. This is because the main focus of this chapter is to represent the interference issues caused by the deployment of the femtocell within a macrocell area. However, although not shown in the network topology the effect arising from the l9-cell design is depicted and considered in the simulation tool while processing the calculations of the simulation.

CHAPTER 4: RESULTS AND DISCUSSION

In this chapter the results obtained from the simulation in order to measure the performance of interference mitigation for heterogeneous LTE-A networks depending on different ICIC schemes or power allocation schemes are presented followed by their analysis and corresponding discussions. In all the cases for the simulation scenarios the total allowable bandwidth for the LTE-A network is considered to be as 20MHz and the modulation scheme chosen is 64QAM. A summary of the network parameter values that are considered while performing the simulations are presented in Table 4.1.

Table 4.1 Simulation parameters

Parameter	Value
Cellular layout	Single macrocell
Number of macros BS	1
Macrocell radius	250m
Macro BS TX power	46dBm
Carrier frequency	2GHz
Femto BS max TX power	20dBm
Femto BS default TX power	11dBm
Exterior walls loss (low)	15 dB
Interior walls loss (low)	7 dB
Bandwidth (MHz)	20
Modulation type	64QAM
Subcarrier spacing	15 kHz
White noise power density	−174 dBm/Hz

The simulation parameters are considered based on the ITU-R guidelines. The network topology is consisted of a single macrocell area of radius 250m throughout which all the users (FU and MU) and the femtocells are randomly scattered. The macro base stations Which are located at the center of the cell is transmitting a power of 46dBm. Whereas the femto base station is transmitting at 11dBm by default which can go up to a maximum Value of 20dBm. LTE-A specifications are followed while determining the system bandwidth and the allocation of resource blocks. The scenario in which the network topology is created is considered to be a typical urban one. Finally the correlation distance for the shadowing is assumed to be as 40m in this experiment.

4.1 Power Control Simulation

To produce the results a network topology consisting of 10 femtocells scattered randomly throughout the macrocell region with one macro user and one femto-user within the macrocell coverage area are considered. The number of buildings to be deployed are selected as four along both x and three along y axis. The simulation results obtained for power control schemes in FBSs - without using any frequency reuse schemes - are presented in Figure 4.1, Figure 4.3 and Figure 4.5 .

The Figure 4.1 reflects the simulation results obtained when a fixed level of power is applied for all the femto base stations within the macrocell region. In the graph the throughput for a potential macro user has been depicted throughout the entire map. A seen from the graph this method provides insufficient throughput for the macro users especially at the cell-edge areas with a FBS located nearby. What happens in this case is that the power received from the macro base station is reduced to a great extent due to the path loss and hence get dominated by the power transmitted by the surrounding femto base stations. The situation get even worse when we consider the indoor environment since the path loss due to the outer walls of the building structures causes the transmitted power from the macro base station to be reduced further. The simulation results for a similar network topology only without the deployment of the building structures presented in Figure 4.2 a gives a clear picture of the mentioned effect. The color intensity in the figure shows that without the physical obstacles the same topology can generate a higher level of throughput for the macro user all over the service area when compared with Figure 4.1.

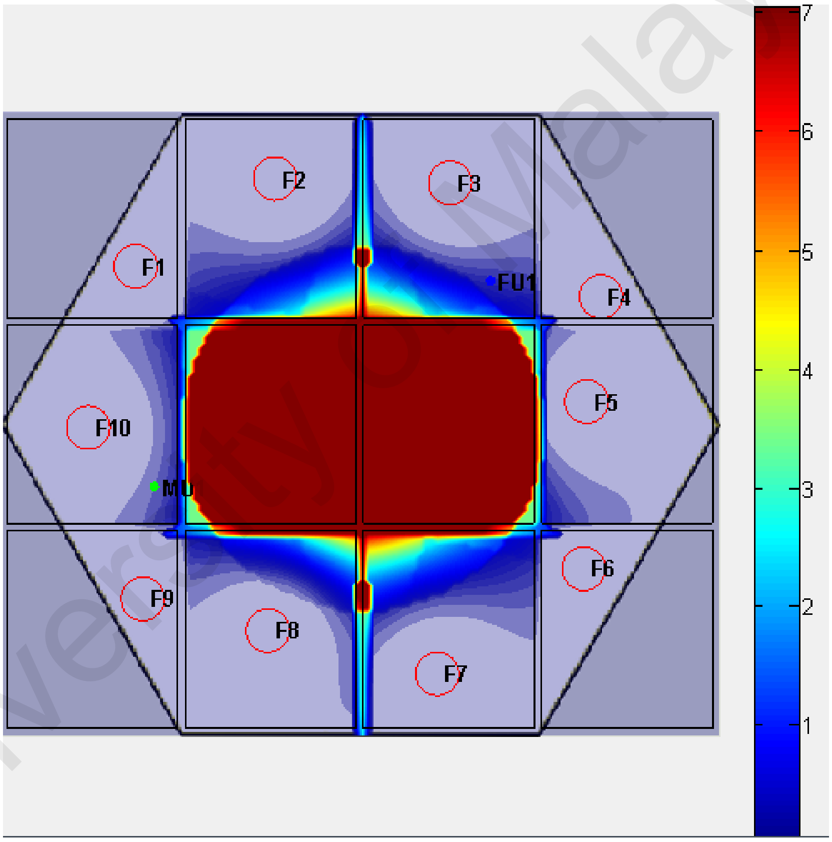

Figure 4.1 Throughput with a common fixed power level for all FBSs for macro user.

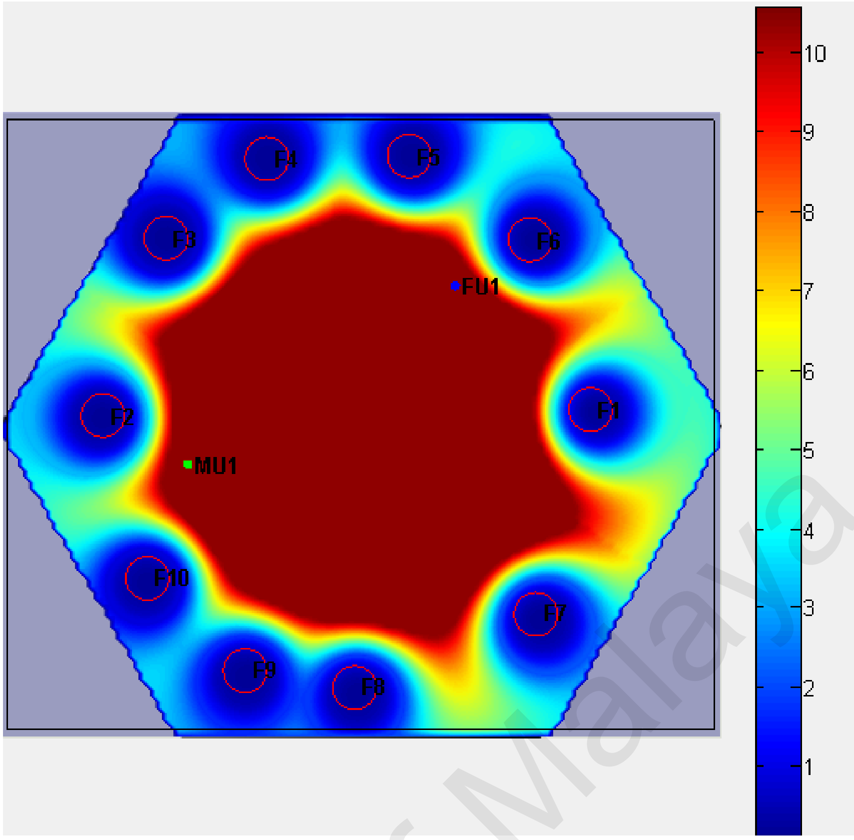

Figure 4.2 Throughput with a common fixed power level for all FBSs for macro user without building.

The simulation results obtained for the throughput for a macro user shows that when all the femtocell base stations adopt the power configuration to maintain a constant radius of FITS coverage is better when compared with the earlier scheme. The result is been presented in Figure 4.3. This power scheme assist in oppressing or enhancing of the transmitted power level of the PBS depending on the requirement and as a result improving the network performance for the macro users.

The simulation results for a similar network topology only without the deployment of the building structures presented in Figure 4.4 a gives a clear picture of the mentioned effect.

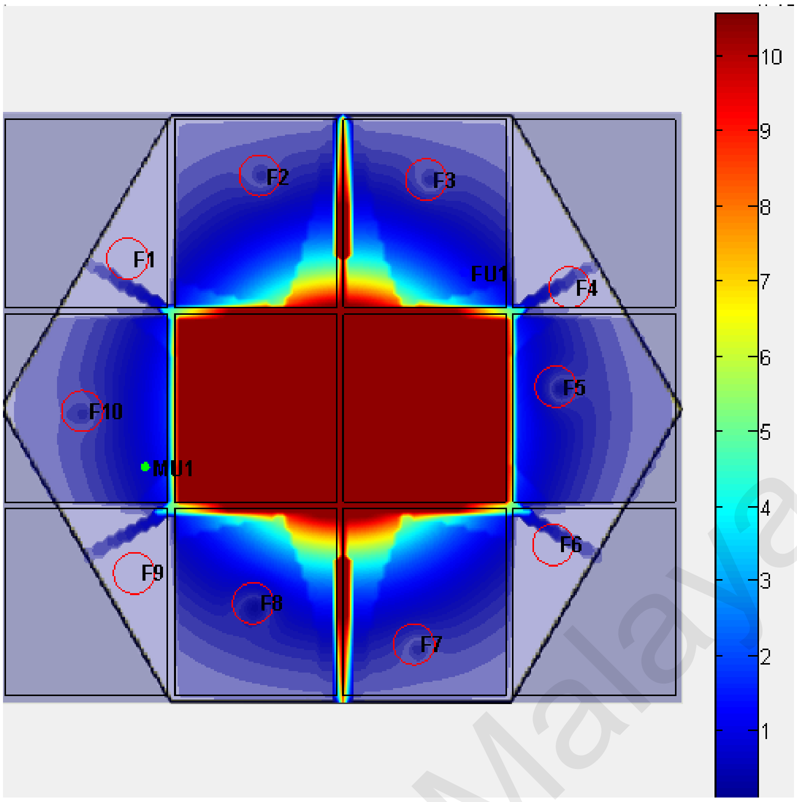

Figure 4.3 Throughput with a constant FBS power level for all FBSs for macro user.

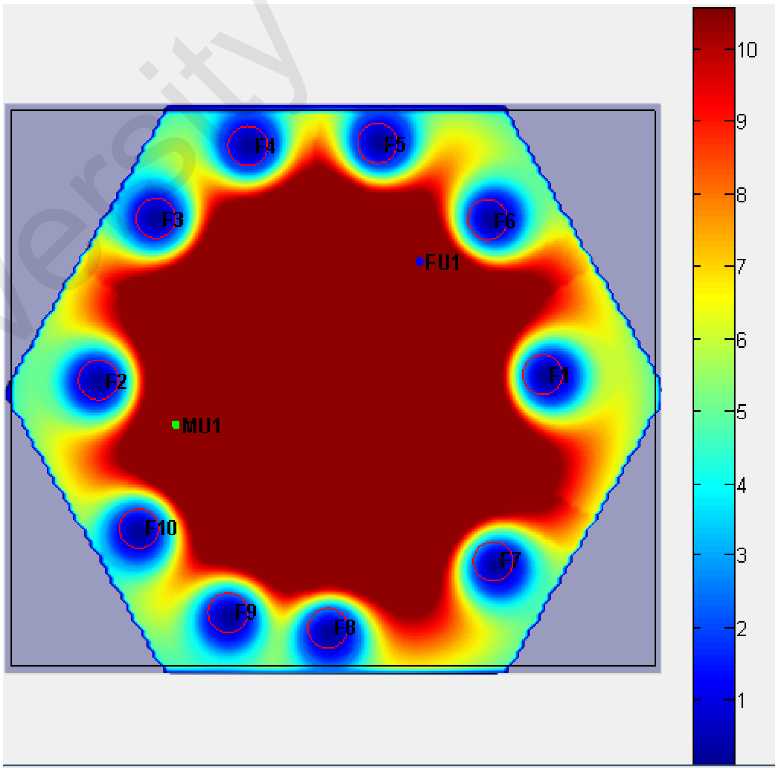

Figure 4.4 Throughput with a constant FBS power level for all FBSs for macro user without buildings.

While the simulation results obtained when a target SINR method is applied for all the femto base stations within the macrocell region. It is clear that this method provides insufficient throughput for the macro users especially at the cell-edge areas with a FBS located nearby as shown in Figure 4.5.

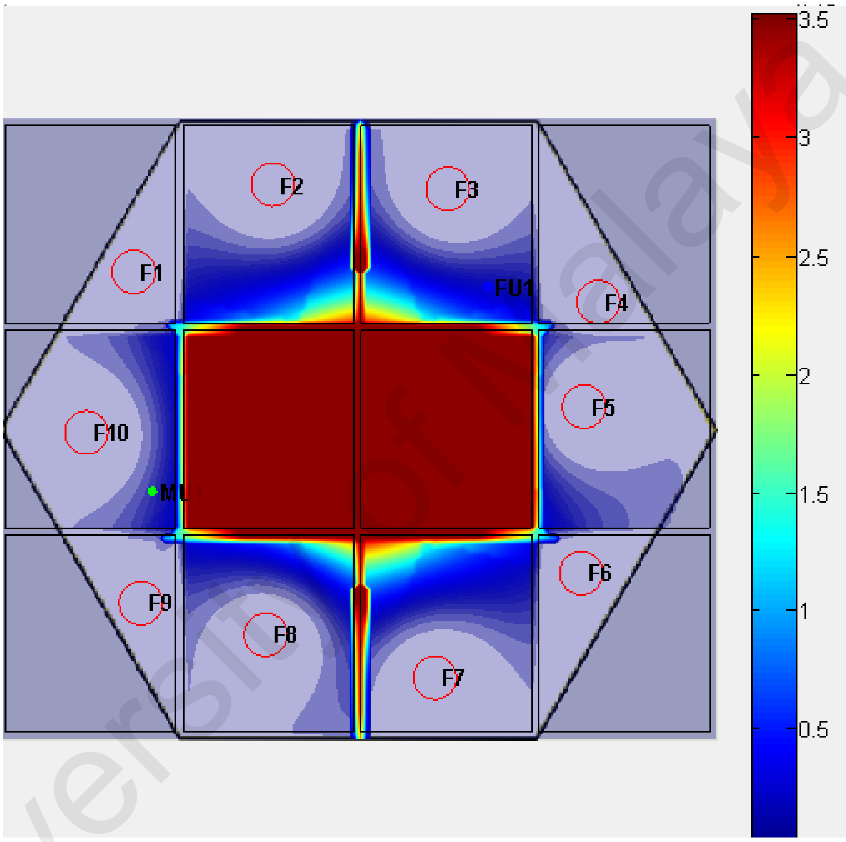

Figure 4.5 Throughput with a target SINR power level for all FBSs for macro user.

It is understood form earlier discussions and the obtained simulation results that the level of throughput to be obtained by a single macro user is highly dependent on the location of the FBS from the macrocell within the service area and hence common power configuration for all the FBSs proves inefficient. Also it is realized that the ratio of the MBS and FBS signal strength is independent of the location of the FBS relative to the MBS and depends only on the distance between the user and the associated FBS.

Although the upper limit of the FBS in the case can create dominance at the cell edge over an adjacent MBS especially when several users are served by the mentioned FBS.

4.2 Frequency Reuse simulation

This experiment was carried on in order to measure the performance of the several different frequency allocation schemes while applied on the heterogeneous LTE-A network. To produce the results a network topology as shown in consisting of 10 femtocells scattered randomly throughout the macrocell region with 5 macro users (MU) and 5 femto users (FU) within the macrocell coverage area are considered. Four scenarios are considered for the experiment. These scenarios are Co-channel operation – No patriating – , IFR , FFR and SFR.

The simulation result for first scenario which is Co-channel operation is presented in Figure 4.6 .

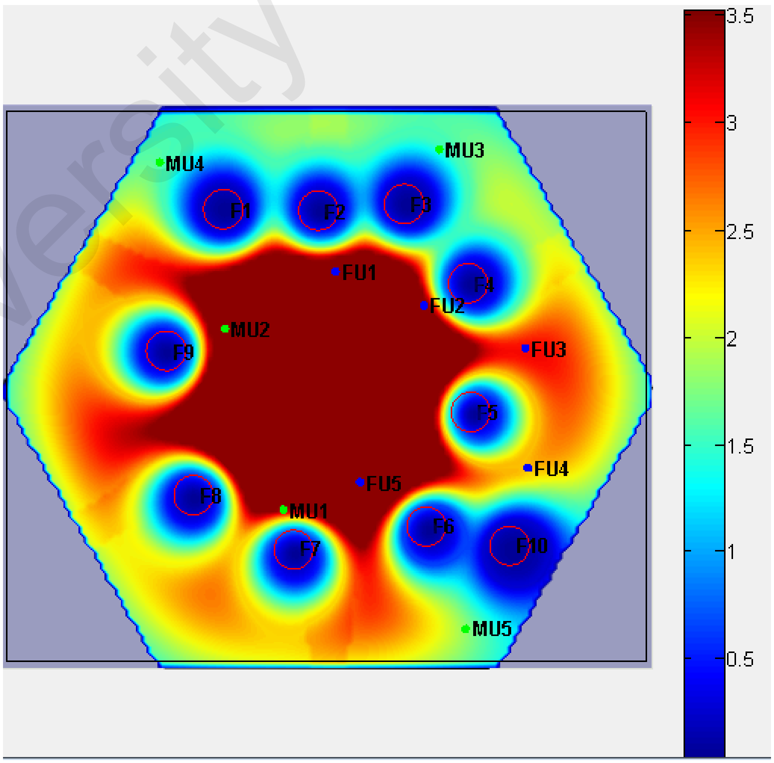

Figure 4.6 Co-channel operation

It is easily understood from the presented Figure 4.6 for co-channel scenario that it is the worst case scenario as expected for the throughput of the macro users over the whole cell area. Specially the users at the edge of the cell are found to be affected more since they are also exposed to additional inter-macrocell interference.

For IFR and FFR scenarios, FFR performs very much similar to the IFR scheme as shown in Figure 4.7 and Figure 4.8. Thus, we can neglect the FFR scheme and discuss the simulation results of IFR. In IFR scenario, It is obvious that IFR and FFR greatly improved the macro user throughput within the macrocell area to almost same extent.

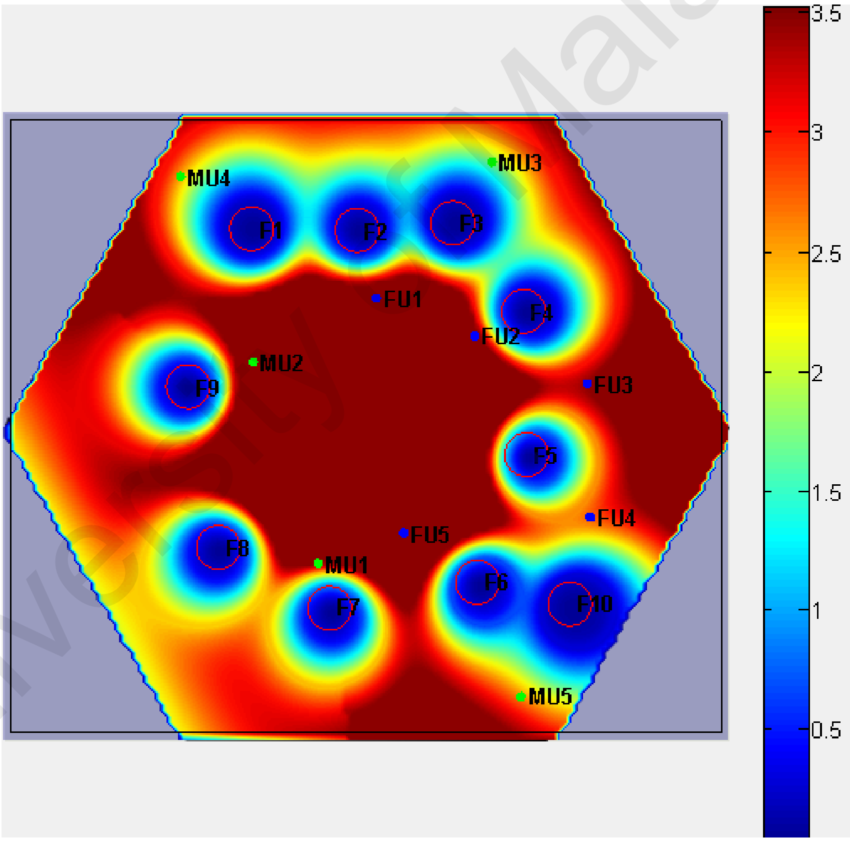

Figure 4.7 IFR Scheme

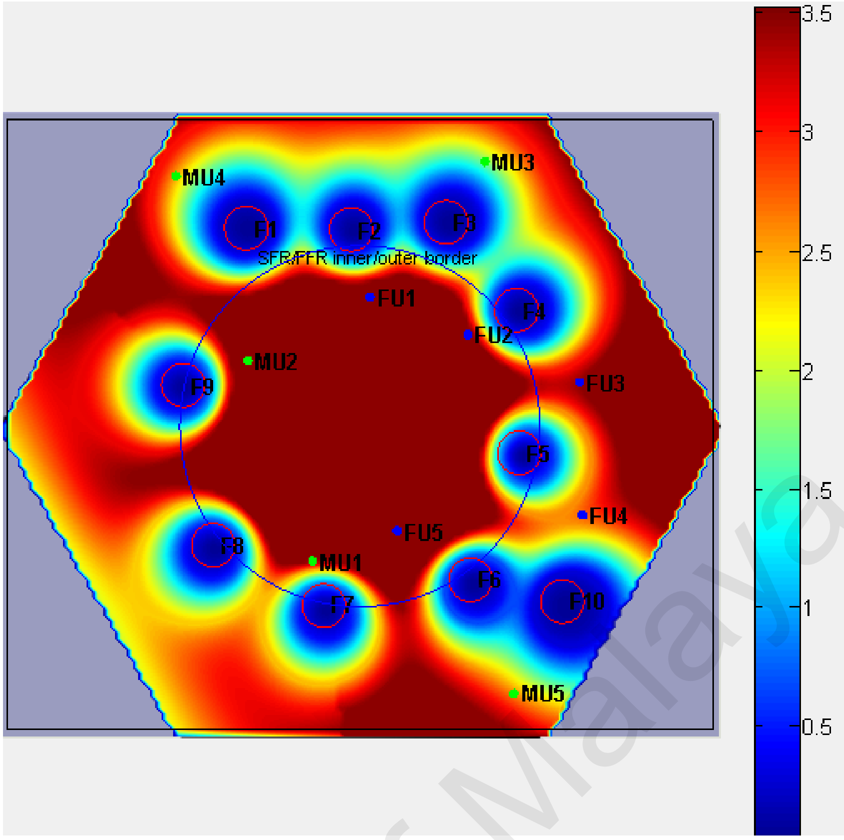

Figure 4.8 FFR Scheme

Finally in Figure 4.9 , we can see the data rate map for macro user is presented while SFR scheme is being deployed for frequency allocation within the communication network. In our experimental setup it is observed that the SFR scheme proves to be the best scheme to provide an overall highest throughput in the whole macrocell region. Especially when we look at the cell edge areas of the macrocell we can see that SFR gives a superior throughput performance compared to any other scheme. The reason behind this superior performance of SFR is that when this scheme is applied the only interference experienced by the cell edge macro users is from any FBS located near the border of the adjacent macrocell using the same frequency channel.

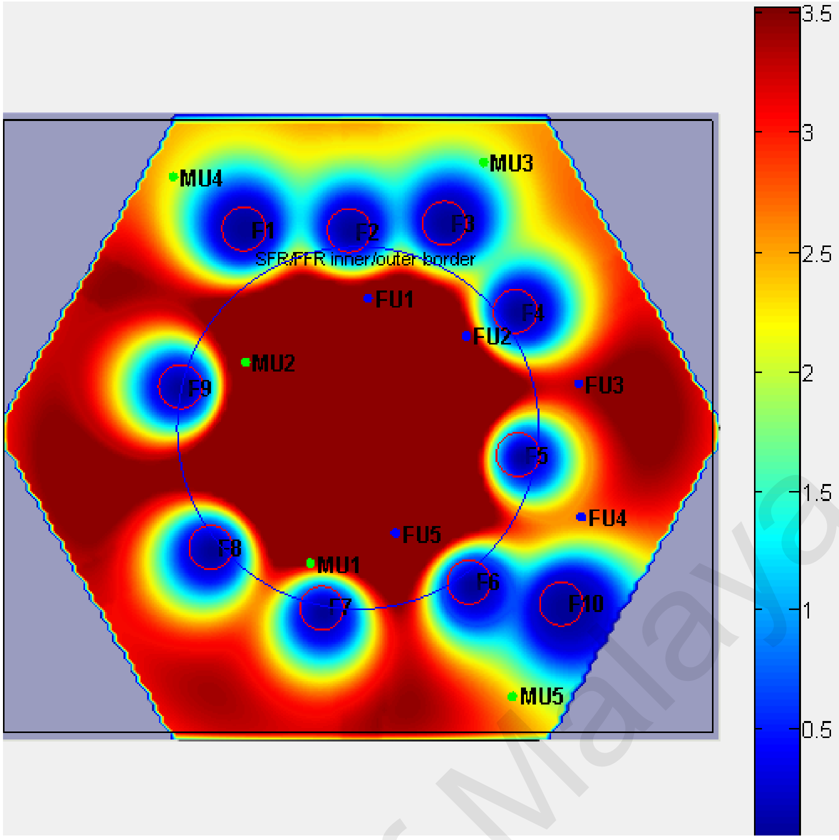

Figure 4.9 SFR Scheme

The simulation results presented in Figure 4.10, Figure 4.11 and Figure 4.12 is generated using a network topology consisting of 10 femto cells scattered randomly throughout the macrocell region with 5 Mus and 5 FUs randomly scattered within the macocell region. The number of buildings to be deployed are selected as four along both X and y axis. So this is actually a further illustration of the results presented in Figure 4.6, Figure 4.7, Figure 4.8 and Figure 4.9 with the exception of building structures being deployed within the service area. The signal loss due to the exterior and Interior walls are considered to be as 15dB and 7dB respectively while doing the Simulation. The scenario for FFR is been neglected in this part since as we a for FFR has been neglected in this part since as we also seen on the previous results that it performs very much similar to the IFR scheme. So as expected SFR and IFR is found to be performed better compared to the co-channel senario as illustrated in data rate maps of Figure 4.6.

The cell edge performance is not observed like the previous results due to the presence of severe additional signal loss caused by the walls of the buildings that are deployed in the scenarios. So observing all the simulation results it is evident that to be aware of the ICIC schemes by the MBSs and FBSs are of greater importance in order to achieve better network performance.

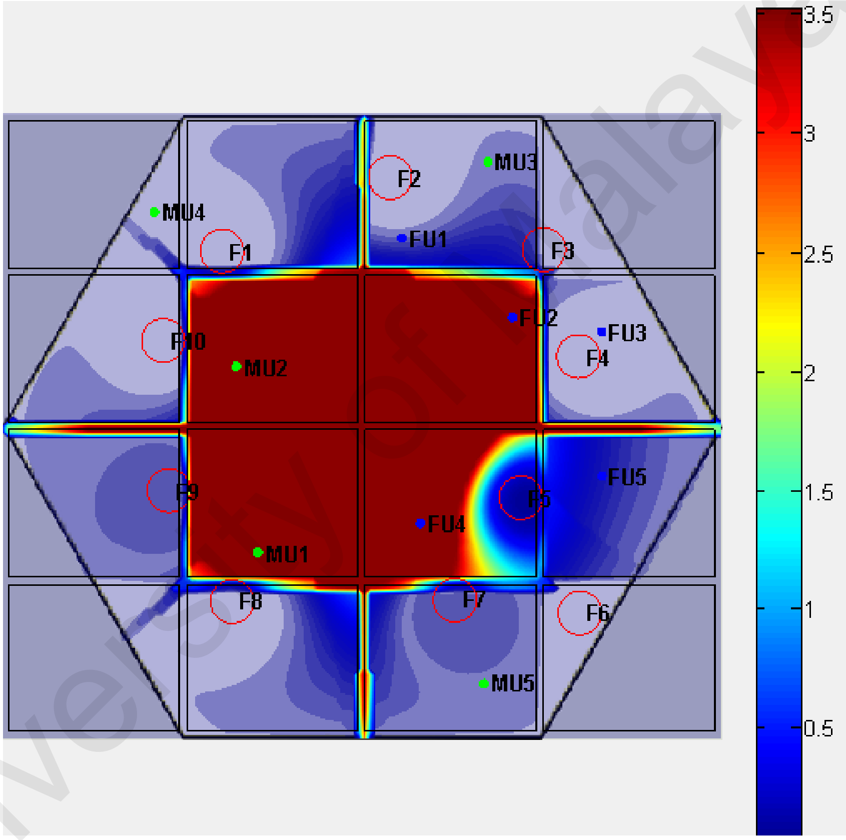

Figure 4.10 Co-channel operation with building

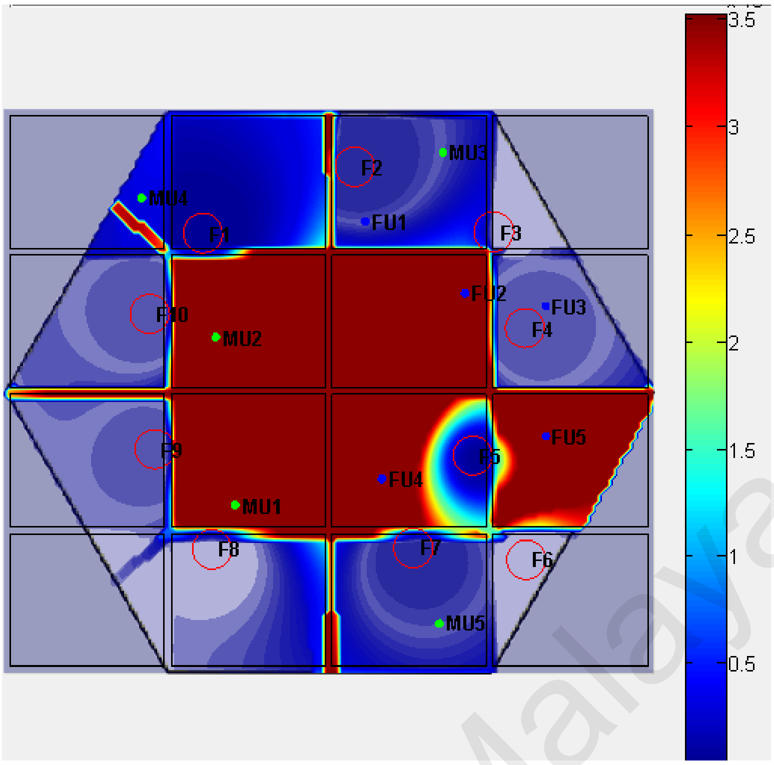

Figure 4.11 IFR scheme with buildings

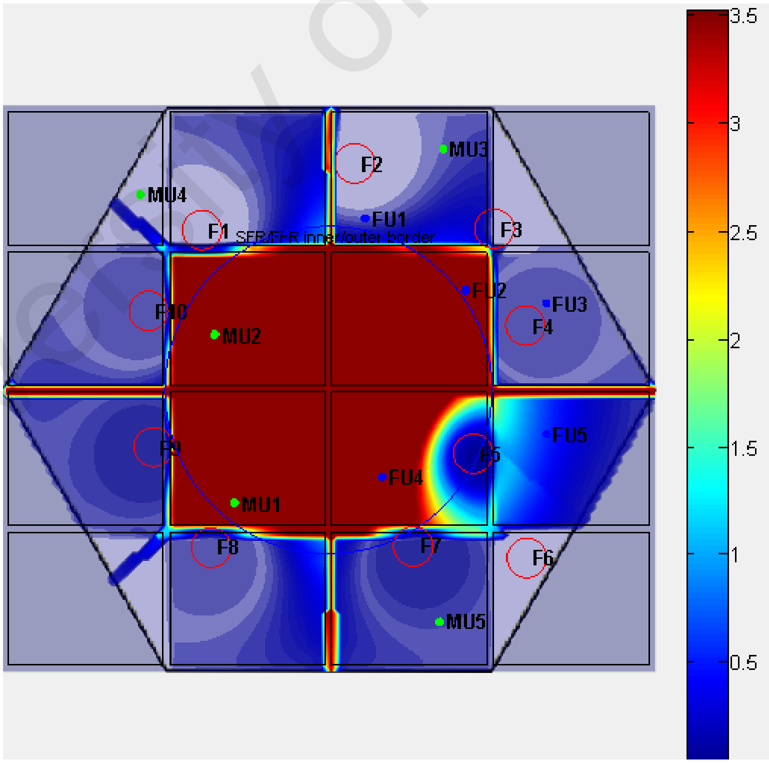

Figure 4.12 SFR scheme with buildings

4.3 Comparison Simulation

This part of the simulation was intended to compare between the different methods that has been discussed and the results for which have been presented in this chapter. The comparison was made on the basis of measuring the cell throughput while varying the femtocell density within the macrocell area. The simulation results were obtained by extending the simulation tool. First, I had to make sure the position of the femto cells are generated randomly the first time and then must be the same for all schemes, so that comparison would happen on the same terms. Then I repeated the simulation for each scheme and for different number of femto cells, and hence calculated the average throughput of a user for all possible positions in the cell (unless I examined cell edge scenario, where I did the same for the positions in the cell edge). Thereafter I put all the data obtained in the graph and thus obtained the comparison graphs. Also while doing the simulations only one user is considered since then can measure the average based on the position of that user in the cell.

The average cell throughput performance comparison is depicted in Figure 4.13. It is observed from the graph that for a small number of femtocell deployments the co-channel operation provides about twice the throughput that has been provided by the FR schemes although this advantage is found to diminish at a rapid rate. However, the co-channel operation starts becoming worse compared to FR schemes when number of femtocell deployment crosses 30 femto cells. This performance measure reflects that large number of femtocell deployment compensates the loss in spectral efficiency caused due to the application of FR schemes by maintaining an optimized network performance. It is clearly observable from the simulation result that FR schemes are much preferable for large scale femtocell deployment in the network. While comparing in between the three FR schemes it is observed that the performance of SFR is slightly better than IFR and FFR which is due to the higher spectral efficiency in the SFR frequency planning scheme.

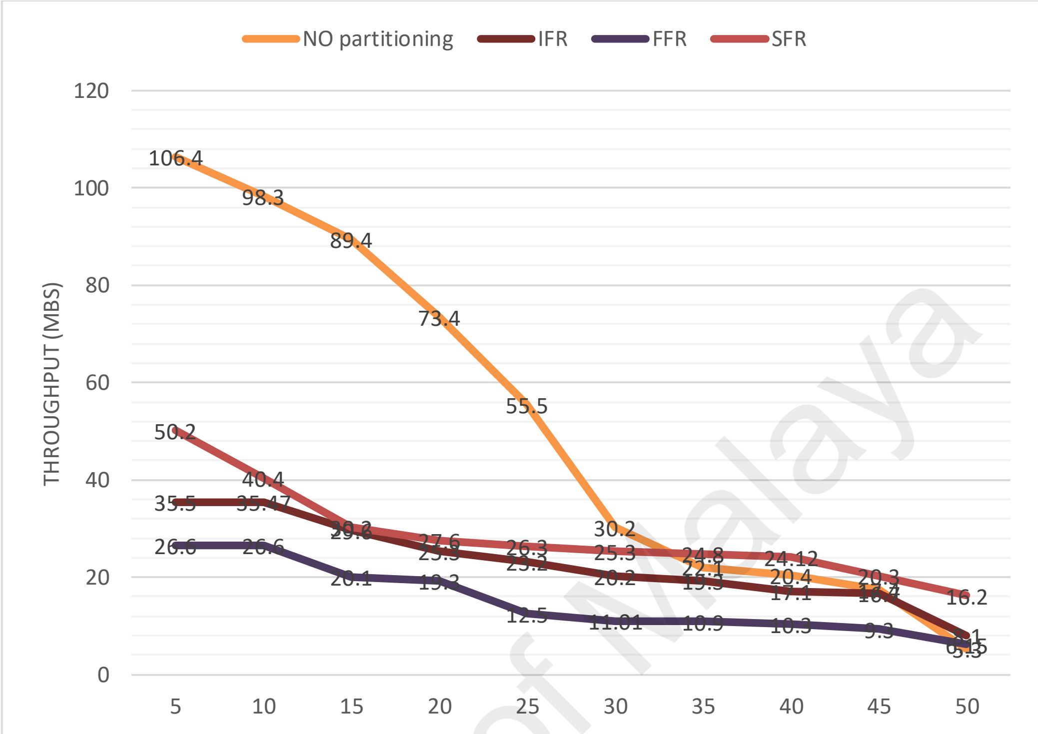

Figure 4.13 The average throughput performance for macro users.

In Figure 4.14 the simulation results reflecting the average cell-edge throughput comparison for macro users based on the different interference mitigation methods is presented. It is observed that the performs best average throughput while IFR and FFR have the same behave. It is also observed that co-channel operation performs worst compared with other frequency reuse schemes. A high scale femtocell deployment is expected at the cell-edge areas since this is the area where the received signal from the MBS gets significantly weaker. So to get a better cell-edge performance in a LTE-A network with the help of femtocell deployment the FR schemes should be the chosen interference mitigation technique as realized from the simulation results.

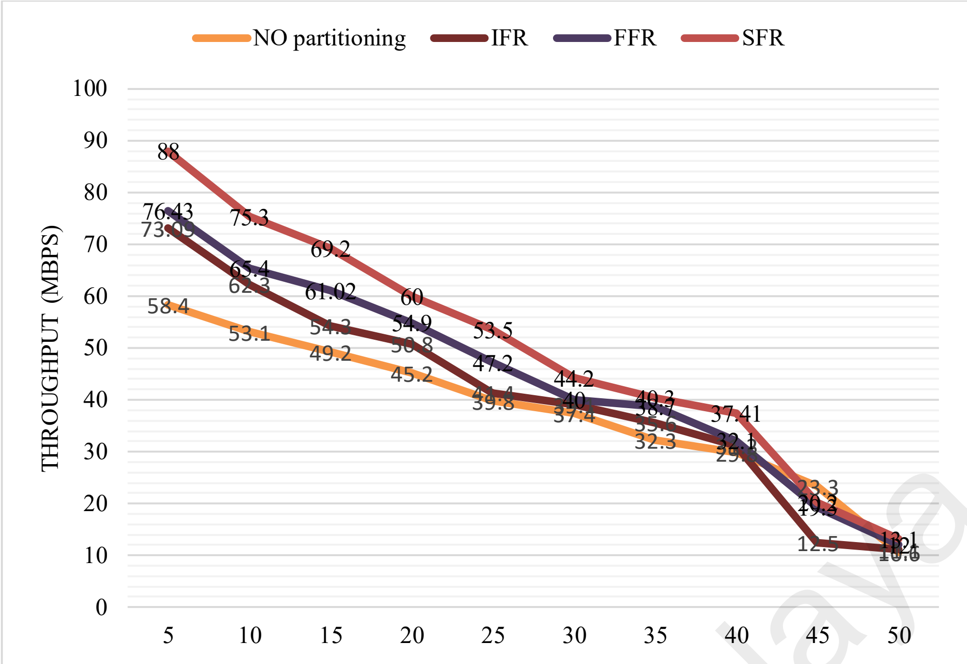

Figure 4.14 The average throughput performance for macro users at cell-edge.

In Figure 4.15 the simulation results reflecting the average cell-edge throughput comparison for macro users based on the different power control schemes is presented. It is observed that the power control scheme based on a constant radius of femtocell coverage the performance compared with other power control schemes.

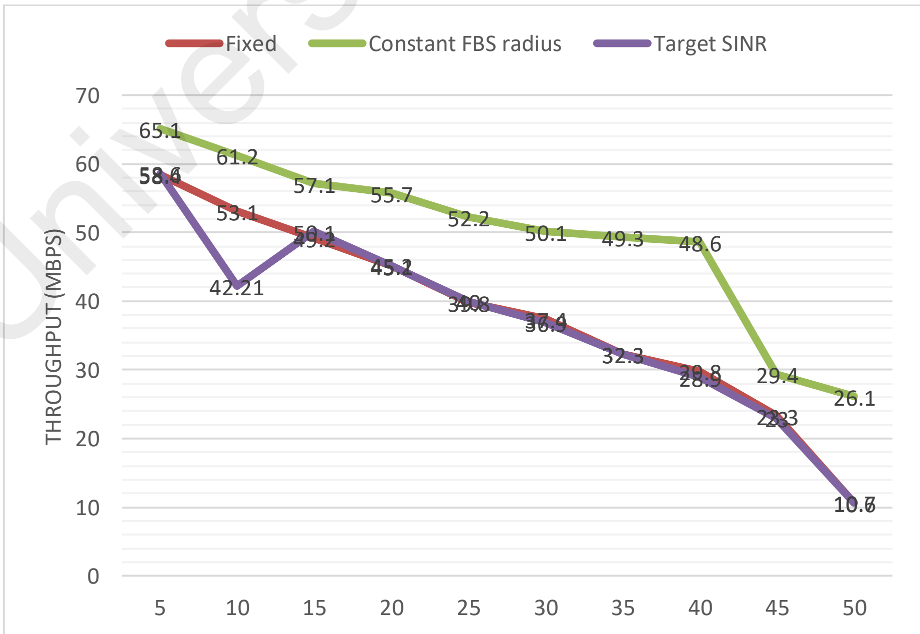

Figure 4.15 The average throughput performance for macro users at cell-edge.

CHAPTER 5: CONCLUSION

The research project is designed to address the interference mitigation approaches in LTE-A network using power control schemes and frequency reuse schemes. Thus, a simulation tool with the ability to design the custom femtocell overlays on the LTE-A network in order to mitigate the interference issues of heterogeneous network has been used. The simulator helped in evaluating the performance of interference mitigation based on some defined frequency reuse and power control schemes. The most prominent frequency reuse techniques and power control techniques are chosen for the evaluation purpose. The simulation results obtained from the experiment helped to investigate the cross-tier interference phenomena. The most significant finding from the simulation results is that for a small number of femto cell deployments power control is the superior scheme among all the schemes discussed in order to mitigate the interference experienced by the macro users. But when the femtocell penetration rate is higher the frequency partition schemes proves to perform better in terms of overall throughput of the macro users in the cell due to the efficient utilization of network resources. While comparing in between the discussed FR schemes we saw that the SFR performed better for chosen number (10 femtocells) of femtocell deployments within the macrocell. Although the situation might change for a different concentration of femtocells as well as the concentration of buildings located within the macrocell region. Also the results have depicted that while using a power control scheme based on a constant radius of femtocell coverage the performance is better while comparing to the approaches of assigning fixed power levels for all the base stations and SINR adaptation of all the base stations. By comparing this study with the earlier studies, I found that the results are the same in order to get the optimal frequency reuse and power control methods.

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