PERFORMANCE STUDY OF FRACTIONAL FREQUENCY REUSE IN OFDMA NETWORK

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**FACULTY OF ENGINEERING
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ABSTRACT

Long Term Evolution (LTE) technology is considered as the most possible candidate for recent generation mobile communications. LTE networks offer high capacity and are specified and designed to accommodate small, high performance, power-efficient end-user devices. One limiting factor that influences LTE performance is the interference from neighbor cells, the so called Inter-Cell Interference (ICI). Fractional Frequency Reuse (FFR) has been proposed as a technique to overcome this problem, since it can efficiently utilize the available frequency spectrum. This project analyzes the FFR scheme which dynamically selects the optimal frequency allocation based on the cell total throughput and user satisfaction. In detail, the mechanism divides the cell into inner and outer regions and then selects the optimal size as well as the optimal frequency allocation between these two regions with main target to maximize the overall throughput and user satisfaction. The mechanism is evaluated through several simulation scenarios that incorporate users' mobility. With the use of MATLAB simulation, which is highly configurable, this project will study a performance of frequency reuse technique in OFDMA. Simulation results show that the adaptation process leads to improved performance and increased total cell throughput and user satisfaction.

ABSTRAK

Teknologi Evolusi Jangka Panjang (LTE) merupakan yang paling berkemungkinan besar di pilih untuk komunikasi mudah alih generasi terbaru. Rangkaian LTE menawarkan kapasiti tinggi dan ditentukan dan direka untuk menampung peranti pengguna akhir yang cekap, berkuasa tinggi dan cekap. Salah satu faktor yang mempengaruhi prestasi LTE ialah gangguan dari sel jiran, yang disebut Inter-Cell Interference (ICI). Penggunaan Frekuensi Fraksional (FFR) telah dicadangkan sebagai teknik untuk mengatasi masalah ini, kerana ia dapat menggunakan spektrum frekuensi yang ada dengan cekap. Projek ini menganalisis skim FFR yang secara dinamik memilih peruntukan kekerapan yang optimum berdasarkan jumlah keseluruhan saluran sel dan kepuasan pengguna. Secara terperinci, mekanisme membahagikan sel ke kawasan dalam dan luar dan kemudian memilih ukuran optimum serta peruntukan kekerapan optimum antara kedua-dua wilayah dengan sasaran utama untuk memaksimumkan keseluruhan output dan kepuasan pengguna. Mekanisme ini dinilai melalui beberapa senario simulasi yang menggabungkan pergerakan pengguna. Dengan menggunakan simulasi Matlab, yang sangat boleh dikonfigurasi, projek ini akan mengkaji prestasi teknik penggunaan kekerapan dalam OFDMA. Hasil simulasi menunjukkan bahawa proses penyesuaian membawa kepada prestasi yang lebih baik dan peningkatan jumlah kesedaran sel dan kepuasan pengguna.

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LIST OF SYMBOLS AND ABBREVIATIONS

LAN	:	Local Area Network
LTE	:	Long Term Evaluation
ICI	:	Inter-Cell Interference
OFDMA	:	Orthogonal Frequency Division Multiple Access
FFR	:	Fractional Frequency Reuse
QoS	:	Quality of Service
Het-Net	:	Heterogeneous Network
SE	:	Spectral Efficiency
PF	:	Proportional Fairness
AMC	:	Adaptive Modulation and Coding
SDMA	:	Special Division Multiple Access
SFR	:	Soft Frequency Reuse
SINR	:	Signal Interference Noise Ratio
UE	:	User Equipment
US	:	User Satisfaction
HFR	:	Hybrid Frequency Reuse
IFR	:	Integer Frequency Reuse
BS	:	Base Station
CCI	:	Co-Channel Interference
FA	:	Frequency Allocation

CHAPTER 1: INTRODUCTION

1.1 Research Background

There are many techniques being proposed for mobile network generations along the time. Orthogonal Frequency Division Multiple Access (OFDMA) is a prosperous mechanism for current mobile networks. The working principle of OFDMA is to divide the entire network spectrum into several orthogonal narrowband subcarriers which can be allocated to different users in the cell. The interference is the most important issue in OFDMA that needs to mitigate, hence many techniques with different working principles are considered. Most of the proposed techniques share the concept of sending in any cell over fraction of the spectrum which is a small part of the overall bandwidth, while the adjacent cell use a different fraction of the spectrum. Furthermore, increasing the capacity and coverage is the main target in usage of cellular network. That goal can be gotten by the efficient reuse of frequency which considers as the main characteristics. Fractional Frequency Reuse (FFR) in OFDMA-based network, as a Long Term Evolution (LTE) is studied at (WiMAX, 2006) to cope the co-channel interference (CCI) issue. The cell area in FFR is split into two zones: internal zone which is around the cell BS and external zone which close to the cell borders. Each cell region is assigned by a different sub-band which is a small portion of the entire frequency band. Consequently, both inter and intra-cell interference eliminated (Necker, 2007b), also the overall throughput is improved. The controlling of the bandwidth allocated to each cell region and the transmission power of each band is the key characteristics of different reuse factor and interference mitigation levels.

The frequency and time resources in OFDMA FFR is split into different sub-bands. Each sub-band is confined for a specific reuse factor and is linked to specific transmission power profile. In particular, FFR considered in downlink channel, in spite of that it can be considered for both uplink and downlink channel. Indeed, downlink is less complicated and required fewer information.

By implementing the interference mitigation scheme, the frequency collisions between adjoining cells will be averted. Static and dynamic are the two ways to avoid the collisions between frequencies, where the static way can be forced by assigning different frequencies to adjoining cells. However, the dynamic way use an intelligent scheduler monitor the collisions. The static method is a particular and most common way that can be used. This can be explained due to the complexity to implement the intelligent scheduler and the signaling overhead.

1.2 Objective and Motivation

In this report, the validation of frequency reuse scheme in controlling the co-channel interference in a network have been studied. Besides, dynamic FFR mechanism to choose the optimal frequency allocation based on specific parameter is proposed.

There are several objectives have been highlighted:

1- To analyze the interference caused by adjacent and co-channel cells.
2- To investigate an effective FFR method to reduce the interference.

All the outcomes are evaluated in concept of overall throughput and user satisfaction. The LTE proposed environment is modelled using MATLAB.

There are many causes to study the performance of Fractional Frequency Reuse (FFR) as a proposed scheme to mitigate the interference in the two-tier network:

The network structure with macro-cells experience high level of interference, while it has dense of users. This is give me motivation to know in detail what is going research about this topic and it is really close to our life. In OFDMA-based networks, such as the

LTE is the most suitable candidate for current generation mobile communication and it becomes more popular. This technique provides a low cost, user friendly and strong connection to the internet.

The technologies to mitigate the interference is really essentially in order to provide a seamless service to the users at any location.

Thus, in order to provide good quality of service and reliable service to the users regardless of the location, we need an effective and functional interference mitigation technique.

1.3 Organization of report

The organization of this report is as follow:

- The literature review about work by other researchers which is related to interference mitigation mechanisms especially by Frequency Reuse Schemes is explained in Chapter 2.
- Chapter 3, clarified the suggested interference mitigation mechanism in LTE network, concepts of related theoretical, and the conducted scenarios.
- Chapter 4 described and discussed the evaluation.
- Lastly, conclusion is set in chapter 5 with some future research idea related to the topic.

CHAPTER 2: LITERATURE REVIEW

2.1 Review on fractional frequency reuse scheme

There are many hurdles facing the improvement of 4G cellular wireless network, where the capacity and cell coverage are most major challenges. The network structure with macro, Pico and femto-cells get along with short range and low power base stations is considered as an effective technique to improve the spectral efficiency of the network. Furthermore, the better QoS, enhancing the coverage of indoor and cell edge users are an advantage of using such technique which is referred to Het-Net. One of the major issues for deployment a hierarchical cell is the interference between different layers and the solutions to mitigate it. Fractional Frequency reuse (FFR) is considering to be one of the efficient techniques to mitigate inter-cell interference in OFDMA based Het-Nets. Consequently, FFR schemes have been fond for researchers and trigged the interesting in this chapter all reviews that related to this interference coordination technique are listed.

The author at (Abushabab, Khodier, & Ismail, 2016) proposes a mechanism that selects the optimal value of inner cell region radius in strict FFR that maximize both throughput and User Satisfaction together using CS algorithm. Fractional Frequency Reuse (FFR) deployment schemes (FFR-3 and FFR-6) are being evaluated for heterogeneous networks (HetNets). Moreover, a new scheme is proposed at (Mohamed, Abdelhamid, & El Ramly, 2016) aiming to minimize the interference on the macro-user (MU) in the cell center. A contention based Fractional Frequency reuse scheme is proposed at (Zhan et al., 2016) where the simulation results show that the proposed scheme not only greatly improves the performance of the edge users but also improve the throughput of the whole network.

Scheme without the application of femto-cell, scheme with randomly application of femto-cell and with preplanned femto-cell scheme are three frequency reuse schemes discussed by the author at (Bouras, Kavourgias, Kokkinos, & Papazois, 2012). While at (Hassan & Assaad, 2009) FFR factor is for the external cell region, the bandwidth allocated to each cell zone and power allocation to all cell users are determined and the optimal parameter is chosen. The previous parameters with the using of Lagrange dual decomposition theory at reasonable computational cost evolve an effective algorithm to deal with sum-power minimization issue which is effected by minimum rate constraints in inner and outer cell regions which in turn relax into a convex optimization issue.

FFR scheme with the concept of normalized Spectral Efficiency (nSE) is suggested to select the optimal scheme in OFDMA network that is discussed by the author at (Fang & Zhang, 2008).However, significant improvement of cell edge users with maximization of SE system is got by applying this theory .Also, the gain of the system SE is about 3% by FFR scheme proposed is illustrated by simulation results. Joint spatial-frequency Proportional Fairness (PF) scheduling with soft frequency reuse at 3GPP and 3GPP2 OFDMA are proposed by the author at (Liu et al., 2006) with the simulation results and its evaluation. Inter-cell interference in 3GPP Long Term Evolution (LTE) and 802.16e WiMAX OFDMA is adopted by the author of (Necker, 2007a) by introducing distributed algorithm for interference coordination. Where the cell edge performance improved with universal information got by central coordinator.

The concept that presented at (Necker, 2007b) is overviewed and extended more at (Tarhini & Chahed, 2007) .The extension concept is debated and the algorithms of interference coordination that can be global or local system knowledge is compared. The research paper on title “On capacity of OFDMA-based IEEE802.16 WiMAX including Adaptive Modulation and Coding (AMC) and inter-cell interference” has been discussed at (Xiang, Luo, & Hartmann, 2007) where different frequency reuses which get Adaptive Modulation and Coding (AMC) and inter-cell interference as a results is studied .Also the downlink capacity OFDMA-based IEEE802.16 WiMAX system in the presence of streaming and elastic as a traffic types is studied.

Several flexible radio resource reuse schemes for the downlink is discussed at (Tomcik, 2006) in the purpose to deal with inter-cell interference issue. The simulation results shown that the soft frequency reuse scheme is better technique to improve cell edge throughput without effecting the average cell throughput. The Mobile Broadband Wireless Access (MBWA) with IEEE 802.20 standard has been examined with applying of TDD and FDD techniques. Furthermore FFR, spatial division multiple access (SDMA), MIMO transmission and pre-coding is deployed in order to allow the system to appropriately select the optimal transmission technique for different terminals according to propagation environment.

A cohesive framework would allow for research into the dynamics and implications of FFR along with other important cellular network research including handoffs, base station cooperation, and FFR in conjunction with relays and/or femto-cells as is shown by (Novlan, Ganti, Ghosh, & Andrews, 2011) in their paper. However, a modern analytical framework in FFR and SFR is introduced to estimate the probability of coverage and average rate. The resulting system proposed guidelines focused on the advantages of those techniques and make comparison between outstanding interference mitigation of FFR and maximum resource efficiency of SFR. Eventually, based on the analytical expression a SINR-proportional resource allocation technology is suggested and we noticed that an increasing in the sum-rate and well-known of improved coverage for cell-edge users by FFR.

The minimization received SINR at the cell edge can be increased through the usage of the proposed FFR power allocation pattern is investigated in (Valcarce, Lucas, & Lopez-Perez, 2012), In general, it has been shown that presented FFR-based scheme maximizes the minimum received SINR when compared to a scheme not using FFR. All that by developed and evaluated an in-cabin soft fractional frequency reuse dual-cell scheme for cross cell interference mitigation and presented a sub-band power allocation framework that improves the UE's DL SINR when using SFR.

The appropriate frequency distribution in light of the aggregate throughput and, clients satisfaction is a dynamic FFR technique that have been proposed for this paper .In details, choosing the optimal frequency distribution as well as optimal size between the internal and external zones of cell that have been divided according to the mechanism .all that in aim of maximize the overall throughput and US .Therefore the FFR scheme that maximize the previous parameter is chosen according to calculation that is taken in periodic time intervals and each time interval .

CHAPTER 3: INTERFERENCE MITIGATION MECHANISM

3.1 INTRODUCTION

The best solution for Long Term Evolution (LTE) mobile system networks for mitigation of inter cell interference (ICI) is frequency reuse schemes. In (Samal, Samal, & Das, 2014), to eliminate intra-cell interference for a single cell of the network due to the orthogonal sub-carriers the chosen method of modulation OFDMA has been implemented in these network which is really helpful.

Whilst, inter-cell interference (ICI) is one of the main problems which affects the overall system throughput and its performance. There are many frequency reuse schemes: some famous are Soft frequency reuse (SFR), Integer frequency reuse (IFR), Hard frequency reuse (HFR), Hybrid frequency reuse scheme (HFR) and Fractional Frequency reuse (FFR).

This chapter introduces a review on frequency allocations and Interference classification at mobile network and supposed scenarios and examined.

3.2 Interference Mechanisms and Types

This part is to study the main classification of interference at cellular network which influences LTE performance.

In general, interference will be in both processes from uplink and downlink. There are two types of interference that happens in multi-cell network (Zahir, Arshad, Nakata, & Moessner, 2013):

The interference that happens between two femto-cells which is known as co-tier interference is the first one. The high density of femto-cells and small separation between them is the major cause of this interference. At uplink process the interference takes place due to move user equipment (UE) next to adjacent femto-cells. In contrast, the downlink interference is due to femto-cell to the adjacent UE. The optimal method to remove co-tier interference problem is by power control. Where the high level of UE power it will interrupt the adjacent femto-cell and vice versa. Secondly, the interference between femto-cell and macro-cell is cross-tier interference. The downlink interference in cross-tier occurs when femto-cell serves as a source of the macro-cell BS. However, in uplink the cross-tier interference place when femto-cell user acts as a source to the outer macro-cell.

- One Tier Interference

This type of interference happens between the network's parts that are in the same tier. In other word, irregular operation between adjacent femto-cells may cause co-tier interference. For example, the interference that takes place between femto-cell user equipment and the BS of the other one as in the following Figure 3.1.

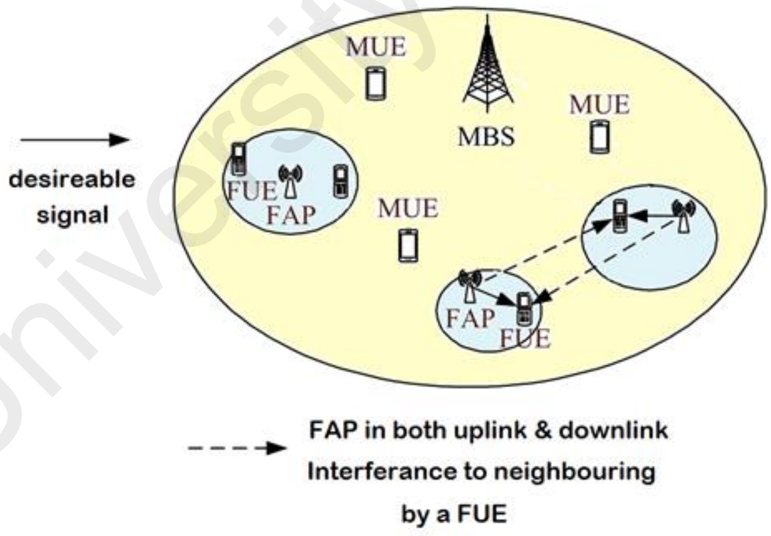

Figure 3.1 co-tier interference scenario among cells

In general, the interference happens between femto-cells and the closest macro-cell. The placement of the femto-cell is random and to avoid interference happened they can be used by joining between each other in any part where the wall split-up are not enough.

The whole interference observed at a femtocell can be higher than any of the individual interfering femto-cells when it got from the operation of many number of femto-cells or in other word in the case of dense deployment. SINR value must take into consideration and kept under specific level. Otherwise, the dead zone at certain location will create.

The co-tier usually used open and close access methods which have a big influence of the whole system interference. The dead zone at close access is bigger than the one at open access. SINR as one of QoS parameter directly related to dead zone, for instant, if the high value of SINR is required the dead zone will be larger.

b) cross-tier interference

This interference takes place between two different tiers. For instant, the interference that happens between macro-cell and femto-cell as shown in Figure 3.2.

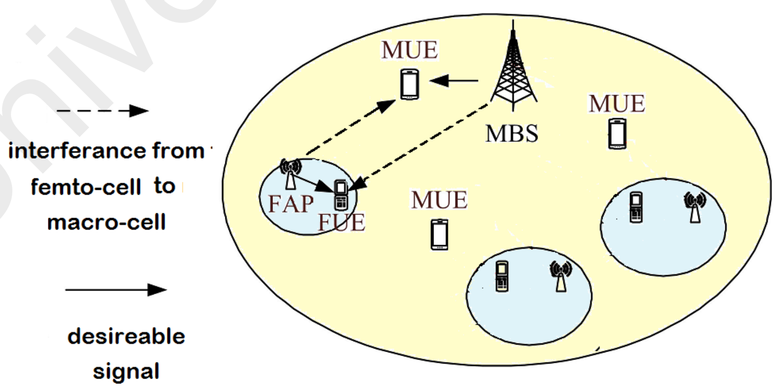

Figure 3.2 Network environment for cross-tier interference between femto-cell and macro-cell.

It belongs to the large amount of interference with neighbors that are using macro-cell service. If the closed access mode facing this problem, it becomes worst. In step to give macro UEs received strong signals to which access is denied and around the femto-cell, there would be giant dead zones by close neighborhood.

Spectrum splitting is another arrangement from another researcher about the cross-tier interference, where in the case of having a separate spectrum the cross-level interference will be removed. Unfortunately, this does not work efficiently due to the high cost of spectrum.

There are many cases of cross-tier interference, one of them is when femto-cell UE service as a source of interference of the macro-cell base station. Another case is when clients allowed to interact with any layer, based on the received signal quality.

In OFDMA systems the interference happens due to placement the femto-cell close to macro-cell BS. The overall efficiency decreased when the sub channel does not use by BS of macro cell as a femto-cell UE is sending an efficient power on that channel. Consequently, the maximum level of power transmitted by femto-cell UE must specified.

Furthermore, cross-tier interference may take place in close access if UE of macro-cell send a high power as in it is far away from the base station of another macro-cell. Thus, femto-cell must assign different sub-channel to mitigate the interference.

3.2.1 Frequency Reuse Allocations Schemes

A. Fractional Frequency Reuse (FFR)

Fractional Frequency Reuse (FFR) is one of the Frequency Reuse Schemes. The principle of (FFR) is to cut the bandwidth that is transmitted to the cell. Thus, the outer-cell users do not experience the interference and the inter-cell interference is reduced.

Amelioration in coverage area of the outer-cell users, rate, spectral efficiency and overall throughput considered because of using FFR.

The usage of FFR reduce co-channel interference (CCI) since outer –cell users receiving co-channel interference from different parts in different cells. Furthermore, the inter-cell users experience the overall frequency band as they less experience the interference of co-channel.

The mechanism of FFR is that the overall system bandwidth is split into two parts . The second half is divided in three more parts as shown in Figure 3.3.

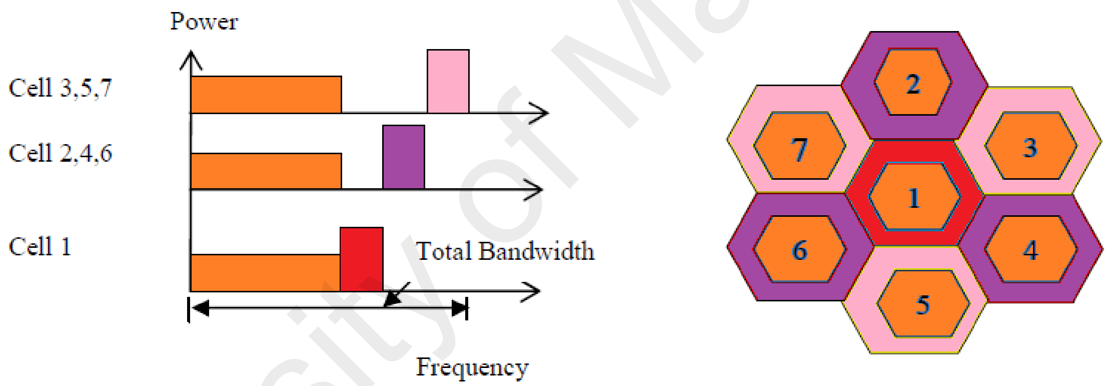

Figure 3.3 FFR

In FFR the location of UEs needs to be known. Hence, additional data is required to calculate inner and outer cell UEs. That is considered as one of the drawbacks.

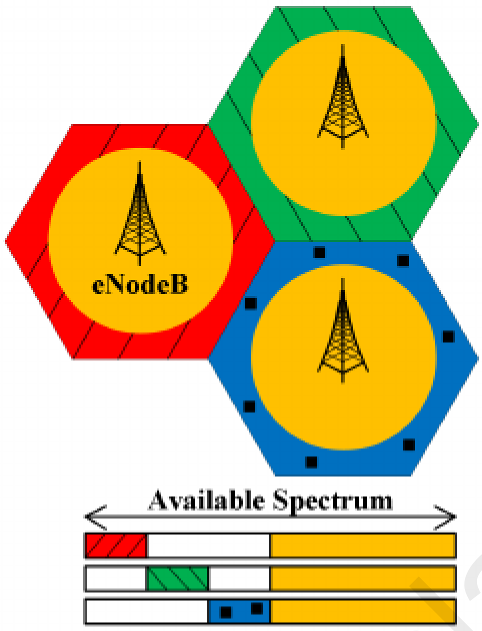

Figure 3.4 Fractional frequency reuse Technique

B. Soft Frequency Reuse (SFR)

The overall system bandwidth in SFR is separated between cell center where the major bands are and cell-edge where the remains bands are (Mao, Maaref, & Teo, 2008). According to this technique the available frequency exploit.

The mechanism of SFR based on divided the overall frequency into three parts as shown in the Figure 3.5. Two-thirds of the frequency is assigned for inter-cell users. However, one third is assigned for the outer cell users. According to that the outer cell users will suffer from lower throughput as a lesser band will result for less capacity.

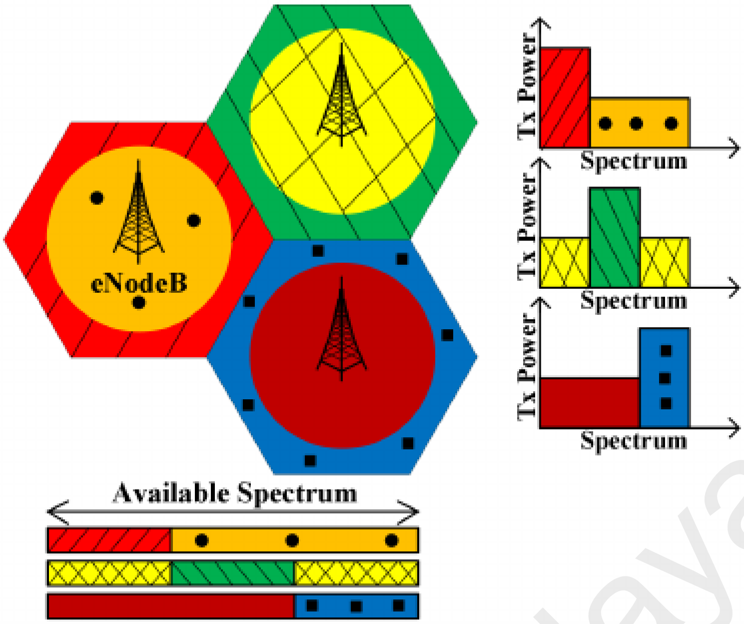

Figure 3.5 SFR

As a result of SFR working principle the transmit power will also vary between both cell regions where the path loss at internal region will be small thus the transmit power will be small as well. Meanwhile, the power level at outer cell usually three times higher than the one at internal zone, consequently the SINR and capacity will improve.

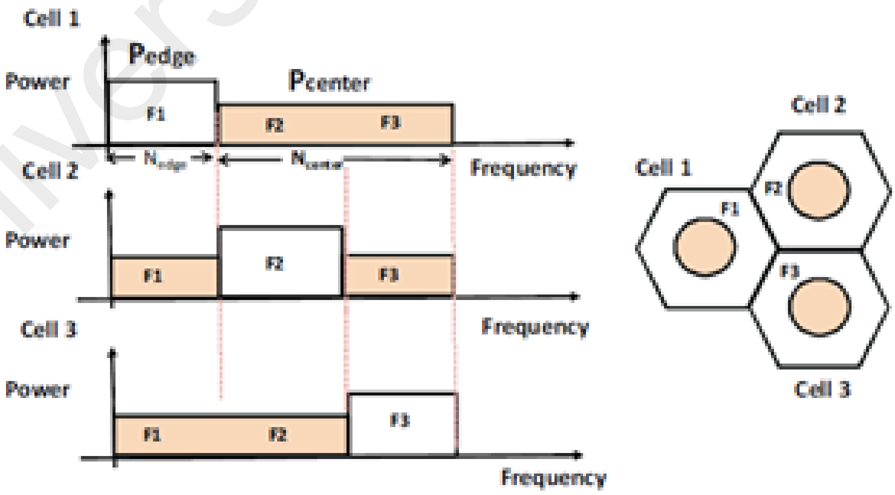

Figure 3.6 frequency reuse Technique

C. **Integer Frequency Reuse (IFR)**

Frequency reuse factor 1 or integer frequency reuse IFR is the third type of frequency reuse schemes which is considered as the primal and simple scheme. In IFR regardless to the user location, all the available frequency can be used at any point of the cell.

All macro-cells and femto-cells in the system able to reuse the whole available frequency band which is the main advantages of this technique beside the high spectral efficiency. On the other hand, the inter-cell interference (ICI) value is extremely high due to sharing the entire frequency band especially for small size macro cell (Arnold, Richter, Fettweis, & Blume, 2010).

The working principle of IFR is illustrated in Figure 3.7 .As shown the entire frequency is reused in the C1, C2, C3 cells .Further, the power level is constant.

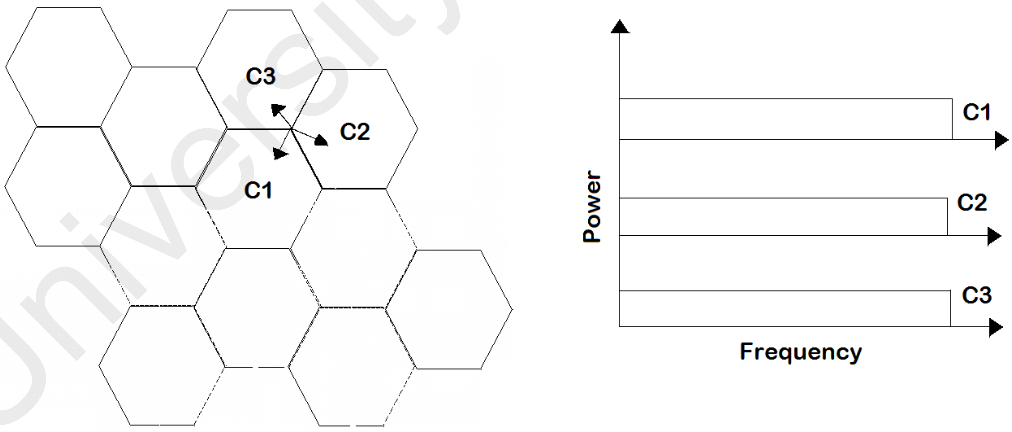

Figure 3.7 Integer Frequency Reuse Technique for IFR1

IFR provide a high data rate for users since the entire channels are exploited. On the other hand, high interference gained from adjacent cell also the capacity of network will be negatively affected.

Frequency Reuse Scheme with the factor 3 IFR3 is introduced as a solution to mitigate the high interference got by IFR1. The mechanism of IFR3 shown in figure 6, where the available spectrum is split in three similar groups. These three sub-carriers are assigned for three neighboring cells which is considering as a cluster. This cluster will be repeated in the aim of covering the entire targeted area.

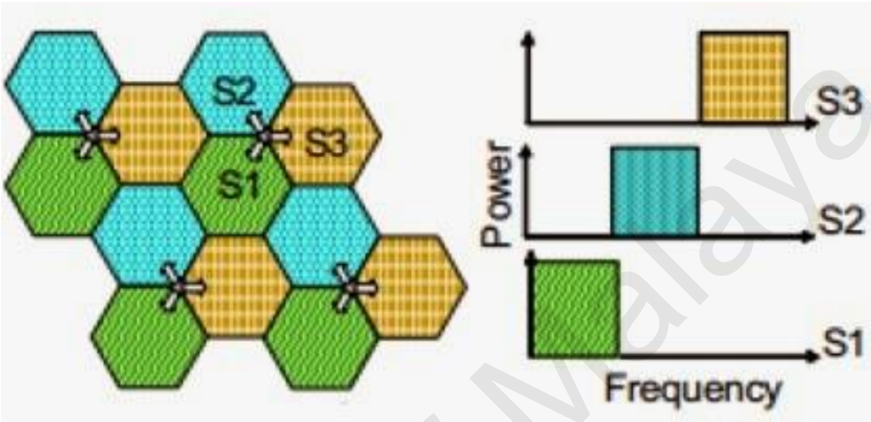

Figure 3.8 Integer Frequency Reuse Technique for IFR3

3.3 Simulation Scenarios

This report comes out with network have been generated and show in order to the output. After the cell is deployed, many parameters must take into consideration for the simulation.

The scenario is divided into two parts:

- The first one shows the examined topology. This topology division shows the structure of the network cells and user location.
- The second one illustrate the theoretical approach in order to measure the SINR, User Satisfaction and throughput. The next section will discuss the experiment results.

The supposed scenario for the simulator as following:

The scenario is for network structure with mobile users. the technique is that choosing the optimal FFR based on the maximum cell throughput. The supposed network divided into 16 cells with 360 users distributed uniformly for each cell.

In details, we focused one cell (which highlighted in Figure 3.9) which located in second row third column. There will be twenty-two (22) users at this cell who will be mobile randomly in the cell borders with 3Kmph speed. The experiment time will be 215 secs with taking into account that the number of users will not change.

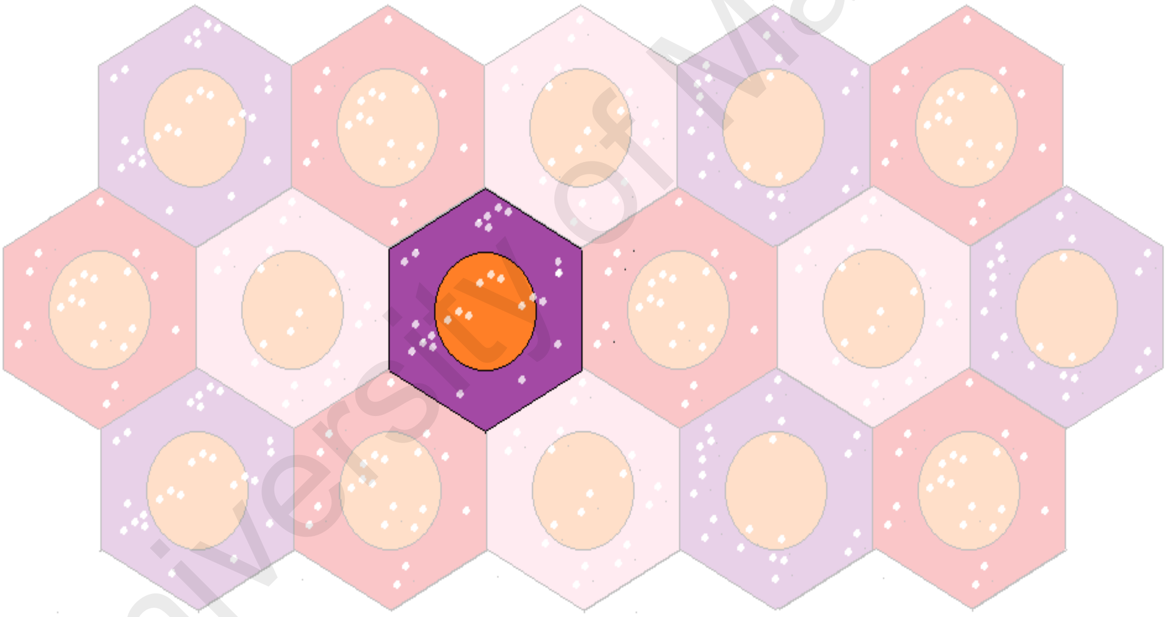

Figure 3.9 the coverage area for the scenario where cell users distributed randomly

3.4 Performance parameters

3.4.1 System Model

The models proposed in the simulator for the cell networks discussed as well as the result performance estimation. Initially, evaluating SINR and throughput are exhibited. Moreover, the calculation of User satisfaction, user capacity and throughput are depicted. The computation of SINR, client satisfaction factor and throughput is going to be done by explain the theory that related to.

a) Calculation of User satisfaction and throughput

Suppose there is a whole network consisting of number (N) of neighboring cells which have number of clients are sharing a set of frequencies. The user could be either in external or internal zone of the cell. The SINR equation that set for x user who is covered by base station b on n of frequencies is given as bellow [1]:

$$SINR = G_{b,x} \, . \, P_{b,n} \, . \, h_{b,x,n} \Big/ \sigma_n^2 \;\; + \sum_{J=1}^{K} G_{J,X} \, . \;\; P_{J,n} \, . \, h_{j,x,n} \qquad [\,1]$$

where:

$G_{b,x}$ Is the path loss related to channel between base station b and user x

$P_{p,n}$ Is the power of base station transmitted on subcarrier n

$h_{b,x,n}$ Is the distributed exponentially channel fast fading power

σ_n^2 Is the Additive white Gaussian Noise (AWGN) channel.

j is the cell index and k is the number of co-channel cells.

In equation (1) we will suppose $h_{b,x,n} = 1$ and the same power transmitted from all BSs equally where $P_{p,n} = P$ and the client interference will be disregard.

The sets detachment of downlinks in the cells zones (either internal or external) occur the interference. The users who considering inside the internal zone of cells and have the same frequency band will experience the interference when the transmission occurs. Otherwise, the denominations of BSs must take in consideration, either interfering BSs transmitting to internal cell users on the same frequency for x user or interfering BSs transmitting to outer cell users on the same frequency for x user.

Throughput is the second approach the will be discuss in the view of calculation theory. The [2] following equation calculated the capacity of user x on number n of subcarrier:

$$C_{n,x} = \Delta f \cdot \log_2(1 + SINR_{x,n}) \qquad [2]$$

Where Δf is signed for the whole bandwidth for every single subcarrier divided by the user's number who are sharing the same subcarrier. Further the user's throughput is given by the following equation:

$$T_x = \sum_n \beta_{x,n} \cdot C_{x,n} \qquad [3]$$

Where the $\beta_{x,n}$ symbol is referred to the subcarrier located for user x .Usually $\beta_{x,n} = 0$ in the case of the subcarrier n is not assigned for user x when $\beta_{x,n} = 1$.

User satisfaction (US) is the third approach that is going to be introduce in the purpose of esteem the performance of the trial .it defines as the comparison between the ratio of the user's throughput and the throughput of the users around him. This comparison is done by the dividing the sum of user's throughput with the product of number of users X and the maximum user’s throughput. Factually this equation shows how close the user’s throughput to the maximum throughput in the service region:

$$US = \sum_{X=1}^{X} T_x \Big/ X.\ userthroughput_{(MAX)}. \qquad [4]$$

Usually US vary between 0 to1. Where US = 1 it means that the same throughput got by users from all corresponding cell, while US = 0 means that there is a big different in throughputs experienced by users in the cell.

A. Fractional Frequency Reuse

The neighboring cells use different frequencies in order to ensure the interference between BSs and clients will be kept under detrimental level. Indeed, each cluster of adjacent cells use a different group of frequencies. These technique of cluster patterns and alike frequencies are reused in uniform model over the whole target area. According to this technique there will be two cells in different cluster use the same frequency hence the distance between the centers of those cells is called frequency reuse distance which is dependent on the size of cluster and the nature of the cell cluster.

Exploit the whole bandwidth in all the system which is known as the spectral efficiency is the one of the basic targets of LTE. This tactic is known as Frequency Reuse 1 where all sub-bands of the whole bandwidth are assigned to each cell and considering as a simplest scheme. However, in Frequency Reuse 3 the whole bandwidth is split into three equal sub-bands each one of these bands is assigned to cells with taking into account no other neighboring cell use the same sub-ban. Advanced frequency planning through different cell becomes superfluous in the presence of full frequency reuse, furthermore this pattern can be effectively going with the basis of frame by frame in each cell. Those approaches we will study and analyze sub-cases of them.

Initially we assume an LTE network with multi-cells. Enhancing the signal to noise ratio, throughput and altogether decrease CCI is the main goal from applying FFR to the network. Figure 3.10 shows the network structure and frequency distribution. The BS will be at the central cell (blue color) then the interference will be from other six neighbors.

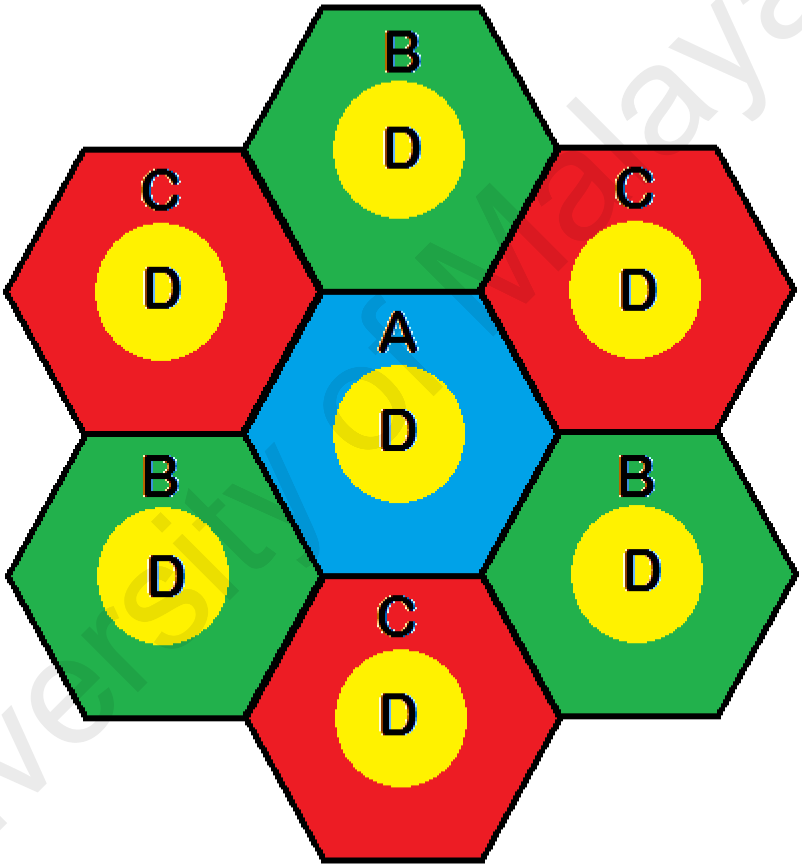

Figure 3.10 suggested frequency band allocation

Our supposed network have a specific area split into 7 cells Figure 3.10 .each cell is divided into two zones internal and external .The whole system's bandwidth is divided into four sets assigned by A (blue).B (green),C (red) and D (yellow) .the sub-bands A , B, C equal bandwidth and allocated in external zone with FR3 technique .Otherwise, sub-band D is assigned in all internal zones with FR1 technique .The tactic of using the same frequency sets in all internal zones are internationally used ,since the users in the inner region are less experience to inter-cell interference . We will use specific FFR scheme in the simulation to preclude this kind of interference effectively.

3.4.2 Frequency Allocation (FA)

The mechanism supposed that there are number of multicast clients who are distributed uniformly in the structure of multi cells.

Moreover, there are 26 frequency allocation (FA) distributed in the cells which divided into two zones internal and external then the total throughput and US will be calculated.

FA will be based on frequency reuse 1 and 3 for both cell zones:

- FA1: all (25) subcarriers are allocated into inner region while no subcarriers are in external one.
- FA2: (24) subcarrier placed in internal zone wile 1/3 subcarrier assigned for external one.
- …
- FA25: one subcarrier assigned for internal zone wile 24/3 subcarrier is for external one.
- FA26: NO subcarriers assigned for internal zone while 25/3 subcarrier is for external one.

After this calculation, the best FFR will be selected based on the maximum throughput and US which is calculated for each user in the internal zone. This process of calculation is repeated from time to time with taking in consideration the mobility of the client in the service area and the optimal FFR that maximize throughput and US will be selected, this periodic process is known as adaptation.

3.4.3 Simulation parameters

The model is traffic model in which UE tries to send and receive the data through the air interference. In other word, this model introduces a theoretical of system load. Table I shows the important simulation parameters that is needs for the trail. The supposed system with bandwidth of 10 MHz which is split into 25 subcarriers everyone has 375 KHz bandwidth. The target area is assumed to be dense urban divided into macro-cells. The calculation of path loss according to Costa-Hata Model (Aragon-Zavala, 2008) and the linkage distance of the shadowing is 40m (Lei, Zhang, Zhang, & Yang, 2007).

Table 1 Simulation Parameters

Parameter	Unit	Value
Power noise density	dbm/Hz	-174
BS transmit power	dBm	46
Path loss	dBm	Cost 231 Hata Model
Users' speed	Kmph	3
Channel model		3GPP Typical Urban
Correlation distance	m	40
Cell radius	m	250
System bandwidth	MHz	10
Subcarriers		25
Subcarrier bandwidth	KHz	375
Carrier frequency	MHz	2000

CHAPTER 4: ANALYSIS OF FREQUENCY REUSE SCHEMES

4.1 Introduction

In the chapter 2, a review on frequency allocations and interference classification at mobile network and scenarios and examined has been introduced.

The analysis presented in previous section is used as core component of the simulation that later receives as input of the cell environment's properties. As example, the location of the user as well as other parameters.

As mentioned previously, the simulation scenario is divided in two parts. The first one shows the examined topology. This topology division shows the structure of the network cells and user location.

On the other hand, the second one illustrate the theoretical approach in order to measure the SINR, User Satisfaction and throughput. The next section will discuss the experiment results. The next section will discuss the experiment results.

4.2 Optimal FFR Scheme Based on Cell Total Throughput

The cell total throughput versus time is shown in figure 4.1. The Figure consists of two curves for comparison purposes. The first one displays throughput when the user mobility is constant which means that frequency allocation and cell radius values will not change. In other word this curve without applying an adaptation process. In contrast, the curve shows the throughput when an adaptation process takes place.

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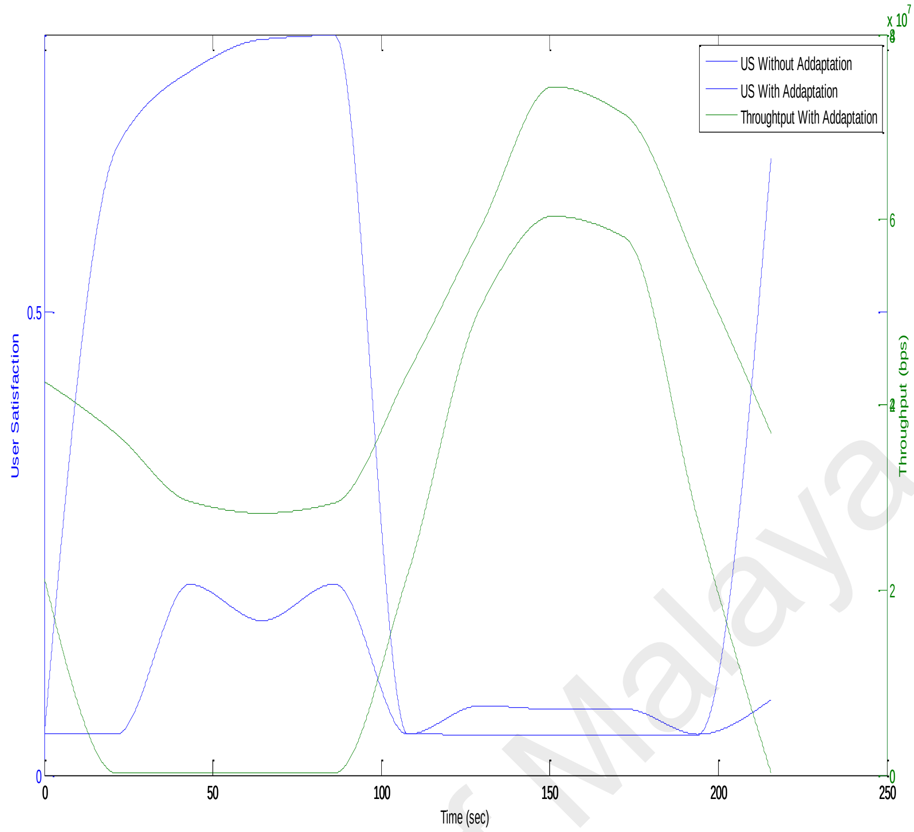

Figure 4.1 Cell total throughput and user satisfaction based on throughput maximization

As it shown in the Figure 4.1 the both curves synchronize in the first few seconds from the experiment. This can be explained by the user cover a small distance thus FA and the internal cell radius values still optimal in the beginning of trail. After this short period of time till the end of duration (215 sec) the curve for throughput with adaptation have better performance that the one without adaptation.

This happens because the users have move for long distance from their initial place, furthermore, another factors (FA and inner cell area) will be re-calculated periodically as long as the use is moving. The process of adaptation will lead to improve the total throughput as shown.

Moreover, Figure 4.1 present the user satisfaction (US) with adaption and without it. In details, the curves can be divided into four period of time, the first one from 0 till 20 sec and third one from 65 till 110 sec where the curves remains coincide and there is not different that can be noted while the second and fourth period (20-65 sec and 110sec till end of trail) . The US curves without adaptation technique remains better than the one with adaptation. This can be explained by the curve without adaptation leads to better US as the total throughput is almost equal to zero which is result in that all users have the same throughput which is off course unbidden, in contrast, the US curve with adaptation have higher throughput users and low throughput users in the cell.

4.3 Optimal FFR Based on User Satisfaction

The goal of setting US is the ensuring the bandwidth of each user across the cell zones will be distributed fairly. As long as US value is high it means that all cell users will experience the same value of throughput. The mechanism of this trail is similar to the previous one in the view of structure and user distribution, furthermore selecting the best FFR scheme that maximizes the US.

Figure 4.2 shows US curves once with adaptation which means the data (distance based on user location, FA and internal cell radius) will be updated periodically, another case is that US without adaptation. Both cases introduced to show the different and effective of adaptation process. In fact, the value of US with adaptation are always better in performance compared to the case without adaptation.

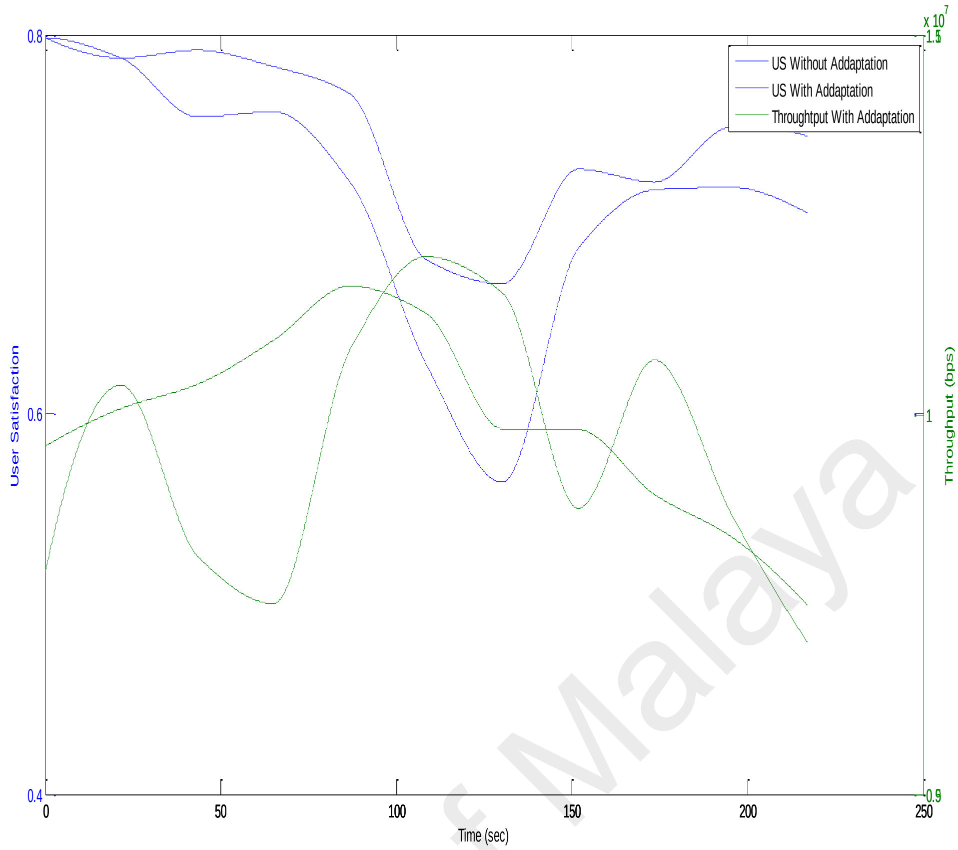

Figure 4.2 Cell total throughput and user satisfaction based on satisfaction maximization

The total throughput curve is also added in the Figure. In any case, the adaptation leads to improve the total throughput.

4.4 Comparison of the two approaches

The maximization of total cell throughput and US are two approaches that the mechanism follows in order to choose the optimal FFR scheme for this part. This happens by direct comparison between both.

The minimum, maximum and average per-user throughput based on US and total throughput approaches is shown in Figure 4.3, while Figure 4.4 shows the allocation of subcarriers and internal cell radius versus time. All these consequences conformable to the scenario of mobility that was introduced previously.

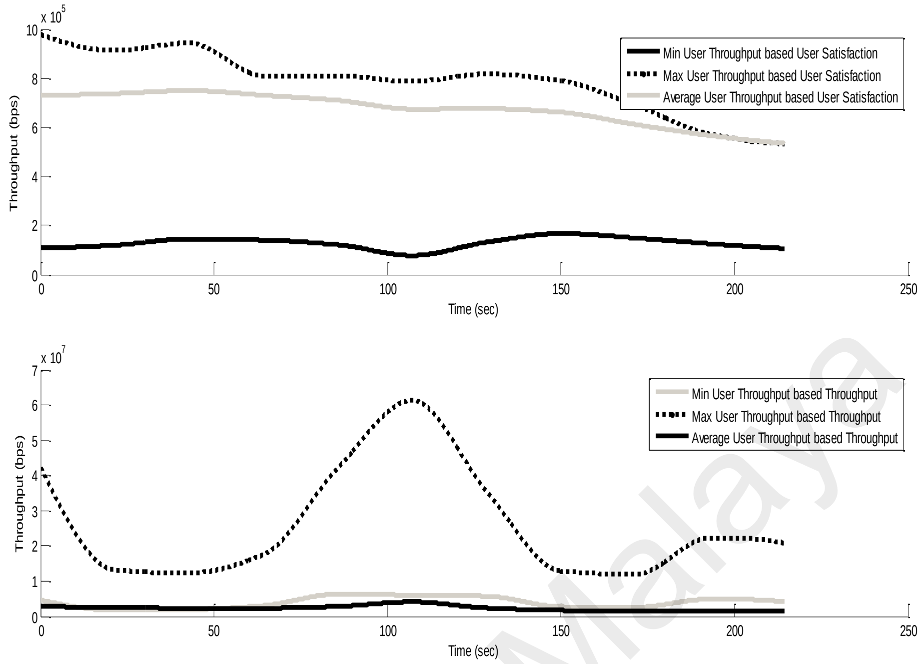

Figure 4.3 Minimum, maximum and average user throughput vs. time for the two approaches when adaptation is applied (up: based on cell total throughput, down: based on user satisfaction).

Based on Figure 4.3 the average throughput of user based on the concept of maximizes the total throughput of the cell is almost equal to the minimum throughput of user which equal to zero in all trail duration. Consequently, most of users got very low or zero throughput while the remains have high values of throughput.

In most cases, the second approach sets the whole system bandwidth in the internal cell zone (all 25 subcarriers are assigned in internal zone) thus only the users in this zone will be served (see Figure 4.3). According to the previous the users at external cell zone will experience zero throughput. As a result, unfairness distributed of the bandwidth between internal and external zones will introduce although this approach leads to higher total cell throughput.

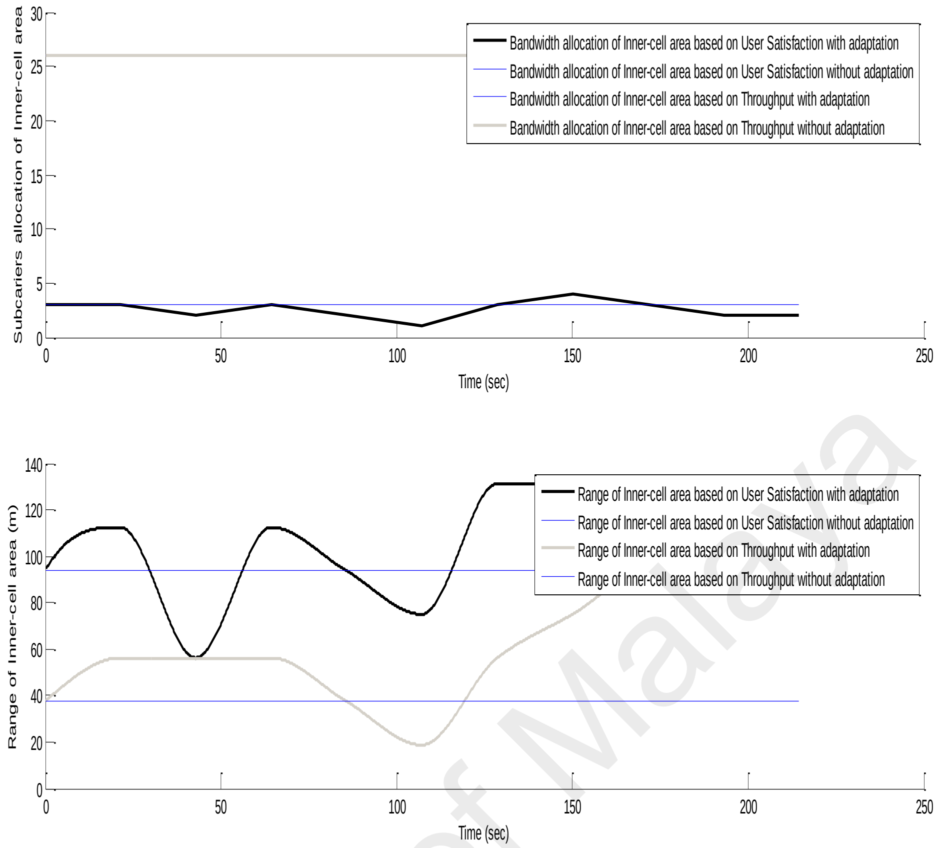

Figure 4.4 Subcarriers' allocation and inner cell radius vs. time for the two approaches when adaptation is applied.

As Figure 4.4 describes, the maximum US will secure that the average amount of user's throughput will be close to the maximum value achieved. Hence most of the users will experience throughput similar to maximum one. Briefly, this approach could lower the total throughput of cells but it provide the fairness of distributing the system bandwidth between cell zones in contrast of the second approach.

CHAPTER 5: CONCLUSIONS

In this work, we analyses the FFR scheme technique as a management mechanism of interference. The SINR, capacity and throughput for each user is measured by FFR mechanism. Thus, the optimal FFR scheme that either maximize the user satisfaction (US) or the overall throughput of the network will be selected based on the calculation of the above parameter. As user location is changing each time which is known as user mobility the adaptation process is used by the mechanism in order to take this parameter into account. The adaptation process is applied periodically. The per user throughput, the entire throughput of the cell and US are re-calculated during the adaptation process for time to time periodically, where the optimal FFR scheme that maximize the previous parameter at each period will selected. Simulation results show improvement in the performance in terms of increasing the total cell throughput and user satisfaction when the adaptation process is applied.

The future research idea of this work could be an expansion of the technique in the purpose to enhance and ease the scanning process. As user mobility, the user location will change then the new user location is expected to be close to the first one. Consequently, will be small change in optimal frequency scheme and optimal cell radius in the inner cell region. Indeed, the expansion technique proposed is tend to minimize the scanning procedure and its complexity in order to consider the prospective frequency allocation and prospective internal cell radius.

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