TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

THESIS NO.: 072/MSI/605

Interference Mitigation and Traffic Offloading in OFDMA Cellular Network Using Adaptive Sectored Fractional Frequency Reuse

by

Ganesh Kumal

A THESIS REPORT

SUBMITTED TO THE DEPARTMENT OF ELECTRONICS AND COMPUTER ENGINEERING IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN INFORMATION AND COMMUNICATION ENGINEERING

DEPARTMENT OF ELECTRONICS AND COMPUTER ENGINEERING

NOVEMBER, 2017

INTERFERENCE MITIGATION AND TRAFFIC OFFLOADING IN OFDMA CELLULAR NETWORK USING ADAPTIVE SECTORED FRACTIONAL FREQUENCY REUSE

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072/MSI/605

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A thesis report submitted in partial fulfillment of the requirements for the degree of Master of Science in Information and Communication Engineering

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November, 2017

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RECOMMENDATION

The undersigned certify that they have read and recommended to the Department of Electronics and Computer Engineering for acceptance, a thesis entitled **“Interference Mitigation and Traffic Offloading in OFDMA Cellular Network Using Adaptive Sectored Fractional Frequency Reuse”**, submitted by **Mr. Ganesh Kumal** in partial fulfillment of the requirement for the award of the degree of **“Master of Science in Information and Communication Engineering”.**

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DEPARTMENTAL ACCEPTANCE

The thesis entitled **“Interference Mitigation and Traffic Offloading in OFDMA Network using Adaptive Sectored Fractional Frequency Reuse”**, submitted by **Ganesh Kumal** in partial fulfillment of the requirement for the award of the degree of **“Master of Science in Information and Communication Engineering “** has been accepted as a bonafide record of work independently carried out by him in the department.

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ACKNOWLEDGEMENT

I would like to express my sincere gratitude to the **Department of Electronics and Computer Engineering**, Institute of Engineering for accepting my thesis on **“Interference Mitigation and Traffic Offloading in OFDMA Cellular Network Using Adaptive Sectored Fractional Frequency Reuse”**. I would like to extend my sincere thanks for providing me with all the essential co-operation, valuable suggestions for choosing the thesis topic.

I am grateful to my supervisor **Prof. Dr. Dinesh Kumar Sharma** for providing useful information, guidance, encouragement and support regarding this thesis work.

I am indebted and express my sincere gratitude to, Head of Department, **Dr. Dibakar Raj Pant** and Program coordinator of Master of Science in Information and Communication Engineering, Pulchowk Campus, **Dr. Basanta Joshi**, for their kind cooperation and guidance.

I would like to express my gratitude to Prof. Dr. Subarna Shakya, Prof. Dr. Shashidhar Ram Joshi, Dr. Surendra Shrestha, Dr. Nanda Bikram Adhikari, Dr. Sanjeev Prasad Panday, Er. Daya Sagar Baral and Er. Dinesh Baniya, Department of Electronics and Computer Engineering, Pulchowk Campus for their encouragement and valuable suggestions.

Last but not the least I would like to express my heartfelt thanks to respected teachers, Er. Chinmay Anand, my families and friends who have helped and supported me directly and indirectly during this thesis work.

ABSTRACT

Orthogonal Frequency Division Multiple Access (OFDMA) is the multi-user version of Orthogonal Frequency Division Multiplexing (OFDM). In multi-cell OFDMA system, if same sub-carriers are assigned to different users in neighboring cells, then inter-cell interference (ICI) occurs. ICI is more prominent for the users at cell boundaries due to which the cell edge users experience lower data rates compared to the users close to the base stations. To achieve Inter-cell Interference Coordination (ICIC), variants of static Fractional Frequency Reuse (FFR) schemes have been implemented. However, these schemes do not give the satisfactory performance in real networks; user distribution is non-uniform as it varies with seasons and the occurrence of major events. This is an important challenge for the mitigation of ICI. In this thesis work, adaptive FFR model is proposed as interference mitigation in order to enhance overall per user quality of service (QoS). Performance of adaptive FFR model is analyzed on the basis of drop probability, throughput, outage probability and coverage. From comparative analysis of static and adaptive frequency reuse method (strict-FFR, FFR-3, FFR-6), it is found that adaptive FFR reuse methods have better performance in terms of drop probability, coverage, outage probability and throughput.

Keywords: Orthogonal Frequency Division Multiple Access (OFDMA), Inter-Cell Interference (ICI), Inter-Cell Interference Coordination, Fractional Frequency Reuse (FFR)

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LIST OF ABBREVIATIONS

3GPP	Third Generation Partnership Project
BS	Base Station
CCUs	Cell Centered Users
CDP	Call Drop Probability
CEUs	Cell Edge Users
eNB	Evolved NodeB
FFR	Fractional Frequency Reuse
GSM	Global System for Mobile Communication
HetNet	Heterogenous Network
HSPA	High Speed Packet Access
ICI	Inter Cell Interference
ICIC	Inter Cell Interference Coordination
LTE	Long Term Evolution
MUEs	Macro Users Equipments
NT	Nepal Telecom
OFDMA	Orthogonal Frequency Division Multiple Access
RB	Resource Block
SINR	Signal to Interference plus Noise Ratio
UEs	User Equipment

CHAPTER 1
INTRODUCTION

1.1 Background and Motivation

Over the past few years, the mobile communications industry has experienced unprecedented explosions in data demand by advent of newer, smarter devices and systems, requiring ubiquitous coverage and seamless quality of experience. Traditional capacity enhancing methods in macro-centric deployments such as increasing spectrum, cell splitting, improved modulation and other physical layer improvements are not sufficient, and hence a Heterogeneous Network (Hetnet) architecture has been proposed by the Third Generation Partnership Project (3GPP) which consists of diverse network tiers with varying transmit powers, densities and coverage areas – macrocells, femtocells and/or distributed antenna systems [1].The resulting Hetnet thus provides improved spatial reuse for higher network capacity, improved coverage, and better energy efficiency with significantly reduced cost.

One of the key challenges in Orthogonal Frequency Division Multiple Access (OFDMA) based cellular networks is Inter-Cell Interference (ICI). Various interference management schemes have been proposed to mitigate ICI. To achieve Inter-cell Interference Coordination (ICIC) variants of the Fractional Frequency Reuse (FFR) scheme have been proposed in [2] and [3], which reduce the amount of ICI received by cell edge users and give good performance based on their target performance metrics such as Signal to Interference plus Noise Ratio (SINR), spectral efficiency, outage probability and system throughput. However, these schemes do not give due consideration to the fact that in real networks, user distribution is non-uniform as it varies with seasons and the occurrence of major events. This is an important challenge for the mitigation of ICI and has also been identified in [4].

I was focused on the fact in FFR schemes, modeling a fixed region of cell edge and cell centre in all cells irrespective of user positions is not optimum for a multi cellular system. There is thus an opportunity to simultaneously exploit the power, frequency and space (user location) to Sectored Adaptive FFR technique. With accurate knowledge of user position, a more dynamic, adaptive scheme can be developed which adapts to medium and long time users position variations. I thus proposed a solution that directly correlates the geographical position of users to their available resource (bandwidth).

1.2 Problem Statement

The major problem in LTE based cellular system is inter-cell interference that is caused by the frequency band overlapping of adjacent cells which eventually leads to severe performance degradation, particularly for users at cell edge. The inter-cell interference issue was already noticed in traditional cellular systems and has been solved to a certain degree in several ICI management techniques.

3GPP release 8 proposes OFDMA as downlink multiple access technique which utilizes orthogonal frequencies for individual streams and streams. Thus, there is no intra-cell interference but there is large inter-cell interference as adjacent cells have same frequencies to assign to their users. The cell edge users might be affected badly with this inter-cell interference.

3GPP release 8 has proposed three different solutions:

- Inter-cell interference coordination technique.
- Inter-cell interference randomization technique.
- Inter-cell interference cancellation technique.

These techniques are applied to counter inter-cell interference problem. Inter-cell interference (ICI) randomization suppresses the interference in the signal, ICI cancellation cancels only the dominating part of the interfering signal and ICI coordination arrange the frequency allocation in the network to mitigate as much ICI as possible. Thus the most appropriate choice is the inter-cell interference coordination technique [16]

All the static FFR schemes implement fixed resource partitioning and traffic densities is varying with seasons and functions therefore had limits the achievable user throughput

[13]. This thesis will analyze adaptive FFR schemes; a flexible resource partitioning is performed between the cell-center and cell edge users, which can be based on factors such as the amount of interference power experienced by users and the traffic density.

1.3 Objectives

This thesis work was focused on the adaptive Fractional Frequency Reuse planning. For addressing the inter cell interference, three different FFR schemes have been proposed. The main objectives of this thesis are:

i. To improve the throughput of users using adaptive Fractional Frequency Reuse (FFR) scheme over the static FFR model.

ii. To improve the traffic offloading of static FFR model using same frequency dynamically on the basis of performance parameters coverage, outage and drop probability.

1.4 Scope of the Work

This thesis only considers downlink transmission, which is transmission from an eNB (base station) to a UE (terminal). Simulation is carried out in static environment which is considered for simplicity. The specification for the 3GPP heterogeneous network assume support for advanced antenna systems including multiple transmit and receive antennas, but the aim of this thesis is not to find absolute values on performance but it suggests a relative comparison between inter-cell Interference management.

1.5 Brief Overview of the Work

Chapter 2 explains the literature review, which includes the previous work done in ICI mitigation along with their drawbacks.

Chapter 3 explains the technical background and basic idea about the cellular concept, overview of 3GPP-LTE system. It also explains the requirement and basic architecture of

LTE. It also focuses on static and adaptive Fractional Frequency Reuse (FFR) models for mitigation of interference.

Chapter 4 provides detail methodology about simulation modules and implementation. In this chapter there are mathematical expressions and assumptions made for different models. The simulation is made under those mathematical expressions.

Chapter 5 presents all simulation results. Static FFR models and adaptive FFR models used for calculating throughput, coverage, outage and drop probability for interference management discussed. Similarly, comparative analysis of static FFR and adaptive FFR is undertaken.

Chapter 6 presents the result discussion and validation and chapter 7 presents the conclusion and future enhancement of thesis with limitations.

CHAPTER 2
LITERATURE REVIEW

In a multi-cell OFDMA system, Inter-Cell Interference (ICI) occurs if the same sub-carriers are assigned to different users in the neighboring cells. The signal transmission in one cell may interfere with the signal transmission in same sub-carrier frequency in the neighboring cells. ICI is particularly detrimental to cell edge users (CEUs) and causes serious degradation of the users' throughput. In LTE, uses Orthogonal Frequency Division Multiplexing Access (OFDMA) in the downlink (DL) and divides the frequency spectrum into blocks called Physical Resource Block (PRB).The PRB corresponds to the resource assignment granularity in LTE. The scheduler located in the base station selects an appropriate number of PRBs to serve users for a predetermined amount of time. An inter-cell interference then occurs when sufficiently close eNBs allocate the same PRB causing a Signal to Interference plus Noise Ratio (SINR) degradation. The interference between two PRBs become more severe in the edge zone of a cell and it leads to a bad channel transmission quality. In order to mitigate ICI, various resource allocation and management schemes as well as inter cell interference coordination (ICIC) technique have been designed [5].

Fractional Frequency Reuse (FFR) is an attractive interference management technique to Co-Channel Interference (CCI) due to its less complexity and significant coverage improvement for cell users [6]. FFR combines the benefits of both low and high frequency reuse by dividing the users within the cell area into two regions: (i) Cell centered region, where users are close to the base station. (ii) Cell edge region, where the users are more suited to the boarder of the cell. The inception behind FFR is basically the partition and allocation of cell's bandwidth in such a way that the interference for the cell edge users is avoided in the adjacent cells. Whereas, interference received or created by the cell center users is greatly reduced. Moreover, FFR offers higher spectral efficiency as compared to conventional frequency reuse schemes [7].

FFR has been used mostly studied for perfect cellular geometry models such as hexagonal grid model [8], while no practical deployment has this degree of symmetry. In realistic deployment, where the cellular layout is irregular, not only propagation conditions vary significantly from cell to cell but also the azimuths are not aligned and hence, cells receive very different amounts of ICI [9]. As a consequence, cell edges are very different in terms of size and SINR levels [10]. Therefore, the performance of traditional ICIC techniques is poor in realistic cellular deployment, where the cellular layout is irregular [11].

Dense frequency reuse scheme aims at improving system capacity by increasing the number of available RBs in each cell. It is a necessity for mobile network operators seeking to fulfill the huge data demands, due to the proliferation of mobile application and the exponential increase in the number of connected devices. Therefore, Inter-Cell Interference Coordination (ICIC) techniques are required to avoid the negative impact of ICI on system performance without largely sacrificing spectral efficiency. ICIC aims at degradation by applying cell specific preferences for different RB subsets, or by employing reduced power for colliding RB [12].

Indoor coverage and capacity are the major limitations of the current systems. In such perspective, femtocells deployment has attracted considerable interest. Most of the previous work analyzes the performance of FFR for perfect cell geometry models. Applying regular resources of the standard FFR scheme to the realistic cellular networks with high irregularity in the cell geometry and channel conditions lead to sub-optimal performance. The sectored-FFR scheme outperforms the conventional FFR schemes in terms of throughput and capacity [13].A femtocell sensing algorithm minimizes cross tier interference by ensuring femtocells select sub-bands not in use by MUEs in close proximity, particularly at boarder of center and edge region which is usually ignored by many previous works. The sectored schemes showed better performance under different system configurations and varying network parameters, validating the model in both noise limited and interference stricken cases [14].

CHAPTER 3
RELATED THEORY

3.1 Frequency Planning

Cellular radio system performs an intelligent allocation and reuse of the available channels through a coverage region. Each cellular base station is provided with group of radio channels which contain completely different channels than neighboring cell. The base station antennas are designed to provide the desired coverage within the particular cell. By limiting the coverage area to within the boundaries of a cell, the same group of channels can be used to different cells that are separated enough from one another to keep interference levels within tolerable limits. This design process of allocating and selecting the group of channels for all base stations throughout coverage regions are called frequency planning or frequency reuse [15].

The basic concept of cellular frequency reuse is shown in figure 3.1, where cells labeled with the same letter use the same group of channels. These reuse plan are overlaid upon a map to show where different frequency channels are used. The hexagonal cell shape shown in figure 3.1 is conceptual and is a simplistic model of the radio coverage for each base station since it permits easy and manageable analysis of a cellular system [15].

Generally a circle is a natural choice to represent the coverage area of a base station, but adjacent circles cannot be overlaid upon a map without leaving gaps or creating overlapping regions. A cell must be designed to serve the weakest mobiles within the coverage area, which are typically located at the edge of the cell. In the case of polygon, a square, rectangle and a hexagon are three sensible choices as it covers the entire area without overlap the same area. For a given distance between the center of a polygon and its farthest perimeter points, the hexagon has the largest area of them all. Thus, by using the hexagon geometry least number of cells can cover a geographic region, and also it closely approximates a circular radiation pattern for an omni-directional base station antenna and free space propagation.

For frequency reuse concept, let us consider a cellular system having S duplex channels available for use. If each cell is allocated a group of K channels (K< S), and S channels are divided among N cells into unique and disjoint channel groups which each have the same number of channels, then the total number of available radio channels will be:

$$S = KN \quad (3.1)$$

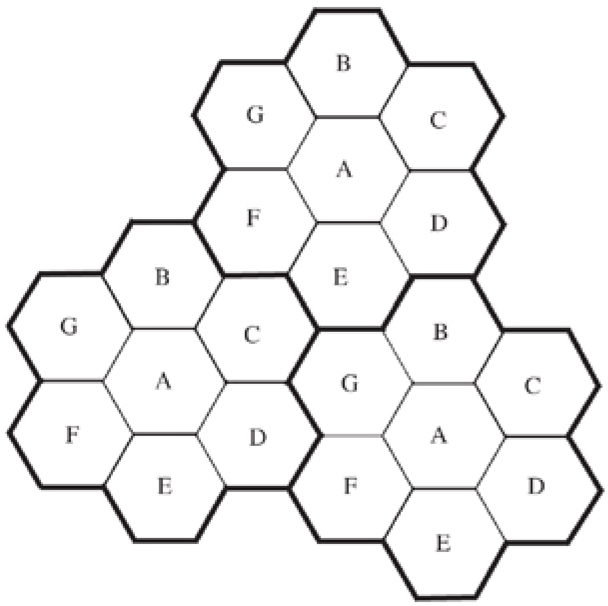


Figure 3.1: Diagram of cellular concept and cellular frequency reuse. Cell with the same letter use the same set of frequency (N=7)[15].

The N cells which uses the complete set of available frequencies is called a cluster. If a cluster is replicated M times within the system, the total number of duplex channels, C, can be used as a measure of capacity and is expressed as [15]:

$$C = MKN = MS \quad (3.2)$$

From equation 3.2, it is seen that the capacity of a cellular system is directly proportional to number of times a cluster is replicated in a fixed service area. The factor N is called cluster size and the value of N is a function for how much interference a mobile or base station can tolerate while performing a sufficient quality of communications. From a design perspective the smallest possible value of N is desirable for maximum capacity in a given coverage area. The frequency reuse factor of a cellular system is given by 1/N, as each cell within a cluster is only assigned 1/N of the total available channels in the system. Since in hexagonal geometry it has six equidistant neighbor and the lines joining the centers of a cell and each of its neighbors are separated by multiples of 60 degrees, there are only certain cluster sizes and cell layouts which are possible.

So in order to connect without gaps between adjacent cells, the geometry of hexagons is such that the number of cells per cluster, N, can only has values which satisfy the equation:

$$N = i^2 + j^2 + ij \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

3.2 Interference

Interference is the major limiting factor in the performance of cellular radio systems. The sources of interference include another mobile in the same cell, a call progress in the neighboring cell, other base stations operating in the same frequency band. Interference causes the cross talk, leads to missed or blocked calls. Interference is more severe in urban areas due to large numbers of base station and mobiles. It has been recognized as a major bottleneck in increasing rate and capacity of cellular network. The two major types of system generated interferences are:

i. Co-channel Interference
ii. Adjacent channel Interference

3.2.1 Co-channel Interference

There are number of cells that use same set of frequencies within entire coverage area. These cells are called co-channel cells and the interference between signals from these cells is called co-channel interference. Co-channel interference cannot be combated by simply increasing the carrier power of a transmitter because an increase in carrier transmits power increase the interference to neighboring co-channel cells. To reduce co-channel interference, co-channel cells must be physically separated by a minimum distance to provide sufficient isolation due to propagation.

When the size of each cell is approximately the same and the base station transmits the same power, the co-channel interference ratio becomes independent of the power transmitted and becomes a function of radius of the cell (R) and the distance between centers of the nearest co-channel cells (D). The parameter Q, called the co-channel reuse ratio, is related to the cluster size. For a hexagonal geometry:

$$Q = \frac{D}{R} = \sqrt{3N} \qquad (3.4)$$

A small value of Q provides larger capacity since the cluster size N is small, where as large value of Q improves the transmission quality, due to a smaller level of co-channel interference. A trade-off must be made between these two objectives in actual cellular design. Then, the signal-to-interference ratio {S/I or SIR} for a mobile receiver which monitors a forward channel can be expressed as:

$$\frac{S}{I} = \frac{S}{\sum_{1}^{i_o} I_i} \qquad (3.5)$$

Where, S = Desired signal power from the desired base station.

I = Interference power caused by the interfering co-channel cell base station.

The average received power, P_r, as a distance d from the transmitting antenna is:

$$P_r = P_o\left(\frac{d}{d_o}\right)^{-n} \qquad (3.6)$$

$$P_r\,(\mathrm{dBm}) = P_o\,(dBm) - 10n\left(\frac{d}{d_o}\right) \qquad (3.7)$$

Where, P_o is the received power at a close-in reference point in the far field region of the antenna at a distance d_o from the transmitting antenna, and n is the path loss exponent. Now considering forward link where the desired is the serving base station and the interference is due to co-channel base stations. If D_i is the distance of the i^{th} interferer from the mobile, the received power at a given mobile due to the ith interfering cell will be proportional to $(D_i)^{-n}$. The path loss exponent typically ranges from 2 to 4 in urban regions.

When the transmit power of base station is equal and path loss exponent is almost same throughout the coverage area. S/I for a mobile can be given as:

$$\frac{S}{I} = \frac{R^{-n}}{\sum_{1}^{i_o} D_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3.8)$$

If we consider only first layer of interfering cell and all the interfering base stations are equidistant from the base station with the distance of D between the cell centers. Then,

$$\frac{S}{I} = \frac{(D/R)^{-n}}{i_0} = \frac{\sqrt{(3N)}}{i_0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3.9)$$

For seven cluster cells as shown in figure 3.2 below, Signal to Interference ratio for worst case scenario is given by,

$$\frac{S}{I} = \frac{R^{-n}}{2(D-R)^{-n} + 2(D+R)^{-n} + 2(D)^{-n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3.10)$$

3.2.2 Adjacent Channel Interference

Interference from signals which are adjacent in frequency to the desired signal is called adjacent channel interference. It results from imperfect receiver filters that allow nearly frequencies to leak into the pass band. The impact is severe if an adjacent channel user is transmitting in every close range to a subscriber’s receiver, while the receiver attempts to receive a base station on the desired channel. This is referred to as the near-far effect, where a nearby transmitter captures the receiver of the subscriber. Also, near far effect may occur when a mobile close to a base station transmits on a channel that is close to one being used by a weak mobile.

Adjacent channel interference can be minimized through proper channel allocations. Since each cell is allocated only a fraction of the available channels, a cell need not be assigned channels which are all adjacent in frequency. By keeping the frequency separation between each channel in a given cell as large as possible; the adjacent channel interference may be reduced considerably. Thus instead of assigning channels which form a contiguous band of frequencies within a particular cell, channels are allocated such that the frequency separation between channels in a given cell is maximized.

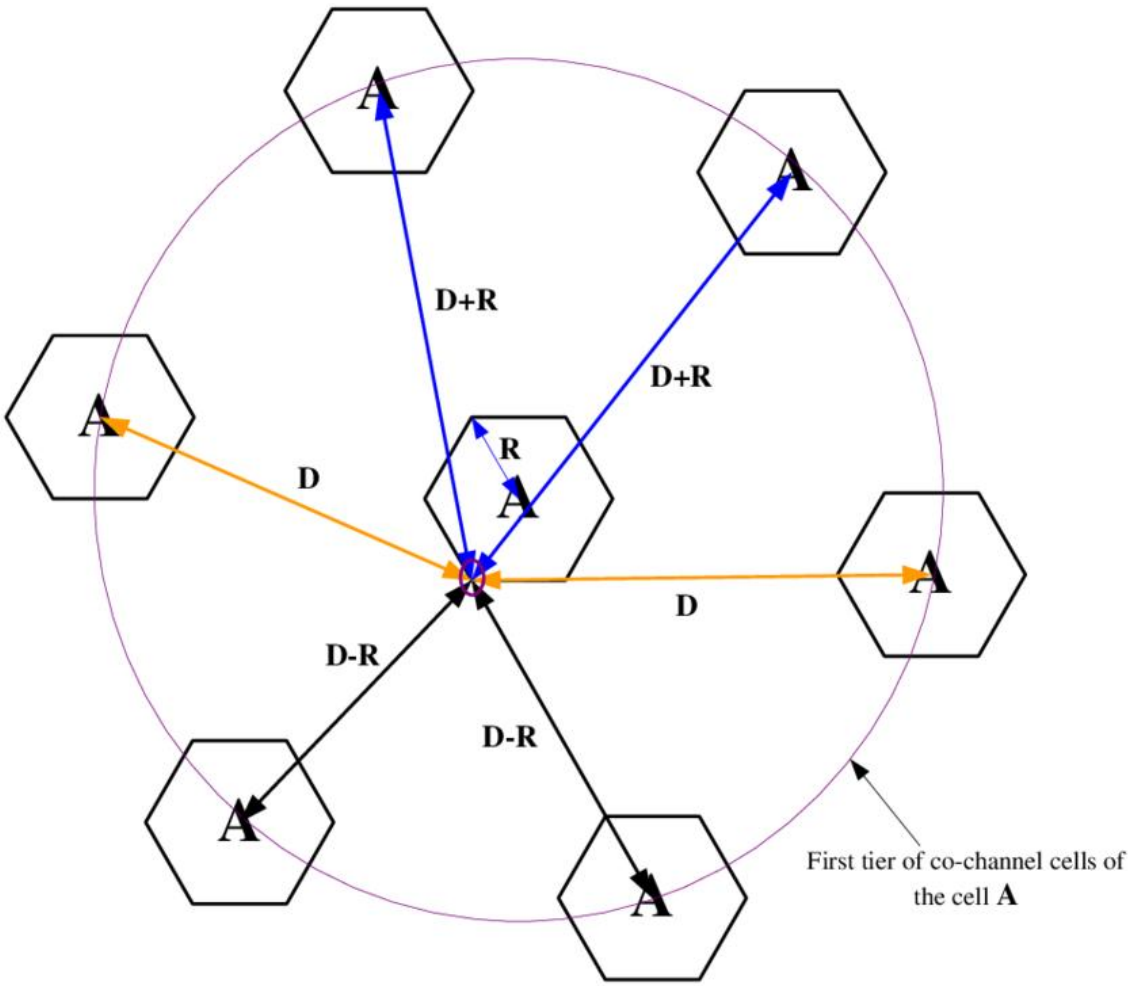


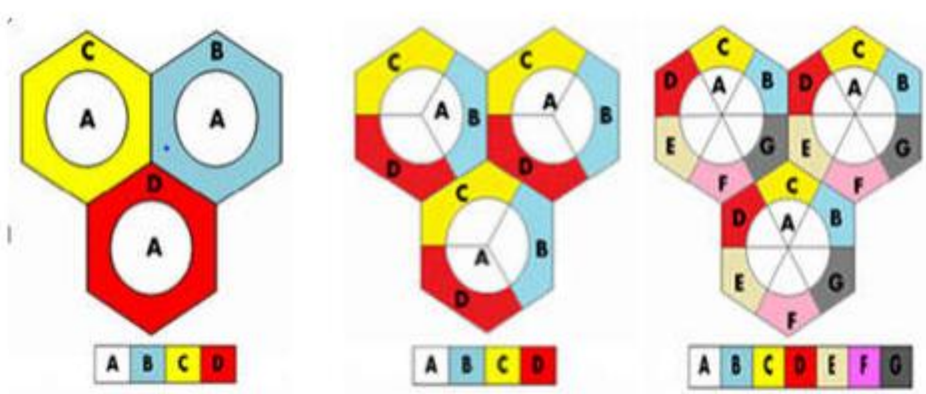
Figure 3.2: First tier of co-channel cells for a cluster size of N=7 [15].

By sequentially assigning successive channels in the frequency band to different cells, many channel allocation techniques are able to separate these adjacent channels in a cell by as many as N channel bandwidths; Where N is the cluster size.

In the case of 3GPP-LTE networks OFDM signals are used to avoid these interferences. In OFDMA scheme signals are orthogonal to each other so the inter-carrier interference is almost negligible. So, in LTE networks co-channel interference also known as Inter cell Interference, as they use aggressive frequency reuse schemes, is major concern in order to avoid the interference in the system.

3.3 Fractional Frequency Reuse (FFR) Scheme

The basic idea of Fractional Frequency Reuse (FFR) is to partition the entire spectrum into multiple sub-bands, such that UEs located close to the base station with good received signal quality utilize full frequency reuse on a certain frequency partition, while those with poor signal quality located at the boundary region of the cell are served with higher reuse factor on other sub-bands to minimize co-channel interference [8]. By so doing, the use of FFR in mobile networks leads to natural tradeoffs between achieving high spectrum utilization with full-frequency reuse system (FR-1) and improved coverage for edge UEs in frequency reuse-n system (e.g. FFR-3, FFR-6). The main FFR deployment models are: Strict FFR, Soft FFR and Sectored FFR (FFR-3, FFR-6 etc.), all of which are shown in Figure 3.3 for a hexagonal deployment.



(a) Strict FFR (b) FFR-3 (c) FFR-6

Figure 3.3: Different FFR variants under Hexagonal mode [13]

3.3.1 Strict FFR

Strict FFR is the base-line FFR where the center region utilizes a common sub-band across all cells with full-frequency reuse (FR-1), while the bandwidth of the edge region is divided across the cells based on a frequency reuse factor, Δ, such that a total of Δ + 1 sub bands are required. In Soft FFR, the edge region employs same bandwidth partitioning as Strict FFR, but the center region can now share edge sub-bands of neighboring cells improving the bandwidth efficiency since all the Δ sub-bands are available in each cell, albeit at the cost of increased interference [9]. Soft FFR therefore employs power control to improve performance of edge UEs. Sectored FFR is an improvement of Strict FFR where directional antennas are employed by the base station to further minimize co-channel interference and also improve spectrum efficiency since all available Δ +1sub-bands are used in each cell. By focusing energy in the desired direction only, received signal quality to intended UEs is significantly increased without the need for complex power control as in Soft FFR.

3.3.2 Fractional Frequency Reuse-3 (FFR-3)

A cell is partitioned into at center cell and edge cell along with three sectors. The frequency band is divided into four sub-bands, namely, A, B, C and D where sub-band A is made larger than others. Sub-band A is allocated to the center zone and remaining three sub-bands are allocated to the edge zone of the three sectors.

3.3.3 Fractional Frequency Reuse (FFR-6)

A cell is partitioned into at center cell and edge cell along with six sectors. The frequency band is divided into seven sub-bands, namely, A, B, C, D, E, F and G where sub-band A is made larger than others. Sub-band A is allocated to the center zone and remaining six sub-bands are allocated to the edge zone of the six sectors.

3.4 Dynamic Reuse Scheme

All the static reuse schemes implement fixed resource partitioning and therefore hard limit the achievable user throughput. In dynamic reuse schemes, a flexible resource partitioning is performed between the cell centre and cell edge users, which can be based on factors such as the amount of interference power experienced by users and the traffic density. Such schemes have the potential of achieving efficient resource utilization and improved system throughput.

Authors in [18] have proposed one variant of FFR specifically tailored for relay assisted cellular network, which performs an intelligent allocation of resources such that no two neighboring edge regions are allocated the same channels. Such a scheme based on interfering neighbor set gives improved edge user's throughput and area spectral efficiency compared to all other variants of reuse schemes. However, in the case of non-uniform traffic density, the resource allocation policy does not perform very well. Thus, we observe that no particular reuse policy works for all possible scenarios. If a policy is optimal for a given scenario and improves one performance metric, then it compromises on other metrics.

3.5 ICI Measurement Parameters

3.5.1 Throughput

Throughput is the rate of successful message delivery over a communication channel. The data, these messages belongs to may be delivered over a physical or logical link or it can pass through a certain network node. Throughput is usually measured in bits per second.

3.5.2 Probability of Outage and Coverage

I also consider outage probability as one of the performance metrics in our analysis. I consider a user to be outage if it experiences SINR below a predefined threshold.

$$\text{Prob(outage)} = \text{Prob}\ (\ \text{UE}_\text{i}(\ \text{SINR}) < \ \text{SINR}_{\text{threshold}}) \dots \dots \dots \dots \dots \dots \dots (\ 3.11)$$

As the cell edge users are more prone to ICI, they are likely to experience low SINR and hence remain in outage. The outage probability comparison for cell edge users is therefore significant when comparing different reuse schemes. Outage probability is expected to be higher in systems using static FFR scheme compared to system employing adaptive FFR.

The coverage probability is the success call rate among the call attempt with in a particular cell.

$$\text{Prob(coversge)} = 1 - \text{Prob(outage)} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (3.12)$$

3.5.3 Call Drop Probability

A handoff could fail due to insufficient bandwidth in the new cell, and in such case, the connection is dropped. The Call Dropping Probability (CDP) is a very important connection-level QoS parameter. It represents the probability that a call is dropped due to a handoff failure. The goal of almost all admission control schemes is to limit the CDP to some target value while maintaining higher bandwidth utilization or lower blocking rates for new calls in the system.

$$\text{Call Drop Prob. (CDP)} = \frac{\text{Number of Call drop due to handoff failure}}{\text{Total no.of calls attempt hanoff}} \dots \dots \dots \dots (\ 3.13)$$

CHAPTER 4
METHODOLOGY

4.1 Flowchart of Proposed Model

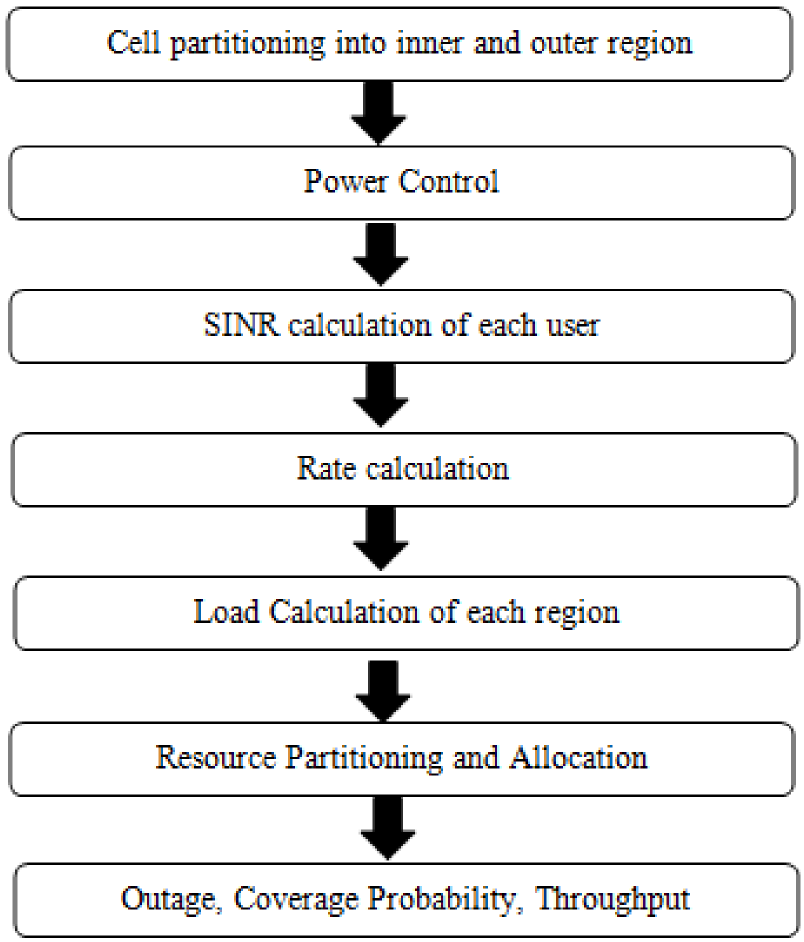


Figure 4.1: Flowchart of proposed FFR Model

4.2 Cell Partition

The cells are divided into two regions: outer region and inner region on the basis of radius of a cell. In this thesis uter radius of a cell is 500 m and inner radius is half of the outer region radius.

4.3 Power control

Let P_{inner} be the transmit power inside the inner cell whereas P_{outer} be the transmit power for the outer cell. Hence the total transmit power in the cell is then given by,

$$P_{total} = P_{inner} + P_{outer} \dots\dots\dots\dots\dots\dots (4.1)$$

4.4 Cell Load Calculation

Resource Partitioning is done depending on the traffic load on each cell. The traffic load on center and edge cell determines the allocation of frequency band on each sector. The high traffic on any of the cell is provided with more spectrum than compared to that of low traffic on other cell.

To derive the performance model, we consider the SINR

$$SINR_i = \frac{P_i g_{ij}}{\sum_{k=1}^{N} P_k g_{kj} \rho_k + \sigma^2} \dots\dots\dots\dots\dots\dots (4.2)$$

Where P_i is the transmit power of the serving cell, g_{ij} represents the channel gain between user antenna and the base station antenna, σ^2 is the noise power. By (4.2), the inter-cell interference grows by the load factor. In effect, ρ_k can be interpreted as the probability of receiving interference originating from cell k on all the sub-carriers of the resource unit. The bit rate per resource unit is given by:

$$R_b = BWlog_2 (1 + SINR_i) \dots\dots\dots.\dots\dots\dots\dots\dots (4.3)$$

Thus to serve demand d_j in cell j, $\frac{d_j}{R_b}$ resource units are required. Let K denote the total number of resource units in the frequency-time domain, and TL_i is the proportion of resource consumption of cell i. By these definitions, we obtain the following equation,

$$TL_i = \frac{d_j}{KR_b} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4.4)$$

Let M be the number of regions in a FFR scheme. Let K be the total number of resource blocks and the total load (TL) of an entire cell is then given by:

$$TL = \sum_{i \in M} TL_i \quad , \quad i = 1,2,3 \dots\dots\dots\dots M, \quad \dots\dots\dots\dots\dots (4.5)$$

Where TL_i denotes the serve demand or load on each FFR region.

We calculate the ratio of partitioning for each region :

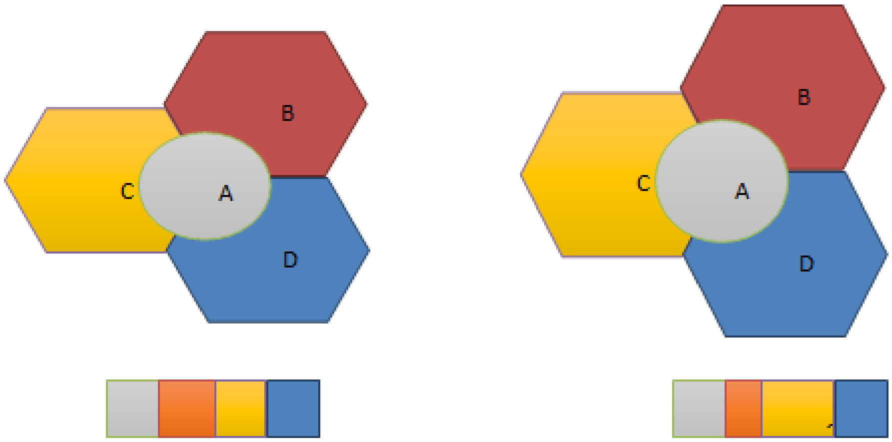
$$\alpha_i = \frac{TL_i}{TL}, \quad i = 1,2,3 \dots\dots M, \qquad \dots\dots\dots\dots\dots\dots\dots (4.6)$$

The total resource allocated in center and edge region is now given by:

$$b_i = a_i K \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4.7)$$

4.5 Frequency Allocation

In our model we divide the cell into two regions: outer region and inner region. Inner region do not suffer from interference whereas the edge cell users are more subjected to inter-cell interference. The key concept of all the FFR schemes is to divide the entire spectrum band equally into all the regions. In figure 4.1 (a) shows a FFR-3 scheme which divides the frequency band equally into four parts



(a) Static FFR-3 (b) Adaptive FFR-3

Figure 4.2: Static and adaptive FFR-3 model

We calculate the ratio of partitioning for each region by:

$$\alpha_A = \frac{TL_A}{TL}, \quad \alpha_B = \frac{TL_B}{TL}, \quad \alpha_C = \frac{TL_C}{TL}, \quad TL_D = \frac{TL_D}{TL} \ldots\ldots\ldots\ldots\ldots (4.9)$$

Let BW be the total bandwidth. The bandwidth allocated in center and edge region is now given by:

$$A = \alpha_A BW, \;\; B = \alpha_B BW, C = \alpha_C BW, D = \alpha_D BW \ldots\ldots (4.10)$$

CHAPTER 5
SIMULATION AND RESULT

Simulation was carried out by coding on MATLAB R2012a. Coding was done considering various simulation parameters for inter-cell interference management. While analysis, different static and adaptive frequency allocation schemes (strict- FFR, FFR-3 and FFR-6) were investigated using graphs obtained from the simulation.

For simulation six modules are considered. First three modules are statically manage the frequency resource in cell center and edge cell users and remaining three modules manage the frequency dynamically with the user traffic density. Simulation result of my thesis had given the comparison plot of performance parameters; coverage, capacity, outage probability with varying signal to interference plus noise ratio (SINR) and throughput with varying user traffic density

.

5.1 Simulation Parameters

Table5.1: Main simulation parameters

Parameters	Value
Total Bandwidth	25 MHz
Edge Cell Transmit Power	43dBm
Cell centered Transmit Power	43/2 dBm
SINR Threshold	[-10, -5, 0, ………………………35, 40] dB
Cell Radius	500m
Cell Edge Users	>250
Cell Center Users	<250
UEs Power	2 dBm
Noise Power	-125 dBm

5.2 Comparative analysis of throughput with the function of SINR

Maximum number of users is taken up to 600 per cell. Both static and adaptive FFR schemes were analyzed with the different users per cell. In each individual FFR scheme as the number of users was increasing, correspondingly throughput was decreasing. My proposed scheme (adaptive FFR) was better than other corresponding static FFR scheme.

Table5.2: Calculation of improvement percentage of throughput of adaptive FFR over static FFR.

Number of users	Throughput(kbps)						% improvement of Throughput over static FFR with Adaptive FFR		
	Static			Adaptive					
	Strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6
20	795.71	852.25	880.69	830.16	880.6	923.5	4.305	3.343	4.791
60	787.82	841.46	868.55	820.47	868.5	909.4	3.979	3.118	4.498
100	772.65	836.94	864.14	817.86	866.2	907.3	5.528	3.381	4.763
140	746.98	829.49	856.18	821.06	869.0	909.8	9.022	4.546	5.893
180	695.92	816.05	842.70	817.72	866.0	907.1	14.89	5.775	7.108
220	634.03	785.91	812.00	815.88	864.4	905.7	22.28	9.084	10.34
260	567.79	766.09	791.73	815.20	863.8	905.2	30.34	11.31	12.53
300	498.84	736.12	763.05	810.41	858.9	899.9	38.44	14.30	15.20
340	441.40	709.43	738.44	791.72	839.2	878.9	44.24	15.46	15.98
380	396.86	676.83	714.16	762.11	807.3	844.9	47.92	16.16	15.48
420	358.41	656.77	706.18	719.80	762.7	798.5	50.20	13.89	11.56
460	322.74	624.15	686.86	666.15	705.2	737.5	51.55	11.49	6.897
500	297.90	600.39	684.23	610.31	646.5	677.8	51.18	7.144	-0.94
540	275.31	558.83	656.87	567.98	600.3	629.6	51.52	6.914	-4.33
580	255.29	513.15	644.07	527.21	557.0	585.0	51.57	7.881	-10.08

Table5.2 shows the comparison of throughput for different static FFR scheme relative to adaptive FFR. Where adaptive strict-FFR has maximum improvement in throughput by 51 percent and overall improvement is good over static FFR. Similarly, in adaptive FFR-3 and FFR-6 overall improvement is good and maximum improvement in throughput is around 15 percent relative to static FFR-3 and FFR-6.

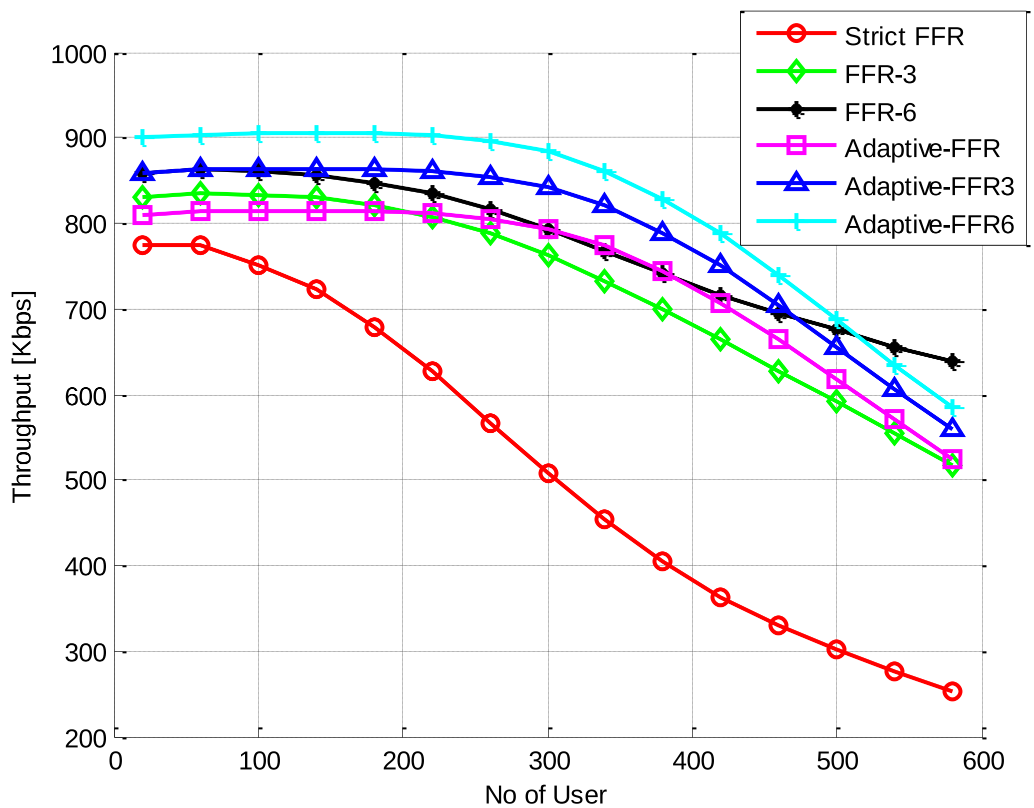


Figure 5.1: Throughput vs. number of users for different FFR

5.3 Comparative analysis of Probability of outage with Threshold SINR.

Table5.3: Calculation of improvement percentage of outage probability of adaptive FFR over static FFR.

SINR(dB)	Probability of outage						% improvement of Probability Of outage over static FFR with Adaptive FFR		
	Static			Adaptive					
	Strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6
-10	0	0	0	0	0	0	0	0	0
-5	0	0	0	0	0	0	0	0	0
0	0.017	0	0	0.0043	0	0	75.2	0	0
5	0.135	0.0805	0.0333	0.0997	0.0267	0.001	26.38	66.893	96.79
10	0.297	0.2504	0.194	0.2651	0.1669	0.073	11.00	33.336	62.34
15	0.475	0.4351	0.3772	0.4491	0.3429	0.231	5.513	21.177	38.63
20	0.667	0.6279	0.5687	0.6427	0.5323	0.412	3.755	15.236	27.51
25	0.850	0.8274	0.7653	0.8368	0.7275	0.604	1.615	12.077	21.03
30	0.932	0.9468	0.932	0.9408	0.8997	0.801	-0.91	4.9761	13.99
35	0.987	0.9872	0.9801	0.9858	0.9724	0.952	0.169	1.4961	2.871
40	1	1	1	0.9973	0.9947	0.992	0.266	0.5333	0.8

Table5.3. shows the comparison of probability of outage for different static FFR schemes relative to adaptive FFR schemes. With increasing the SINR values the outage probability is increased in each FFR model. But the outage probability of adaptive FFR scheme over each corresponding static FFR scheme is lesser, which is better and clearly seen in figure 5.2. The maximum improvement of outage probability of adaptive FFR scheme over corresponding static FFR (strict FFR, FFR-3 and FFR-6) scheme is 75.2, 66.89 and 96.79 percent.

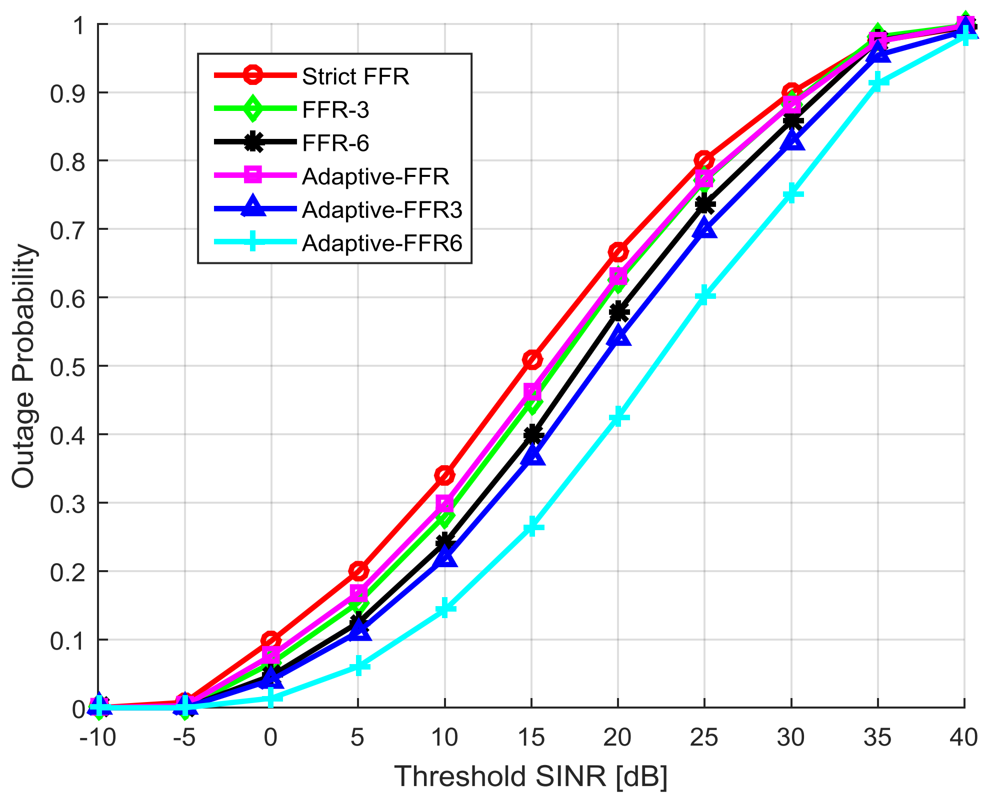


Figure 5.2: Outage probability vs. SINR for different FFR.

5.4 Comparative analysis of Probability of Coverage with Threshold SINR.

Table5.4: Calculation of improvement percentage of probability of coverage of adaptive FFR over static FFR.

SINR(dB)	Probability of Coverage						% improvement of Prob. Of Coverage over static FFR with Adaptive FFR		
	Static			Adaptive					
	Strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6
-10	1	1	1	1	1	1	0	0	0
-5	1	1	1	1	1	1	0	0	0
0	0.982	1	1	0.995	1	1	1.2993	0	0
5	0.864	0.919	0.966	0.900	0.973	0.9989	3.9711	5.5357	3.2218
10	0.702	0.749	0.806	0.734	0.833	0.9269	4.4606	10.020	13.051
15	0.524	0.564	0.622	0.550	0.657	0.7685	4.756	14.022	18.958
20	0.332	0.372	0.431	0.357	0.467	0.5877	7.0173	20.455	26.622
25	0.149	0.172	0.234	0.163	0.272	0.3957	8.4177	36.667	40.682
30	0.067	0.053	0.068	0.059	0.100	0.1984	-14.42	46.990	65.730
35	0.012	0.012	0.019	0.014	0.027	0.048	11.794	53.601	58.643
40	0	0	0	0.002	0.005	0.008	100	100	100

Table5.4. shows the comparison of probability of Coverage for different static FFR schemes relative to adaptive FFR schemes. With increasing the SINR values probability of coverage is decreasing in each FFR model, which is clearly seen in figure 5.3. The improvement coverage probability of adaptive FFR scheme over each corresponding static FFR scheme is good. The maximum improvement of coverage of adaptive FFR relative to corresponding strict-FFR, FFR-3 and FFR-6 is 11, 53, and 65 percent.

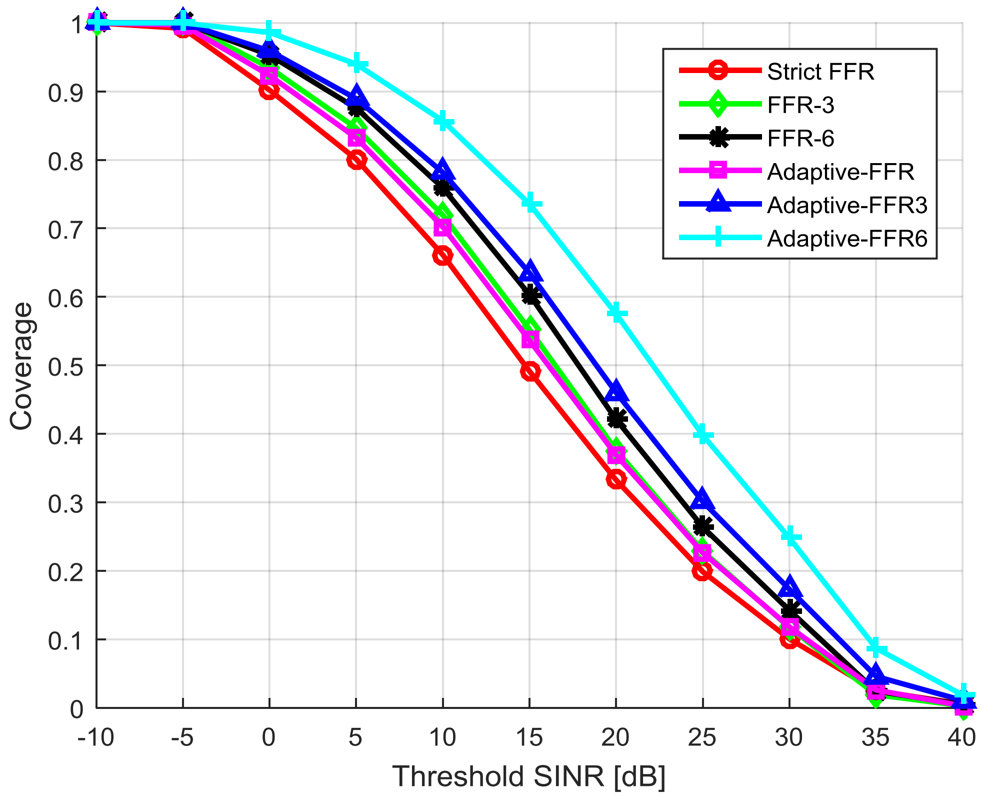


Figure 5.3: Probability of Coverage vs. SINR for different FFR.

5.5 Comparative analysis of drop probability with number of users.

Table 5.5: Calculation of improvement percentage of drop probability of adaptive FFR over static FFR.

Number of Users	Drop Probability						% improvement of Drop probability over static FFR with Adaptive FFR		
	Static			Adaptive					
	Strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6
20	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0
140	0.021	0	0	0	0	0	100	0	0
180	0.061	0.011	0.011	0	0	0	100	100	100
220	0.190	0.059	0.059	0	0	0	100	100	100
260	0.315	0.0576	0.057	0	0	0	100	100	100
300	0.38	0.156	0.156	0		0	100	100	100
340	0.452	0.108	0.108	0	0	0	100	100	100
380	0.510	0.186	0.173	0.036	0.034	0.034	92.78	81.69	80.30
420	0.557	0.207	0.190	0.114	0.111	0.111	79.48	45.97	41.25
460	0.595	0.245	0.189	0.189	0.186	0.184	68.24	23.89	2.298
500	0.628	0.27	0.25	0.25	0.25	0.194	60.19	7.407	22.4
540	0.655	0.314	0.309	0.309	0.305	0.242	52.82	2.941	21.55
580	0.679	0.375	0.355	0.353	0.353	0.239	47.96	5.963	32.52

Table5.5. shows the comparison of drop probability for different static FFR schemes relative to adaptive FFR schemes. With increasing the number of users drop probability is increased in each FFR model. In adaptive FFR model, there is no drop up to 340 users, which is clearly seen in figure 5.4. The improvement of drop probability of adaptive FFR scheme over each corresponding static FFR scheme is good. The maximum improvement of drop probability of adaptive strict-FFR, FFR-3 and FFR-is 92 %, 81 %, and 80 % at 380 users.

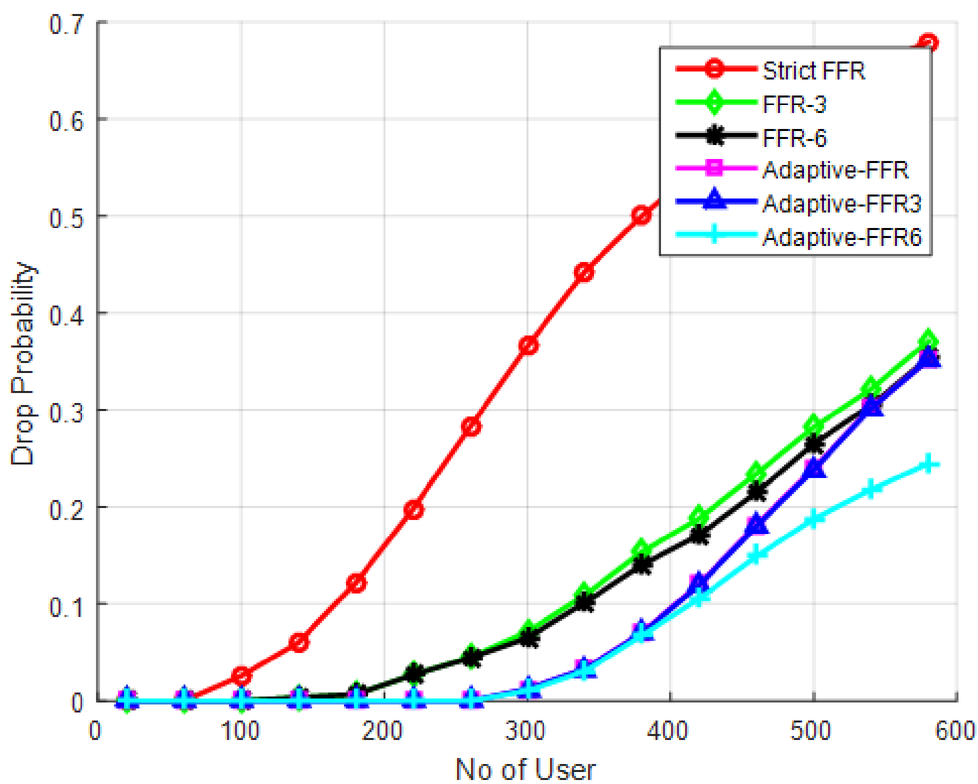


Figure 5.4: Drop Probability vs. number of users for different FFR.

CHAPTER 6

RESULT DISSCUSSION AND VALIDATION

6.1 Result Discussion

From this thesis work, it is found that ICI is more important for cell edge users than cell center users. For mitigation of ICI both static and adaptive FFR schemes are used. Proposed adaptive FFR (strict FFR, FFR-3, FFR-6) schemes have better throughput, probability of coverage, outage and drop probability. The throughput was increased at each adaptive FFR model corresponding to respective static FFR model up to 460 users. Over the 460 users in FFR-6 model, static method is good than adaptive FFR. By using more frequency reuse more users can access the channel but throughput is decreased. So, we need to tradeoff between traffic offloading and throughput in adaptive FFR model. The maximum percentage improvement of throughput is 51 % over static FFR, 16 % and 15 % over FFR-3 and FFR-6.

The outage probability was increased in each FFR model with increasing the threshold SINR. For the same SINR value, the outage probability of each adaptive FFR model was decreased with corresponding static FFR model. This means inter-cell interference is decreased at adaptive FFR model. The maximum improvement of outage probability was 96.79% of adaptive FFR-6 at 5db SINR. But overall adaptive FFR is good relative to static FFR. The coverage is also maximum, 99 %, of adaptive FFR-6 at 5 db SINR. But percentage improvement of coverage was maximum for adaptive FFR-6 at 30 db SINR. The drop probability was increasing with the number of users increasing in each model. But there is no drop in adaptive FFR model up to 340 users. Over 340 users, there was also slightly dropped off call. The maximum improvement of drop probability is around 80 % at 380 users in each adaptive FFR model over static FFR model.

From comparative analysis of adaptive FFR model over static model, overall performance is improved in adaptive FFR. Thus, inter-cell interference is mitigated in adaptive FFR over static FFR model and traffic offloading is also less in my proposed adaptive sectored FFR model.

6.2 Validation

To validate the simulation result of MAT LAB, related data was collected from Nepal Telecom (NT). NT provided the one week's data of three different cells used in LTE network. Throughput of Simulated result of adaptive FFR scheme and Nepal Telecom data are normalized in the range 100 Kbps to 500 Kbps for the validation purpose. From the normalized data, percentage improvement of throughput of adaptive FFR scheme over three different cells is calculated separately which are tabulated in table 6.1, table 6.2 and table 6.3.

Table6.1: Calculation of improvement percentage of throughput of adaptive FFR over Cell-1.

Number of users	Throughput(Kbps)				% improvement of throughput over cell-1 w.r.t. adaptive FFR		
		Adaptive					
	Cell-1	strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6
6	500	500	500	500	0	0	0
10	455.8348	458.8927	464.5297	468.9111	1	2	3
11	416.2129	449.419	456.3729	461.7718	8	10	11
17	363.5626	435.5844	444.4936	451.395	20	22	24
17	305.6173	436.9378	445.5925	452.3186	43	46	48
28	255.4911	432.7273	441.9977	449.1874	69	73	76
32	207.0297	428.8585	437.727	446.3662	107	111	116
34	170.2755	425.7553	433.2222	441.9093	150	154	160
42	149.2884	402.9023	410.5758	417.5199	170	175	180
42	139.9227	360.9433	367.5567	373.7532	158	163	167
42	133.0057	307.5871	312.4973	316.7715	131	135	138
44	125.3907	241.7649	245.661	247.7398	93	96	98
48	111.052	168.4238	171.232	171.6129	52	54	55
50	100	100	100	100	0	0	0

Table 6.1 shows the throughput of cell-1, and different adaptive FFR models. Throughput of cell-1 is the real data of Nepal Telecom network. Throughput of three different adaptive FFR is simulated result from MAT LAB. The maximum improvement of throughput of strict FFR, FFR-3 and FFR-6 are 170 %, 175 % and 180 % respectively over real throughput of cell-1 data.

Table6.2: Calculation of percentage improvement of adaptive FFR over Cell-2.

Number of users	Throughput(Kbps)				% improvement of throughput over cell-2 w.r.t. adaptive FFR		
		Adaptive					
	Cell-2	Strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6
6	500	500	500	500	0	0	0
10	447.8651	458.9064	464.5181	468.9076	2	4	5
11	402.7038	449.337	456.3627	461.7603	12	13	15
17	358.2911	435.5844	444.4821	451.3832	22	24	26
17	319.3253	436.9378	445.5864	452.3172	37	40	42
28	289.3425	432.7273	441.9943	449.1781	50	53	55
32	262.6299	428.8859	437.7237	446.3633	63	67	70
34	243.0781	425.7553	433.2136	441.9012	75	78	82
42	228.4117	402.8982	410.5701	417.5149	76	80	83
42	218.1285	360.9433	367.558	373.7495	65	69	71
42	201.6892	307.5871	312.4925	316.8181	53	55	57
44	185.8311	241.7635	245.6529	247.7324	30	32	33
48	140.7289	168.4211	171.23	171.6034	20	22	22
50	100	100	100	100	0	0	0

Table 6.2 shows the throughput of cell-2, which is real data of NTC network. Throughput of adaptive strict FFR, FFR-3 and FFR-6 is the simulation result obtained from MAT LAB. The throughput improvement percentage of adaptive FFR over real data of cell-2 is also calculated. The maximum improvement of throughput of adaptive strict FFR, FFR-3 and FFR-6 is 76 %, 80 % and 83 % respectively over real throughput of cell-2.

Table 6 3: Calculation of percentage improvement of throughput of adaptive FFR over Cell-3.

Number of users	Throughput(Kbps)				% improvement of throughput over cell-3 w.r.t. adaptive FFR		
		Adaptive					
	Cell-3	strict FFR	FFR-3	FFR-6	Strict FFR	FFR-3	FFR-6
6	500	500	500	500	0	0	0
10	455.8348	458.8927	464.5181	468.9085	1	2	3
11	416.2129	449.419	456.3627	461.7615	8	10	11
17	363.5626	435.5844	444.4555	451.3847	20	22	24
17	305.6173	436.9378	445.5864	452.3186	43	46	48
28	255.4911	432.7273	441.9943	449.1796	69	73	76
32	207.0297	428.8859	437.7237	446.3649	107	111	116
34	170.2755	425.7553	433.1471	441.9028	150	154	160
42	149.2884	402.8982	410.5701	417.5173	170	175	180
42	139.9227	360.9433	367.558	373.7532	158	163	167
42	133.0057	307.5871	312.4925	316.8234	131	135	138
44	125.3907	241.7635	245.6529	247.7398	93	96	98
48	111.052	168.4211	171.23	171.6129	52	54	55
50	100	100	100	100	0	0	0

Table 6.3 shows the throughput of cell-3, which is real data of Nepal Telecom network. Throughput of adaptive strict FFR, FFR-3 and FFR-6 is the simulation result obtained from MAT LAB. The throughput improvement percentage of adaptive FFR over real data of cell-2 is also calculated. The maximum improvement of throughput of adaptive strict FFR, FFR-3 and FFR-6 is 170 %, 175 % and 180 % respectively over real throughput of cell-3.

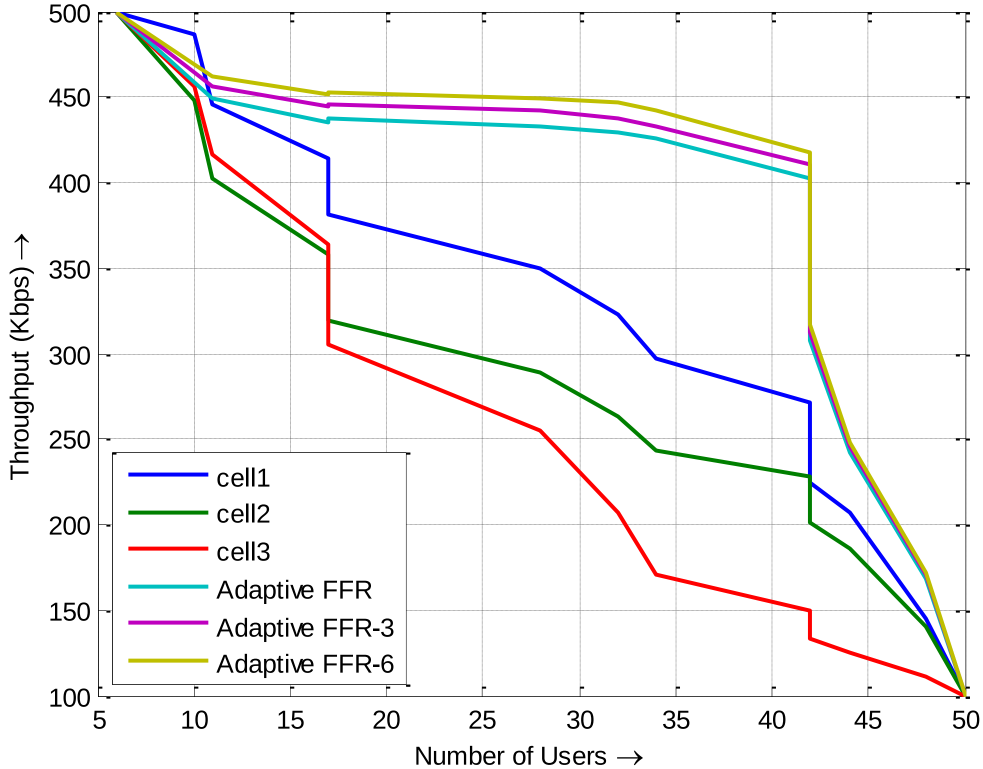


Figure 6.1: Throughput vs. number of users for NT data and FFR model.

Figure 6.1 shows the graph of throughput with number of users varied. Throughput of adaptive FFR scheme is better than the real throughput of Cell-1, Cell-2 and Cell-3 of Nepal Telecom network. The throughput of adaptive FFR-6 model is 180 % improvement over real data of cell-1 and cell-3, and 83 % improvement over cell-2 of Nepal Telecom network.

CHAPTER 7

CONCLUSION AND FUTURE ENHANCEMENT

7.1 Conclusion

From this thesis work, it is found that ICI is more important for cell edge users than cell center users. For mitigation of ICI both static and adaptive FFR schemes are used. Proposed adaptive (strict FFR, FFR-3, FFR-6) scheme has better throughput, probability of coverage and outage. The maximum improvement of throughput in adaptive FFR is by 51 percentages over strict FFR, 16 percentages over FFR-3 and 15 percentages over FFR-6.

The outage probability of adaptive FFR scheme is better over each corresponding static FFR. The maximum improvement of outage probability of adaptive FFR scheme over corresponding static FFR (static FFR, FFR-3 and FFR-6) is 75.2, 66.89 and 96.79 percentages respectively. Similarly, the maximum improvement of coverage of adaptive FFR relative to corresponding static FFR, FFR-3 and FFR-6 is 11, 53 and 65 percentages respectively.

In adaptive FFR model, there is no call drop up to 340 users but in static FFR model we can see the measurable drop probability. Over the 340 users, there is small drop in adaptive FFR model but smaller than corresponding static FFR scheme. The maximum improvement of drop probability in adaptive FFR over corresponding static FFR is 92, 81 and 80 percent over strict FFR, FFR-3 and FFR-6 respectively. So, inter-cell interference is mitigated in cell edge users at adaptive FFR model.

From the analysis, strict FFR is better for throughput maximization and FFR-3 and FFR-6 is better for probability of outage and coverage improvement. So there should be tradeoff between throughput and traffic offloading of network in order to avoid inter-cell interference and upgrade SINR using adaptive FFR model.

7.2 Limitations

Adaptive Fractional Frequency Reuse (FFR) model was used to mitigate the Inter-Cell Interference (ICI) in this thesis work. I did the comparative analysis of different static and adaptive FFR schemes on the basis of performance parameters; throughput, coverage, outage and drop probability. All the performance parameters of ICI measurement have good results in adaptive FFR scheme over static FFR. The throughput of adaptive FFR model was better than the present NT network, which was validated by the real data provided by NT. But LTE users in Nepal Telecom (NT) network are very less, so other parameters (outage probability, coverage probability and call drop probability) are difficult to validate. These are the major limitations of my thesis in current scenario of Nepal.

7.3 Future Enhancement

This thesis work had performed on the basis of hexagonal cell deployment which has certain limitation in coverage area. So the future work can be done in irregular cell deployment which improves the coverage area. This thesis basically focused on the downlink transmission scheme only, where as interference avoidance in uplink should also be considered for future work.

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APPENDIX:

Raw Data of NTC for Validation Purpose:

Start Time	Cell ID	L.Traffic.User.Max	_TOTALDATA_GBYTES
10/24/2017 08:00:00	Cell ID	18	0.219
10/24/2017 08:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	13	0.224
10/24/2017 08:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	17	0.15
10/24/2017 09:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	20	0.112
10/24/2017 09:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	29	0.202
10/24/2017 09:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	32	0.17
10/24/2017 10:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	26	0.108

10/24/2017 10:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	34	0.174
10/24/2017 10:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	42	0.155
10/24/2017 11:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	34	0.115
10/24/2017 11:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	35	0.166
10/24/2017 11:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	42	0.201
10/24/2017 12:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	32	0.104
10/24/2017 12:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	32	0.151
10/24/2017 12:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB	44	0.202

	ID=103321, Cell FDD TDD indication=CELL_FDD		
10/24/2017 13:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	32	0.099
10/24/2017 13:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	35	0.022
10/24/2017 13:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	50	0.19
10/24/2017 14:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	33	0.119
10/24/2017 14:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	40	0.141
10/24/2017 14:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	48	0.162
10/24/2017 15:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	33	0.105
10/24/2017 15:00:00	eNodeB Function Name=KTMeNB321_3_TTC,	33	0.238

	Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD		
10/24/2017 15:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	42	0.189
10/24/2017 16:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	43	0.082
10/24/2017 16:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	40	0.071
10/24/2017 16:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	50	0.156
10/24/2017 17:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	27	0.125
10/24/2017 17:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	29	0.189
10/24/2017 17:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	34	0.196

10/24/2017 18:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	20	0.152
10/24/2017 18:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	30	0.169
10/24/2017 18:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	28	0.064
10/24/2017 19:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	18	0.189
10/24/2017 19:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	25	0.19
10/24/2017 19:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	17	0.147
10/24/2017 20:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	14	0.216
10/24/2017 20:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB	14	0.257

	ID=103321, Cell FDD TDD indication=CELL_FDD		
10/24/2017 20:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	11	0.239
10/24/2017 21:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	11	0.246
10/24/2017 21:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	12	0.279
10/24/2017 21:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	10	0.24
10/24/2017 22:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=0, Cell Name=TTC-J3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	8	0.263
10/24/2017 22:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=2, Cell Name=TTC-L3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	8	0.304
10/24/2017 22:00:00	eNodeB Function Name=KTMeNB321_3_TTC, Local Cell ID=1, Cell Name=TTC-K3, eNodeB ID=103321, Cell FDD TDD indication=CELL_FDD	6	0.246