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LTE Quality Enhancement using Beam forming Fractional Frequency Reuse Techniques

تحسين جودة التطور طويل الأجل بإستخدام تشكيل الحزم وتقنيات إعادة إستخدام التردد الكسري

A Research Submitted in Partial fulfillment for the Requirements of the Degree of M.Sc. degree in Electronics Engineering (Communication)

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بسم الله الرحمن الرحيم

قال تعالى:

(يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ)

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Dedication

الي من أحمل اسمه بكل أفتخار

الي من علمني العطاء دون انتظار

الي من أفتقده في مواجهة الصعاب

الي من لو تمهله الدنيا لأرتوي من حنانه وحكمته

أبي

الي من تتسابق الكلمات لتعبر عن مكنون ذاتها

الي رمز الحب و بلسم الشفاء

الي من علمتني و دعمتني بالدعاء

أمي

الي أساتذتي

الي زملائي و زميلاتي

الي كل من علمني حرفا

أهدي هذا البحث

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In the first and before all I thank ALLAH for every things I'm reaching and going to it in our life.

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Abstract

A Long Term Evolution (LTE) technology is the most possible candidate for next generation mobile wireless communications. One impairment of LTE is an interference from neighboring cells, so called Inter-Cell Interference (ICI). In this thesis Fractional soft FFR technique has been introduced for better utilization of frequency spectrum. In addition, beamforming technique is considered to be the solution to improve the performance of wireless communication systems, this thesis proposes a new beamforming matrix suitable for LTE systems in which the coverage area is divided into three 120°- sectors. The optimum number of array antenna elements and beam patterns for covering all over 120º sector is 5 and 3, respectively. The computer simulation in terms of beam patterns confirms the proposed concept. From the simulation results, it can be said that the soft FFR including beamforming technique is one of the best choices to improve the performance of LTE systems The obtained results show, the probability density function (PDF) of the SIR for the systems with various scenarios and we found the Soft FFR Sector with beamforming gave highest SIR 35 db and also highest Channel capacity 3.5531 bit/s.

المستخلص

تقنية التطور طويل الاجل هي مرشح اخرممكن للاتصالات اللاسلكية المتنقلة للجيل القادم للاتصالات اللاسلكية,واحد من انخفاض في تقنية التطور طويل الاجل هو تداخل من الخلايا المجاورة، ما يسمى التداخل بين الخلايا . في هذا البحث يقترح استخدام تقنيات التردد كسري لمعالجة مشكلة التداخل. ك استخدام التداخل المرن وقد أدخلت هذه التقنية لتحسين استعمال طيف الترددات. بالإضافة إلى ذلك، تقنية تشكيل الشعاع التي يعتبر الحل لتحسين أداء أنظمة الاتصالات اللاسلكية. كذلك، هذا البحث يقترح مصفوفة تشكيل حزمة جديدة مناسبة لأنظمة تقنية التطورطويل الاجل التي تقسم منطقة التغطية إلى ثلاثة 120 °قطاع. ويناقش العدد المناسب لعناصر الهوائي وأنماط الحزمة ومن خلال برنامج المحاكاة وجد ان الرقم الامثل لعناصر مصفوفة الهوائي و انماط الحزمة لتغطي كل قطاع 120 هي 3 و 5 علي التوالي . محاكاة الكمبيوتر من حيث أنماط الشعاع تؤكد المفهوم المقترح.

النتائج التي تم الحصول عليها من برنامج المحاكاة تظهر دالة الكثافة الاحتمالية تعطي اعلي قيمة اشارة الي نسبة التداخل وهي 35 ديسبل في حالة الترردد الكسري مع القطاع ونشكيل الحزم وايضا تعطي اعلي سعة قناة 3.5531 بت / في الثانية . بهذا يمكننا القول ان التردد الكسري المرن مع القطاع وتشكيل الحزم افضل خيار لتحسين اداء انظمة التطور طويل الاجل .

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LIST OF ABBREVIATIONS

LTE	Long term evolution
BS	Base Station
BF	Beam forming
FFR	Fractional Frequency Reuse
SFFR	Soft Fractional Frequency Reuse
ICI	Inter cell Interference
CN	Core Network
SIR	Signal to Interference Ratio
GSM	Global System for Mobile
HSPA	high-speed packet access
NTT	Nippon Telephone and Telegraph
ITU	International Telecommunication Union
DSP	Digital Signal processing
PS	Packet Switched
QoS	Quality of Service
RAN	Radio-Access Network
eNBs	Evolved Node B
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
EPC	Evolved Packet Core
3GPP	The 3rd Generation Partnership Project
HSS	Home Subscriber Server
IC	Interference Cancelation
LTE	Long Term Evaluation
IP	internet protocol
S-GW	Serving Gateway
MATLAB	Mathematical Laboratory
MME	Mobility Management Entity
P-GW	Packet Data Gateway Network
RRC	Radio Resource Control
RLC	Radio Link Control
OFDM	Orthogonal Frequency Division Multiplexing
PDCP	Packet Data Convergence Protocol
PDF	Probability Density Function
UMTS	Universal Mobile Telecommunication System
SC-FDMA	Single Carrier-Frequency Division Multiple Access

OFDMA	Orthogonal Frequency Division Multiple Access

CHAPTER ONE

INTRODUCTION

Chapter one

Introduction

1.1Preface

Recently, mobile wireless communication users have rapidly demanded the use of multimedia services with the requirement of higher data access capability to the subscribers with guaranteed quality of services. In addition, the number of users has grown with unprecedented speed. A Long Term Evolution (LTE) system is the most possible candidate for next generation mobile wireless communications. From the 1st to 3rd Generation of mobile wireless communications, the development has been paid to support a fast data transfer rate devoted to transmission of voice, image and video. However, some impairments have been left from previous generations in which the next generation of mobile wireless communications is envisaged to tackle the problems e.g. higher speed data transfer-rate, global standard to support usage in different areas, stable connection for multi-media and video or wireless teleconference .The objective is to obtain high data rate, low latency, and packet optimized radio access technology. The goal of LTE is to provide a high data-rate transmission, low-latency, packet-optimized radio-access technology supporting flexible bandwidth deployments and an improved quality of service to reduce the delay [1]. However, the LTE technology cannot provide full benefits for mobile communications due to the problem of interference signal from neighboring cells, so called Inter-Cell

Interference The ICI problem is more pronounced when users are moving away from cell center towards cell edge. Therefore, a smart antenna technology cooperating with Soft FFR technique is envisaged to be the best solution to enhance the system quality Fractional Frequency Reuse (FFR) is one technique to relieve ICI problem this technique offers separation of frequency spectrum resource into sectors. The smart antennas are firmed technology which is constituted by antenna array and signal processing unit [2]. The key success of smart antennas is to form its main beam to a desired direction while its nulls or side lobes can be pointed to the directions of interference signals, so called beamforming. Which it combines different radio signals in order to simulate the behavior of a large directional antenna. The virtual antenna can then be directed using an additional signal processing, without the need to physically move the antenna. Beamforming is used to lower interference and increase the overall quality of a telecommunication network. With the use of adaptive beamforming, the main lobe of radiation can be pointed virtually to any direction. LTE has employed several techniques to mitigate ICI.

Here some literatures to mitigate ICI and increase capacity one the previous studies implementation of Adaptive Modulation and Coding Technique using by Sami H.O.Salih,Mamoun M.A.Suliman adaptive modulation allows wireless technologies to yielding higher throughputs while also covering long distances [3]. Sérgio G. Nunes, António Rodrigues propose a solution using Beamforming, mitigating the effects of interference, increasing the quality of network coverage and thus improving the fairness of service to users [4].Greeshma R Sindhe (M.Tech), study proposed paper Interference Suppression in 4G-LTE Downlink through Beamforming Technique [5]. Simon Yiu, Mai Vu, and Vahid Tarokh proposed beamforming with multiple primary users and secondary users sharing the same spectrum in cognitive Network to reduce interference [6]. Lin Hui and Wang Wen Bo. Introduce a few implementations of coordinated beamforming technology with different levels of coordination [7]. Manli Qian, Wibowo Hardjawana1, Yonghui Li, Branka Vucetic, Jinglin Shi Xuezhi Yang they proposed SFR scheme to improve the capacity by jointly optimizing subcarrier and power allocation in multi-cell LTE networks[8]. Anand B. Patel and Prof. Sukant Kumar Chhotaray and Prof. Niteen B proposed Frequency Reuse Schemes for Interference Management in LTE Femtocell Networks: Issues and Approaches [9]. Vishnupriya proposed Mitigation of co-channel interference in long term evaluation using fractional frequency reused scheme [10].

1.2 Problem Definition:

One impairment of LTE is an interference from neighboring cells, so called Inter-Cell Interference (ICI) The ICI problem is more pronounced when users are moving away from cell center towards cell edge. According to this, the Signal-to-Interference Ratio (SIR) at user or mobile terminal is reduced due to two major reasons as follows:

- Firstly, the signal transmitted from base station to mobile terminals is dropped because of an increase in path loss.
- Secondly, ICI from neighboring cells becomes more pronounced when users are moving to cell edge.

1.3 Thesis Objectives:

The objectives of thesis are:

- To study and understand beamforming and FFR technique.

- LTE System performance when employing beamforming and FFR technique.
- To simulate LTE System performance when employing FFR technique with and without beamforming .
- Evaluate LTE system performance when using FFR technique with and without beamforming .

1.4 Methodology:

In this thesis will evaluate the performance of LTE system by develop Matlab programming. Two parameters indicating the system performance, also signal quality, are: Signal-to-Interference Ratio (SIR) and channel capacity. Using the MATLAB programming and mathematical model, simulations will make to evaluate the benefits of using beamforming and FFR technique, and will do that with graphical form and calculation.

1.5 Thesis outlines:

This thesis will contain of five chapters

- Chapter one: introduction.
- Chapter two: background and literature Review.
- Chapter three: interference scenario system model.
- Chapter four: Represent the basic chapter that takes the overall practical in individual steps, so MATLAB will be used to shows the simulation results and its analysis.
- Chapter five: The main ideas presented in the thesis are collected and summarized in this chapter and recommendation for future work

CHAPTER TWO

LITERATURE REVIEW

Chapter 2

Literature Review

2.1 Background

The Global system for mobile communications (GSM) is the dominant wireless cellular standard with over 3.5 billion subscribers worldwide covering more than 85% of the global mobile market. Furthermore, the number of worldwide subscribers using high-speed packet access(HSPA)network stopped 70 millionin2008.HSPA is a 3G evolution of GSM supporting high-speed data transmissions using WCDMA technology. Global uptake of HSPA technology among consumers and businesses is accelerating, indicating continued traffic growth for high speed mobile networks worldwide. In order to meet the continued traffic growth demands, an extensive effort has been underway in the 3G Partnership Project (3GPP) to develop a new standard for the evolution of GSM/HSPA technology towards a packet-optimized system referred to as Long-Term Evolution (LTE). The goal of the LTE standard is to create specifications for a new radio-access technology geared to higher data rates, low latency and greater spectral efficiency. The spectral efficiency target for the LTE system is three to four times higher than the current HSPA system .

In this thesis the techniques have proposed to mitigate the ICI, Fractional Frequency Reuse (FFR) technique divides a whole frequency band into several sub-bands wisely allocated to some specific areas in order to improve signal quality at cell edge. Recently, a soft FFR has been proposed by managing different levels of transmitted power respective to distance between users and cell center. However, the mentioned technique cannot completely mitigate ICI. Therefore, a smart antenna technology cooperating with soft FFR technique is envisaged to be the best solution to enhance the system quality. The smart antennas are firmed technology which is constituted by antenna array and signal processing unit [11].

2.2 Evolution of Mobile Wireless Communications Systems:

Mobile cellular systems are the most popular one for wireless communication systems nowadays as they have a profound impact on people's daily lives. As a mobile wireless communications are a factor of five for human life so they have grown with unprecedented speed. In 1979, the first cellular systems were introduced by Nippon Telephone and Telegraph (NTT) in Tokyo, Japan. So far, mobile Cellular systems evolution has been categorized into generations as shown In Fig 2.1. The 1st Generation of mobile wireless communications (1G) transmits analog signal for speech services. The 1G systems offer handover and roaming capabilities but the 1G cellular network are unable to interoperate between countries. The mentioned impairment is one of the inevitable disadvantages of 1G mobile network. - The 2nd Generation of mobile wireless communications (2G) was introduced in the end of 1980s. Compared to 1G system, 2G systems use digital multiple access technologies, such as Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). These 2G systems provide circuit switched data communication services at a low speed transmission [12]. Compared with 1G system, higher spectrum efficiency, better data services and more advanced roaming can be offered from 2G systems. In Europe, the Global System for Mobile Communications (GSM) was deployed to provide a single unified standard. This has enabled seamless services throughout Europe by means of international roaming. The GSM uses TDMA technology to support multiple users during development over more than 20 years. The GSM technology has been continuously improved to offer better services in the market. New technologies have been developed based on the original GSM system, leading to some more advanced systems known as 2.5 Generation (2.5G) systems. So far, third generation (3G) systems have been introduced in the market, but their penetration is quite limited because of several techno-economic reasons. – For 3rd Generation of mobile wireless communications (3G), International Telecommunication Union (ITU) defined the demands for 3G mobile networks with the IMT-2000 standard. An organization called 3rd Generation Partnership Project (3GPP) has continued that work by defining mobile systems which fulfill the IMT- 2000 standard. The 3G networks enable network operators to offer a wider range of more advanced services while achieving greater network capacity through improved spectral efficiency. Services include wide area wireless voice telephony, video calls, and broadband wireless data, all in a mobile environment. Additional features also include HSPA (High Speed Packet Access) data transmission capabilities which allow delivery of transmission speed up to 14.4 Mbps on downlink and 5.8 Mbps on uplink - New technologies in mobile communication systems and also the ever increasing growth of user demand have triggered researchers and industries to come up with a comprehensive manifestation of the upcoming 4G (4th Generation) mobile communication systems. In contrast to 3G, the new 4G framework tries to accomplish new levels of user experience and multi-service capacity by also integrating all the mobile technologies that exist (e.g. GSM – Global System for Mobile Communications, GPRS - General Packet Radio Service, IMT-2000 - International Mobile Communications, Wi-Fi – Wireless Fidelity and Bluetooth). Industry experts say that users will not be able to take advantages of multimedia content across wireless networks with 3G. In contrast, the 4G systems will feature extremely high quality video of quality comparable to HD (High Definition) TV. Its wireless download speed reaches to 100 Mbps, i.e. 50 times of 3G [10].

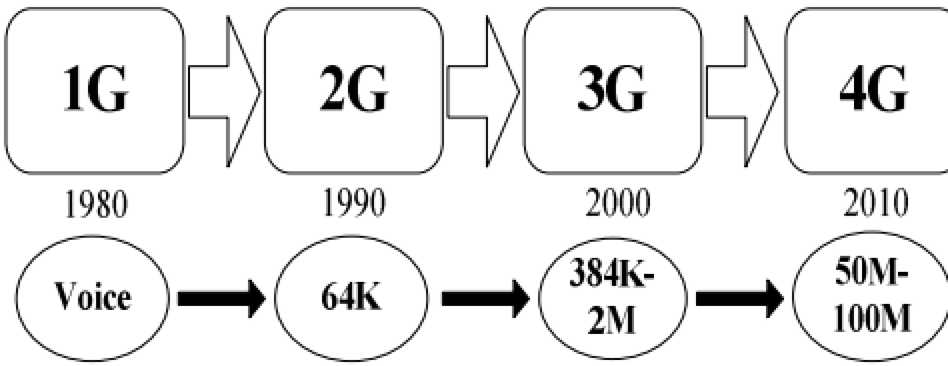


Figure 2.1: Evolution of mobile wireless communications.

2.3 Long Term Evolution:

A LTE is a standard for wireless data communication technology and an evolution of the GSM/UMTS standards. The goal of LTE is to increase the capacity and speed of wireless data networks using new DSP (Digital Signal Processing) techniques and modulations which were developed around the turn of the millennium. A further goal is the redesign and simplification of the network architecture to an IP-based system with significantly reduced transfer latency compared to the 3G architecture. The LTE wireless interface is incompatible with 2G and 3G networks, so that it must be operated on a separate wireless spectrum.

Various technology standards bodies began to explore options for their 4G wireless technology offerings. Two groups, the Third Generation Partnership Project (3GPP), representing the family of networks generally referred to as GSM, and the Third Generation Partnership Project 2 (3GPP2), representing the family of networks generally referred to as CDMA, are working together to lay the foundation for LTE.

Established in 1998, 3GPP is a collaborative agreement that brought together multiple telecommunications standards bodies known as Organizational Partners. This group initiated the 3GPP LTE standards project to improve the UMTS mobile phone standard and to better meet future wireless technology needs. UMTS is one of the many 3G wireless technologies in use today. The most common form of UMTS uses W-CDMA as its underlying air interface and represents the European answer to the ITU IMT-2000 requirements for 3G cellular radio systems. 3GPP2 represents collaboration between the numerous telecommunications associations that helped develop CDMA standards for 3G. LTE is a global 4G standard, with researchers and development engineers throughout the world participating in the joint LTE radio access standardization effort, involving more than 60 operators, vendors, and research institutes. This is the same standards body that researched and established the GSM, GPRS, W-CDMA, and HSPA wireless standards. The LTE standard is tightly integrated with GPRS/UMTS networks and represents an evolution of radio access technologies and networks for UMTS.

2.3.1LTE Standards Evolution:

The 3GPP body began its initial investigation of the LTE standard as a viable technology in 2004. In March 2005, 3GPP began a feasibility study whose key goals were to agree on network architecture and a multiple access method, in terms of the functional split between the radio access and the core network. The study concluded September 2006 when 3GPP finalized selection of the multiple access and basic radio access network architecture. 3GPP decided to use OFDMA in the downlink direction and use SC-FDMA in the uplink direction. The specifications for the LTE standard were approved by 3GPP in January 2007. The specifications are now under change control, leading to their inclusion in 3GPP Release 8. While the LTE requirements are finalized, the standard is not fully completed. LTE Release 8 was completed by late 2008.

2.3.2 Requirements for Long Term Evolution:

LTE is focusing on an optimum support of Packet Switched (PS) services. Main requirements for the design of an LTE system were identified in the beginning of the standardization work on LTE in 2004[16] .They can be summarized as follows:

Data Rate: Peak data rates target 100 Mbps (downlink) and 50 Mbps (uplink) for 20 MHz spectrum allocation, assuming 2 receive antennas and 1 transmit antenna at the terminal.

Throughput: Target for downlink average user throughput per MHz is 3-4 times better than 3GPP Release 6. Target for uplink average user throughput per MHz is 2-3 times better than 3GPP Release 6.

Spectrum Efficiency: Downlink target is 3-4 times better than 3GPP Release Uplink target is 2-3 times better than 3GPP Release 6. The following table summarizes the data rate and spectrum efficiency requirements set for LTE.

Downlink (20 MHz)			Uplink (20 MHz)		
Unit	Mbps	bps/Hz	Unit	Mbps	bps/Hz
Requirement	100	5.0	Requirement	50	2.5
2x2 MIMO	172.8	8.6	16QAM	57.6	2.9
4x4 MIMO	326.4	16.3	64QAM	86.4	4.3

Table 2.1: Data rate and spectrum efficiency requirements defined for LTE.

Latency:

- User plane latency: The one-way transit time between a packet being available at the IP layer in either the device or radio access network and the availability of this packet at IP layer in the radio access network/device shall be less than 30 ms.
- Control plane latency. Also C-plane, that means the time it takes to transfer the device from a passive connection with the network (IDLE state) to an active connection (CONNECTED state) shall be further reduced, e.g. less than 100 ms to allow fast transition times.

Bandwidth: LTE supports a subset of bandwidths of 1.4, 3, 5, 10, 15 and 20 MHz
Interworking: Interworking with existing UTRAN/GERAN systems and non-3GPP specified systems was ensured. Multimode terminals shall support handover to and from UTRAN and GERAN as well as inter-RAT measurements. Interruption time for handover between E-UTRAN and UTRAN/GERAN shall be less than 300 ms for real time services and less than 500 ms for non-real time services.

Multimedia Broadcast Multicast Services (MBMS): MBMS shall be further enhanced and is then referred to as Enhanced-MBMS (E-MBMS).

Note: Physical layer aspects for E-MBMS have been taken into account already in 3GPP Release 8, where the support by higher layers has been largely moved to 3GPP Release 9.

Costs: Reduced CAPEX and OPEX including backhaul shall be achieved. Cost effective migration from 3GPP Release 6 UTRA radio interface and architecture shall be possible. Reasonable system and terminal complexity, cost and power consumption shall be ensured. All the interfaces specified shall be open for multi-vendor equipment interoperability.

Mobility: The system should be optimized for low mobile speed (0-15 km/h), but higher mobile speeds shall be supported as well including high speed train environment as special case.

Spectrum allocation: Operation in paired (Frequency Division Duplex / FDD mode) and unpaired spectrum (Time Division Duplex / TDD mode) is possible. Co-existence: Co-existence in the same geographical area and co-location with GERAN/UTRAN shall be ensured. Also, co-existence between operators in adjacent bands as well as cross-border co-existence is a requirement.

Quality of Service: End-to-end Quality of Service (QoS) shall be supported. Voice over Internet Protocol (VoIP) should be supported with at least as good radio and backhaul efficiency and latency as voice traffic over the UMTS circuit switched networks.

Network synchronization: Time synchronization of different network sites shall not be mandated.

2.4 LTE System Architecture:

LTE is, by definition, a radio-access technology, specifying the Radio-Access Network (RAN). Associated with the RAN is the Core Network (CN) needed for the RAN to be able to provide any services. The LTE RAN is used together with a CN which is referred to as the Evolved Packet Core (EPC), and together they form the so called Evolved Packet System (EPS) in 3GPP, the terminology to denote a terminal is UE or User Equipment [12].

2.4.1 Core Network:

In comparison to earlier CN technologies, the EPC is a radical evolution, supporting packet-switched domain only with no support for the circuit-switched domain. Core network is an IP based network in LTE and all of the interfaces in this network use internet protocol (IP) that is why it is also called as Evolved Packet Core (EPC) [17][18]. EPC has flat a structure and entities in EPC; the EPC is built up of many different types of nodes, described below and depicted in Figure 2.2.

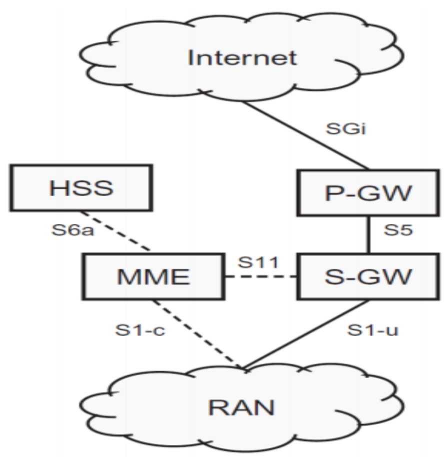


Figure 2.2: EPC architecture.

The Mobility Management Entity (MME) is the control-plane, and has responsibility over, among others, the connection and release of radio bearers to the terminals as well as the UE's state transitioning. The user-plane node, connecting the EPC to the RAN is called the Serving Gateway (S-GW), Moreover; it serves as a mobility anchor when UEs switch between different base stations and gathers information and statistics used for charging. The EPC is connected to the internet through the Packet Data Gateway Network (P-GW), which also allocates IP addresses for specific terminals. Finally, the Home Subscriber Service node, HSS is responsible for containing subscriber information [13]

2.4.2 Radio Access Network:

The Evolved-UTRAN (E-UTRAN) has one single element, the Evolved-NodeB (eNB), where all functions related to radio aspects are performed. Compared with HSPA, the eNB has new features organized into three main groups: Radio Link Control (RLC) Layer, Radio Resource Control (RRC) and Packet Data Convergence Protocol (PDCP). In this way, eNB performs all RRM operations, as admission control, radio barrier control, or dynamic resource allocation.

eNBs interact with each other through the interface X2. The link to core network is provided by S1 interface that connects the eNBs to the Evolved Packet Core (EPC). EPC is constituted by the Mobility Management Entity (MME), which performs control plane signaling, the Serving Gateway (S-GW) and the Packet Data Network Gateway (P-GW), both responsible, mainly, for user-plane data processing as well as integration with other radio access and transport technologies. [13].

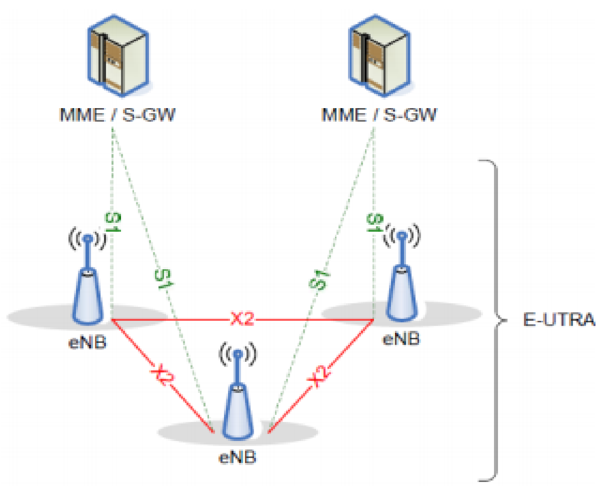


Figure 2.3: LTE's architecture.

2.5 LTE Performance Estimates and Technical Attributes:

Once fully deployed, LTE technology offers a number of distinct advantages over other wireless technologies. These advantages include increased performance attributes, such as high peak data rates and low latency, and greater efficiencies in using the wireless spectrum. Improved performance and increased spectral efficiency will allow wireless carriers using LTE as their 4G technology to offer higher quality services and products for their customers.

2.5.1Benefits expected from LTE technology:

- High peak speeds.
- At least 200 active voice users in every 5 MHz (i.e., can support up to 200 active phone calls).
- Low latency.
- Scalable bandwidth.
- Improved spectrum efficiency.
- Improved cell edge data rates.
- Packet domain only.
- Enhanced support for end-to-end quality of service.

2.6 Interference in LTE basic Aspect:

However, LTE technology cannot provide full benefits due to the problem of interference signal coming from neighboring cells, When LTE was defined, OFDMA networks were supposed to use frequency reuse, each cell should use the whole spectrum for transmission, Interference levels tend to impact on the performance of all mobile communications systems, especially when these work with a frequency reuse factor of 1 to maximize the spectral efficiency.

Interference can be divided into two classes:

- Intra-Cell Interference (Adjacent-channel interference) , as shown in Fig 2.4, appears when UE devices interfere with each other, but as the subcarriers in the intra-cell are orthogonal with each other, intra-cell interference can be avoided efficiently [23]
- Inter-Cell Interference (ICI) (Co-channel interference), as shown in Fig 2.5, ICI happens when UE receives interfering signals from neighboring cells. Aggressive frequency reuse can offer higher system capacity but at the same time increases the interference from the other cells, in other words, increases ICI. This results in a degradation of the Signal to Interference Ratio (SIR) for cell-edge users, which severely limits cell-edge spectrum efficiency [24].

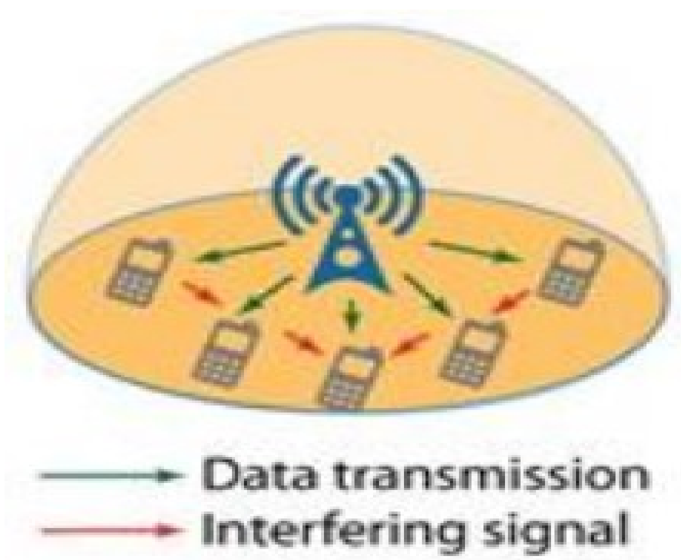


Figure 2.4: Intera-Cell Interference scenario.

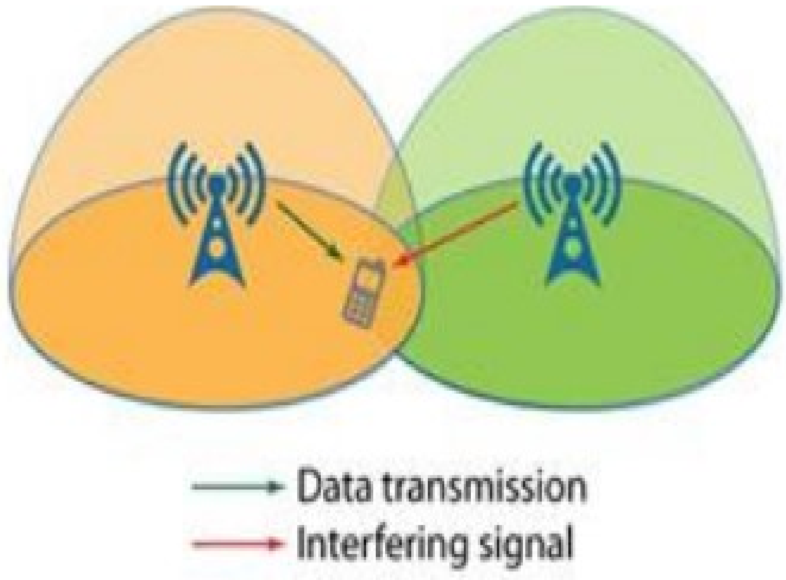


Figure 2.5: Inter-Cell Interference scenario.

The techniques proposed to mitigate the ICI can be classified in several types as they can be surveyed in [14]. So far, Fractional Frequency Reuse (FFR) technique divides a whole frequency band into several sub-bands wisely allocated to some specific areas in order to improve signal quality at cell edge. In this thesis a soft FFR proposed by managing different levels of transmitted power respective to distance between users and cell center. However, the mentioned technique cannot completely mitigate ICI. Therefore, a smart antenna technology cooperating with soft FFR technique is envisaged to be the best solution to enhance the system quality.

2.7 Fractional Frequency Reuse:

So far, the LTE has employed several techniques to mitigate ICI. A Fractional Frequency Reuse (FFR) is one technique to relieve ICI problem

Fractional Frequency Reuse (FFR) is a compromise between reuse-1 and reuse-N models. Each cell is divided into cell-center and cell-edge zones, where frequency reuse-1 model is used in the cell-center zone, while a higher frequency reuse factor is used in cell-edge zone. The available spectrum is divided into two sub-bands: the first one is permanently used in cell-center zones, while the second sub-band is used according to frequency reuse-N model in the cell-edge zones. Consequently, SNR for cell edge UEs is improved [15], since they operate on disjoint spectrum. One disadvantage of FFR is that a portion of the available spectrum is permanently unused in each cell.

This technique offers separation of frequency spectrum resource into sectors. The reused frequency spectrum resource is shown in Fig 2.6. This method also provides maximum utilization of frequency spectrum. Lately, soft FFR technique has been proposed for better utilization of frequency spectrum as shown in Fig 2.7 for this technique, the transmitted power at some sub-frequencies is higher to cover the area of cell edge. This technique provides power allocation arrangement to improve cell edge SIR while degrading SIR for users towards the other cells.

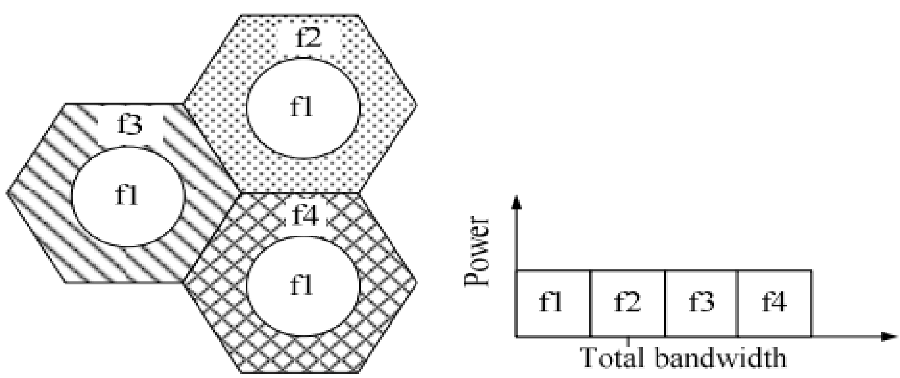


Figure 2.6: Fractional Frequency Reuse.

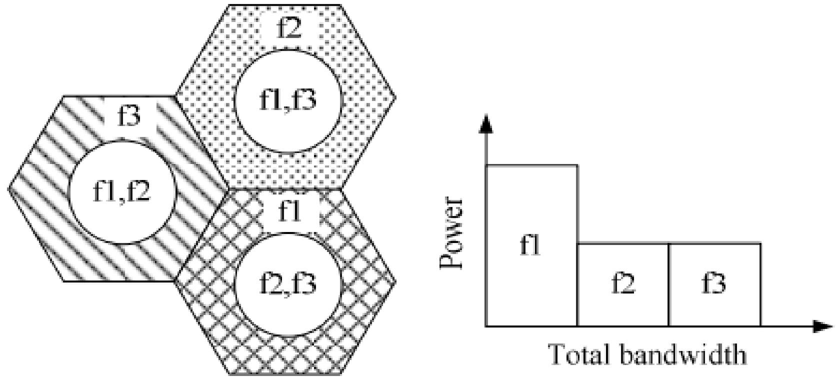


Figure 2.7: Soft Fractional Frequency Reuse.

2.8 Smart Antenna Technology:

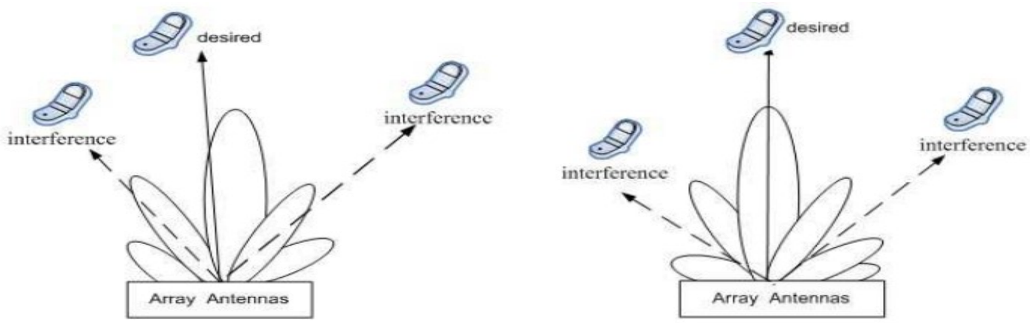
Smart antennas are an antenna technology with capacity of beamforming to a specific direction while pointing nulls or side lobes to directions of interference signal, resulting in an increase in transmission rate and quality. The smart antennas are constituted by an antenna array cooperating with signal processing unit. For some beamforming schemes, the direction of interest is calculated so that the beam can be adjusted to the desired target destination. According to this, the smart antennas can improve link quality by combating the effect of multipath propagation or constructively exploiting the different paths, and also increasing the system capacity by mitigating interference and allowing transmission of different data streams from different antennas. Moreover, the delay arrival of signal caused by environment can be decreased. In general, there are two typical configurations of smart antennas [19].

2.8.1 Switched beam antennas:

Switched-beam antennas are the simplest type of smart antenna technique [19, 20]. The switched beam antennas are constituted by an antenna array working with signal beamforming network, so called beamformer. The interelement spacing in the array is generally distanced definitely. They provide multiple-fixed beams with high sensitivity in particular directions. The beam formation scenario of switched beam antennas is illustrated in Fig. 2.8 (a). Generally, the switched-beam procedures are based on a basic switching function. Firstly, the systems search for the signal strength from all formed beams. When a beam having the highest signal strength has been identified, the systems switch beam to such direction. These procedures are repeated when the user starts moving from one place to another. These systems are not complicated so that they have gained lots of attention from researcher and also companies lately. However, the speed of tracking users totally depends on beams switching rate. In addition, SIR is relatively low when interference sources are in the region of main beam.

2.8.2. Adaptive antennas:

Adaptive antennas are constituted by components similar to switched beam antennas, which are antenna array and beamforming networks. However, signal processing scheme utilized on adaptive antennas is totally different. There are some comparisons between system output and desired signal (or reference signal) after performing beam-formation process. The error from the mentioned comparison is fed back to adjust the weighting coefficients repeatedly. This procedure is called adaptive process which will be stopped when there is no error in the mentioned comparison. This adaptive process helps the beamformer can point its main beam to a desired direction while pointing nulls to undesired directions as shown in Fig 2.8 (b). According to this, the systems are able to provide higher SIR comparing with switched beam antennas. In addition, there is no need for antenna calibration and also the systems work well even when the number of signal is greater than that of antenna elements. However, these systems require hi-speed processing unit to calculate the weighting coefficients utilized for an independent-beam adjustment. Moreover, they need a good reference signal for maximum performance. From the above brief discussion, switched beam antennas excluding adaptive processing are suitable for implementing at base station as they are low of cost and complexity. Therefore, this paper investigates into the performance of switched beam antennas on cellular networks.



(a) (b)

Figure 2.8: Beam formation for (a) switched beam antennas and (b) adaptive antennas

2.8.3 Beam-Formation Concept for LTE:

As mentioned in 2.8.1, switched beam antennas are the most suitable choice for implementing at base station. The basic configuration of these systems is presented in Fig 2.9 consisting of antenna array, beamforming networks and beam selector. The beam selection can be simply performed using basic switching networks which do not require a fast or high computational function in which they are out of scope for this thesis. Also, a wellknown Butler matrix beamformer is the most popular technique for beamforming network so far [21-22]. According to the original concept, Butler matrix requires 4 inputs received from 4×1 antenna array, and then provides 4 outputs for 4 different beam patterns. However, this kind of beamformer has been introduced for general propose in which the maximum performance of cellular systems has not been addressed.

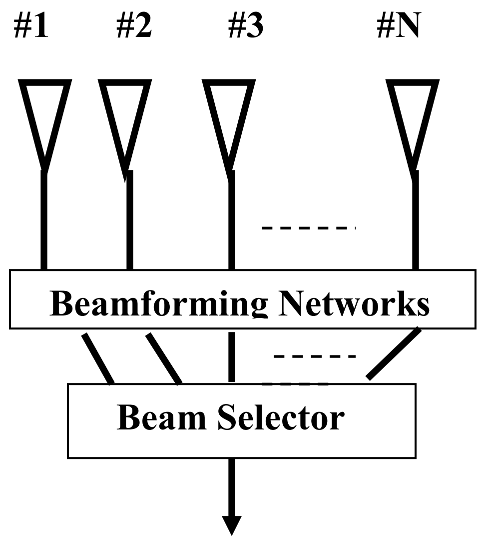


Figure 2.9: Configuration of switched beam antennas.

2.9 Related works:

Implementation of Adaptive Modulation and Coding Technique using has been proposed by SamiH.O.Salih,MamounM.ASuliman to mitigate the interference that Different order modulations combined with different coding schemes, allow sending more bits per symbol, thus achieving higher throughputs and better spectral efficiencies. However, it must also be noted that when using a modulation technique such as 64-QAM with less overhead bits, better signal-to-noise ratios (SNRs) are needed to overcome any Intersymbol Interference (ISI) and maintain a certain bit error ratio (BER) e ratios (SNRs) are needed to overcome any Intersymbol Interference (ISI) and maintain a certain bit error ratio (BER). The use of adaptive modulation allows wireless technologies to yielding higher throughputs while also covering long distances he focusing on the physical layer design [3].

Multi-Cell Interference Coordination in LTE Systems using Beamforming Techniques has been proposed by Sérgio G. Nunes, António Rodrigues and Nuno Cota The main objective of this work was to present the problem of the effect of interference in a LTE (Long-term Evolution) network and propose a solution using Beamforming, mitigating the effects of interference, increasing the quality of network coverage and thus improving the fairness of service to users. Various scenarios are proposed in order to obtain a comparison between a system with and without Beamforming. The results show that in the presence of strong interference, the quality of the coverage of a LTE cell is greatly affected. The use of beamforming allows for an increase of Signal to noise plus interference ratio (SINR) power in cell-edge of around +11 dB and this is reflected with an increase of up to +54 Mbps of downlink throughput for the cell-edge user. Spectral efficiency is also greatly improved with results showing a significant increase of up to +3 bits/Hz. These results lead to the conclusion that the use of beamforming applied to LTE technology has enormous potential, especially in scenarios where there is a lot of inter-cell interference and therefore these techniques can be considered as a valid alternative for Inter-cell Interference Coordination (ICIC). The performance of a system with Beamforming is directly related to the number of antennas installed, being that with 8 antennas, the array is able to create beams with higher directivity and lower scattering losses, therefore increasing the transmitted power to the wanted user. Beamforming also allows for the reduction of interference to other users in other cells and when these two factors are combined, the results are promising. [4].

Interference Suppression in 4G-LTE Downlink through Beamforming Technique has been proposed by Greeshma R Sindhe and Mrs. Latha.M , With the substantial escalation of mobile applications and smart-phones, there is an increasing trend of technical adaptation of 3G (third generation). But with the exponential growing of massive traffic, it is seen that even 3G network is completely not capable of catering to the dynamic needs of the customers. A variable step size based least square algorithm is formulated for an orthogonal frequency division multiple access, in its channel estimation. The weighting co-efficient can be updated on the channel condition using the unbiased channel estimation method. It uses phase weighting scheme where noise statistics and channel information are not required, which eliminates the fluctuation of signals due to noise and decision errors. Towards the true channel co-efficient its convergences is generated. The smart antenna has investigated with its application as LTE with the study of beamforming techniques. Performance of 4G-LTE variable step size comparing with the 4G-LTE fixed step size and 3G-LTE is evaluated by using simulations on MATLAB. The Authors have discussed various significant contribution of the past research attempts. They said that the prime aim their work was to understand the effectiveness in the techniques for improving the LTE network. Their work towards future direction will be to design an efficient framework that can address the research gap highlighted in it. Their work concentrates on the downlink in which the algorithms namely are 3G-LTE, 4G-LTE fixed step size and 4G-LTE variable are implemented. There are three algorithms are studied for various cases namely less antenna elements and single jammer, less antenna elements and multiple jammers, more antenna elements and single jammer and finally more antenna elements and multiple jammers . For all the three cases 4G-LTE variable algorithms performs the best. More ever the convergence factor is hugely improved [5].

Interference Reduction by Beamforming in Cognitive Networks has been proposed by Simon Yiu, Mai Vu, and Vahid Tarokh they consider beamforming in a cognitive network with multiple primary users and secondary users sharing the same spectrum. In particular, they assume that each secondary transmitter has Nt antennas and transmits data to its single antenna receiver using beamforming. The beamformer is designed to maximize the cognitive user's signal-to-interferencemratio (SIR), defined as the ratio of the received signal power at the desired cognitive receiver to the total interference created at all the primary receivers. Using mathematical tools from random matrix theory, they derive both lower and upper bounds on the average interference at the primary receivers and the average SIR of the cognitive user. They further analyze and prove the convergence of these two performance measures asymptotically as the number of antennas Nt or primary users Np increases. Specifically, the average interference per primary receiver converges to the expected value of the path loss in the network whereas the average SIR of the secondary user decays as 1/c when $c = Np/Nt \rightarrow \infty$. In the special case of Nt = Np, the average total interference approaches 0 and the average SIR approaches ∞ they consider a cognitive network which consists of multiple primary users and multiple cognitive users. The secondary cognitive transmitters are allowed to transmit concurrently with the primary licensed transmitters. To mitigate interference, the secondary users transmit signals using multiple antennas with a beamforming vector. The beamforming vector is designed to maximize the SIR of the secondary user. We derive bounds and provide asymptotic analyses for the average SIR and the average interference caused to all primary receivers. In particular, we have shown that if the number of antennas at the secondary transmitters can be of the same as the number of primary receivers, the interference caused to the primary receivers can be made zero, creating an infinite SIR at the cognitive user. On the other hand, if the number of primary receivers outgrows the number of antennas at the secondary transmitter, then both the average interference and the average SIR approach fixed limits. These analyses can be useful in deciding the number of antennas to deploy in the secondary transmitters [6]

Coordinated Beamforming technology in TD-LTE-Advanced system has been proposed by Lin Hui and Wang Wen Bo , they wrote that as extension of MIMO technology in cellular system with multiple cell sites, Cooperative Network MIMO is a hot topic for the research of future wireless communication. In current study of TD-LTE-Advanced (LTE-Advanced TDD) system, various coordinated beamforming schemes have shown to be very promising candidates. They introduce a few implementations of coordinated beamforming technology with different levels of coordination, together with system level simulations and analysis; they use traditional single user scheme as baseline. Then spatial coordination of multiple-user scheme shows significant gain from the simulation evaluation. Such effect can be further enhanced by intercell coordination. Simple solution of intercell coordinated scheduling can be supported with limited backhaul requirement. In case of no backhaul limitation (e.g. cells are connected with fiber, or even share the same site), more sophisticated schemes can be applied to approach theoretical capacity bound associated with equivalent broadcasting channel. For schemes with different level of coordination, they have conducted performance analysis in their work. However the schemes evaluated in their work preliminary and the purpose is to show possible performance situation [7].

Inter-cell Interference Coordination through Adaptive Soft Frequency Reuse in LTE Networks has been proposed by Manli Qian1,2,3,4, Wibowo Hardjawana1, Yonghui Li1, Branka Vucetic1, Jinglin Shi2,4, Xuezhi Yang5 , they wrote that In 3GPP Long Term Evolution (LTE) networks, the frequency reuse schemes such as fractional frequency reuse (FFR) and soft frequency reuse (SFR) are used to improve system capacity. The allocation of transmit power and subcarriers to each cell in these schemes are fixed prior to network deployment. This limits the potential performance of these frequency reuse schemes. their work they propose to improve the capacity of SFR scheme by jointly optimizing subcarrier and power allocation in multi-cell LTE networks. An iterative algorithm that can adaptively vary the number of major subcarriers and adjust the transmit power for each cell according to wireless traffic loads is proposed. Simulation results show that the proposed algorithm outperforms the existing Reuse 1, FFR and static SFR schemes in both system throughput and cell edge user performance. They proposed an adaptive soft frequency reuse algorithm to solve the multi-cell resource allocation problem in LTE networks. The proposed algorithm adaptively allocates the major subcarriers and transmits power to each cell according to system traffic environment so as to maximize the SFR system capacity [8].

Frequency Reuse Schemes for Interference Management in LTE Femtocell Networks: Issues and Approaches, has been proposed by Anand B. Patel and Prof. Sukant Kumar Chhotaray and Prof. Niteen B. Patel they wrote LTE networks are becoming more and more popular nowadays. There are two main problems in implementing LTE networks - coverage and capacity. Both these problems can be solved by deploying femtocells in LTE networks. Interference occurs between newly added femtocell and pre existing macrocell as macrocell and femtocell share same frequency band. Macrocell-femtocell interference management is biggest issue when we talk about LTE femtocell networks. Effective frequency allocation scheme should be used for macrocell-femtocell interference management in LTE femtocell network. Various frequency allocation schemes used for interference management in LTE femtocell networks are discussed in this article. LTE-femtocell combination provides very effective solution for wireless communication networks. Choosing a frequency allocation scheme is very difficult question in LTE femtocell network. Main aspect to consider in their work is macrocell-femtocell interference but the parameters like user capacity per cell, system complexity should also be taken into consideration. The main objective should be to provide best services to users. As they can see FFR is the best solution in terms of interference reduction but practical implementation is very difficult as it requires four base stations per cell and band division is also very difficult. They cannot predict exact number of users or traffic in a specific region of cell. In that way we can say that Scheme that can provide least interface may not be an appropriate option as other parameters are also affected [9].

Mitigation of co-channel interference in long term evaluation using fractional frequency reused scheme has been proposed by Vishnupriya he wrote Co-channel interference in Long Term Evolution (LTE) cellular network is caused due to usage of same frequencies between the neighboring cells at the same region. The term co-channel interference is otherwise known as inter-cell interference. It is important to mitigate co-channel interference at micro-cells in order to improve the communication performance of the cellular network. In his paper, he proposes a fractional frequency reuse approach for microcells to mitigate the co-channel interference. In this approach, the cell is partitioned into inner region & outer region and selects the optimal frequency allocation for each region in the cell to enhance the overall throughput and user satisfaction [10].

CHAPTER THREE

METHODOLOGY

Chapter Three

Methodology

The ICI problem is more pronounced when users are moving away from cell center towards cell edge. According to this, the Signal to Interference Ratio (SIR) at user or mobile terminal is reduced.

3.1 Intercell Interference Scenario:

However, LTE technology cannot provide full benefits due to the problem of interference signal coming from neighboring cells, so called Inter-Cell Interference (ICI). Fig.3.1 shows scenario of ICI. The ICI occurs when users are moving away from cell center towards cell edge. According to this, the SIR at a mobile terminal is reduced due to two reasons as follows. Firstly, the signal transmitted from base station to mobile terminals is dropped because of an increase in path loss. Secondly, ICI from neighboring cells becomes more pronounced when users are close to their cell edge

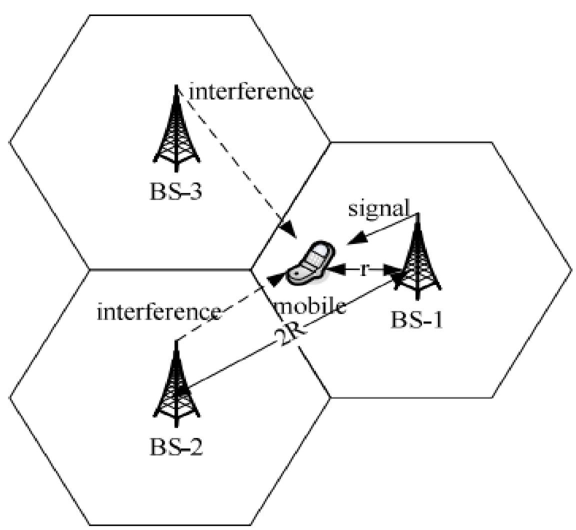


Figure 3.1: Inter-Cell Interference scenario

3.2 System Model:

Both FFR and soft FFR have been introduced in order to relieve the effect of ICI, especially at the region of cell edge. Also, beamforming technique is expected to be another solution to boost up the system performance, the proposed system consists of, (1) Modeling system, (2) Calculation SIR and Capacity when using FFR schemes without beamforming. (3) Calculation SIR and Capacity when using FFR schemes with beamforming, the General block system Diagram shown in fig 3.2.

3.3 Modeling system of LTE:

System has been modeled using macro cell, the total number of adjacent base stations is assumed by 19 cells. Every base station is assumed to transmit an equal power to the same number of mobile users. The scenarios of simulations are based on several schemes of FFR which are (a) sector (b) FFR (c) sector with FFR (d) soft FFR and (e) sector with soft FFR. Both FFR and soft FFR have been introduced in order to relieve the effect of ICI, especially at the region of cell edge. Also, beamforming technique is expected to be another solution to boost up the system performance.

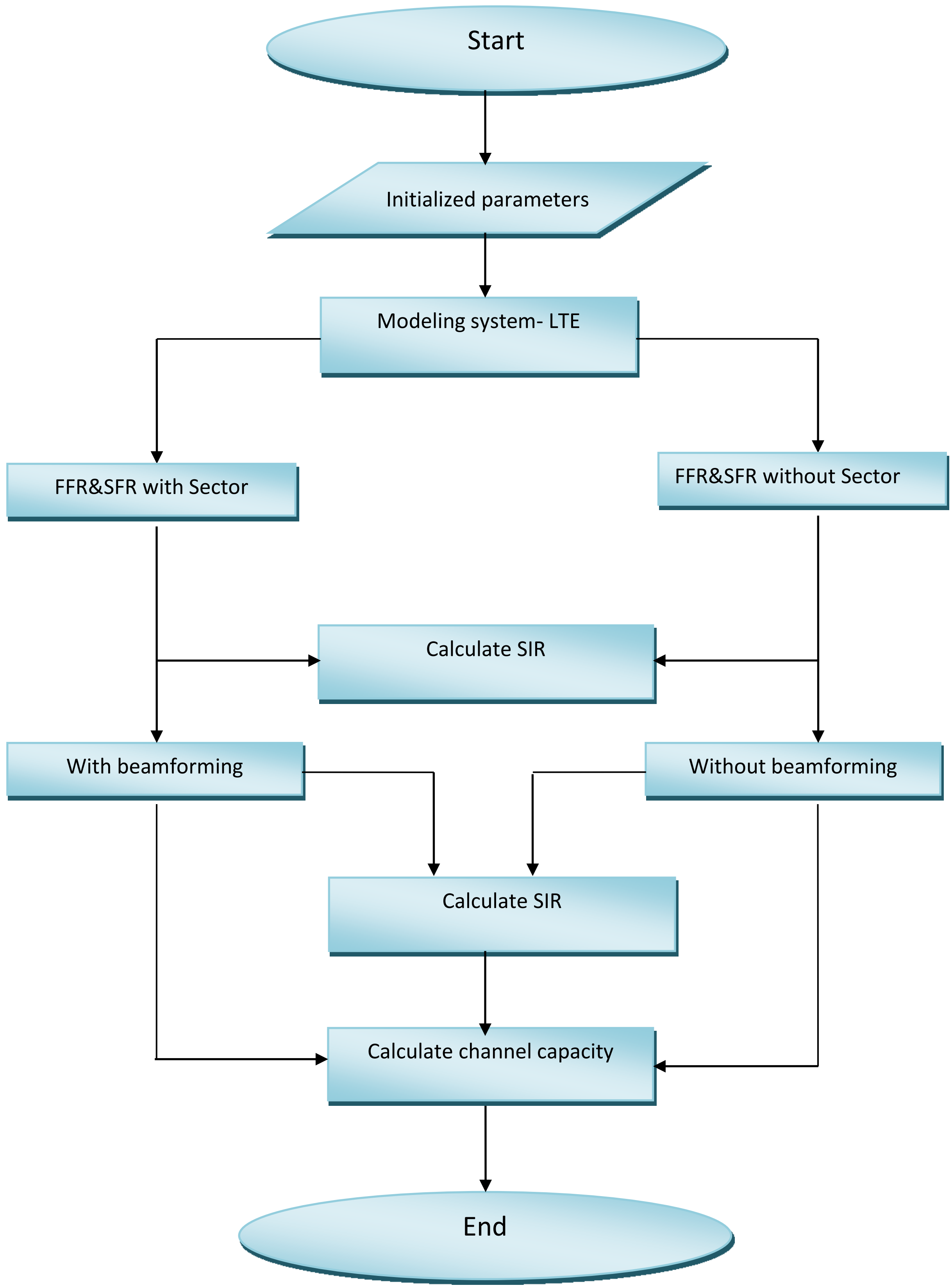


Figure 3.2: System Diagram.

3.4 FFR schemes without beamforming:

The scenarios of simulations are based on several schemes of FFR shown in Fig 3.3 which are

(a) Sector

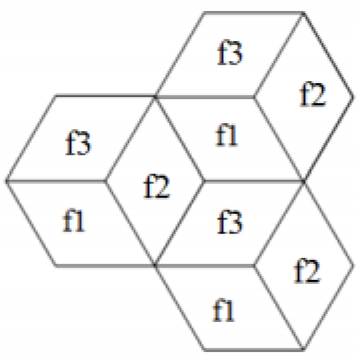
(b) FFR

(c) Sector with FFR

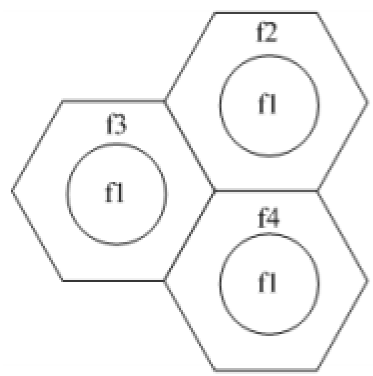
(d) Soft FFR and

(e) Sector with soft FFR.

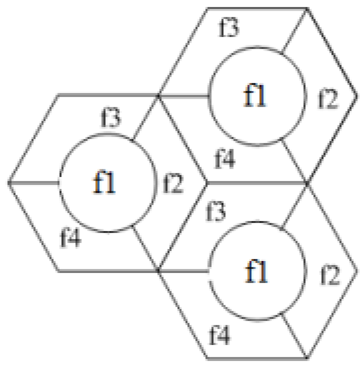
Both FFR and soft FFR have been introduced in order to relieve the effect of ICI, especially at the region of cell edge.

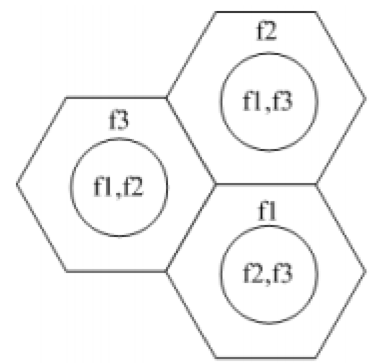


(a)

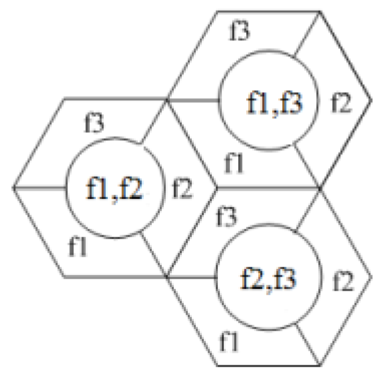


(b)





(c) **(d)**



(d)

Figure 3.3: Configuration of FFR schemes. (a) Sector (b) FFR (c) FFR sector (d) Soft FFR (e) Soft FFR sector.

3.5 FFR schemes with beamforming:

This thesis also takes into account employing of beamforming. Same scenarios in 3.4 section use with beamforming these are expected to be another solution to boost up the system performance.

3.6 Suitable Beam-Formation for 120^0 sector:

this thesis investigate into the optimum number of antenna elements which effects on the optimum number of beam patterns and beam width for LTE cellular systems. In this investigation, the coverage area is assumed to be equally divided into three sectors (120°/sector). From running a number of simulations, we have found that using three beams gives maximum SIR covering 120° sector as depicted in Fig 3.4, according to this, the beam width of each beam is 40°.

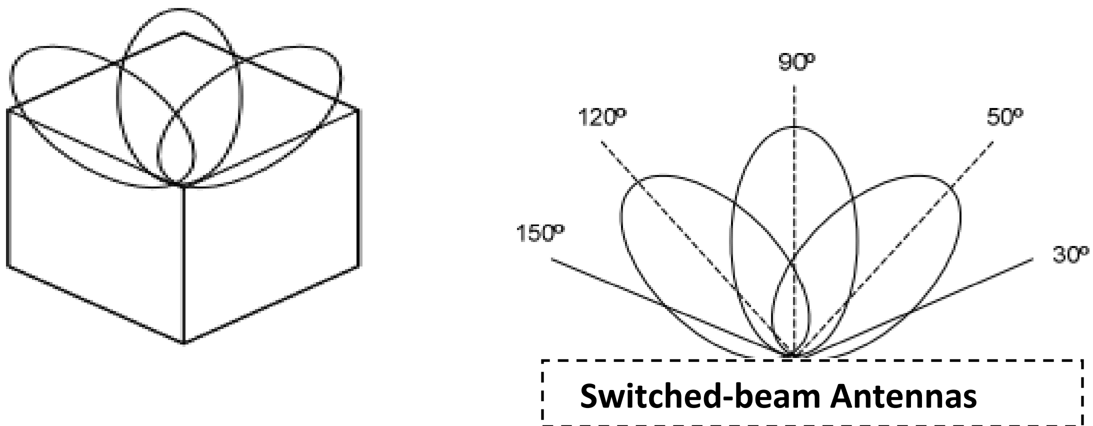


Figure 3.4: Beam formation in 120° section.

3.7 performance Metrics:

The systems performance in this thesis is reflected through two indicators: Signal-to Interference Ratio (SIR) and capacity.

3.7.1 Signal to Interference ratio:

The SIR for the case when beamforming is excluded can be calculated using (3.1) but the expression shown in (3.2) is used to calculate SIR in case of including beamforming.

$$SIR = \frac{P_C r_C^{-\alpha}}{\sum_{i=1}^{n} P_{Ei} r_{Ei}^{-\alpha}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.1)}$$

$$SIR = \frac{G(\theta)_c P_c r_c^{-\alpha}}{\sum_{i=1}^{n} G(\theta)_c P_{Ei} r_{Ei}^{-\alpha}} \quad \ldots\ldots (3.2)$$

Where:

- α :is path-loss exponent.
- P_c: is transmitted power from base station to cell center area of interest.
- P_{Ei} : is transmitted power in region of cell edge belonging to the i^{th} base station (neighboring cell).
- r_c : is distance from a user to own base station at cell center.
- r_{Ei} :is distance from a user staying in cell edge region of neighboring cell to the base station of interest.
- $G(\theta)_c$: is gain of antenna at base station transmitting to region of cell center and $G(\theta)_{Ei}$: is gain of antenna at base station transmitting to region of cell edge.

3.7.2 Channel Capacity:

For the evaluation of channel capacity for LTE systems, the formulas of channel capacity according to Shannon capacity are introduced in (3.3) to (3.7).Please note that the beamforming technique was not taken into account for:

$$\frac{C}{B} = \log_2(1 + SIR) \quad \ldots\ldots (3.3)$$

$$\frac{C}{B} = \frac{1}{4}\log_2(1 + SIR_{center}) + \frac{1}{4}\log_2(1 + SIR_{edge}) \ldots\ldots (3.4)$$

$$\frac{C}{B} = \frac{1}{4}\log_2(1 + SIR_{center}) + \frac{3}{4}\log_2(1 + SIR_{edge}) \quad \ldots\ldots (3.5)$$

$$\frac{C}{B} = \frac{2}{3}\log_2(1 + SIR_{center}) + \frac{1}{3}\log_2(1 + SIR_{edge}) \quad \ldots\ldots (3.6)$$

$$\frac{C}{B} = \frac{4}{3}\log_2(1 + SIR_{center}) + \log_2(1 + SIR_{edge}) \ldots\ldots\ldots\ldots\ (3.7)$$

Where:

- C: is Channel Capacity per cell.
- B: is a Channel bandwidth.
- SIR_{center}: is SIR in the region of cell center.
- SIR_{edge}: is SIR in the region of cell edge.

These equations are in order with respect to the configuration illustrated in Figs 3.3 (a) to (e).

CHAPTER FOUR

RESULTS AND DISCUSSION

Chapter Four

Results and discussion

4.1 Descriptive Analysis:

This thesis investigates into the LTE system performance when employing FFR schemes including conventional FFR and soft FFR. Also, several scenarios are assumed including 120-degree secterization and beamforming. In this thesis, two parameters indicating the system performance, also signal quality, are Signal-to-Interference Ratio (SIR) and channel capacity. The performance of LTE systems in this thesis is evaluated by own developed Matlab programming. The total number of adjacent base stations is assumed by 19 cells. Every base station is assumed to transmit an equal power to the same number of mobile users. The scenarios of simulations are based on several schemes of FFR which are (a) sector (b) FFR (c) sector with FFR (d) soft FFR and (e) sector with soft FFR. Both FFR and soft FFR have been introduced in order to relieve the effect of ICI, especially at the region of cell edge. Also, beamforming technique is expected to be another solution to boost up the system performance.

4.2 Simulation setup:

The performance of LTE systems in this thesis is evaluated by own developed MATLAB programming , MATLAB is an integrated technical computing environment that combines numeric computation, advanced graphics, visualization, and a high level programming language. It uses to graph functions, solve equations, perform statistical tests, and do much more.

The code which describes the simulation is shown in appendix (A) and the simulation parameters are shown in tables 4.1 and 4.2 for the cases of excluding and including beamforming, respectively.

Parameters	Values
Number of base station	19
Inter-base station distance	1000m
Pathloss model 3GPP Macro cell	[4]
Number of antenna elements	5
Number of users random	100
Degree of sector	120º
Inter-element spacing	d=λ/2

Table 4.1 Simulation parameters for case of FFR without beamforming schemes

Parameters	Values
Number of base station	19
Inter-base station distance	1000m
Pathloss model 3GPP Macro cell	[4]
Number of antenna elements	5
Number of users random	100
Degree of sector	120º
Inter-element spacing	d=λ/2
Antenna Array 5 element	Linear array antenna
Element of antenna	5
Frequency	2.595 GHz

Table 4.2 Simulation parameters for case of FFR with beamforming Schemes

4.3 Simulation Results:

After the execution of simulation software program we get the following results in terms of tables and graphs.

4.3.1 Signal to Interference Ratio:

Fig 4.1 shows Probability Density Function (PDF) of SIR for the systems with various scenarios. There is a comparison of cases: sector no FFR, only FFR, soft FFR. As we can see, cellular systems with the use of FFR and secterization statistically provide higher SIR comparing with the ones without FFR and sector.

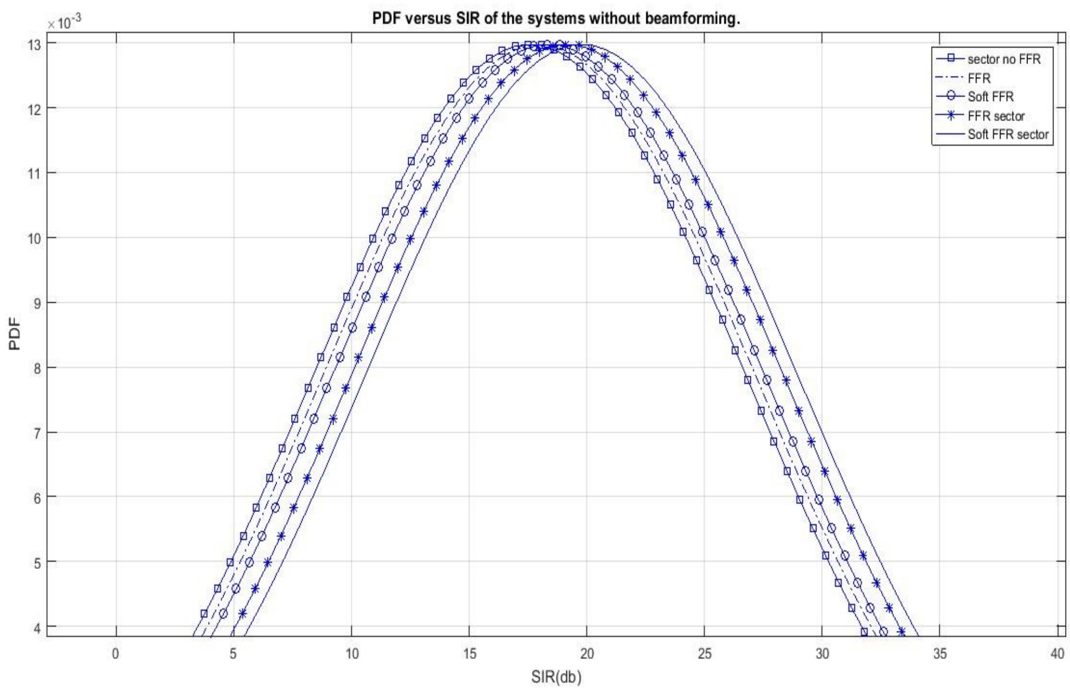


Figure 4.1: PDF versus SIR of the systems without beamforming

Similarly for the ones including beamforming technique, soft FFR with secterization statistically gives the highest SIR as seen in Fig 4.2. This is because of the benefits from allocating different transmitted power between cell center and cell edge (soft FFR). This brings to the reduction of ICI. Also, allocating different frequencies to sectors can reduce effect of ICI,

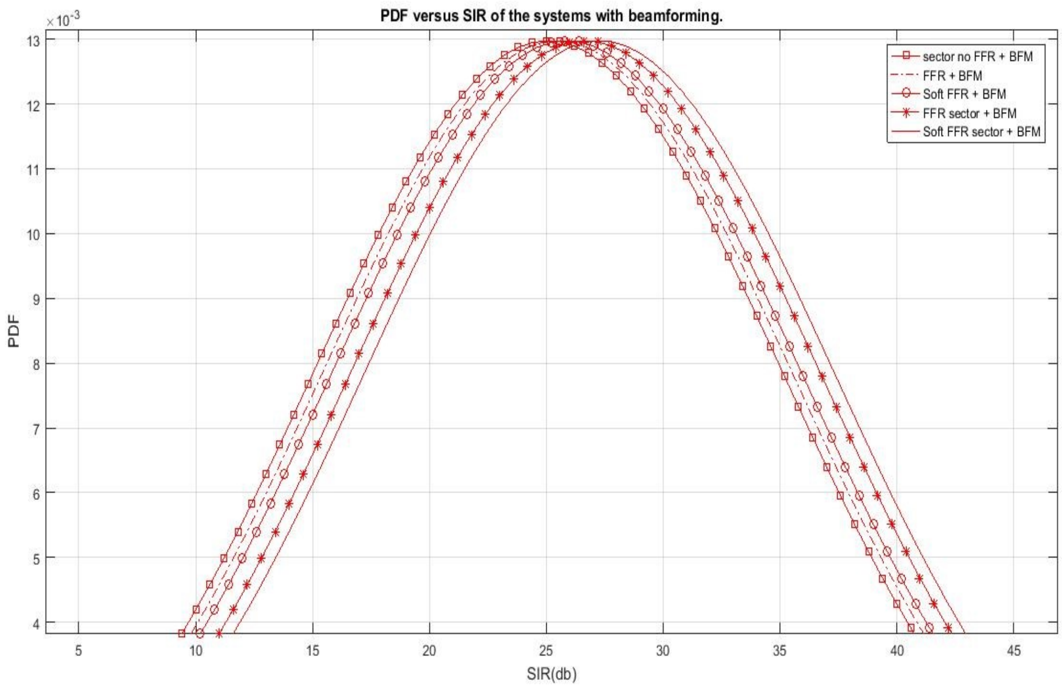


Figure 4.2: PDF versus SIR of the systems with beamforming

for clearer understanding, these two cases (with and without beamforming) are also combined as shown in Fig 4.3 As we can see, the group of SIR employing beamforming technique statistically provides higher SIR even the case of without FFR. This is because the beamforming technique helps an increase in antenna gain at the desired direction while providing low gain in directions of interference signal resulting in ICI reduction

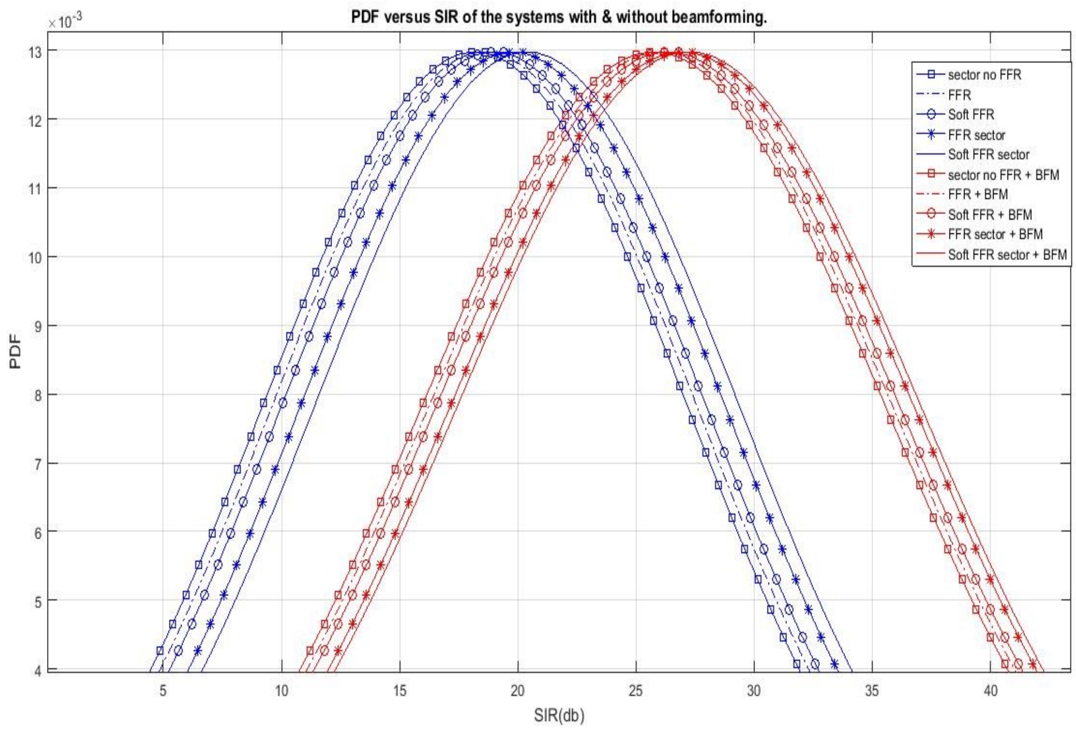


Figure 4.3: Comparison of SIR for cellular systems: with and without beamforming techniques.

4.3.2 Channel capacity:

For the evaluation of channel capacity for LTE systems, the formulas of channel capacity according to Shannon capacity are introduced in equations from (3.3) to (3.7).FFR sector and soft FFR sector, the capacity in this thesis is calculated per cell. Table 4.3 shows the calculated channel capacity for those 5 cases. It reveals that utilizing soft FFR technique including beamforming provides the highest channel capacity for both cases: with and without beamforming. This is because soft FFR provides the best SIR from the previous results presented in Figures 4.1 and 4.2

Type	Without beamforming	With beamforming
Sector no FFR	1.4655	2.0127
FFR	2.4513	2.9962
FFR sector	2.9987	3.3491
Soft FFR	2.8769	3.2697
Soft FFR sector	3.0176	3.5531

Table 4.3 simulated channel capacity.

From the above simulation results, it can be said that soft FFR including beamforming technique is one of the best choice to improve the performance of LTE systems. Next section shows the discussion of beamforming concept suitable for LTE systems.

4.3.3 Beamforming:

From running a number of simulations, we have found that using three beams gives maximum SIR covering 120° sector as depicted in Fig 3.4. According to this, the beamwidth of each beam is 40°.

Some computer simulations have been developed to validate the concept as follows. Fig.4.4 shows the beam pattern of linear array employing 4, 5 and 6 antenna elements. The obtained results show that we can have beam width of 54°, 42° and 30°, respectively. According to this, 5 antenna elements providing 42° beam width is the most suitable choice when a 120° sector having 40 beam widths is require. Also, Fig.4.5 shows some simulation investigating the optimum number of beams per sector. For this simulation, the number of antenna elements 4, 5 and 6 are assumed. As we can see, utilizing 3-beams provides maximum SIR for all three cases.

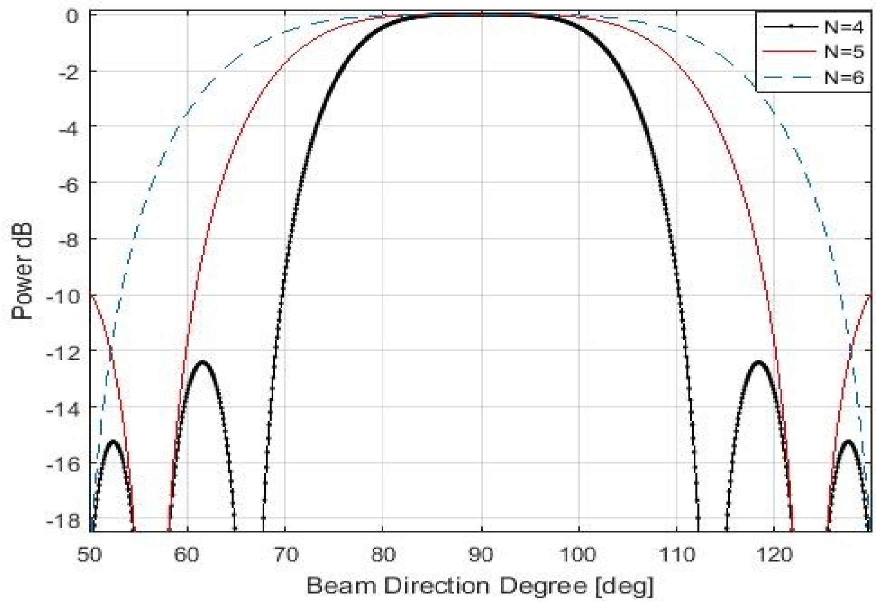


Figure 4.4 simulated beam patterns employing linear array antennas having 4, 5 and 6 antenna elements.

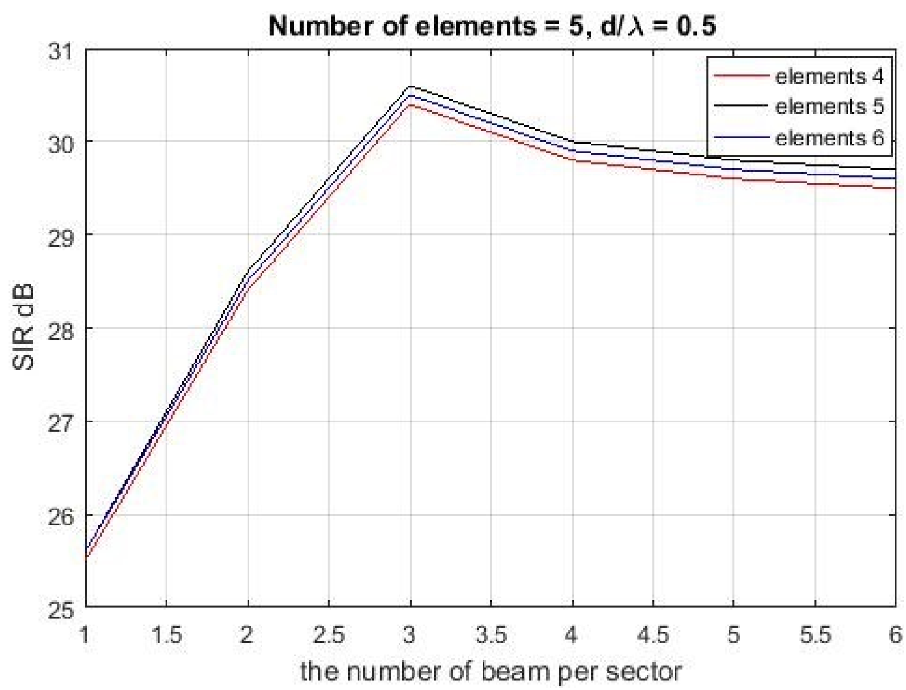


Fig 4.5: SIR VS. Number of beam per sector.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATINS

Chapter five

Conclusion and Recommendations

5.1 Conclusion:

In this thesis we define the impairment of LTE as an interference from neighboring cells, so called Inter-Cell Interference (ICI). So a Fractional Frequency Reuse (FFR) has been proposed to handle the problem. In addition, beamforming technique is considered to be the solution to improve the performance of wireless communication systems. Therefore this thesis has investigated benefit of several types of frequency reuse techniques for LTE systems. The simulations results have indicated that soft FFR is the best choice providing maximum performance in terms of SIR and channel capacity. Moreover, the investigation has included the beam formation into the systems. Then, from running a number of simulations, the optimum number of array antenna elements and beam patterns for covering all over 120º sector is 5 and 3, respectively. Therefore, soft FFR plus secterization and beamforming provides maximum SIR and channel capacity.

5.2 Recommendations:

The following points have been proposed as a future work to further studies

- Studying and implementing other proposed FFR schemes such as Incremental frequency reuse (IFR).
- Design prototype for beamformer and compare with the simulation results.
- Beam former for others Secterization in LTE systems

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Appendix

```
nbs=19;
h=0.45; %meter
inbsd=1000;
pthlos=-4;
elem=5;
users=100;
sector_degree=120;
d=h/2;   %Ielnt_spac
%% Simulation parameters for case of FFR without beamforming schemes.
nbs=19;
h=0.45; %meter
inbsd=1000;
pthlos=-4;
elem=5;
users=100;
sector_degree=120;
d=h/2;   %Ielnt_spac
frequency =2.595; %GHz
%%setting SIR parameters
sir= [-10 -5 5 10 15 20 25 30 35 40 45 50 55];
b=20;
%% cpacity calculations
for i=1:length(sir)

c1(i)=b*log2(1+sir(i));

end

mu=0;
sigma=1;
noise= sigma *randn(1,10)+mu;


L=100000; %Sample length for the random signal
mu=10;
```

```
sigma=2;
X=sigma*randn(L,1)+mu;

figure()
n=100; %number of Histrogram bins
[f,x]=hist(X,n);
sir_db = -10:0.55:60;
sir_db = sir_db(1,1:100);
%bar(x,f/trapz(x,f)); hold on;
%Theoretical PDF of Gaussian Random Variable
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(sir_db,g/5,'bs-');
hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(sir_db+0.3,g/5,'b-.');

hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(sir_db+0.6,g/5,'b-o');


hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(sir_db+1.2,g/5,'b-*');


hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(sir_db+1.5,g/5,'b-');

grid on;
axis([-10 55 0 0.014])
title('PDF versus SIR of the systems without beamforming.');
legend('sector no FFR','FFR','Soft FFR','FFR sector','Soft FFR sector');
xlabel('SIR(db)');
ylabel('PDF');

%% with beamforming
```

```
figure()
n=100; %number of Histrogram bins
[f,x]=hist(X,n);
snr_db = -05:0.6:60;
snr_db = snr_db(1,1:100);

%bar(x,f/trapz(x,f)); hold on;
%Theoretical PDF of Gaussian Random Variable
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*.46;
plot(snr_db,g/5,'rs-');
hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(snr_db+0.3,g/5,'r-.');

hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(snr_db+0.6,g/5,'r-o');


hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(snr_db+1.2,g/5,'r-*');

hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(snr_db+1.5,g/5,'r-');

grid on;
axis([-10 55 0 0.014])

title('PDF versus SIR of the systems with beamforming.');
legend('sector no FFR + BFM','FFR + BFM','Soft FFR + BFM','FFR sector +
BFM','Soft FFR sector + BFM');
xlabel('SIR(db)');
ylabel('PDF');

figure()
% compare
```

```
n=100; %number of Histrogram bins
[f,x]=hist(X,n);
sir_db = -10:0.55:60;
sir_db = sir_db(1,1:100);
%bar(x,f/trapz(x,f)); hold on;
%Theoretical PDF of Gaussian Random Variable

g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(sir_db,g/5,'bs-');
hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(sir_db+0.3,g/5,'b-.');

hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(sir_db+0.6,g/5,'b-o');


hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(sir_db+1.2,g/5,'b-*');


hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(sir_db+1.5,g/5,'b-');

grid on;
axis([-10 55 0 0.014])
%title('PDF versus SIR of the systems without beamforming.');
%legend('sector no FFR','FFR','Soft FFR','FFR sector','Soft FFR sector');
%xlabel('SIR(db)');
%ylabel('PDF');

%%
n=100; %number of Histrogram bins
[f,x]=hist(X,n);
snr_db = -05:0.6:60;
```

```
snr_db = snr_db(1,1:100);

%bar(x,f/trapz(x,f)); hold on;
%Theoretical PDF of Gaussian Random Variable
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*.46;
plot(snr_db,g/5,'rs-');
hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(snr_db+0.3,g/5,'r-.');

hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(snr_db+0.6,g/5,'r-o');


hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(snr_db+1.2,g/5,'r-*');

hold on
g=((1/(sqrt(4*pi)*sigma))*exp(-((x-mu).^2)/(4*sigma^2)))*0.46;
plot(snr_db+1.5,g/5,'r-');
grid on;
axis([-10 55 0 0.014])
title('PDF versus SIR of the systems with & without beamforming.');
legend('sector no FFR','FFR','Soft FFR','FFR sector','Soft FFR sector');
xlabel('SIR(db)');
ylabel('PDF');

%legend('sector no FFR + BFM','FFR + BFM','Soft FFR + BFM','FFR sector +
BFM','Soft FFR sector + BFM');
%xlabel('SIR(db)');
%ylabel('PDF');

%%  new


N = 5;
```

```
d_l = .5;
alfa0 = 25;
alfa = -120:0.1:120;        % direction angle
%Ed = abs(sin(pi*d_l*8*(sind(alfa) - sind(alfa0) ))./...
 %                       sin(pi*d_l*(sind(alfa) - sind(alfa0))))/8;
%Ed0 = abs(sin(pi*d_l*6*(sind(alfa) - sind(alfa0) ))./...
 %                      sin(pi*d_l*(sind(alfa) - sind(alfa0))))/6;
%Ed01 = abs(sin(pi*d_l*4*(sind(alfa) - sind(alfa0) ))./...
                       % sin(pi*d_l*(sind(alfa) - sind(alfa0))))/4;
Ed0 = abs(sin(pi*d_l*5*(sind(alfa)))./...
                        sin(pi*d_l*sind(alfa)))/5;
Ed01 = abs(sin(pi*d_l*4*(sind(alfa)))./...
                        sin(pi*d_l*sind(alfa)))/4;
Ed= abs(sin(pi*d_l*8*(sind(alfa)))./...
                       sin(pi*d_l*sind(alfa)))/8;
Edl = 20*log10(Ed);
Edl0= 20*log10(Ed0);
Ed01l= 20*log10(Ed01);
%     fig = figure(16);
%     set(fig,'Position', [100, 100, 1049, 400]);
%     plot(alfa,Ed);
%     hold on;
%     plot(alfa,Ed0,'r');
%     grid on;
%     axis([-90 90 0 1]);
%     xlabel('angle [deg]');
%     ylabel('Normalized array factor,Radiation pattern');
%     title(['Number of elements = ',num2str(N),', d/\lambda = 0.5']);
%     legend('\beta = 120 deg','\beta = 0 deg','Location','NorthWest')
    figure(17);
    plot(3*alfa,Edl,'k.-');
    hold on;
    plot(3*alfa,Edl0,'r');
    plot(3*alfa,Ed01l,'--');
    grid on;
    legend('N=4','N=5','N=6','Location','NorthWest')
    axis([-100 180 -20 0]);
    xlabel('Beam Direction Degree [deg]');
```

```
    ylabel('Power dB');


    %%
figure()
x=[1   2   3   4   5   6];
y1=[25.5 28.4 30.4 29.8 29.6 29.5];
y3=[25.6 28.5 30.5 29.9 29.7 29.6];
y2=[25.6 28.6 30.6 30.0 29.8 29.7];

plot (x,y1,'r');
hold on

plot (x,y2,'k');
hold on

plot (x,y3,'b');
hold on
grid on
 xlabel('the number of beam per sector');
 ylabel('SIR dB');
 title(['Number of elements = ',num2str(N),', d/\lambda = 0.5']);
 legend('elements 4','elements 5','elements 6')
```