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Performance Analysis Resources Allocation in Coordinated Multi-cell systems

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DECLARATION

قال تعالى:

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

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DEDICATION

All praises to **Allah** for the strength and his blessing in completing this research. We dedicate this research to beloved people who have meant and continue to mean so much to us. Our dedication is extended also to our caring mothers; who held our hands in the first day of school, and be always there for us giving all the love, supporting, and care, to our fathers; who always be proud of us and for sacrifices they have made to educate us, and to our friends; who always be there when we needed them. To **Emad Drdiri Ahmed** the father of our colleague **Tasbeeh** who leafed this life we ask **Allah** to bless his soul. Finally to all our friends, and teachers who we met them in Sudan University of Science and Technology in all our educational march, ***Thanks to all of you.***

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In preparing this thesis we met many wonderful, and great people who stand, encourage, and support us, we say to them from our hearts thank you for all that, and we dedicate this thesis to you. To supervisor **Dr. Ibrahim Kidder** special thanks to you for your guidance, supports, and encouragement. Special thanks to **Dr. Fath Elrahman Ismael Khalifa** for his support. Special greeting to **eng: Rajaa Omer** from **Sudatel Company** for her support. Great love to our families because of their love and their patience.

ABSTRACT

The main aim of this thesis is study the optimum usage methods of wireless networks resources. Because of great growing requests of telecommunications services that have high efficient and quality, emerges of real-time systems, and multimedia systems, all of those reasons and else caused of consuming and wasting the resources especially Long Term Evolution (LTE-4G) networks. In this generation the number of subscribers becomes great, so organizing, coordinating, and allocating the resources consider a critical process to ensure that the service that has acceptable quality, and efficiency is available for all subscribers Quality of Service (QoS) consider one of the metrics of measuring the work, and performance any communication system especially in 4G networks, Coordinating process aims to participating and cooperating between neighboring evolved Node Base Station (eNodeB) to achieve suitable coverage to cell, do not occur an interference and noise because of those neighboring eNodeBs in particular in the edges of cells. Allocation process is one of the important processes to enhance, and developing any communication systems, where specifies and allocates resources that we want to distribute them among users based on dedicated algorithms, and equations for this purpose.

المستخلص

الهدف الأساسي لهذه الدراسة هو معرفة طرق الإستغلال الأمثل لمصادر الشبكات اللاسلكية ، و بسبب الطلب المتزايد لخدمات الإتصالات المتنقلة ذات كفاءة و جودة عالية وظهور خدمات الأنظمة الآنية ، و أنظمة الوسائط المتعددة كل هذة العوامل و غيرها تسببت في استنزافٍ كبيرٍ جداً لمصادر الشبكات اللاسلكية و بالأخص أنظمة الإتصالات المتطورة (شبكات الجيل الرابع) حيث في هذا الجيل بذات أصبح عدد المشتركين كبير جداً، فلذلك تحتم تنظيم و تنسيق و تخصيص استخدام هذة المصادر لكي تتوفر الخدمة لكل المشتركين بكفاءة و جودة عالية; جودة الخدمة تعتبر من مقاييس عمل أي نظام إتصالات الذي أصبح من أهم متطلبات أنظمة الإتصالات المتطورة (شبكات الجيل الرابع) حيث لابد من أخذه بالإعتبار في تصميم أي نظام أو إجراء فيه.ان عملية التنسيق تهدف للسماح بالتشارك و التعاون بين محطات الأرسال المتجاورة لتحقيق أنسب تغطية للخلية و عدم حدوث التداخل و التشويش بين كلا المحطتين و بالأخص في المناطق الموجودة على حواف هذة الخلايا .عملية التخصيص هي من العمليات الأساسية في تحسين و تطوير أي نظام إتصالات حيث يتم فيها تخصيص و تحديد المصادر المراد توزيعها على المستخدمين بناءأ على خوارزميات و معادلات رياضية مخصصة لذلك.عملية الجدولة هي من طرق التخصيص المهمة حيث تقوم بترتيب الأولويات و المهام الضرورية الواجب تنفيذها وفق متطلبات الخدمة المقدمة، وهناك نوعان لعملية الجدولة النوع الأول يضمن العدالة بين جميع المستخدمين للخدمة المقدمة ،أما النوع الأخر فإنه يوفر عدالة نسبية لكل المستخدمين على حسب متطلباتهم مع ضمان جودة الخدمة لهم جميعاً.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

LTE	Long Term Evolution
HSPA	High Speed Packet Access
3G	Third Generation of Cellular Wireless Standards
MIMO	Multiple Input Multiple Output
FDD	Frequency Division Duplex
TDD	Time Division Duplex
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
SC-FDMA	Single Carrier Frequency Division Multiple Access
FDMA	Frequency Division Multiple Access
BS	Base Station
eNodeB	evolved Node Base Station
MS	Mobile Station
UE	User Equipment
RB	Resource Block
RE	Resource Element
SNIR	Signal to Noise-Interference Ratio
RR	Round Robin
PF	Proportional Fair
DL	Downlink
HSDPA	High Speed Downlink Packet Access
EUL	Enhanced Uplink

SC	Single Carrier
SISO	Single Input Single Output
MME	Mobility Management Entity
CP	Cyclic Prefix
HARQ	Hybrid Automatic Retransmission Request
RS	Reference Signal
CIR	channel impulse response
PRN	pseudorandom number
WCDM	Wideband Code Division Multiple Access
PHY	Physical layer
MAC	Medium Access Control
RLC	Radio Link Control
RRC	Radio Resource Control
IEEE	Institute of Electrical and Electronics Engineers
4G	Fourth Generation of Cellular Wireless Standards
SNR	Signal to Noise Ratio
PS	Packet Scheduler
TTI	Transmission Time Interval
MCS	Modulation and Coding Scheme
QoS	Quality of Service
AMC	Adaptive modulation and coding
PRBs	Physical Resource Blocks
RRM	Radio Resource Management
CCI	co-channel interference
VoIP	Voice over Internet Protocol
QPSK	Quadrature Phase-Shift Keying
QAM	Quadrature Amplitude Modulation

C QI	Channel Quality Indicator
ICIC	Inter cell Interference Coordinated
eICIC	enhanced Inter cell Interference Coordinate

LIST OF SYMBOLS

y_k	-	Received Signals.
$h_k{}^H$	-	No Channels for each user.
x	-	Transmitted$\sum_{k=1}^{kr} S_k$ Signals.
n_k	-	Noise for each user, $n_k \in \mathbb{C}$.
C_k	-	Coordination from **BS_k.**
Di	-	Data from BS_k.
Si	-	Signal.
$\sum_{i=1}^{kr}$ DiSi	-	Transmitted Signals.
$SINR_k$	-	**S**ignal –to-Noise Interference –Ratio.
U(r)	-	Utility function.
r_i	-	is the allocated rate to the UE**.**
MS_k	-	is measured by an arbitrary continuous**.**

LIST OF APPENDICES

Chapter One

Introduction

Chapter1
Introduction

1.1 Preface:

The rapid growth usage of wireless technology led to consume the resources of the network, so we must optimize the resources and divide them wisely. Cell is the main core in wireless communications so the geographical allocation is very important to provide suitable coverage. Users have disparate needs from area to area, for example rural areas differ from urban area so. Antenna is a backbone of wireless system so its location inside the cell is crucial factor to propagate frequency through cell. Resources allocation are necessary to prevent wasting our limited resources. Increasing BSs increases the costs and complicates the system. A possible solution is to allow the network to grow in an organic fashion. This calls for self-configurable approaches for resource allocation which not only improve the performance but also decrease the network planning as well as maintenance costs. The performance means the spectrum efficiency, peak data rate, cell-edge data rate, of current cellular systems is mainly limited due to the presence of inter-cell interference.

1.2 Problem Statement:

The variation of performance in a network and consuming its resources considered a weak point in it.

1.3 Proposed Solution :

The allocation of resources is necessary to make a network works efficiency by using scheduling algorithm and coordination techniques to allocate the resources of a network.

1.4 Objectives:

The objectives of thesis are to:

- To study the resources allocation techniques.
- To model some of its techniques (Scheduling, Coordination).
- To simulate and evaluate the performance of resource allocation techniques. Using round-robin, first come first serve (fcfs) (Scheduling). Zero-forcing (ZF) (Coordination).

1.5 Methodology:

Describe the Resource allocations techniques that implemented in the network, by using mathematical modeling then simulate using **MATLAB.**

1.6 Thesis Outline:

This thesis includes the following:

Chapter 1 presents the introduction.

Chapter 2 describes the background.

Chapter 3 explain modelling of resource allocation techniques.

Chapter 4 presents the simulation and results.

Chapter 5 shows the conclusion and recommendations.

Chapter Two

Background

&

Literature Review

Chapter 2
Background

2.1 Introduction:

In economic resource allocation means assignment of available resources to every uses. Mobile Communication today is wide speared technology and as any technology we must manage its resources and develop techniques to use it effectively. The concept of resource allocation is defined as allocating transmit power among users and spatial directions, while satisfying a set of power constraints that have physical, regulatory, and economic implications. Resources in mobile communication: (Power-Frequency-Time). Mobile communication faces two main challenges, once is to determine the success of phone, second respective data traffic that generated by these devices.

2.1.1 Quick Overview of Wireless Standards:

In the past two decades we have seen the introduction of various mobile standards, from 2G to 3G to the present 4G, and we expect the trend to continue (see Figure 2- 1). The primary mandate of the 2G standards was the support of mobile telephony and voice applications. The 3G standards marked the beginning of the packet-based data revolution and the support of Internet applications such as email, Web browsing, text messaging, and other client-server services. The 4G standards will feature all-IP packet-based networks and will support the explosive demand for bandwidth-hungry applications such as mobile video-on-demand services.

Historically, standards for mobile communication have been developed by consortia of network providers and operators, separately in North America, Europe, and other regions of the world. The second-generation (2G) digital mobile communications systems were introduced in the early 1990s. The technology supporting these 2G systems were circuit-switched data communications.

The GSM (Global System for Mobile Communications) in Europe and the IS-54 (Interim Standard 54) in North America were among the first 2G standards. Both were based on the Time Division Multiple Access (TDMA) technology. In TDMA, a narrowband communication channel is subdivided into a number of time slots and multiple users share the spectrum at allocated slots. In terms of data rates, for example, GSM systems support voice services up to 13 kbps and data services up to 9.6 kbps.

The GSM standard later evolved into the Generalized Packet Radio Service (GPRS), supporting a peak data rate of 171.2 kbps. The GPRS standard marked the introduction of the split-core wireless networks, in which packet-based switching technology supports data transmission and circuit-switched technology supports voice transmission. The GPRS technology further evolved into Enhanced Data Rates for Global Evolution (EDGE), which introduced a higher-rate modulation scheme (8-PSK, Phase Shift Keying) and further enhanced the peak data rate to 384 kbps.

In North America, the introduction of IS-95 marked the first commercial deployment of a Code Division Multiple Access (CDMA) technology. CDMA in IS-95 is based on a direct spread spectrum technology, where multiple users share a wider bandwidth by using orthogonal spreading codes. IS-95 employs a 1.2284 MHz bandwidth and allows for a maximum of 64 voice channels per cell, with a peak data rate of 14.4 kbps per fundamental channel. The IS-95-B revision of the standard was developed to support high-speed packet-based data transmission. With the introduction of the new supplemental code channel supporting high-speed packet data, IS-95-B supported a peak data rate of 115.2 kbps. [1]

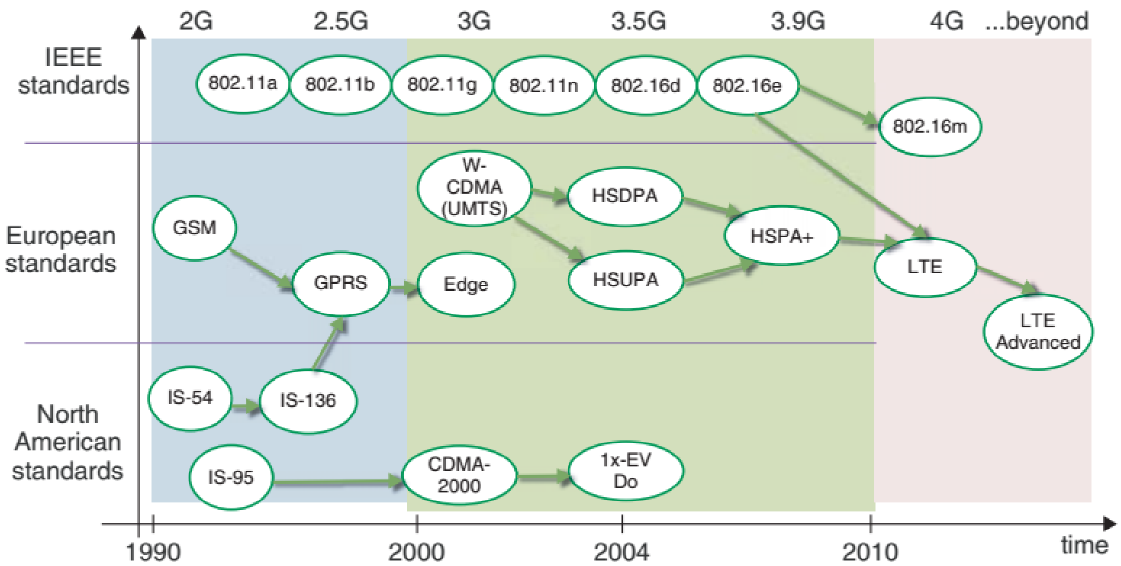

Figure 2- 1: evaluation of wireless systems from 2G to 4G [1].

3GPP (3rd generation partnership project) introduced the LTE. Attain the revolution in the up-and-coming applications with high throughput, low packet loss ratio, less delay and useful bandwidth.

The ultimate goal of LTE is enhancing data rate. It provides radio resources for many of applications to meet with optimize level of QoS, for all connected users [1].

LTE support many of applications like video streaming, video conferencing, voice over IP (VoIP), web browsing, file transfer etc. Now with approximate 500 million LTE users as of early 2015 are present. Due to this reason, both researchers and industrialists are trying their best to enhance the system quality for LTE heterogeneous network [2].

2.1.2 OFDMA:

OFDMA (orthogonal frequency division multiplexing) technology is utilized by LTE system for downlink. OFDMA divides the given bandwidth into various subcarriers. This also provides group of subcarriers to the user, meeting with QoS standards [3].

To meet the performance objectives, it is very essential to design an efficient scheduling algorithm for resource allocation and fairness, with enhancing the spectral efficiency of the system. Scheduling is essential also for distinguishing the services of one wireless network to the other [4].

2.2.1 Overview of LTE Network Architecture:

In the previous technology, separate Radio Access Network (RAN) was employ to connect with User Equipment's (UEs). However eNB (evolved Node Base station) in LTE (latest technology), have the duty of caring for these protocols. Hence LTE required lesser number of nodes, which have the benefits of low system delay and improved overall performance of the system [5].

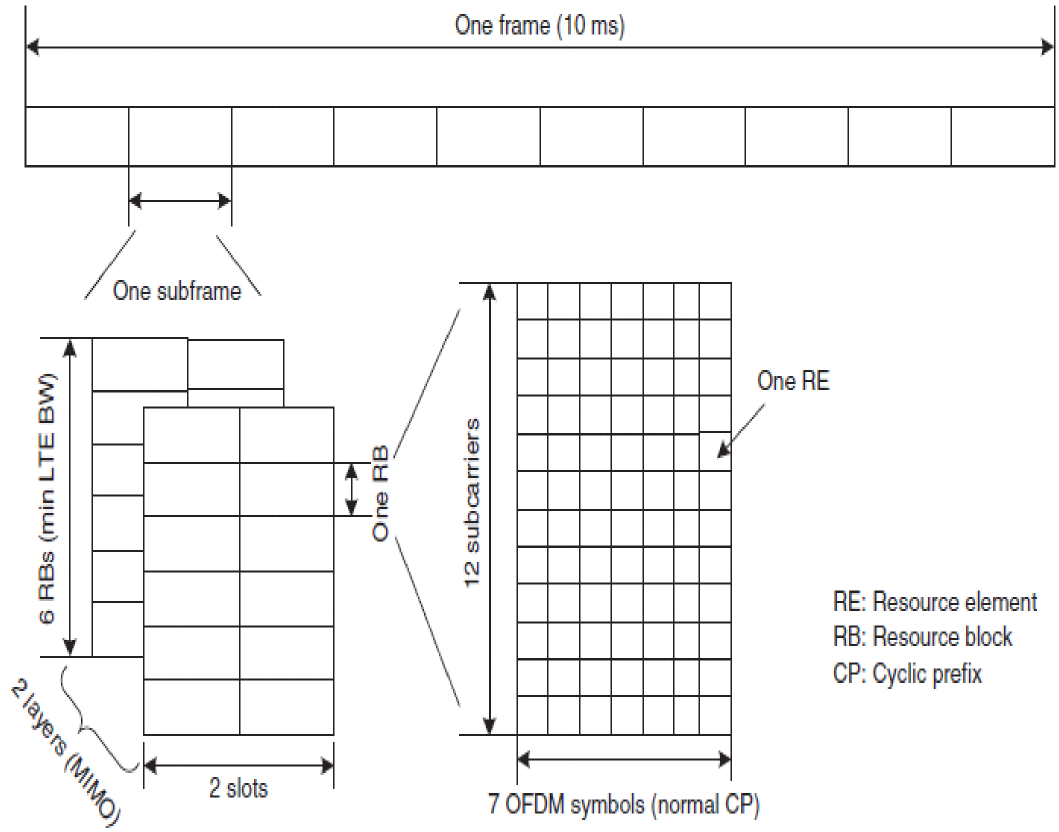

Figure 2- 2: LTE frame structure [2].

2.2.2 Resource Block:

In the time domain RB consists of duration of0.5ms time slot and in frequency domain RB (Resource Block) consists of 12 consecutive subcarriers. Recombination of these two slots makes an allocation period. Smallest allowance unit in LTE is the Resource Block.

TTI: Transmit Time Interval (TTI) is also called scheduling period and its duration is 1ms [6].

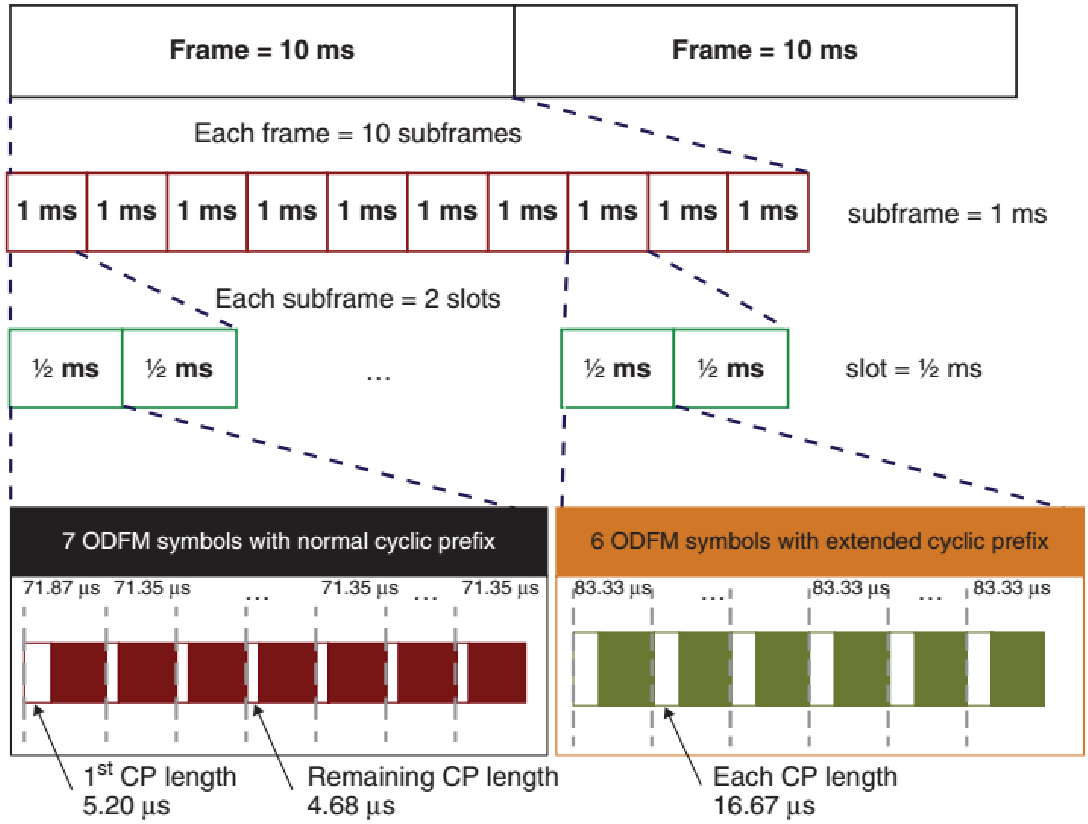

Figure 2- 3: LTE Downlink Resource Block Structures [1].

2.2.3 LTE-Advanced:

LTE-A is also the mobile communication standard and advance version of LTE. To support the rising demand, hundred times of increase in capacity is required, that's why LTE-A was introduced. LTE-A provides high capacity, high bit rate in efficient cost. This can be get by increasing the network density, by providing more spectrums and with the improvement of spectral efficiency. And network density can be increased by arranging small cells overlay networks over the area of macro coverage. LTE, termed as 4G Standards are given below [7].

Table 2.1 evolution of network peak data rates [1].

Technology	Theoretical peak data rate (at low mobility)
GSM	9.6 kbps
IS-95	14.4 kbps
GPRS	171.2 kbps
EDGE	473 kbps
CDMA-2000 (1xRTT)	307 kbps
WCDMA (UMTS)	1.92 Mbps
HSDPA (Rel 5)	14 Mbps
CDMA-2000 (1x-EV-DO)	3.1 Mbps
HSPA+ (Rel 6)	84 Mbps
WiMAX (802.16e)	26 Mbps
LTE (Rel 8)	300 Mbps
WiMAX (802.16m)	303 Mbps
LTE-Advanced (Rel 10)	1 Gbps

Table 2- 2: Main LTE Performance Targets [7].

Feature	Performance
Peak Data Rate	-Downlink: 100 Mbps -Uplink: 50 Mbps
Spectral Efficiency	2 – 4 times better than 3G systems
Cell-Edge Bit-Rate	Increased whilst maintaining same site location as deployed today
Mobility	- Optimized for low mobility up to 15 km/h

	- High performance for speed up to 120 km/h - Maintaining connection up to350 km/h
Scalable Bandwidth	From 1.4 to 20MHz
RRM	- Enhanced support for end-to-end QoS - Efficient transmission and operation of higher layer protocols
Service Support	- Efficient support of several services (e.g., web-browsing, FTP, video-streaming, VoIP) - VoIP should be supported with at least a good quality as voice traffic over the UMTS network

2.3 Heterogeneous Network:

Small cells of different types together with the macro cells form a network known as Heterogeneous Network [7].

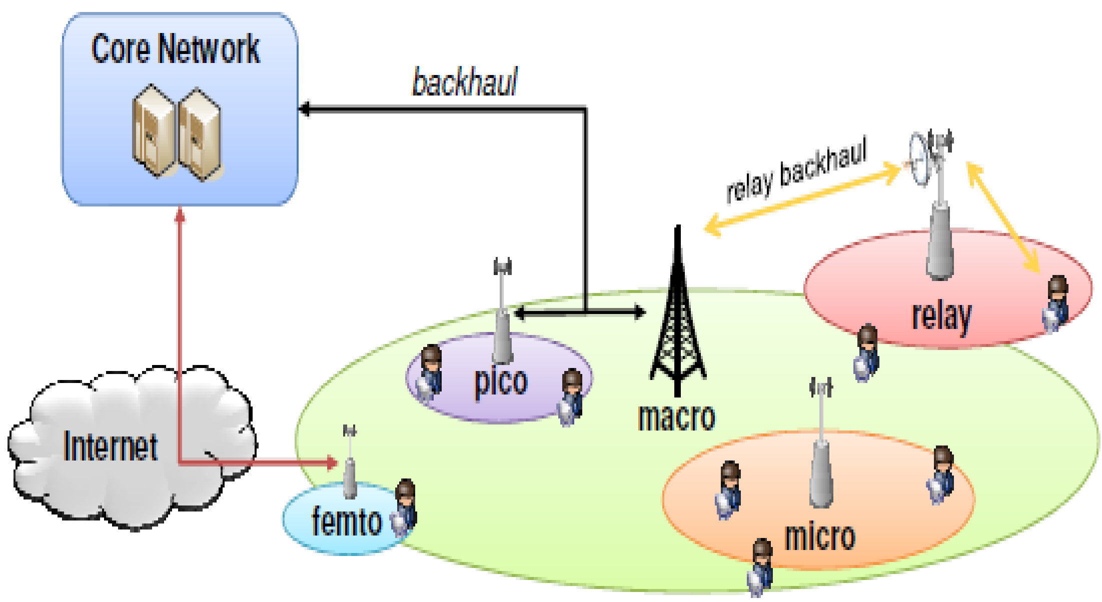

Figure 2- 4: Heterogeneous Network (Small cell deployment) [7]

2.3.1 Small Cell:

These small cells relieve of the data-load from the macro region. These kinds of small cell also get better the reuse of frequency. A small cell can be indoor femto cell or outdoor pico cell. Small cells also reduce the cost with improving network capacity [8].

2.3.2 FemtoCell (FC):

LTE-A utilizes FC technology. FC provides efficient connection with the macro cell network through a broadband backhaul i.e. cable modem and DSL (Digital Subscriber Line). FC is a low range, less cost and less power home base station [8].

2.3.3 Microcells and Picocells:

These are deployed to facilitate hundreds of users. These are used in small networks which may or may be not in the range of a MC. Picocell are designed for the network operating in the premises of indoor areas like airports, bus station and office place etc.

2.3.4 MacroCells (MCs):

MCs are the common cells sites supporting technologies like LTE. Their normal range is from a few hundred meters to a few kilometers [8].

2.3.5 Radio Resource Management (RRM):

RRM is used to deal with all of wireless associated tasks i.e. management, allocation and division etc… [9].

2.3.6 FemtoCell (FC)

LTE-A Femtocells (FCs) provides a higly benifit to the always growing bandwidth requirement of cellular phone devices. With the deployment of FC, the on the whole capability of the cellular phone system could be highly enhanced. FCs are simply installed exclusive of having a mid point setting, with offering a peak speed of data connection, while utilising the bounded coverage area. Here we disscussed the FC access networks types and Femto acess modes for dense area. We also discussed the challenges and their solutions for the interference and mobility management to the FC network. Finally, we provide a guide line for dense areas network planning for LTE FC technology [10].

2.4.1 HetNet Scenario:

Further moving on, the 3GPP has launched in the LTE-A terms, this is opportunity of set up a Het-Net (Heterogeneous Network) consist of macro and less-range (like micro, pico, and femto) cells [11].

2.4.2 Mobility management scheme (MMS):

MMS is a solution test, like in condition of a high capacity operation. This cannot achievable to a FC for find the path by its nearer for handover procedure. That’s why a MMS is planned, there a middle joint called a HeNB (Home-evolved Node Base) Gateway is established; for the purpose of solution of the security and scalability problems caused by heavily large deployment of FCs [12].

2.4.3 The handover mechanism:

This mechanism principally defines the Quality of Service and speed of the user equipment for handover. Dissimilar to the customary UMTS (Universal Mobile Telecommunication System) FC handover scheme. Because this scheme doesn't let the maximum speed subscribers for handover, but less speed subscribers be allowed from MC to FC. All at once, real-time and non-real-time (NRT) subscribers are also distinguished by this mechanism. The scheme could diminish a redundant handover particularly for maximum speed subscribers and NRT subscribers. Therefore entire quantity of handovers is lessened [13] .

2.4.4 Interferences:

In situation of a FC system, following types of interferences happen [13].

2.4.4.1 Co-tier interference: It happens among nearby FCs, which use the similar sub channels.

2.4.4.2 Cross-tier interference: This happens between FCs and MCs

2.4.5 Fractional Frequency Reuse (FFR) and Resource Distributions:

A fundamental method for FFR scheme makes partition of the whole frequency band into numerous sub bands. Further, every co-spectrum is allocated to every MC or co-region of the MC, in a different way. Because the resource for MeNB and HeNB don't interfere to each other. FFR method does lessen both of the interferences [14].

2.4.6 AGuide Line for arrangement in a high capacity area network:

- **1st Step**: for raise of the capacity, a raise in the quantity of the femto approach positions is required by the help of related schemes for minimizing finishing the interference.
- **2nd Step**: for FC nature and its related approach criteria, this is vital to alter the nature of FC, from home to metro enterprise or place the admission control approach for adaptive consisting for capacity of the FC.
- **3rd Step**: for the mitigation of interference, a hybrid interference management technique proved essential. This scheme joins the energy manage with the resource distribution such as FFR.
- **4th Step**, to get the top user offloading for the femto network level. For this purpose, femto access nodes ought to be installed on the spaces, where there exist encouraging channel settings for the femto approach nodes. Finally, adaptive FC access mode must be utilized [15].

2.5 Scheduling:

Main goal of a Scheduler is to get the optimize allocation of the resources in the units like time, frequency and power etc for the UEs, with satisfying level of QoS. "Scheduling means if you have number of resources and you have to decide that how to distribute them in different active users for their QoS requirements".

Scheduler exists in the Base Station. It controls the assigning of RBs among Users with the defending of intra-cell interference. For different networks there are different schedulers [10].

2.5.1 Smart scheduler and its features:

Boosting cell edge performance is the main purpose of Smart Scheduler [16]. Frequency Selective Scheduling (FSS) is the most important part of Smart Scheduler.

2.5.2 Smart scheduler uses the following features:

- Frequency Selective Scheduling (FSS): It enhances network efficiency in the event for frequency selective fading and fractional inter-cell interference. This also consists of Interference Aware Scheduling (IAS) and Channel Aware Scheduling (CAS). FSS can improve cell edge data rates by more than 30%.
- When allocating the uplink transmission power, Uplink power control with interference awareness takes into account the adjacent cells. This feature helps to boost uplink data rates and minimizes inter-cell interference.
- In weak channel conditions, QoS differentiation improves cell edge performance by allocating more resources. For example for video streaming services QoS conditions can be used to maintain the data rate. The minimum cell edge data rate that is ensured can also be obtained by a Nominal Bit Rate (NBR) and it works even without QoS classes with ensured bit rates. There is a minor impact of Cell edge prioritization on the cell total throughput limit. The capacity is high measured in the number of satisfied subscribers. At the cost of

5% cell throughput capacity, the cell edge throughput improvement of 30% can be obtained [17].

2.5.3 Packet scheduling:

Its job is the use of different sources of information to allocate resources and coordinate activities, so that interference can be avoided. It also has the freedom of controlling the allocation of resources in time, frequency and power domains. Packet scheduler at radio base station done the assigning the portions of spectrum divided among users. In LTE system its main feature is the scheduling and we know it by the name of packet scheduling. Packet scheduler works for making the channel quality drop minimum. In cellular technologies we have different types of service of real-time multimedia like online video flows and VoIP service [18].

In video streaming a main requirement occurs which to deliver the information packet in the time limit. And the packet scheduler works by prioritizing the user on different aspects like its channel condition, traffic, type of service and packet delay. An inherited scheduler is used for best performance for application-stage video excellence which is proposed by the authors. And its basic function is to improve the accuracy of prioritization.

It is also used to divide the resources between different subscribers with a useful and appropriate method to enhance the network performance, increase the system throughput and improving the system fairness. In downlink networks, the scheduling is the main phenomenon which determines the downlink performance. LTE uses Hybrid ARQ for the fast and quick transmission of those packets which are un-correct. And HARQ is also used to keep the radio interference to the minimum extent [19].

2.5.4. Scheduling Strategies:

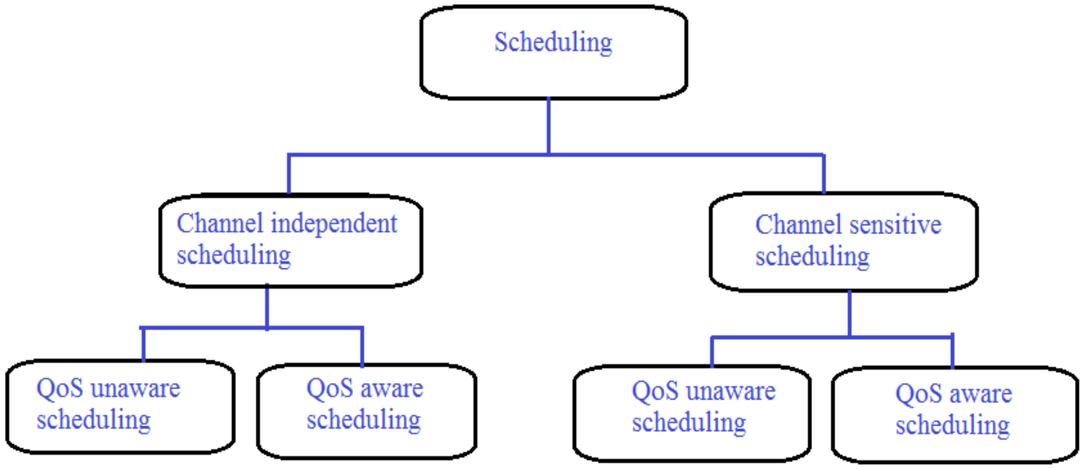

Figure 2- 5: General classifications of scheduling [19].

2.5.5 Channel sensitive scheduling:

The UEs sent CQI (Channel Quality Indicator) value reports to the eNB. Here the Scheduler can adjust the channel quality of each UE. This is called channel sensitive scheduling (CSS). Examples of channel sensitive schedulers are Proportional Fairness (PF), Maximum-largest weighted delay first (M-LWDF**),** Buffer-Aware scheduler etc. Figure (2.6)

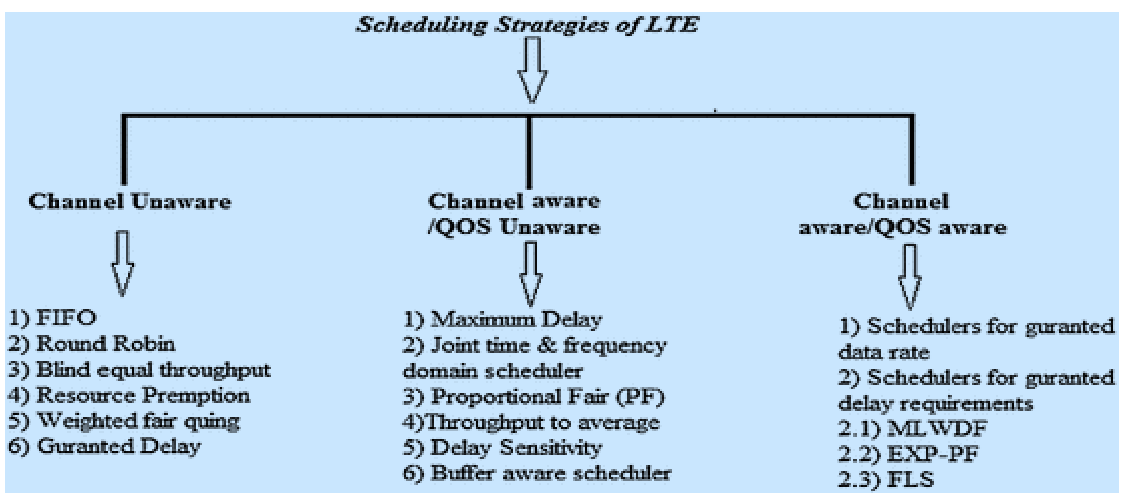

Figure 2- 6: Scheduling Strategies of LTE [19]

Table 2- 3: Comparison between different scheduling Algorithms [7].

Scheduler Type	**Advantages**	**Drawbacks**
1. Proportional Fairness (PF)	• Optimization of Throughput • Allocation of more resources to the users with Fairness • High spectral efficiency	• Real-time multimedia traffic can't be supported
2. M-LWDF	• Good Fairness • High Spectral Efficiency • Less Packet loss ratio • Less queuing delay • Capable to deal with Real time and no real time flows, easily.	• More energy consumption • More complex. • Inefficient in overloaded conditions.
3. Exponential Scheduler	• High user fairness • High throughput • Low packet loss ratio in multimedia traffic • Capable to deal with Real time and non real time flows, easily.	• Low spectral efficiency • More energy consumption • Complex

4. Round Robin (RR)	• Simple • High user fairness • Provide resources cyclically to the users	• Low throughput performance • Not suitable for real-time multimedia traffic • Inefficient • Channel conditions not known
5. Buffer-Aware Scheduler	• Maximum throughput • High spectral efficiency	• Real-time multimedia traffic can't supported • Less user fairness
6. Max-Min Scheduler	• High throughput • High spectral efficiency • Less packet loss ratio	• Less user fairness • Not suitable for real-time multimedia traffic

Key design aspects are: Complexity and Scalability, Spectral efficiency, Fairness, QoS Provisioning.

2.5.6 Best CQI:

This scheduling works by checking the radio link on the basis of the channel quality, the best radio link will get the resource block. Resource block is assigned to the user with the best CQI because the higher CQI means better conditions of the channel. It works by sending the CQI to base station (BS) [20].

2.7 Coordination concept cellular systems:

The coordination in conventional cellular systems, each base station transmits signals intended for users within its cell coverage. The objective of network coordination is to enable cooperation between the base stations so that useful signals, as opposed to the interference, can be received from the neighboring base antennas [21].

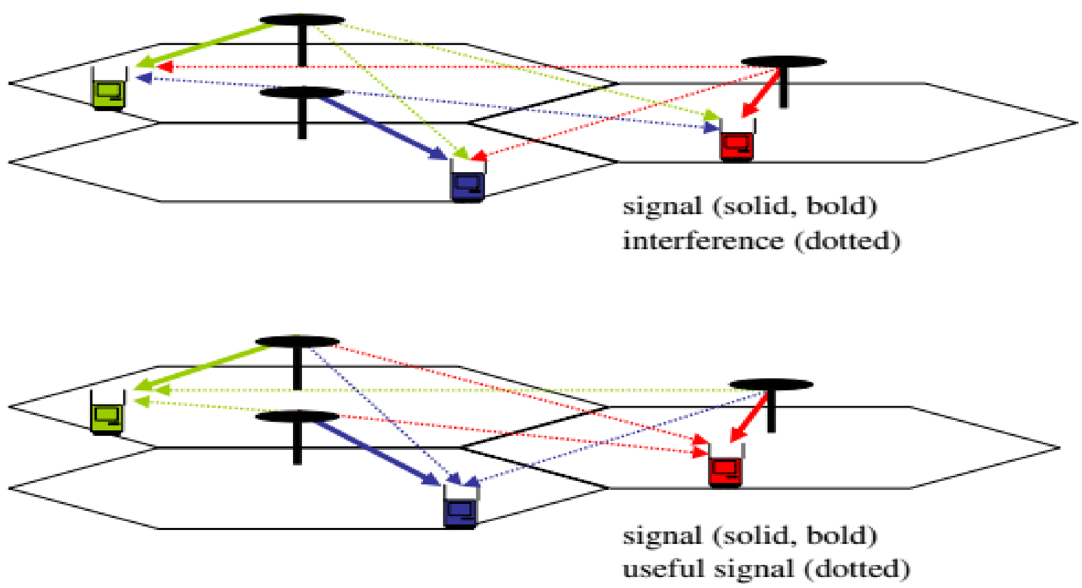

Figure 2- 7: Conventional Cellular Networks (top) vs. Coordinated Networks (bottom) [21].

2.8 The Coordinated Networks Transmission Methods are:

- ER-ZF-CCT: Equal rate, multiple base, coherently coordinated transmission based on zero forcing (ZF). ZF transmission serves each user in a way that does not cause interference to any other user.
- ER-DPC-CCT: Equal rate, coherently coordinated transmission employing dirty paper coding (DPC). DPC is a form of known-interference

cancelling stemming from the fact that it is the collective of all network bases that is the source of signals to the users. Consequently, the bases' knowledge of all downlink network signals enables the encoding of a desired user's signals so that its interference is invisible to certain other users. The specific (suboptimal) form of DPC that we use will be combined with a reduced form of ZF so that together all interference is removed.

- FP-SBT: Full power, single-base transmission. Under this method, each user receives a signal from its assigned base that is transmitted at full power. This is only included because the method is so simple, and it is of some interest to see what is achieved when nothing is done to mitigate interference apart from the assignment of 10% of the users to outage.
- ER-SBT: Equal rate, single-base transmission with power control.

The concept of resource allocation is defined as allocating transmit power among users and spatial directions, while satisfying a set of power constraints that have physical, regulatory, and economic implications. A major complication in resource allocation is the inter-user interference that arises and limits the performance when multiple users are served in parallel [22].

The concept of cell outage management has been introduced. This concept consider a functional aim to detect and mitigate outages that occur in radio networks due to unexpected failures, detect, and compensate outages as well as to develop and evaluate the required algorithms. We envisage that future radio networks autonomously detect an outage based on measurements, from e.g., user equipment and base stations, and alter the configuration of surrounding radio base stations in order to compensate for the outage-induced coverage and service quality degradations and satisfy the operator-specified performance requirements as much as possible.[23].

The Coordinated Multi-Point (CoMP) to improve and develop the 3GPP, LTE-Advanced Standard. In downlink CoMP coordinated beamforming systems. MIMO transmit precoding and resource allocation are linked to the underlying proportional-fair scheduling to ensure a good trade-off between cell-average and cell-edge user spectral-efficiency .To solve for optimal operating point for MIMO CoMP network, a parallel successive convex approximation (SCA)-based algorithm is introduced. The introduced scheme enables all base stations to update their optimization variables in parallel by solving a sequence of strongly convex subproblems. The result of optimizing problem becomes nonconvex. To solve for optimal resource allocation strategies including downlink precoding and power allocation for CoMP-CB transmissions, we have introduced a stochastic parallel successive convex approximation based algorithmic framework for a general non convex stochastic network proportional-fair metric optimization problem. The introduced novel decomposition enables all base stations to update their optimization variables in parallel by solving a sequence of strongly convex sub problems. Moreover, closed form expressions of the locally optimal solution are characterized in some special cases as well as in both high and low SNR regimes [24].

The techniques for multi-cell MIMO (multiple input multiple output) introduced cooperation in wireless networks and the techniques used to treat mobile communication challenges. Interference is a major challenge facing any designer of mobile communication. Interference restricts the reusability of the spectral resource (time, frequency slots, codes, etc.), also fading is a challenge in mobile communication it puts limits on the coverage and reliability of any point-to-point wireless connection. In dense networks where interference emerges as the key capacity limiting factor, multi-cell cooperation can dramatically improve the system performance. Remarkably, such techniques literally exploit inter-cell interference by allowing the user data to be jointly processed by several interfering base stations, thus mimicking the benefits of a large virtual MIMO array. Inter-cell interference is treated as noise at the receiver side and is handled by resorting to improved point-to-point communications between the base station (BS) and the mobile station (MS), using efficient coding and/or single-link multiple-antenna techniques. Some interference mitigation is offered by limited inter-cell coordination, which is conventionally restricted to scheduling or user assignment mechanisms (e.g. cell breathing) or soft handover techniques. Cooperative systems are still in their infancy and much further research is required in order to fully understand. Unlike standard MIMO systems where the cost of multi-antenna processing lies in the extra hardware and software at individual devices, cooperative MIMO techniques do not necessarily require extra antennas, also the information exchange is subject to tight delay constraints which are difficult to meet over a large network. MIMO-cooperation offers additional benefits over simpler beamforming coordination schemes, but it requires user data sharing among several BSs and more complex precoding and decoding. Fading is included in the Wyner model, but the fading parameters are always assumed to be known perfectly at the mobiles and/or base stations. Future work must consider the impact of channel uncertainty, and the cost of measuring the channels in the network. Bounds on capacity under channel uncertainty are needed, and the coupling of channel uncertainty with limited backhaul bandwidth is an important area yet to be explored. Information-theoretic models provide tractable, elegant capacity formulas that are amenable to optimization, and performance bounds against which practical schemes can be compared [25].

The formulation of the resource allocation problem as a utility optimization and the development to distribute the algorithm for joint power control and user scheduling. The algorithm makes novel use of a class of fairness measures for determining user scheduling and is shown to be very efficient for realistic network parameters. Additionally, using a practical model for the LTE air interface that captures geographic distribution of users and buildings, we provide for a framework that allows comparison of different resource allocation algorithms. A variety of problem formulations, including femtocell density, resource tradeoff, and complexity-optimality tradeoff are derived and analyzed using a geometry-based stochastic LTE air interface model. Our analysis also offers useful guidelines for the planning and design of macro cells and femto cells .LTE networks comprising macro cells plus femto cells are beginning to offer economically viable solutions to achieving high user capacity. The above coupled with the growing impetus for frequency reuse, underscores the need for efficient resource allocation mechanisms in such networks [26].

The benefit of coordinating transmission strategies and resource allocation schemes across multiple cells for interference mitigation has been examined, for a multicellular network serving multiple users per cell sectors and where both the base-stations and the remote users are equipped with multiple antennas, and proposes a joint proportionally fair scheduling, spatial multiplexing, and power spectrum adaptation method that coordinates multiple base stations with an objective of optimizing the overall network utility. The main goal here is to show that by jointly setting the scheduling, power allocation, and beam forming strategies of multiple base stations and multiple mobile users within each cell, inter cell interference can already be alleviated, and the overall performance of the network can already be improved significantly as compared to the current generation of wireless networks where cells operate independently [27].

The use of multiple antennas at base stations is a key component in the design of cellular communication systems that can meet high-capacity demands in the downlink. Under ideal conditions, the gain of employing multiple antennas is well-recognized: the data throughput increases linearly with the number of transmit antennas if the spatial dimension is utilized to serve many users in parallel. The practical performance of multi-cell systems is, however, limited by a variety of non-idealities, such as insufficient channel knowledge, high computational complexity, heterogeneous user conditions, limited backhaul capacity, transceiver impairments, and the constrained level of coordination between base stations. The general framework for modeling different multi-cell scenarios, including clustered joint transmission, coordinated beamforming, interference channels, cognitive radio, and spectrum sharing between operators. The framework enables joint analysis and insights that are both scenario independent and dependent. The performance of multi-cell systems depends on the resource allocation; that is, how the time, power, frequency, and spatial resources are divided among users. The concept of resource allocation is defined as allocating transmit power among users and spatial directions, while satisfying a set of power constraints that have physical, regulatory, and economic implications.

Resource allocation is particularly complex when multiple antennas are employed at each base station. However, the throughput, user satisfaction, and revenue of multi-cell systems can be greatly improved if we understand the nature of multi-cell resource allocation and how to exploit the spatial domain to obtain high spectral efficiencies. The user performance depends on functions of the SINRs (e.g., information rate, MSE, or error probability), which in turn depends on the selection of signal correlation matrices. Ideally, the optimal resource allocation is computed at a central control station with aggregate CSI (Channel State Information) knowledge from the whole system, but this is practically infeasible in terms of computational complexity, backhaul signaling, delays, and scalability [28].

LTE is the evolution of the Universal Mobile Telecommunications System (UMTS). LTE intends to create a new radio-access technology which will provide high data rates, a low latency and a greater spectral efficiency. The downlink physical resource of the LTE is represented as a time-frequency resource grid consisting of multiple Resource Blocks (RB). A scheduler is a key element in the Base Station (BS) and it assigns the time and frequency resources to different users in the cell. In this thesis the Best CQI and Round Robin scheduling algorithms were investigated. The implementation, analysis and comparison of both scheduling algorithms were done through simulations executed on a MATLAB-based downlink link level simulator from the Vienna University. The impact of the scheduling schemes on the throughput was examined and the fairness of each scheduling scheme was investigated [29].

Chapter Three

Explain modelling of resource allocation techniques

Chapter 3

Explain modelling of resource allocation techniques

3.1 Mathematical Modeling:

In representation of wireless communication we use vector analysis techniques. It is generally impossible to find perfect models of reality, or as famously noted in: “Remember that all system models are wrong.” Therefore, the goal is to formulate a model that enables analysis and at the same time is accurate enough to provide valuable insights. A major complication in resource allocation is the inter-user interference that arises and limits the performance when multiple users are served in parallel. Resource allocation is particularly complex when multiple antennas are employed at each base station. Mathematically, resource allocation corresponds to the selection of a signal correlation matrix for each user. This enables computation of the corresponding signal-to-interference-and-noise ratio (SINR) of each user [30].

3.1.1 Single cell antenna can formulate as following:

$$y_k = h_k^H x + n_k \qquad (3.1)$$

$y_k \in \mathbb{C}$: Received Signals,

h_k^H: No Channels for each user.

x:Transmitted $\sum_{k=1}^{kr} S_k$ Signals.

n_k: Noise for each user, $n_k \in \mathbb{C}$.

3.1.2 Multi-cell antenna can formulate as following:

$$y_k = h_k^H C_k \sum_{i=1}^{kr} DiSi + n_k \qquad (3.2)$$

y_k:Received Signals,

h_k^H :No Channels for each user

C_k: coordination from $\mathbf{BS_k}$.

Di :Data from BS_k .

Si: Signal .

$\sum_{i=1}^{kr}$ DiSi: Transmitted Signals.

n_k : Noise for each channel **.**

The performance of MS_k is measured by an arbitrary continuous, differentiable, and strictly monotonically increasing12 function $g_k(SINR_k)$ of the SINR. This function satisfies $g_k(0) = 0$, for notational convenience.

$$SINR_k(S_1,\ldots,S_{Kr}) = \frac{h_k^H C_k D_k S_k D_k^H C_k^H h_k}{\sigma_k^2 + h_k^H C_k (\sum_{i \neq k} D_i S_i D_i^H) C_k^H h_k} = \frac{h_k^H D_k S_k D_k^H h_k}{\sigma_k^2 + h_k^H C_k (\sum_{i \in I_k} D_i S_i D_i^H) C_k^H h_k} \quad (3.3)$$

$SINR_k$: Signal –to-Noise Interference –Ratio.

The mathematical field of MOPs Without loss of generality, our resource allocation problem is formulated as maximize**S**1**0**N,...,**S**Kr**0**N{$g_1(SINR_1),\ldots,g_{Kr}$ $(SINR_{Kr})$ subject to

$$\sum_{k=1}^{kr} 1tr(\mathbf{Q}lk\ \mathbf{S}k) \leq ql\ \forall l. \qquad (3.4)$$

This MOP can be interpreted as searching for a transmit strategy S1,...,SKr that satisfies the power constraints and maximizes the performance $g_k(SINR_k)$ of all users. Since the performance of different users are coupled by both power constraints and inter-user interference, there is generally not a single transmit strategy that simultaneously maximizes the performance of all users [30].

3.2 Resource Allocation:

The world of radio resource allocation for wireless s communications has had numerous directions relying chiefly on miscellaneous methods from linear algebra, machine learning, queuing theory, and so forth. An overwhelming of QoS-based radio resource allocation works that have been formulated as optimization problems in the realm of linear algebra and leverage application utility functions to define traffic requirements [31

].

3.2.1 Application Utility Functions:

Application utility functions have been used in a wide variety of researches which model characteristic features of the system. For modern cellular network, resource of applications running on the smart devices should account for QoS requirements for the traffic generated by the running applications. The degree to which the QoS requirements of application traffic are fulfilled can be expressed by the concept of application utility function, which maps a feasible rate allocation to a utility function value that is the QoS fulfillment percentage for that particular application.

The application utility functions modeling the QoS satisfaction of the elastic traffic generated by delay-tolerant applications, here, we can observe a decreasing return in the value of the application utility function as the allocated rate is increased. As we can see, the application utility function is convex everywhere. Other applications like telephony generate an inelastic traffic which needs rate in order to arrive within a given delay bound even though it does not care if the data arrives earlier.

The application performs poorly if the data packets arrive later than the delay bound. Utility function, which is denoted as $U(r)$ for the allocated rate$r$. Application utility functions have the following main properties:

- $U(0) = 0$.
- $U(r)$ is an increasing function r.
- $U(r)$ is twice differentiable in r.
- $U(r)$ is upper-bounded.

QoS is conducively modeled by sigmoidal and logarithmic utility functions in Eqs. (2.2) and (2.1) in that order

$$U(r) = c\left(\frac{1}{1 + e^{-a(r-b)}} - d\right) \qquad (3.5)$$

Here, $d = \frac{1}{1+e^{ab}}$ and $c = \frac{1+e^{ab}}{e^{ab}}$. It can be verified that *U(∞)* = 1 and *U*(0*)* = 0,where the latter is one of the formerly mentioned utility function properties and the former indicates that an infinite resource assignment leads to 100 % satisfaction. Moreover, it can be derived that the inflection point of the function in Eq. (2.1) is at $r = r$ inf $= b$ where the superscript "inf" stands for "infliction." This can be done by differentiating *U(r)* with respect to *r* twice and setting the second derivative equal to zero, i.e. , $\frac{\partial 2U}{\partial r2} = 0 \rightarrow r = b$.

Here, *r* max is the maximum rate where the application QoS is satisfied fully (100 % utility) and *k* is the utility function increase with increasing the rate *r*. It can be investigated that *U(r* max*)* = 1 and *U(*0*)* = 0 where the latter is the basic property of the utility functions and the former indicates that a 100 % QoS satisfaction is at *r* = *r max*. The normalized logarithmic function inflection point occurs at *r* = *r* inf = 0.

$$U(r) = \frac{log(1 + kr)}{log(1 + kr^{max})} \qquad (3.6)$$

3.2.2. Resource Allocation Formulations:

In the mathematics literature germane to utility functions and resource allocation, a wide variety of formulations have been presented and numerous solutions have been proposed [31].

- **Max-Min Resource Allocation:**

A feasible resource allocation achieves max-min fairness if an attempt for increasing a rate assignment to an entity in the system leads to reducing the assignment in another entity which do not have more resources than the entity which got more resources. Hence, this method obtains the highest utility value with the lowest values of utility. Using max-min fairness, we can shape the traffic, versus a First-Come First-Serve (FCFS) multiplexing, by not allowing a heavy flow of large packages block serving other flows in the network. In particular, for the utility function *U(r)* where *r* is the allocated rate, the max-min fairness can be formalized as Eq (3.7) max-min fairness policy cannot deal with bottlenecks in the network. Next, we look at the proportional fairness policy for resource allocation.[31]

$$r = argmax_r min_r U(r) \qquad (3.7)$$

- **Proportional Fairness:**

A feasible resource allocation achieves proportional fairness if it maximizes the system overall utility while providing with a minimal service to system entities needing resources. This is performed by assigning each flow a rate inversely proportional to its resource need. For the utility function $U_i(r_i)$, where r_i is the allocated rate to the ith UE, proportional fairness can be formalized as Eq. (3.8).

We observe that $U_i(r_i = 0) = 0$ which zeros the system utility, i.e., iN =1 $U_i(r_i)$. So, no UE will be assigned a zero rate under this formulation. Various methods of solving proportional fairness optimizations have been introduced in literature and the salient of them are the Weighted Fair Queuing (WFQ) and Frank Kelly algorithm. Frank Kelly algorithm is an iterative that allows UEs bid for resources until the algorithm reaches optimal allocation and the shadow price (amount of consumed resources per data bit). On the other hand, proportional fairness can be obtained by setting the inverse shadow price as the weights used for the WFQ [31].

$$r_i = argmax r_i \prod_{i=1}^{N} U_i(r_i) \qquad (3.8)$$

- **Round Robin Scheduling:**

Round robin method is used to allocate the radio resources to users, the first user will be served with the whole frequency spectrum for a specific period of time and then serve the next user for another time period. The previously served user will be placed at the end of the waiting queue to be served again in the next round. The entire new resources requests will also be placed at the end of the waiting queue. This scheme offers great fairness in radio resource assignment among the users but with low throughput. The principal advantage of Round Robin scheduling is the guaranty of fairness for all users. Furthermore Round Robin is easy to implement, that is the reason why it is usually used by many systems. Since, Round Robin does not take the channel quality information into consideration; it results in low user throughput. The flowchart of the Round Robin scheduling is shown in Fig (3.3) [29].

- **Frank Kelly Algorithm**:

Frank Kelly algorithm was a seminal work to achieve proportional fairness and proved that their method brings about Pareto optimal resource allocation for a proportional fairness formulation. The procedure commences as UEs send their bids w_i to a resource allocation manager entity that obtains the shadow price as addition of the bids averaged on the whole resources R available for the manager entity, i.e., $p = \frac{\sum_i^N w_i}{R}$. The bids to the shadow price ratio, $r_i = \frac{w_i}{p}$, derives the rates. Next, users check whether the rate are optimalby solving $r_{i,textopt} = arg\ maxr_i(U_i(r_i) - pr_i)$ and if $r_i \neq r_{i,opt}$, they transmit new bids $w_i = r_{i,opt}\, p$ to the resource allocation manager and the procedure iterates until a convergence occurs; that is the utility function derivative equals the shadow price $\frac{\partial Ui}{\partial ri}|_{ri=ri,opt} = p$ [31]

Algorithm 1 *Frank Kelly Algorithm*
Send initial bid wi(n = 1) to the resource allocation managing entity. ***loop*** *Calculateshadow price p(n)=* $\frac{\sum_i^N w_i}{R}$ *Receive shadow price p(n) from the resource allocation managing entity.* *Calculate allocated rate ri =* $\frac{w_i\ (n)}{p(n)}$

Solve $r_{i,textopt} = arg\ max r_i (U_i(r_i) - pr_i)$ *.s*

if $r_i \neq r_{i,opt}$ ***then***

Calculate $w_i = r_{i,opt}\ p$.

Send the bid wi(n) to the resource allocation managing entity.

end if

end loop

3.3 Type of Resource Allocation:

The resource allocation can be divided in two types:

- Centralized Resource Allocation.
- Distributed Resource Allocation [30].

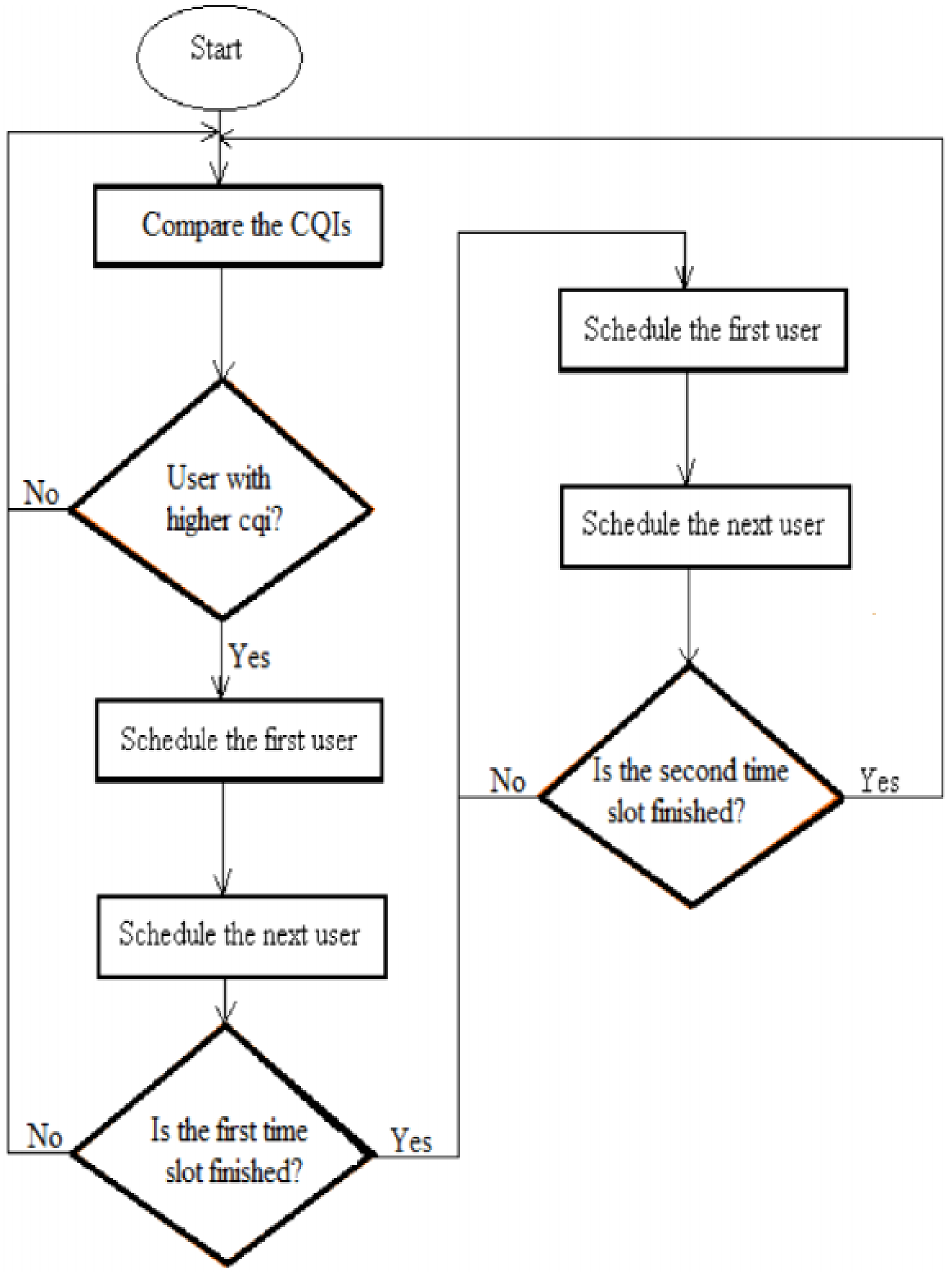

Figure 3- 1: Proportional fairness [28].

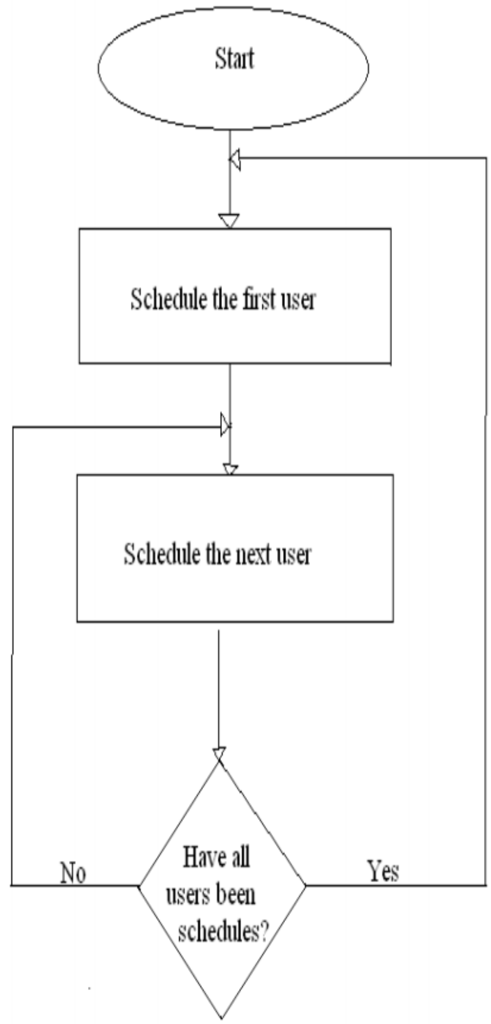

Figure 3- 2: Round Robin Scheduling [28].

Chapter Four

Simulation

&

Results

Chapter 4

Simulation and Results

4.1 Simulation

The aim of a simulation is to describe and imagine the proposed scenario, to predict the results and the outages. In our thesis we will use Matlab program to simulate the proposed scenario to show the outage and result. The main feature of Matlab is that you just formulate the mathematical equation and write it in the program, and define its parameters and values. Matlab has feature of showing the result as graphs (curves, bars), or numerical results.

4.2 Utility Function

Application utility functions have been used in a wide variety of researches which model characteristic features of the system. For modern cellular network, resource of applications running on the smart devices should account for QoS requirements for the traffic generated by the running applications. The degree to which the QoS requirements of application traffic are fulfilled can be expressed by the concept of application utility function, which maps a feasible rate allocation to a utility function value that is the QoS fulfilment percentage for that particular application. There are two shapes of utility function curves. Logarithmic Utility function used for elastic traffic generated by delay-tolerant applications look Fig 4-1.

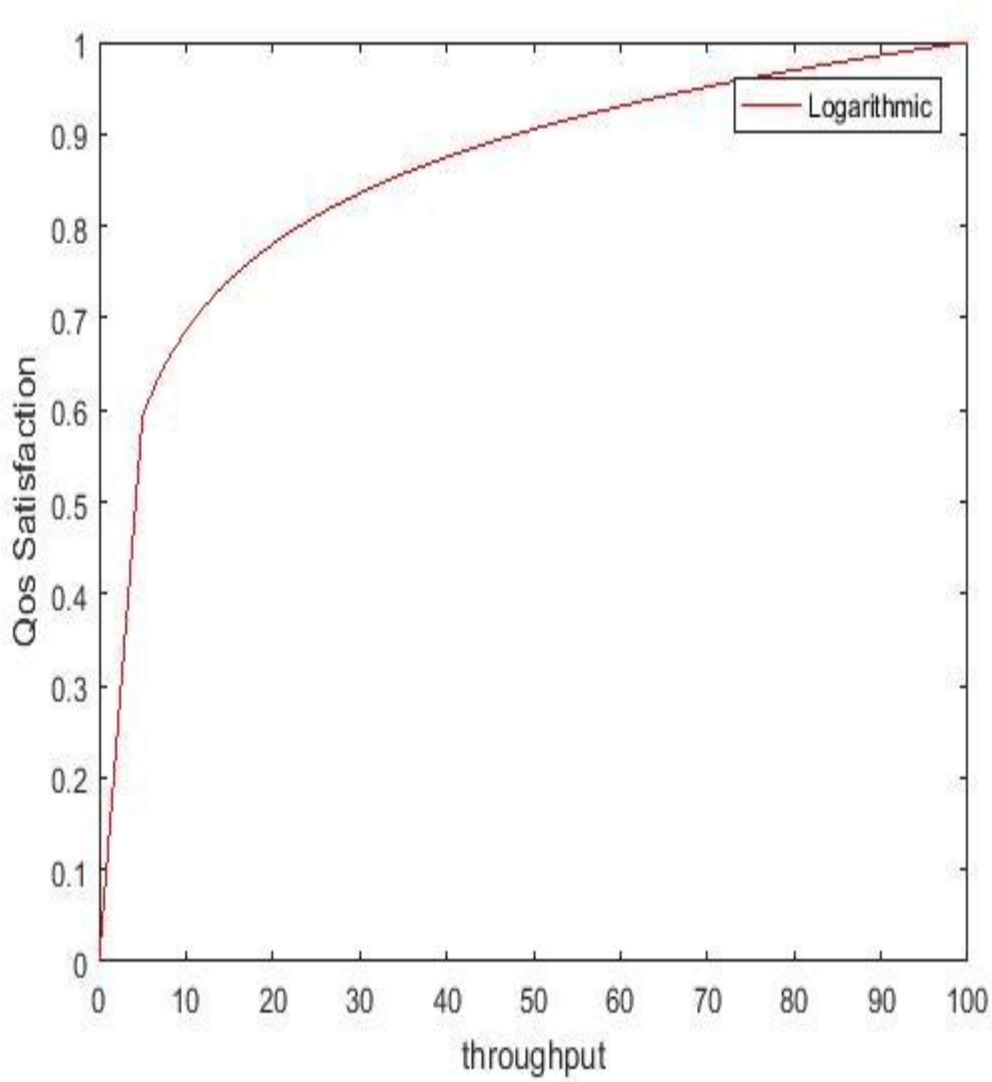

Figure 4-1: Logarithmic Utility function.

Sigmoidal Utility Function used for the inelastic traffic produced by real-time applications is like figure 4- 2.

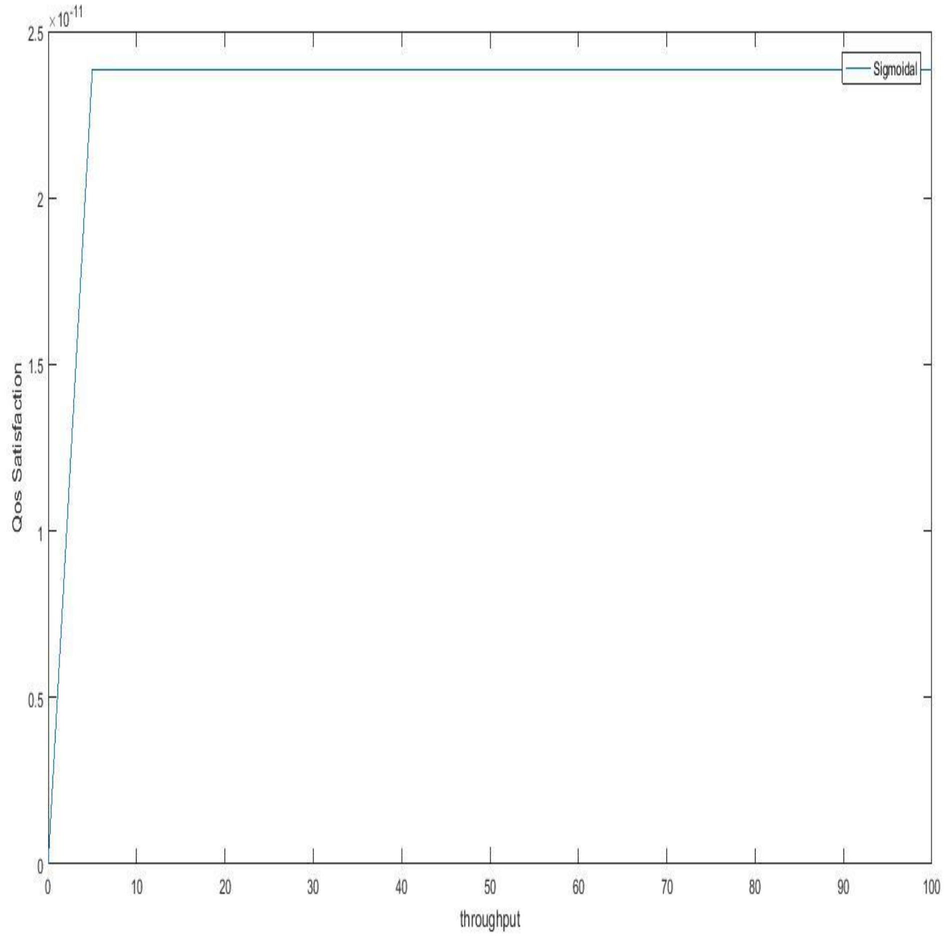

Figure 4-2: Sigmoidal Utility function.

Utility function, which is denoted as *U(r)* for the allocated rate *r*.

4.3 The Proposed Scenario:

Consider there is one macro-cell in it there are 2 femto-cell and there are 10 users in a macro-cell, and 5 users in each femto-cell.

4.4 Implementation of scheduling algorithm:

Here we will implement 3 scheduling algorithm:

- Round-Robin Algorithm

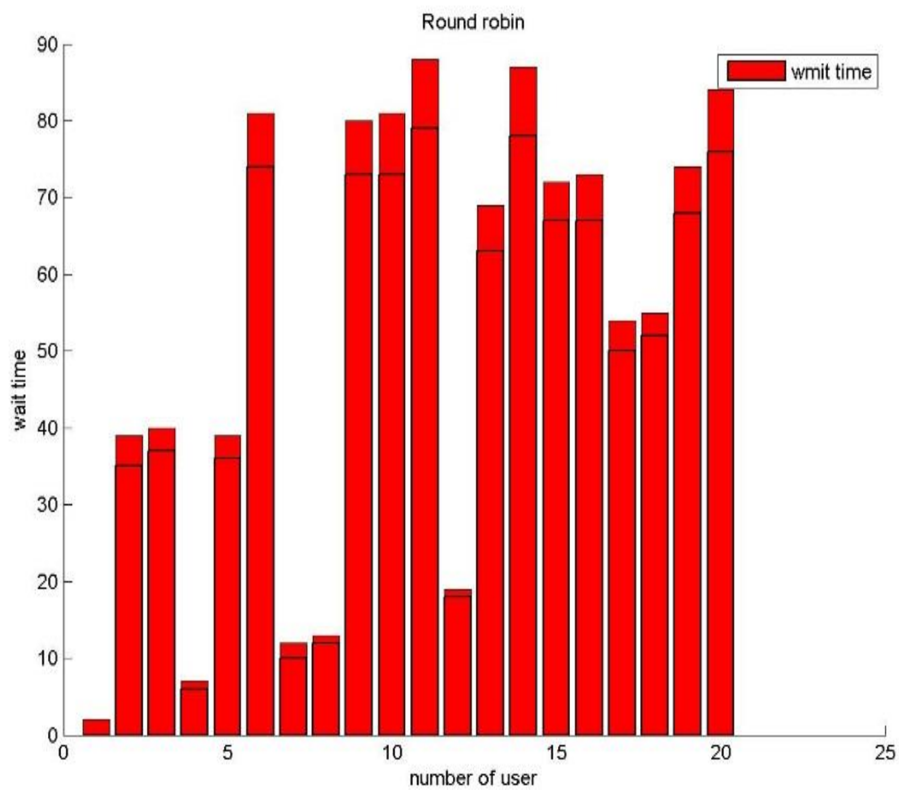

Figure 4- 3: Round-Robin Algorithm.

In round-robin algorithm each user take a slice time called 'quanta time' if it's finished it take another slice of time and waits its turn.

- First Come First Serve Algorithm

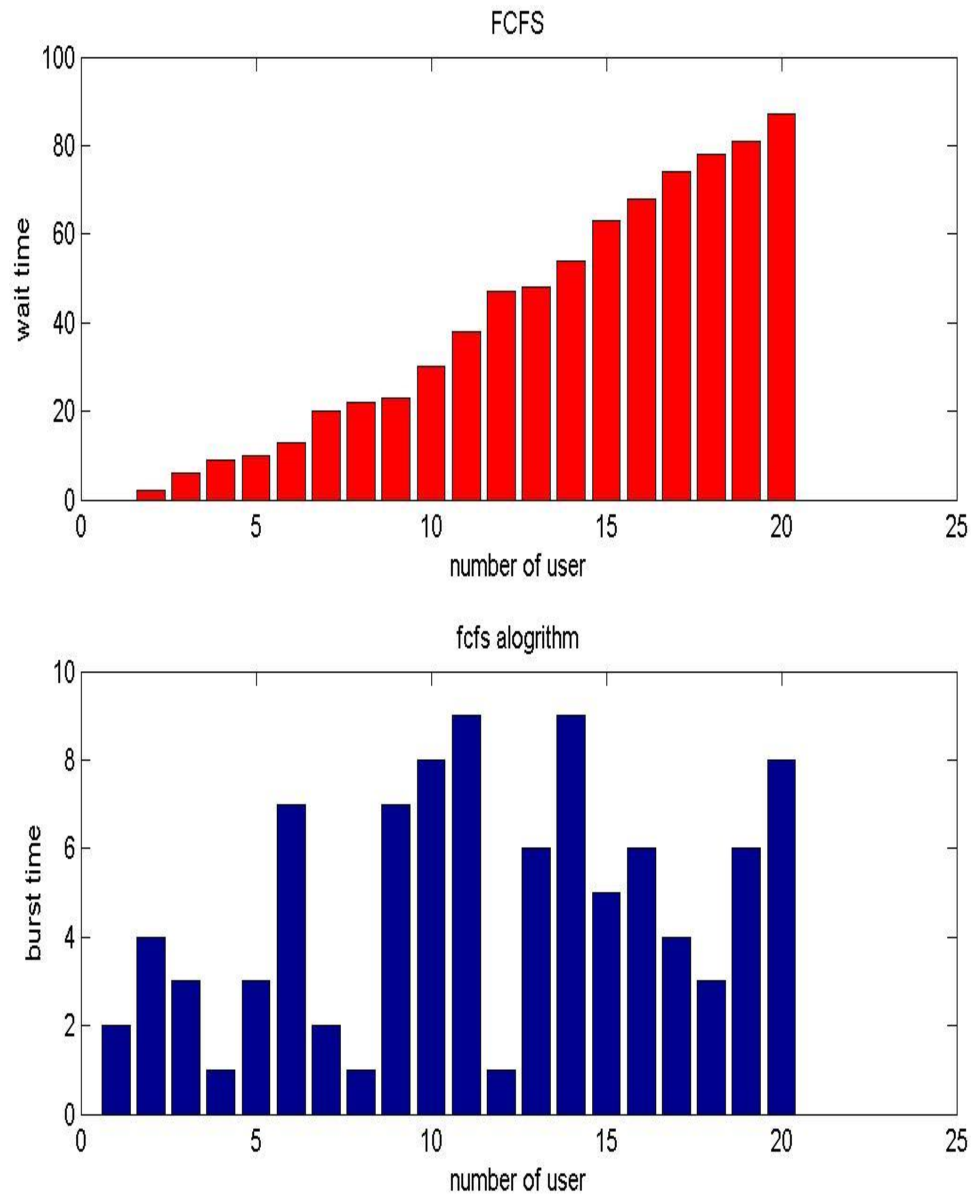

Figure 4- 4: fcfs Algorithm

- In fcfs who came first will work and other users wait its until it finishes all their works.
- Proportional Fairness Algorithm

4.5 Implementation of Coordination for example: Zero Forcing

- **Case1:** Zero Forcing Equalization with Successive Interference Cancellation (ZF-SIC).

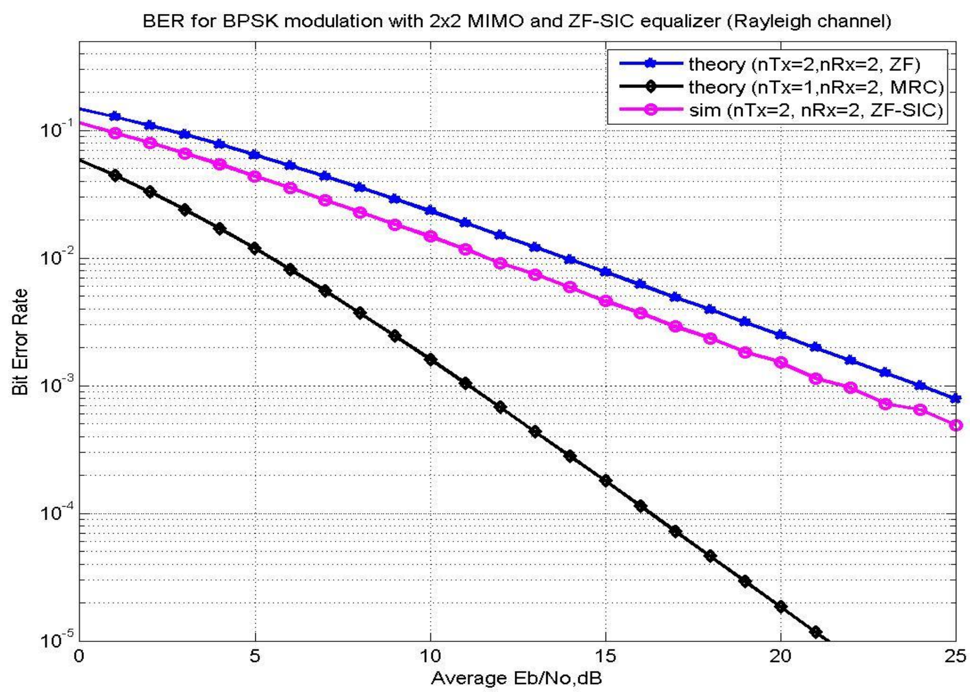

Figure 4- 5: ZF-SIC.

Computing the BER for BPSK modulation in a Rayleigh fading channel with 2Tx, 2Rx MIMO channel Zero Forcing Equalization with Successive Interference Cancellation (ZF-SIC). Eb/No.dB = [0:25].

- **Case2**: Zero forcing equalizer with additive noise in the received signals.

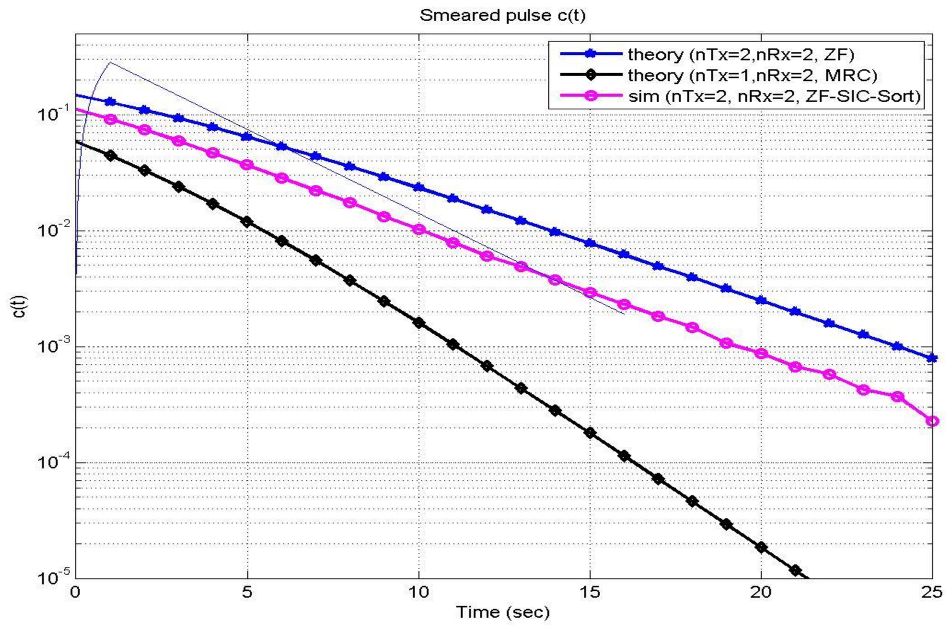

Figure 4- 6: Zero forcing equalizer with additive noise in Rx.

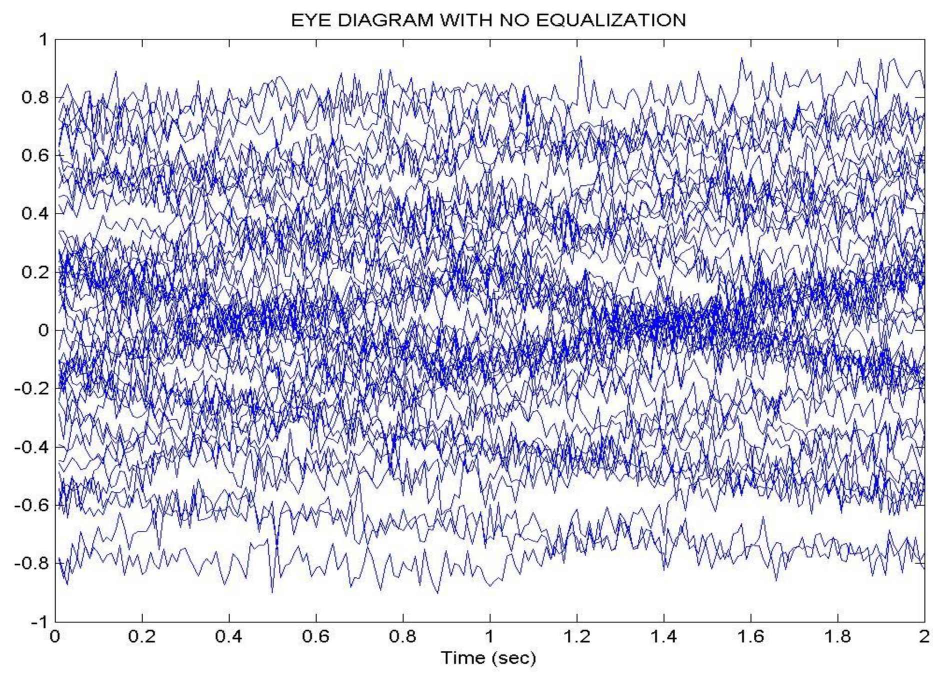

Figure 4- 7: no Equalizer.

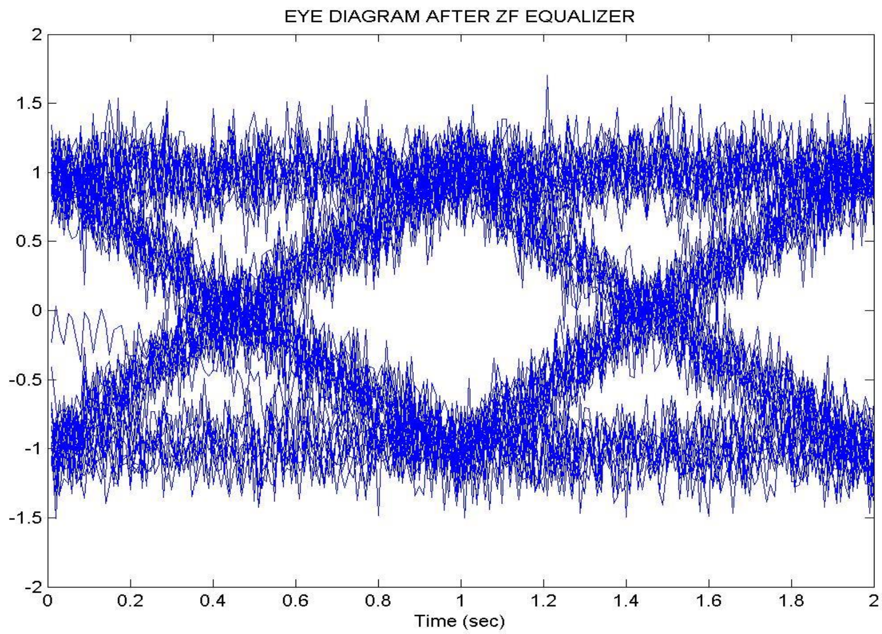

Figure 4- 8: after ZF Equalizer.

Zero forcing equalizer with additive noise in the received signals.

T = 1; % Bit period.

tau = 3; % Time constant of channel.

SNR = 100; % Ratio of signal power to noise power (NOT in dB).

dt = 0.01; % Sampling time in simulation.

N = 100; % Number of bits to generate.

4.6 Results:

4.6.1 Utility Function:

- Used to capture various design objectives, such as throughput and allocation fairness.
- The logarithmic utility function suitable in delay-tolerant.
- The sigmoidal utility function is suitable in real-time applications.

4.6.2 Scheduling Algorithm:

- The aim of scheduling algorithm is spread resource blocks through all users of the network.
- There are two Types of scheduling algorithms, fairness like Round-Robin algorithm, proportional fairness like WFQ, frank Kelly.
- Round-robin algorithm gives as an optimum when waiting time (Wtime)
  Is small as possible.
- Proportional fairness is used today in real-world. Because fairness algorithms causes bottleneck problem.

4.6.3 Coordination

- The benefit of coordination is reducing and suppressing an interference and ICIC, and eICIC.
- Zero Forcing is a type of coordination process
- Zero Forcing Equalizer refers to a form of linear equalization algorithm used in communication systems which applies the inverse of the frequency response of the channel. This form of equalizer

was first proposed by Robert Lucky. The Zero-Forcing Equalizer applies the inverse of the channel frequency response to the received signal, to restore the signal after the channel.

4.6.4 Resource Allocation

- In power allocation the famous algorithm is water-filling.
- In frequency allocation the famous technique is frequency reuse.

Chapter five

Conclusion and Recommendations

Chapter 5

Conclusion and Recommendations

5.1 Conclusions:

Resource allocation today consider an important process because of growing number of mobile users. Resource allocation also provide economical solutions. To design an optimum resource allocation we must gather various knowledge as optimization theory, queuing theory, and linear algebra. Proportional fairness scheduling today is the most popular algorithm because it assigns a rate for each flow rate inversely proportional to its resource need. Frank Kelly algorithm can achieve proportional fairness. The utility function, U(r) is used to capture various design, such as throughput efficient and allocation fairness. Calculating SINR is an important parameter for calculation power consumption of the traffic. Max-Min policy cannot deal with bottlenecks in the network and this is a weak point in it.

5.2 Recommendations:

This thesis can cover wide coverage of wireless communication standrds as follow:

- Resource allocation can cover all radio systems such as, LTE, LTE-A, WiMAX, WiFi to gain optimal allocation and reducing losses, and wasting of our resources.
- New technologies in lte, and lte-a such as MIMO, OFDMA needs researches and studies to be implemented effectively.
- Economic decisions must be a factor in any implement of optimization system for any system resource.

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Appendix

A. Utility Function

```
 clear all
clc
syms x
k=15;
a=1;
b=25;
c=(1+exp(a.*b))./(exp(a.*b));
d=1./(1+exp(a.*b));


%%%%%Application Utility Functions%%%%%
for i=1:length(a)
    %Sigmoid utility function
y(i)=c(i).*(1./(1+exp(-a(i).*(a-b(i))))-d(i));

%logarithmic utility function
y2(i)=log(k(i).*x+1)./(log(k(i).*100+1));
m(i)=exp(-a(i).*(x-b(i)));
dy_log(i)=k(i)./((1+k(i)*x).*log(1+k(i).*x));
end
%%%%%%%%%%%%%%%%%%%%%
yy(1)=0;
yy2(1)=0;
for j=50:1:1000
```

```
    x0(j)=0.1*j;
    yy(j)=subs(y(i),x0(j));
    yy2(j)=subs(y2(i),x0(j));
    r= min((yy2(j)));
    w= max(r);
end
figure
plot(x0,yy);
legend('Sigmoidal');
figure
plot(x0,yy2,'r');
legend('Logarithmic');
%%%

figure
plot(yy2,w,'r')
legend('max-min');
```

B. Round-Robin

```
function rr1()
%%
  %sudan University of science& technology%%
  %Department electronics Engineering%%
  %resource allocation in coordiates multi cell
  system%%
  %%
  clc
  close all
  n=20;                     %no of users
  btime=[2 4 3 1 3 7 2 1 7 8 9 1 6 9 5 6 4 3 6
  8];     %burst time // call duration
  q=2;                      %quantum time
  tatime=zeros(1,n);        %turn around time
  wtime=zeros(1,n);         %waiting time
  rtime=btime;              %intially remaining time=
  waiting time
  b=0;
  t=0;
  flag=0;                   %this is set if user has
  burst time left after quantum time is
  completed
  for i=1:1:n               %running the user for 1
  quantum
      if(rtime(i)>=q)
          fprintf('P%d\n',i);
```

```
        for j=1:1:n
            if(j==i)
                rtime(i)=rtime(i)-q;
%setting the remaining time if it is the user
scheduled
            else if(rtime(j)>0)
                    wtime(j)=wtime(j)+q;
%incrementing wait time if it is not the user
scheduled
                end
            end
        end
    else if(rtime(i)>0)
            fprintf('P%d\n',i);
            for j=1:1:n
              if(j==i)
                rtime(i)=0;
%as the remaining time is less than quantum it
will run the process and end it
              else if(rtime(j)>0)

wtime(j)=wtime(j)+rtime(i);     %incrementing
wait time if it is not the process scheduled
                  end
              end
            end
        end
```

```
    end
end
for i=1:1:n
    if(rtime(i)>0)        %if remaining time is
left set flag
        flag=1;
    end
end
while(flag==1)            %if flag is set run
the above process again
    flag=0;
    for i=1:1:n
        if(rtime(i)>=q)
            fprintf('P%d\n',i);
            for j=1:1:n
                if(j==i)
                    rtime(i)=rtime(i)-q;
                else if(rtime(j)>0)
                       wtime(j)=wtime(j)+q;
                    end
                end

            end
        else if(rtime(i)>0)
                fprintf('P%d\n',i);
                for j=1:1:n
                    if(j==i)
```

```
                    rtime(i)=0;
                else if(rtime(j)>0)

wtime(j)=wtime(j)+rtime(i);
                    end
                end
            end
        end
    end
end
for i=1:1:n
    if(rtime(i)>0)
        flag=1;
    end
end
end
for i=1:1:n
    tatime(i)=wtime(i)+btime(i);
%calculating turn around time for each process
by adding waiting time and burst time
end
disp('user  Burst time  Waiting time    Turn
Around time'); %displaying the final values
for i=1:1:n

fprintf('P%d\t\t\t%d\t\t\t%d\t\t\t\t%d\n',(i+1),
btime(i),wtime(i),tatime(i));
```

```
 b=b+wtime(i);
   t=t+tatime(i);
end
fprintf('Average waiting time: %f\n',(b/n));
fprintf('Average turn around time:%f\n',(t/n))
  %stem(btime)
  figure
 bar(wtime)
 title('round robin')
 xlabel('number of user')
  figure
 bar(tatime)
 plot(k,l)
  title('Round robin')
  xlabel('number of user')
  ylabel('wait time')
```

C. First Come First Serve

```
function fcfs()
%%Sndan University of Science&technology%%
%%Resource allocation in coordinates multicell
system%%
```

```
t1=0;
t2=0;
n=20;                         %no of user
btime=[2 4 3 1 3 7 2 1 7 8 9 1 6 9 5 6 4 3 6 8];
%burst time
wtime=zeros(1,n);       %waiting time
tatime=zeros(1,n);      %turn around time
for i=2:1:n
   wtime(i)=btime(i-1)+wtime(i-1);  %waiting time
will be sum of burst time of previous user and
waiting time of previous user
   t1=t1+wtime(i);                  %calculating
total time
end
for i=1:1:n
    tatime(i)=btime(i)+wtime(i);    %turn around
time=burst time +wait time
    t2=t2+tatime(i);                %total turn
around time
end
disp('user   Burst time  Waiting time    Turn
Around time'); %displaying final values
for i=1:1:n

fprintf('P%d\t\t\t%d\t\t\t%d\t\t\t\t%d\n',(i+1),bt
ime(i),wtime(i),tatime(i));
end
```

```
fprintf('Average waiting time: %f\n',(t1/n));
fprintf('Average turn around time: %f\n',(t2/n));
figure
hold on
subplot(2,1,1);
bar(wtime,'r')
title('FCFS')
xlabel('number of user')
ylabel('wait time')

subplot(2,1,2);
bar(btime);
title('fcfs alogrithm');
xlabel('number of user');
ylabel('burst time');
hold off
```

D. Zero Forcing Equalization with Successive Interference Cancellation (ZF-SIC).

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%
```

```
% Script for computing the BER for BPSK modulation
in a
% Rayleigh fading channel with 2 Tx, 2Rx MIMO
channel
% Zero Forcing Equalization with Successive
Interference
% Cancellation (ZF-SIC)

clear
N = 10^6; % number of bits or symbols
Eb_N0_dB = [0:25]; % multiple Eb/N0 values
nTx = 2;
nRx = 2;
for ii = 1:length(Eb_N0_dB)

    % Transmitter
    ip = rand(1,N)>0.5; % generating 0,1 with
equal probability
    s = 2*ip-1; % BPSK modulation 0 -> -1; 1 -> 0

    sMod = kron(s,ones(nRx,1)); %
    sMod = reshape(sMod,[nRx,nTx,N/nTx]); %
grouping in [nRx,nTx,N/NTx ] matrix

    h = 1/sqrt(2)*[randn(nRx,nTx,N/nTx) +
j*randn(nRx,nTx,N/nTx)]; % Rayleigh channel
```

```
    n = 1/sqrt(2)*[randn(nRx,N/nTx) +
j*randn(nRx,N/nTx)]; % white gaussian noise, 0dB
variance

    % Channel and noise Noise addition
    y = squeeze(sum(h.*sMod,2)) + 10^(-
Eb_N0_dB(ii)/20)*n;

    % Receiver

    % Forming the ZF equalization matrix W =
inv(H^H*H)*H^H
    % H^H*H is of dimension [nTx x nTx]. In this
case [2 x 2]
    % Inverse of a [2x2] matrix [a b; c d] =
1/(ad-bc)[d -b;-c a]
    hCof = zeros(2,2,N/nTx)  ;
    hCof(1,1,:) = sum(h(:,2,:).*conj(h(:,2,:)),1)
;  % d term
    hCof(2,2,:) = sum(h(:,1,:).*conj(h(:,1,:)),1)
;  % a term
    hCof(2,1,:) = -
sum(h(:,2,:).*conj(h(:,1,:)),1); % c term
    hCof(1,2,:) = -
sum(h(:,1,:).*conj(h(:,2,:)),1); % b term
    hDen = ((hCof(1,1,:).*hCof(2,2,:)) -
(hCof(1,2,:).*hCof(2,1,:))); % ad-bc term
```

```
    hDen =
reshape(kron(reshape(hDen,1,N/nTx),ones(2,2)),2,2,
N/nTx);  % formatting for division
    hInv = hCof./hDen; % inv(H^H*H)

    hMod =  reshape(conj(h),nRx,N); % H^H
operation

    yMod = kron(y,ones(1,2)); % formatting the
received symbol for equalization
    yMod = sum(hMod.*yMod,1); % H^H * y
    yMod =  kron(reshape(yMod,2,N/nTx),ones(1,2));
% formatting
    yHat = sum(reshape(hInv,2,N).*yMod,1); %
inv(H^H*H)*H^H*y

    % receiver - hard decision decoding on second
spatial dimension
    ipHat2SS = real(yHat(2:2:end))>0;
    ipHatMod2SS = 2*ipHat2SS-1;
    ipHatMod2SS = kron(ipHatMod2SS,ones(nRx,1));
    ipHatMod2SS =
reshape(ipHatMod2SS,[nRx,1,N/nTx]);

    % new received symbol - removing the effect
from second spatial dimension
```

```
    h2SS = h(:,2,:); % channel in the second
spatial dimension
    r = y - squeeze(h2SS.*ipHatMod2SS);

    % maximal ratio combining - for symbol in the
first spatial dimension
    h1SS = squeeze(h(:,1,:));
    yHat1SS =
sum(conj(h1SS).*r,1)./sum(h1SS.*conj(h1SS),1);
    yHat(1:2:end) = yHat1SS;

    % receiver - hard decision decoding
    ipHat = real(yHat)>0;

    % counting the errors
    nErr(ii) = size(find([ip- ipHat]),2);

end

simBer = nErr/N; % simulated ber
EbN0Lin = 10.^(Eb_N0_dB/10);
theoryBer_nRx1 = 0.5.*(1-1*(1+1./EbN0Lin).^(-
0.5));
p = 1/2 - 1/2*(1+1./EbN0Lin).^(-1/2);
theoryBerMRC_nRx2 = p.^2.*(1+2*(1-p));

close all
```

```
figure
semilogy(Eb_N0_dB,theoryBer_nRx1,'bp-
','LineWidth',2);
hold on
semilogy(Eb_N0_dB,theoryBerMRC_nRx2,'kd-
','LineWidth',2);
semilogy(Eb_N0_dB,simBer,'mo-','LineWidth',2);
axis([0 25 10^-5 0.5])
grid on
legend('theory (nTx=2,nRx=2, ZF)', 'theory
(nTx=1,nRx=2, MRC)', 'sim (nTx=2, nRx=2, ZF-
SIC)');
xlabel('Average Eb/No,dB');
ylabel('Bit Error Rate');
title('BER for BPSK modulation with 2x2 MIMO and
ZF-SIC equalizer (Rayleigh channel)');
```

E. Zero Forcing Equalizer

```
% Zero forcing equalizer with additive noise in
the received signals.
T = 1;       % Bit period
tau = 3;     % Time constant of channel
```

```
SNR = 100;   % Ratio of signal power to noise
power (NOT in dB)
dt = 0.01;  % Sampling time in simulation
N = 100;    % Number of bits to generate


clear t1 t2 c x y
% Create output pulse: rectangular pulse convolved
with first-order
% low-pass filter impulse response.
t1 = (dt:dt:T)';
c(1:100,1) = 1 - exp(-t1/tau);
t2 = (T+dt:dt:T+5*tau)';
c(101:100+length(t2),1) = c(100)*exp(-(t2-T)/tau);
figure(1)
plot([t1; t2], c)
xlabel('Time (sec)')
ylabel('c(t)')
title('Smeared pulse c(t)')
% Generate bit stream
b = rand(N,1);
z0 = find(b < 0.5);
z1 = find(b >= 0.5);
b(z0) = -1*ones(size(z0));
b(z1) = +1*ones(size(z1));
% Create received signal with ISI
nT = T/dt;
```

```
nc = length(c);
nx = N*nT;
x = zeros(nx, 1);
for n=1:N
  i1 = (n-1)*nT;
  y = [zeros(i1,1); b(n)*c; zeros(N*nT-i1-nc,1)];
  x = x + y(1:nx);
end
% Add noise of the specified level
sp = sum(x.*x)/length(x);  % Signal power
np = sp/SNR;               % Noise power
noise = sqrt(np) * randn(length(x),1);
x = x + noise;
% Plot eye diagram
figure(2)
t3 = dt:dt:2;
plot(t3, x(1:200));
hold on
for n=3:2:N
  plot(t3, x((n-1)*nT+1:(n+1)*nT));
end
hold off
xlabel('Time (sec)')
title('EYE DIAGRAM WITH NO EQUALIZATION')

% Compute number of bit errors
xT = x(nT:nT:nx);
```

```
dz0 = find(xT < 0);
dz1 = find(xT >= 0);
db = b;
db(dz0) = -1*ones(size(dz0));
db(dz1) = +1*ones(size(dz1));
err = find(db ~= b);
fprintf('No equalizer: %d bits out of %d in
error\n', length(err), N);
% Define length of zero-forcing equalizer
Ne = 5*tau/T;
% Get samples of c(t) to solve for ZF equalizer
weights
cT = c(nT:nT:nc);
csamp = [zeros(2*Ne,1); cT; zeros(2*Ne+1-
length(cT),1)];

% Construct the matrix on the left side of ZF
equalizer equation
C = zeros(2*Ne+1,2*Ne+1);
for ne = 1:2*Ne+1
  C(ne,:) = csamp(2*Ne+ne:-1:ne)';
end
% Right side of ZF equalizer weight equation
r = [zeros(Ne,1); 1; zeros(Ne,1)];
% Solve for ZF equalizer weights
w = C \ r;
```

```
% Process the received signal with the ZF
equalizer
nw = length(w);
z99 = [1; zeros(nT-1,1)];
hzf = kron(w, z99);          % Impulse response of
equalizer
yall = conv(x, hzf);         % Do the equalization
filtering
y = yall((Ne*nT+1):(length(yall)-(Ne+1)*nT)+1);


% Eye diagram of equalized signal
figure(3)
plot(t3, y(1:200));
hold on
for n=3:2:N
  plot(t3, y((n-1)*nT+1:(n+1)*nT));
end
hold off
xlabel('Time (sec)')
title('EYE DIAGRAM AFTER ZF EQUALIZER')
% Compute number of bit errors
yT = y(nT:nT:nx);
dz0 = find(yT < 0);
dz1 = find(yT >= 0);
db = b;
db(dz0) = -1*ones(size(dz0));
```

```
db(dz1) = +1*ones(size(dz1));
err = find(db ~= b);
fprintf('ZF equalizer: %d bits out of %d in
error\n', length(err), N);
```