Sudan University of Science and Technology

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Cooperative Virtual Multiple Input Multiple Output in Long Term Evolution

A Research Submitted in partial Fulfillment for the Requirement of the Degree of B-Tech (Honors)in Electronics Engineering

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الإستهلال

قال تعالى:

﴿ ويسألونك عن الروح قُلِ الرُّوحُ مِنْ أَمْرِ رَبِّي وَمَا أُوتِيتُمْ مِنَ الْعِلْمِ إِلَّا قَلِيلًا ﴾

(٨٥ الإسراء)

Dedication

We dedicate this modest work to our fathers

and mothers who have provided us with tenderness and love.

We tell them: You've to give us the gift of life and hope and nurture the passion for knowledge.

And to all our brothers, sisters and our family

To all our teachers, friends and colleagues

To candles that burn to light up for others

To everyone who teaches us a character...

Acknowledgement

First, thanks to God who lights our ways and our minds. And then to the supervisor **Dr, FathElrahman Ismael Khalifa** who has guided us and direct us for the duration of the search.

Abstract

Long Term Evaluation (LTE) is one of the modern technologies used to provide high quality network and data usage, providing a good service to the user .Many techniques emerged in it, the weak received signal which leads to decrease in the performance of the services offered to the user. The Co-operative virtual MIMO One of the techniques used to improve the quality of network service. This project is based on the study of the CO-operative Virtual Multiple Input Multiple Output (MIMO) for the purpose of analyzing and measuring the performance of the service before and after the use of this technology, in which the study of the fourth generation networks and the developments that took place in it. The CO-operative Virtual MIMO is one of the most promising technologies in the field of communications, By using the number of three Relay and support one user so that this user receives signal from each Relay (receive three signal) and compared with the normal Relay and found that the new technology is the best. The Data and Frequency, and system bandwidth is constant value in simulation code. The MATLAB program was used to measure the performance of the user before the use of the CO-operative Virtual MIMO and the change that occurs after the use of the technology and the results obtained in SINR, DR, TH, SE and DT and enhanced by respectively in 251.69%, 164.07%, 35.29%, 332.2% and 277.2%.

المستخلص

التتقيم طويل الاجل واحدة من التقنيات الحديثة المستخدمة التى تقدم جودة عالية للشبكة والبيانات المستخدمة وتوفر خدمة جيدة للمستخدم , ظهرت فيها العديد من التقنيات . ان ضعف الاشارة المستقبلة للمستخدم تنقص من جودة اداء الخدمة , التعاون الافتراضى للهوائيات هى واحدة من التقنيات المستخدمة لتحسين جودة خدمة الشبكة . هذا المشروع قام علي دراسه التعاون الافتراضي للهوائيات بغرض تحليل وقياس اداء الخدمه قبل وبعد استخدام التقنيه , وضعت فيه دراسه عن شبكات الجيل الرابع والتطورات التي حدثت فيها ، التعاون الافتراضي للهوئيات هي واحده من التقنيات الواعده جدا في مجال الاتصالات حيث تعمل على زياده اداء الخدمه عن طريق المقارنة بين التقوية العادية وتقنية التعاون الافتراضى للهوائيات . حيث تقوم هذة التقنية بجمع ثلاثة مقويات لدعم مستخدم واحد بحيث يتلقى هذا المستخدم إشارة من كل مقوى(تلقي ثلاثة إشارات) ومقارنتها مع المقوى العادى ووجد ان تقنية التعاون الافتراضى للهوائى هى الافضل , تم استخدام برنامج الماتلاب لقياس مدى التحسن الذى يمكن ان يحدث عندما يتم استخدام تقنية التعاون الافتراضى للهوائى وظهرت زيادة فى نسبة التداخل والضوضاء وتحسن زيادة معدل اداء البيانات وزيادة الطاقة الانتاجية وتحسن فى الطيف الترددى وتحسن زمن التاخير بالنسب الاتية على التوالى :

277.2% , 332.2% , 35.39% , 164.07% , 251.69%

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List of Symbols

Symbol	Description
SINR	Signal to interference and noise ratio
PR	Power Receive in Mobile
G	Gain of antenna
N	Noise
I	Interference
DR	Data Rate
BW	Bandwidth
M	Type of Modulation
C	Coding Rate
TH	Throughput
DT	Delay Transmission
D	Data

Abbreviations

Abbreviation	Description
3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project2
4G	Fourth Generation
AMPS	Advanced Mobile Phone System
AMC	Adaptive Modulation and Coding
BW	Band Width
CP	Cyclic Prefix
C	Capacity
C	Coding rate
CDMA	Code Division Multiple Access
CA	Carrier Aggression
COMP	Coordinated Multi Point
DR	Data Rate
DPC	Dirty Paper Coding
DL	Down Link
eICIC	Inter-cell Interference Coordination
EDGE	Enhanced Data rate for Global Evolution
eNode	Enhanced NodeB
E-UTRAN	Evolved UMTS Terrestrial Radio Access
FDD	Frequency Division Duplex
FFT	Fast Fourier Transform
FEC	Forward Error Correction
GSM	Global System For Mobile Communication

GPRS	General Packet Radio Services
GGSN	Gateway GPRS
GW	Gateway
Gbps	Gigabit Per Second
GBR	Guaranteed Bit Rate
HSPA	High Speed Packet Access
HSCSD	High Speed Down link packet Access
HRPD	High Rate Packet Access
HET NET	Heterogeneous Network
IP	Internet Protocol
ITU	International Telecommunication union
ITU-IMT-2000	International Telecommunication union –International Mobile Telecommuncation-2000
ITU	International Telecommunication union
IFFT	Inverse Fast Fourier Transform
LTE	Long Tern Evaluation
LTE –A	Long Tern Evaluation-Advanced
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
NMT	Nordic Mobile Telephone System
OFDM	Orthogonal Frequency Multiple
OFDMA	Orthogonal Frequency Multiple Access
OCI	Other Cell Interference
QAM	Quarter Amplitude Modulation
QPSK	Quarter Phase Shift Keying
16 QAM	16 Quarter Phase Shift Keying

64 QAM	64 Quarter Phase Shift Keying
RAN	Radio Access Network
RNC	Radio Network Controller
RF	Radio Frequency
UMTS	universal mobile telecommunications system

CHAPTER ONE

INTRODUCTION

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1-1 Preface

In telecommunication, long Term Evaluation (LTE) for high-speed wireless communication for mobile device and data terminals , based on the Global System For Mobile Communication (GSM) / Enhanced Data rate for Global Evolution (EDGE) and universal mobile telecommunications system (UMTS) / High Speed Packet Access (HSPA) technologies, It increases the capacity and speed using a different radio interface together with core network improvements. The standard is developed by the 3rd Generation Partnership Project (3GPP) . The different LTE frequencies and bands used in different countries mean that only multi-band phones are able to use LTE in all countries where it is supported [1].

This project achieves performance high throughput gains and increases SINR of broadband network and quality signal and capacity by using cooperative relay virtual multiple input multiple output (V-MIMO) technology in Long Term Evolution (LTE) promises to provide performance gains comparable to conventional Relay , summation total the power receive of cooperative relay to give high quality of signal server to users.

1-2 Problem Statement

The user located in cell edge suffers from weak received signal which leads to decrease in the performance of the services offered to the user. Although MIMO can be consider as one solution to enhance the performance, but the realization of MIMO in current cellular system limited by the complexity of user equipment (UE).

1-3 Proposed Solution

The cooperative relay virtual MIMO can be used to achieve better signal strength to end users at cell edge and hence good performance can be gained.

1-4 Aim and Objectives

The general aims to evaluate the performance of using virual MIMO in LTE advanced systems.

The detailed objectives include:

- To improve SINR (signal to noise ratio).
- To increase data rate.
- To enhance the overall system throughput.
- To enhance spectral efficiency.
- To decrease the transmission delay.

1-5 Methodology

The Methodology of this research is composed of several phases, include:

The first phase: concerning background environment through the overview of LTE along with their architecture and technologies that's used in the LTE advanced.

The second phase: study Co-operative relay Virtual MIMO to enhance the Performance and Quality of the services (QOS) for the user.

Thirdly research: using number of relay to enhance the SINR to the user by using CO-VMIMO (summing SINR of Relays) and compared it with the normal relay and prove that the Co-VMIMO is the best one and enhanced the performance of the user.

The fourth phase: has been used MATLAB to write simulation code that give result in form of figure.

1-6 Thesis Outlines

This thesis is divided into five chapters their outlines are as follows:

Chapter Two is a Literature review that presents some basic background on LTE, Their technology and architecture, radio resource management and some related work to our project.

Chapter Three is a Methodology includes all the details such as, blocks diagram and mathematical equation of performance metrics.

The Fourth chapter is the results and discussion that shows the simulation results gained through code using MATLAB and their discussion.

The last chapter conclusion and Recommendations concludes the research and gives tips for future works.

CHAPTER TWO

LITERATURE REVIW

CHAPTER TWO

LITERATURE REVIW

2-1 LTE Overview

LTE is a standard for wireless communication of high-speed data for mobile phones and data terminals. It is based on the GSM/ EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using a different radio interface together with core network improvements. The standard is developed by the 3GPP (3rd Generation Partnership Project) and is specified in its Release 8 document series, with minor enhancements described in Release 9,The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations , to an IP-based system with significantly reduced transfer latency compared to the3G architecture .and wireless interface is incompatible with 2G and 3G networks, so that it must be operated on a separate radio spectrum [2,3,4].

2-1-1 Technology of LTE

The LTE depended on SC-FDMA in the uplink and OFDMA in downlink to increase channel Capacity (spatial multiplexing) or enhanced signal robustness (space frequency /time coding), OFDM, Hybrid ARQ and ICIC is introduced in LTE release-8 [1].

2-1-1-1 Orthogonal Frequency Division Multiplex (OFDM)

Orthogonal frequency division multiplex (OFDM) is form of transmission that uses large number of close spaced carrier that are modulated with low data rate. Normally, these signals would be expected to interfere with each other, but making the signals orthogonal to each other there is no mutual interference [5].

2-1-1-2 Orthogonal Frequency Division Multiple Access

OFDMA is suitable for high data rate transmission in wideband wireless system due to its spectral efficiency and good immunity to multipath fading . In It's one of most the important access technologies, used to allow multiple users to access the network resource. OFDMA is used on the down link, but since it presents a high Peak-to-average Power Ratio it is not possible to use it on the uplink. The main difference between an OFDM and an OFDMA system see next Figure (2:1): OFDM VS OFDMA. if the fact that in the OFDM the user are allocated on the time domain only while using an OFDMA system the user would be allocated by both time and frequency as we can say in OFDMA use multiple sub-carriers in same time and in OFDM use one sub-carriers [6].

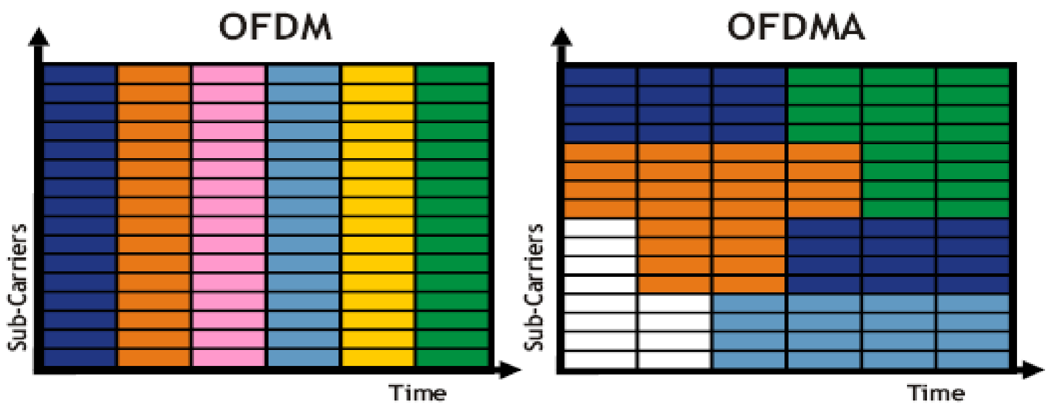

Figure (2. 1) OFDM VS OFDMA

2-1-1-3 Single Carrier - Frequency Division Multiplexing Access

SC-FDMA (Single Carrier FDMA) presents the benefit of a single carrier multiplexing of having a lower Peak-to-average Power

Ratio. On SC-FDMA before applying the IFFT the symbols are pre-coded by a Discrete Fourier Transform (DFT). This way each subcarrier after IFFT will contain part of each symbol. Figure (2-2) represents the description of the difference between SC-FDMA and OFDMA, and also, it is possible to notice that the inter symbol interference will be reduced since all subcarriers on a period of time represent the same symbol [7].

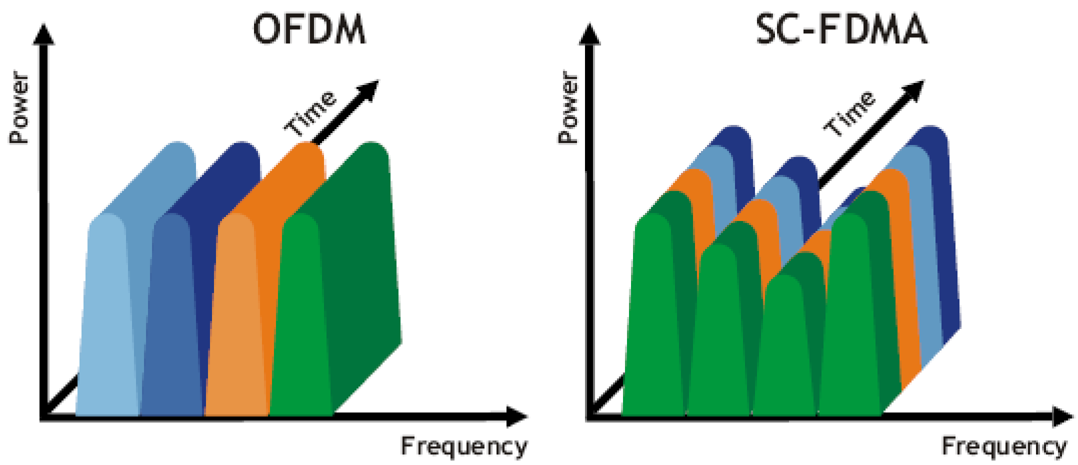

Figure (2. 2) OFDMA VS SC-FDMA

2-1-1-4 LTE Multiple- Input Multiple –Out put

MIMO has been a cornerstone of the LTE standard ; operation principle in spatial multiplexing is sending signals from two or more different antennas with different data streams and by signal processing means in the receiver separating the data stream, hence increasing the peak data rates by factor of 2 or 4 with 4 by 4 antenna configurations. Figure (2-3) below show This technology provides LTE with the ability to further improve its data throughput and spectral efficiency above that obtained by the use of OFDM [8].

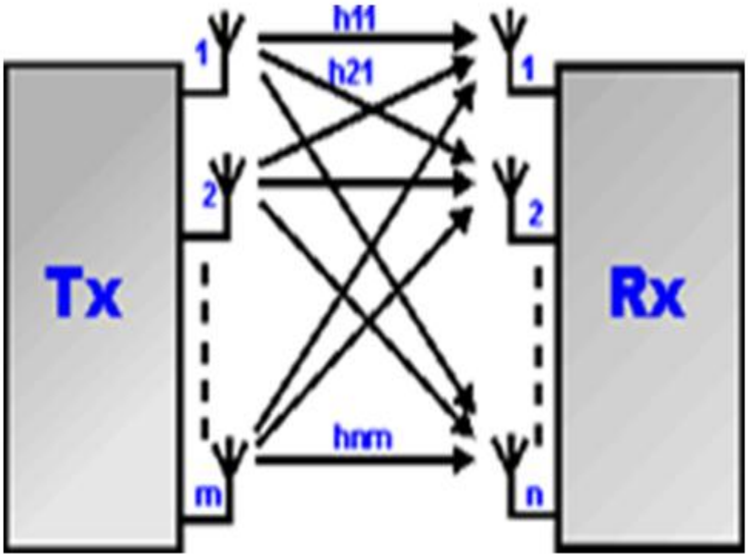

Figure (2. 3) MIMO Transmission scenario.

2-2 LTE-Advanced

The new capabilities of these IMT Advanced systems are envisaged to handle a wide range of supported data rates according to economic and service demands in multi-user environments with target peak data rates of up to approximately 100 Mbps for high mobility and up to 1Gbps for low mobility such as nomadic/local wireless access, and supports both frequency division duplexing (FDD) and time-division duplexing (TDD) and The IP-based network architecture, called the Evolved Packet Core (EPC) designed to replace the GPRS Core Network, supports seamless handovers for both voice and data to cell towers with older network technology such as GSM, UMTS and CDMA2000, The data to be transmitted is split across all the carriers to give resilience against selective fading from multi-path effects [2].

2-2-1 Network LTE-Advanced Architecture

The core network of the LTE-Advanced system is separated into many parts. Figure (2-4) show each component in the LTE-Advanced network is connected to each other. NodeB in 3G system was replaced by evolved NodeB (eNB), which is a combination of eNB and radio network controller (RNC). The eNB communicates with User Equipment’s (UE's) and can serve one or several cells at one time. Home eNB (HeNB) is also considered to serve a femto cell that covers a small indoor area. The evolved packet core (EPC) comprises of the following four components. The serving gateway (SGW) is responsible for routing and forwarding packets between UE's and packet data network (PDN) responsible for handover serve as UE's mobility. The mobility management entity (MME) manages UE access and mobility, and establishes the bearer path for UE's. Packet data network gateway (PDN GW) is a gateway to the PDN, policy and charging rules function (PCRF) manages policy and charging rules [2].

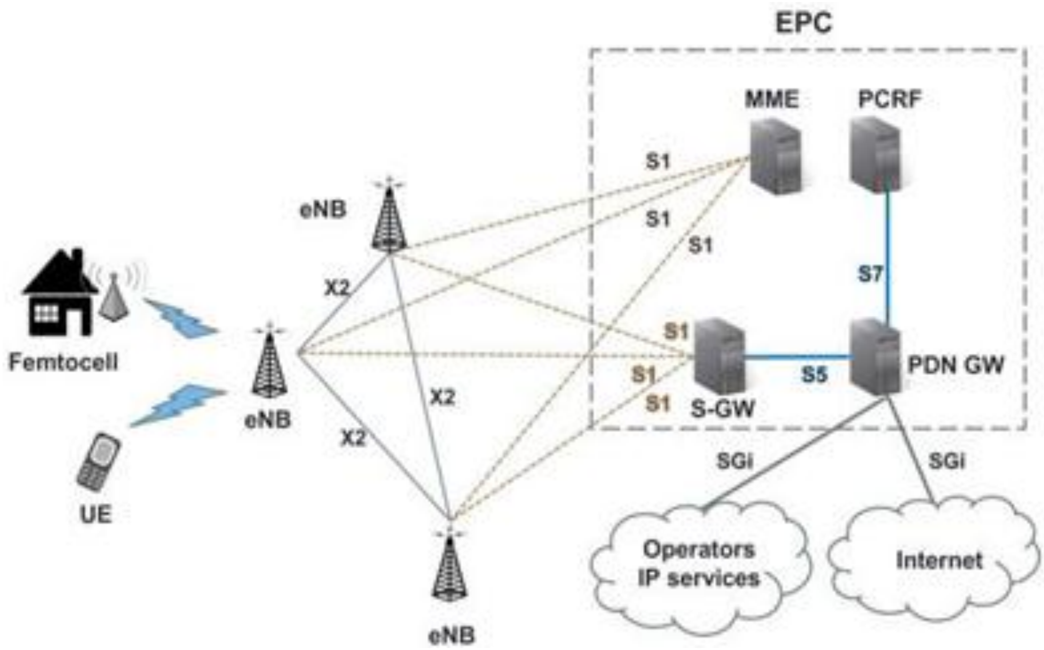

Figure (2. 4) LTE -Advanced architecture

2-2-1-1 LTE Relay Technology

The aim of LTE relaying is to enhance both coverage and capacity; one of the main uses of LTE is the high data rates that can be achieved. However, all technologies suffer from reduced data rates at the cell edge where signal levels are lower and interference levels are typically higher. LTE relaying is different to the use of a repeater which re-broadcasts the signal. A relay will actually receive, demodulates and decodes the data, apply any error correction and then re-transmitting a new signal. The UEs communicate with the relay node, which in turn communicates with a donor eNB. See Figure (2. 5) LTE relay used to increase network density, LTE relay nodes can be deployed very easily in situations where the aim is to increase network capacity by increasing the number of eNBs to ensure good signal levels are received by all users [1,6].

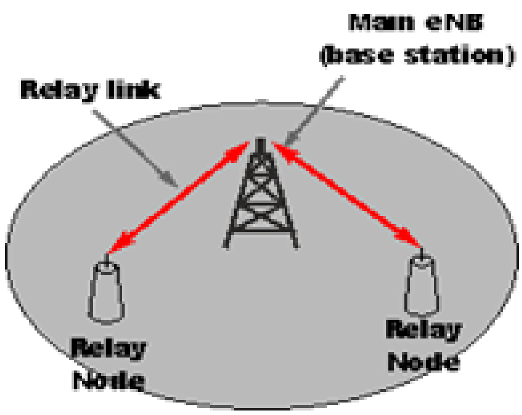

Figure (2. 5) LTE relay used to increase network density

2-2-1-2 LTE Coordinated Multi-point Transmission/Reception

LTE-Coordinated multipoint transmission and reception actually refers to a wide range of techniques that enable dynamic coordination transmission and reception with multiple geographically separated eNBs.

Its aim is to enhance the overall system performance, utilize the resources more effectively and improve the end user service quality. The cell edges are the most challenging. Not only is the signal lower in strength because of the distance from the base station (eNB), but also interference levels from neighboring eNBs are likely to be higher as the UE will be closer to them. When apply dynamically coordinate to provide joint scheduling and transmissions as well as proving joint processing of the received signals. In this way, see Figure (2.6) Coordinated Multipoint, a UE at the edge of a cell is able to be served by two or more eNBs to improve signals reception/transmission and increase throughput particularly under cell edge conditions [9].

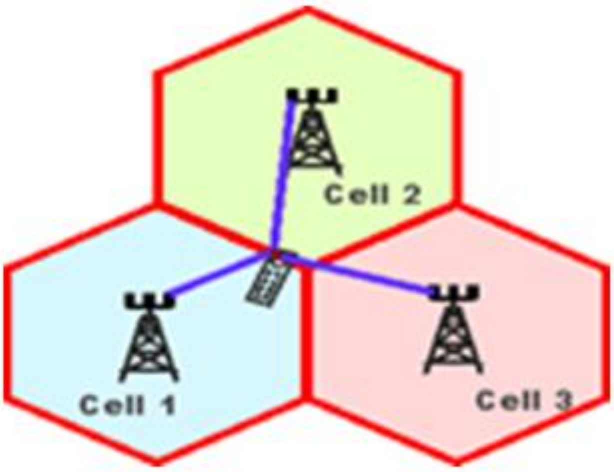

Figure (2. 6) Coordinated Multipoint

2-2-1-3 LTE-Advanced Carrier Aggregation

4G LTE- Advanced CA, carrier aggregation or channel aggregation enables multiple LTE carriers to be used together to provide the high data rates required for 4G LTE-advanced and in this way, increase the overall transmission bandwidth. These channels or carriers may be in contiguous elements of the spectrum, or they may be in different bands. Carrier aggregation is supported by both formats of LTE, namely the FDD and TDD variants. This ensures that both FDD LTE and TDD LTE are able to meet the high data throughput requirements placed upon them [1].

2-3 Radio Resource Management (RRM)

Radio Resource Management (RRM) is an eNB application level, function that ensures the efficient use of available radio resources. RRM manages the assignment, re-assignment and release of radio resources considering single and multi-cell aspects.

The primary goal of RRM is to control the use of radio resources in the system while also ensuring that the Quality of Service (QoS) requirements of the individual radio bearers are met and the overall usage of radio resources on the system level is minimized. The objective of RRM is to satisfy the service requirements at the smallest possible cost to the system, ensuring optimized use of spectrum. Long Term Evolution (LTE) RRM includes a variety of algorithms that provide services, such as power control, resource allocation, mobility control, and QoS management to ensure the best use of available radio resources [4].

2.4 Adaptive Modulation and Coding

Adaptive Modulation and Coding (AMC) refers to the ability of the network to determine the modulation type and the coding rate dynamically based on the current RF channel conditions reported by the UE in Measurement Reports.

The RF digital modulation used to modulate the information is QPSK, 16-QAM, and 64-QAM. Figure (2.7) illustrates the ideal constellations for each modulation where each dot represents a possible symbol. In the QPSK case, there are four possible symbol states and each symbol carries two bits of information. In 16-QAM, there are 16 symbol states. Each 16-QAM symbol carries 4 bits. In 64-QAM, there are 64 symbol states. Each 64-QAM symbol carries 6 bits. Higher-order modulation is more sensitive to poor channel conditions than the lower-order modulation because the detector in the receiver must resolve smaller differences as the constellations become more dense[10,11,12].

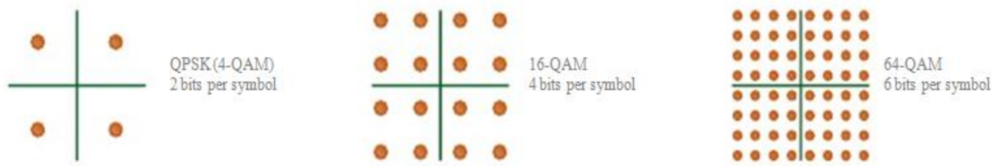

Figure (2.7) Adaptive Modulations and Coding (AMC)

Coding refers to an error-correction methodology that adds extra bits to the data stream that allow error correction. Specified as fractions, Code Rates specify the number of data bits in the numerator and the total number of bits in the denominator. Thus if the Code Rate is 1/3, protection bits are added so one bit of data is sent as three bits. See next table for SINR, M and C, as show in the table (2:1) the Modulation Level and code rate increase when the SINR increased [11].

Table 2.1: LTE Adaptive Modulation

Modulation	**Coding rate**	**Receiver SNR threshold (Db)**
BPSK	½	6.4
QPSK	½	9.4
QPSK	¾	11.2
QAM-16	½	16.4
QAM-16	¾	18.2
QAM-64	½	22.7
QAM-64	¾	24.2

2-5 MIMO System

MIMO stands for Multiple-Input Multiple-Output, meaning that MIMO systems use more than one transmit antenna (Tx) to send a signal on the same frequency to more than one receive antenna (Rx). Although MIMO has been deployed for years in WLAN networks, 2 it is a relatively new feature in commercial wireless networks. MIMO technology is a standard feature of next-generation LTE networks, and it is a major piece of LTE’s promise to significantly boost data rates and overall system capacity. However, MIMO also represents a new challenge for network operators. Traditional cellular networks generally provide the best service under line-of-sight conditions. MIMO thrives under rich scattering conditions, where signals bounce around the environment. Under rich scattering conditions, signals from different Tx take multiple paths to reach the user equipment (UE) at different times, as shown in Figure (2.8). In order to achieve promised throughputs in LTE systems, operators must optimize their networks' multipath conditions for MIMO, targeting both rich scattering conditions and high SNR for each multipath signal. This optimization process requires accurate measurement of these multipath conditions in order to achieve the best performance for a given environment while avoiding the time and expense of guesswork. With strong measurements, however, an optimized MIMO system can result in massive throughput gains without the expenses associated with adding spectrum or eNodeBs[13].

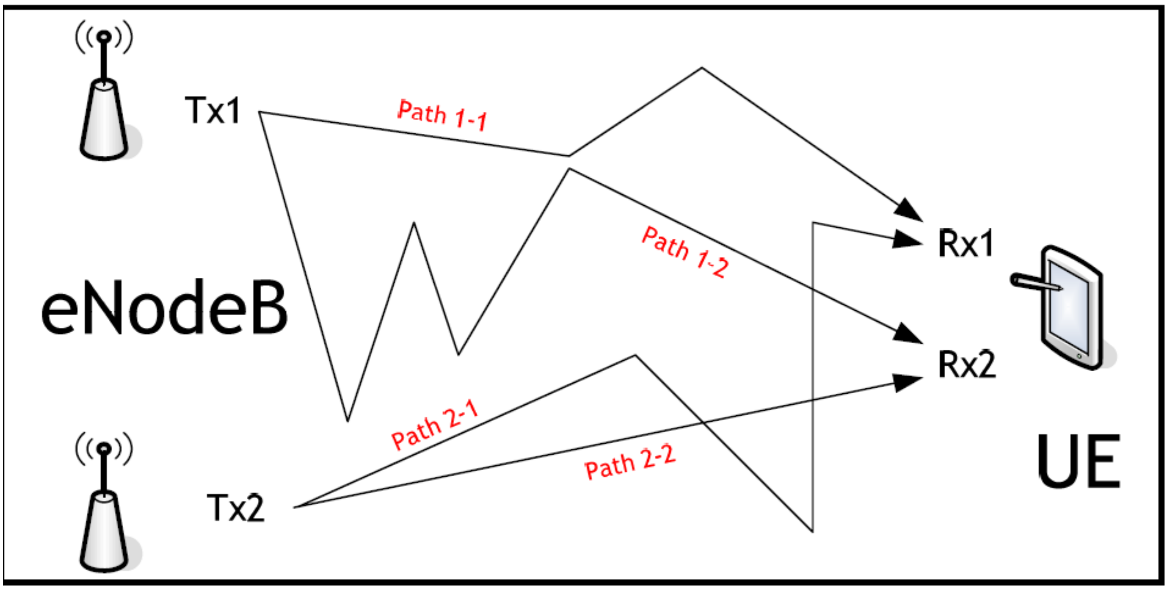

Figure (2.8) Multiple paths for eNodes to UE in 2X2 MIMO

MIMO can work as a combination of SIMO and MISO techniques, resulting in even greater SNR gains, further boosting coverage and data rates. However, when SNR is high, additional throughput gains are minimal, and there is little benefit from further boosting SNR (see Figure 2.9). To achieve throughput gains where SNR is already very high, LTE uses a MIMO technique called spatial multiplexing. In spatial multiplexing, each Tx sends a different data stream to multiple Rx. These data streams are then reconstructed separately by the UE. It may seem counterintuitive that two signals sent at the same time and frequency within the same sector can result in increased throughput rather than interference. However, spatial multiplexing can be compared to conventional spectrum re-use, where signals are transmitted in the same frequency in different cells. For spectrum re-use, the cells must be far enough Apart that is, they must occupy different space in order to avoid interference. With spatial multiplexing, the signals, instead of occupying a completely different cell, occupy different space-time in the same cell. Good multipath conditions create the signal orthogonality that effectively turns a single cell into multiple cells with respect to the amount of data that can be sent on a particular frequency band[13].

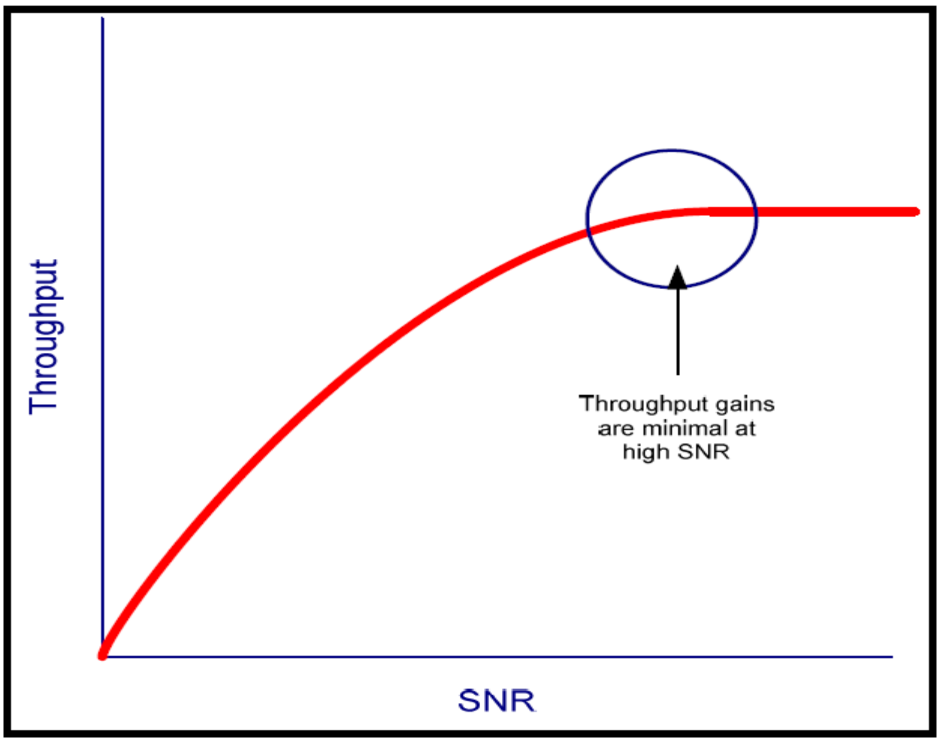

Figure (2.9) Diminishing returns of throughput gains from increase SINR.

2.6 Types of cooperative virtual MIMO

2.6.1 COOPERATIVE MIMO IN CELLULAR SYSTEMS COMP

CoMP [2] is an emerging technique to combat intercell interference and improve cell edge performance. The system architecture is illustrated in Figure . 1a. The idea is to share data and channel state information (CSI) among neighboring base stations (BSs) to coordinate their transmissions in the downlink and jointly process the received signals in the uplink. CoMP techniques can effectively turn otherwise harmful inter cell interference into useful signals, allowing significant power gain, channel rank advantage, and/or diversity gains to be exploited. The promised advantages of CoMP rely on a high-speed backbone enabling the exchange of information (e.g., data, control information, and CSI) between the BSs. CoMP has been studied intensively in both academia and industry over recent years, and is a very strong candidate technology for 4G standards. CoMP systems are only concerned with the BS to mobile station (MS) channels, which are fixed-to-mobile (F2M) channels[14].

2.6.2 FIXED RELAYS

As illustrated in Fig. 1b, fixed relays are low-cost and fixed radio infrastructures without wired backhaul connections. They store data received from the BS and forward to the MSs, and vice versa. Fixed relay stations (RSs) typically have smaller transmission powers and coverage areas than a BS. They can be deployed strategically and cost effectively in cellular networks to extend coverage, reduce total transmission power, enhance the capacity of a specific region with high traffic demands, and/or improve signal reception. By combining the signals from the relays and possibly the source signal from the BS, the MS is able to exploit the inherent diversity of the relay channel.

The disadvantages of fixed relays are first the additional delays introduced in the relaying process, and second the potentially increased levels of interference due to frequency reuse at the RSs. As the most mature cooperative MIMO technology, fixed relay has attracted significant support in major cellular communication standards.

The IEEE 802.16j specification has incorporated fixed relays to enhance WiMAX performance. Fixed relay is also a very strong candidate technology for 4G, with possible mesh extensions in a later standard release. As shown in Fig. 1b, fixed relay systems involve different types of links, including BS-MS, BS-RS, RS-RS, and RSMS links. The BS-RS and RS-RS channels are fixed-to-fixed (F2F) channels, while the BS-MS and RS-MS channels are F2M channels [14].

2.6.3 MOBILE RELAYS

Mobile relays differ from fixed relays in the sense that the RSs are mobile and are not deployed as the infrastructure of a network. Mobile relays are therefore more flexible in accommodating varying traffic patterns and adapting to different propagation environments. For example, when a target MS temporarily suffers from bad channel conditions or requires relatively high-rate service, its neighboring MSs can help to provide multi hop coverage or increase the data rate by relaying information to the target MS. Moreover, mobile relays enable faster and lower-cost network rollout. Similar to fixed relays, mobile relays can enlarge the coverage area, reduce the overall transmit power, and/or increase the capacity at cell edges. On the other hand, due to their opportunistic nature, mobile relays are less reliable than fixed relays since the network topology is highly dynamic and unstable. As shown in Figure (2.10). 1c, two types of mobile relay systems can be distinguished: moving networks and mobile user relays. The moving network employs dedicated RSs on moving vehicles (e.g., trains) to receive data from the BS and forward to the user MSs onboard, and vice versa. The purpose of the moving network is to improve coverage on the vehicle. The mobile user relay enables distributed MSs to self-organize into a wireless ad hoc network, which complements the cellular network infrastructure using multi hop transmissions. Theoretical studies have shown that mobile user relays have a fundamental advantage in that the total network capacity, measured as the sum of the throughputs of the users, can scale linearly with the number of users given sufficient infrastructure supports.

Mobile user relays are therefore a desirable enhancement to future cellular systems. However, mobile user relays also face huge challenges in routing, radio resource management, and interference management. The major disadvantage of mobile user relays is that MS batteries can be used up by relay transmissions even if the user does not use them. Mobile user relays also complicate the billing problem (i.e., who shall pay the bill when a user helps other users as a relay)[14].

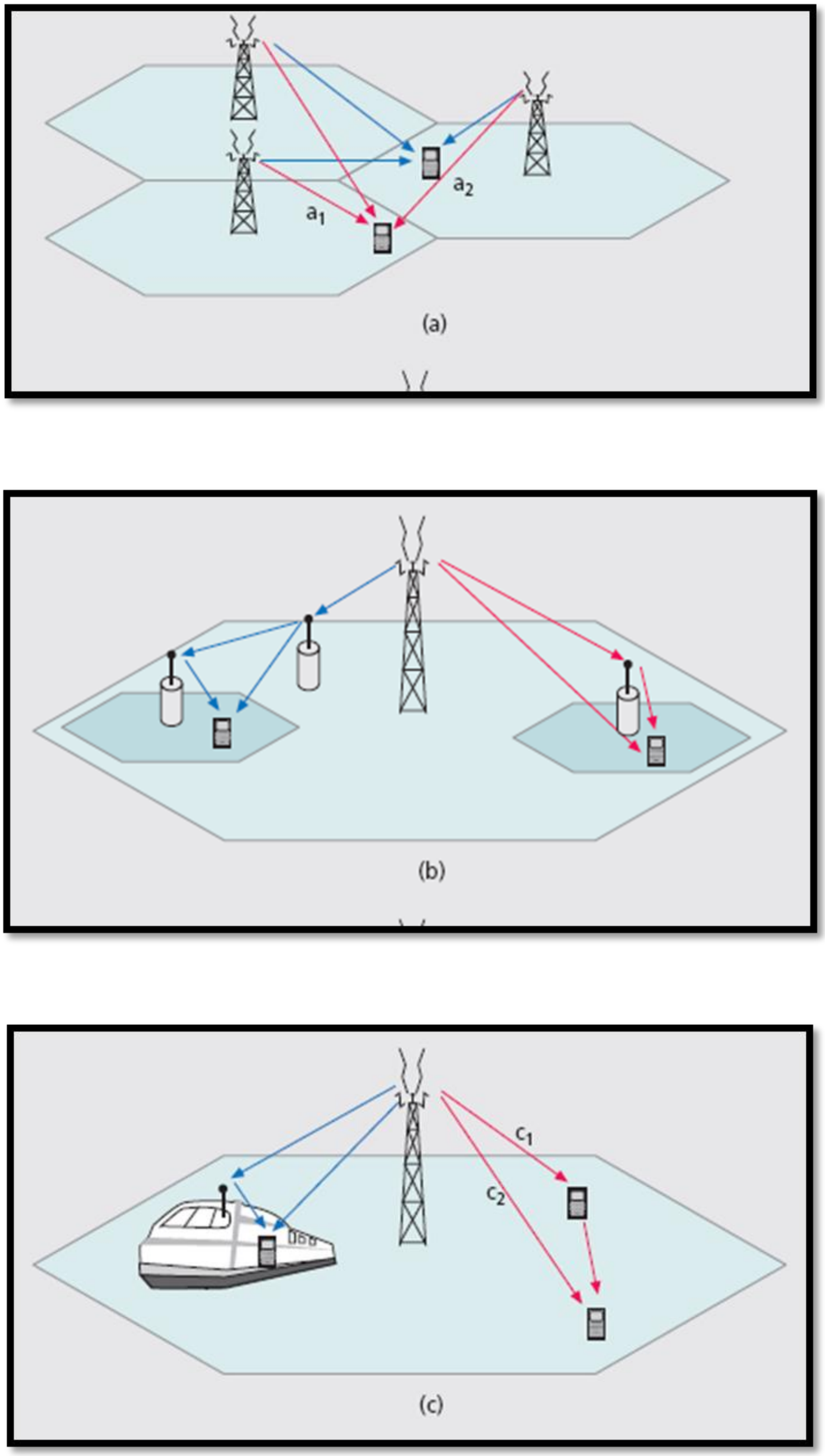

Figure (2.10): Three types of cooperative MIMO schemes in cellular systems: a) CoMP; b) fixed relay; c) mobile relay.

2.7 Related Works

In [15], the authors discussed the impact of multiple linear amplify and- forward relays on the capacity of rank-deficient MIMO channels. We derive a general system model for wireless networks with one source/destination pair and several linear amplify-and-forward relay nodes which assist the communication between source and destination. All nodes may be equipped with multiple antennas. For a given allocation of gain factors at the relay nodes we give an analytical expression of the capacity by generalizing the results in. We compare the performance of a relay assisted MIMO link in a line-of-sight environment with a MIMO link without relay nodes. Our results show that the proposed cooperative signaling scheme solves a fundamental problem of MIMO systems: the rich scattering requirement.

In [16], Multi-Input Multi-Output (MIMO) techniques can be used to increase the data rate for a given bit error rate (BER) and transmission power. Due to the small form factor, energy and processing constraints of wireless sensor nodes, a cooperative Virtual MIMO as opposed to True MIMO system architecture is considered more feasible for wireless sensor network (WSN) applications. Virtual MIMO with Vertical-Bell Labs Layered Space-Time (V-BLAST) multiplexing architecture has been recently established to enhance WSN performance. In this paper, we further investigate the impact of different modulation techniques, and analyze for the first time, the performance of a cooperative Virtual MIMO system based on V-BLAST architecture with multi-carrier modulation techniques. Through analytical models and simulations using real hardware and environment settings, both communication and processing energy consumptions, BER, spectral efficiency, and total time delay of multiple cooperative nodes each with single antenna are evaluated. The results show that cooperative Virtual-MIMO with Binary Phase Shift Keying-Wavelet based Orthogonal Frequency Division Multiplexing (BPSK-WOFDM) modulation is a promising solution for future high data-rate and energy-efficient WSNs.

In [17], The capacity of the multi-input multi-output (MIMO) wireless channel with uniform linear arrays of antennas at the transmitter and receiver is investigated. It is assumed that the receiver knows the channel perfectly but that the transmitter knows only the channel statistics. The analysis is carried out using an equivalent virtual representation of the channel that is obtained via a spatial discrete Fourier transform. A key property of the virtual representation that is exploited is that the components of virtual channel matrix are approximately independent. With this approximation, the virtual representation allows for a general capacity analysis without the common simplifying assumptions of Gaussian statistics and product-form correlation (Kronecker model) for the channel matrix elements. A deterministic line-of-sight (LOS) component in the channel is also easily incorporated in much of the analysis. It is shown that in the virtual domain the capacity achieving input vector consists of independent zero-mean proper-complex Gaussian entries, whose variances can be computed numerically using standard convex programming algorithms based on the channel statistics. Furthermore, in the asymptotic regime of low signal to-noise ratio (SNR), it is shown that beam forming along one virtual transmit angle is asymptotically optimal. Necessary and sufficient conditions for the optimality of beam forming, and the value of the corresponding optimal virtual angle, are also derived based on only the second moments of the virtual channel coefficients. Numerical results indicate that beam forming may be close to optimum even at moderate values of SNR for sparse scattering environments. Finally, the capacity is investigated in the asymptotic regime where the number of receive and transmit antennas go to infinity, with their ratio being kept constant. Using a result of Girko, an expression for the asymptotic capacity scaling with the number of antennas is obtained in terms of the two-dimensional spatial scattering function of the channel. This asymptotic formula for the capacity is shown to be accurate even for small numbers of transmits and receives antennas in numerical examples.

CHAPTER THREE

Co-operative Virtual MIMO

CHAPTER THREE

3. Co-operative Virtual MIMO

3.1 Cooperative Virtual MIMO

MIMO techniques are capable of providing high system performance without additional transmission power and bandwidth. However, due to the small form factor and limited energy of sensor nodes, it is often not realistic to equip each sensor with multiple antennas to implement MIMO. Instead, a cluster of single-antenna sensor nodes can cooperate to form a virtual antenna array (VAA) to achieve virtual MIMO communication. Virtual MIMO systems are distributed in nature because multiple nodes are placed at different physical locations to cooperate with each other as show in the Figure (3.1) and (3.2). With proper timing and frequency synchronization between constituent nodes of the VAA, virtual MIMO can realize the advantages of true MIMO techniques for WSNs, [18,19].

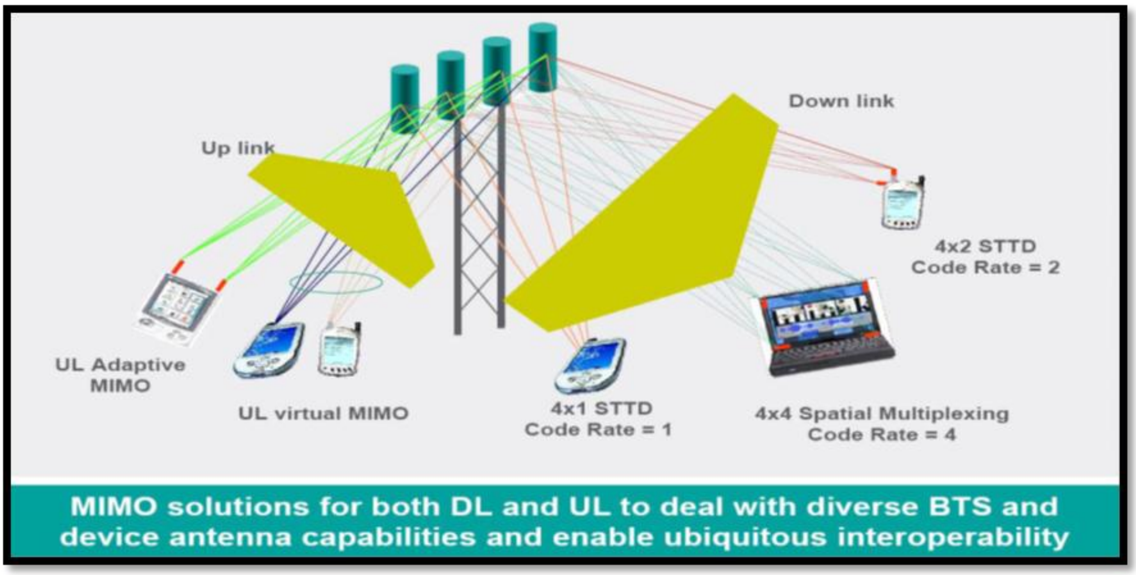

Figure (3.1) MIMO diverse BTS

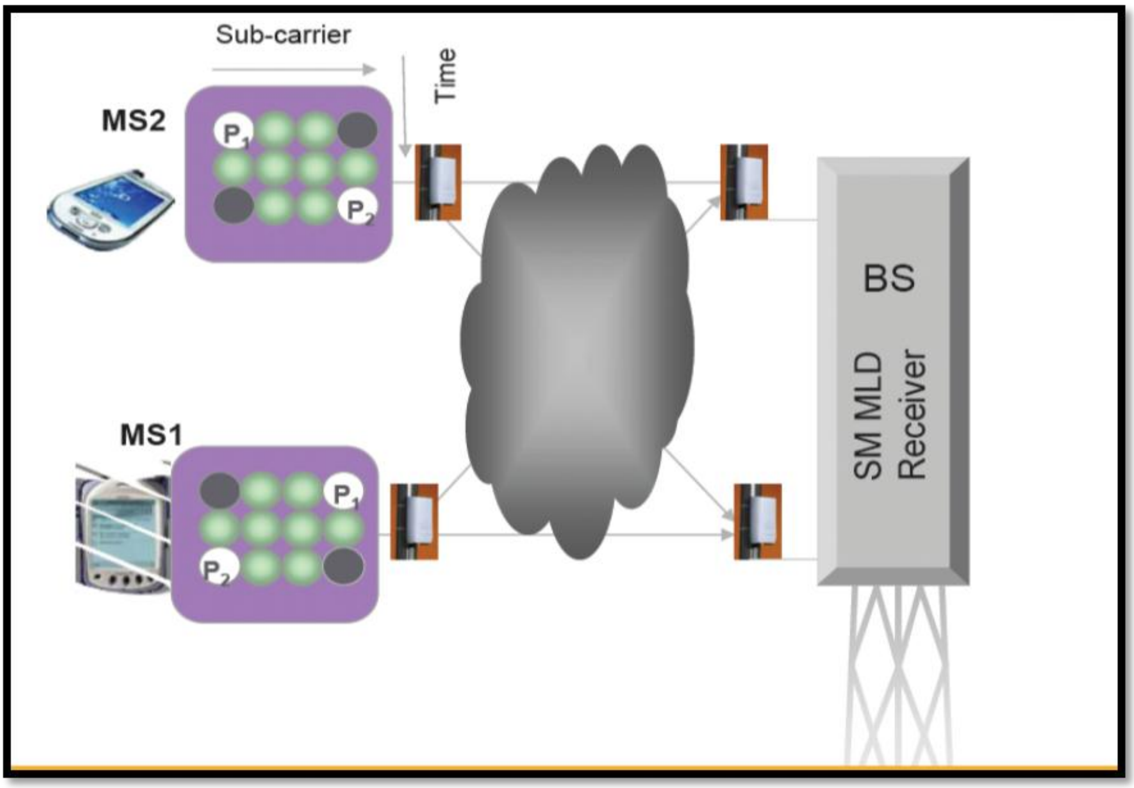

Figure (3.2) uplink virtual MIMO

3.2 Cooperative Diversity

3.2.1 Motivation

In MIMO, size of the antenna array must be several times the wavelength of the RF carrier. Unattractive choice to achieve receives diversity in small handsets/cellular phones.

3.2.2 Cooperative diversity

Transmitting nodes use idle nodes as relays to reduce multi-path fading effect in wireless channels.

3.2.3 Methods

Amplify and forward, Decode and forward, finally Coded Cooperation.

3.3 Comparison of Cooperative Diversity Scheme

As show in Figure (3.3) consists of Decode and Forward, Amplify and Forward and Coded Cooperation.

3.3.1 Decode and Forward

Simple and adaptable to channel condition (power allocation), If detection in relay node unsuccessful detrimental for detection in receiver (adaptive algorithm can fix the problem), Receiver needs CSI between source and relay for optimum decoding.

3.3.2 Amplify and Forward

Achieve full diversity, Performance better than direct transmission and decode-and-forward, achieve the capacity when number of relays tends to infinity.

3.3.3 Coded Cooperation

Transmit incremental redundancy for partner, Automatic manage through code design, no feedback required between the source and relay, Rely on full decoding at the relay cannot achieve full diversity, Not scalable to large cooperating groups [17,20,21].

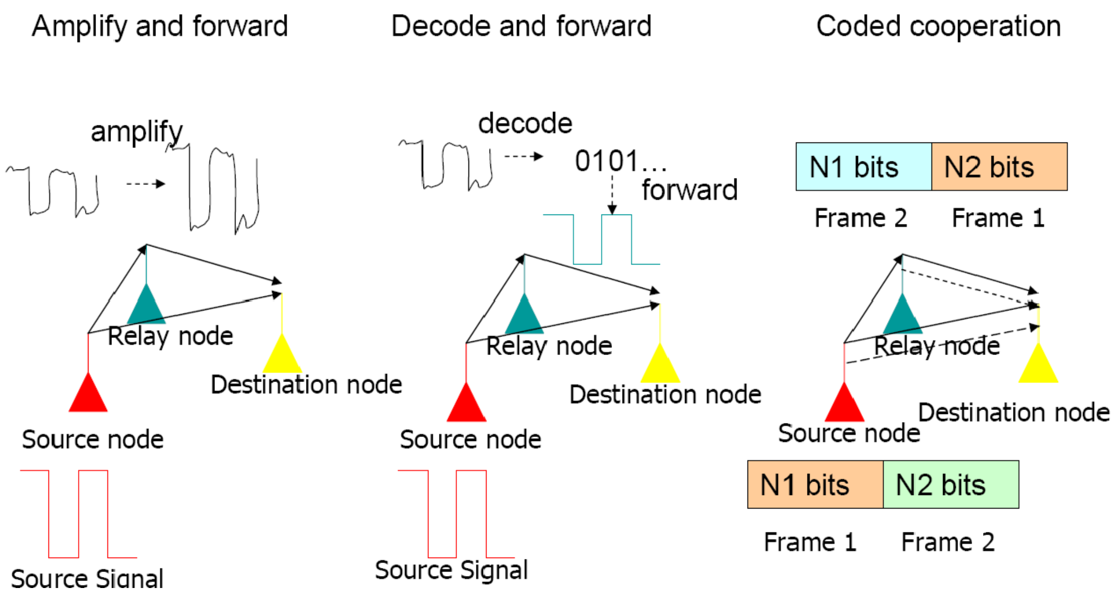

Figure (3.3): Cooperative Diversity Schemes

3.4 Mathematical Equations

The Mathematical Equations that's used in simulation in MATLABE are flow :

3.4.1 Signal to interference noise ratio

The signal to interference is very importance in mobile station and it relate with data rate, spectrum efficiency, throughput, and delay. And its calculate by power receiver, antenna gain, interference, distance and noise. Equation 3.1 calculate the Signal to interference noise ratio (SINR)

$$Pr = Pt + Gt + Gr - Pl \quad 3.1$$

$$Pl = 20\log(D) + 20\log(f) - 174.55 \quad 3.2$$

$$SINR = Pr - I - N \quad 3.3$$

Where:

SINR = Signal to interference noise ratio in (dB).

Pt = power transmit in (dB).

Pr = power Receiver in Mobile in (dB).

Gr = gain antenna receive in (dB).

Gt = gain antenna transmit in (dB).

N = noise in (db).

D = Distance (Meter).

F = Frequency (Hz).

I = interference in (dB).

Pl= Path loss (dB)

3.4.2 Data Rate

Data rate: is the average number of bits per unit time unit (bits/second). Equation 3.2 calculates the Data rate (DR).

$$DR = \; Bw * M * C \qquad 3.4$$

Where:

DR = data rate in (dB).

Bw = Bandwidth in (Hz).

M = type of modulation. [number of bits per symbole].

C = coding rate.

3.4.3 Throughput

Throughput: System throughput is defined as the total number of bits correctly received by all users and can be mathematically expressed Equation 3.3 calculate the Throughput (TH)

$$TH = \sum_{n=1}^{n} (DR(1) + DR(2) + DR(n)) \text{ Bits/second} \qquad 3.5$$

Where:

TH = Throughput in (bit/sec).

SINR = Signal to interference noise ratio in (dB).

N = number of small cell.

3.4.4 Spectral Efficiency

Spectral Efficiency: refers to the information rate that can be transmitted over a given bandwidth in a given system(bit/s/Hz), Equation 3.6 calculate the Spectral Efficiency (SE)

$$SE = \frac{DR}{Bw} \qquad 3.6$$

Where:

SE = Spectral Efficiency in (bit/s/Hz).

DR = Data rate in (bit/sec).

Bw = Bandwidth in (Hz).

3.4.5 Delay transmission

Delay transmission: System delay gives the average of the total queuing delay of all packets in the buffers at the eNBs in the system, System delay can be mathematically expressed Equation 3.7 calculate the Delay transmission (DT)

$$\mathrm{DT} = \frac{\mathrm{data}}{\mathrm{DR}}\ \mathrm{Sec} \qquad 3.7$$

Where:

DT = Delay transmission in (sec).

Data = data transmit in (bit/sec).

DR = Data rate in (bit/sec).

3.4.6 Co-operative virtual MIMO

The co-operative virtual MIMO: is the summation of signals that the user receives from deferent Relay station and co-operates in the mobile but in deferent phases as express in equation 3.8

$$\mathrm{Co-operattive\ Virtual\ MIMO\ Signal} = \sum_{n=1}^{n} \mathrm{alpha}(1) * \mathrm{SINR}(1) + \mathrm{alpha}(2) * \mathrm{SINR}(2) + \mathrm{alpha}(\mathrm{n}) * \mathrm{SINR}(\mathrm{n}) \qquad 3.8$$

Where:

Alpha: is phase factor (0 to 1).

SINR: Signal Interference Noise Ratio.

3.5 Simulation Scenario

The MATLAP program was used to measure the performance of the user before the use of the CO-operative Virtual MIMO and the change that occurs after the use of the technology and the results obtained in SINR, DR, TH, SE and DT.

The comparison between the normal Relay and the CO-operative Virtual MIMO technique, where this technique combines the number of three Relay and support one user so that this user receives signal from each Relay (receive three signal) and compared with the normal Relay and found that the new technology is the best,   The Data and Frequency, and system bandwidth is constant value in simulation code. Used graphical user interface (GUI) program that works with MATLAB that facilitates data and helps to change the number of parameter, Changes in the allowable range of network quality are permitted entered in the MATLAB code.

CHAPTER FOUR

RESULTS AND DISCUSSION

CHAPTER FOUR

4. RESULTS AND DISCUSSION

Introduction

In This chapter describes what have been simulated, simulation parameters used, the results of the simulations, and a brief discussion for each result. The simulations were conducted on a MATLAB Programme.

In our system we have two scenarios assumed that a user use co-operative virtual MIMO method and same user when uses normal relay.

4.1 Simulation Parameter

Initialization step parameters is defined as setting the default parameters that used to calculate the general configuration variables, these variables are calculated from the table 4.1 of the simulation default parameters.

Table (4. 1) Simulation default parameters:

Parameter	**Values**
Bandwidth	20 MHz
Time	100s
Number of eNBs	1
Number of Relay nodes	3
Number of Ues	1

Number of Tx antennas	4
Number of Rx antennas	5
Modulation	BPSK, QPSK, 16QAM, 64QAM
Gain BS	15 dB m
Gain any node	To 25 db m
Power TX BS	25 db
Power TX any node	25 db
Noise ratio	5db m
Interference	6 db
Cooperative signal from 3 nodes	Virtual MIMO method

4.2 Simulation Results

The simulation results are shown in the following section in the form of line graphs.

4.2.1 Signal to interference noise ratio

Figure 4.1 shows that SINR Relay and SINR cooperative, the change in the values of the SINR is due to the case of continuous movement and the noise and interference values were taken randomly, Figure 4.1 shows the enhanced in SINR in Co-operative virtual MIMO by 251.1% this is because the user receives signals after Co-operative from three relay, Thus, the signal received became high, so the SINR cooperative become best than the relay .

Figure (4.1) SINR Relay and SINR cooperative virtual MIMO

4.2.2 Instantaneous Data rate

Figure 4.2 shows the change in the data rate, the change is due to use AMC, which makes us get a different modulation in each case to signal, Figure 4.2 show the enhanced in data rate due to increase SINR by 164.07% and very clear that the instantaneous data rate increases MIMO by cooperative due to use of high Modulation and code rate and SINR.

,

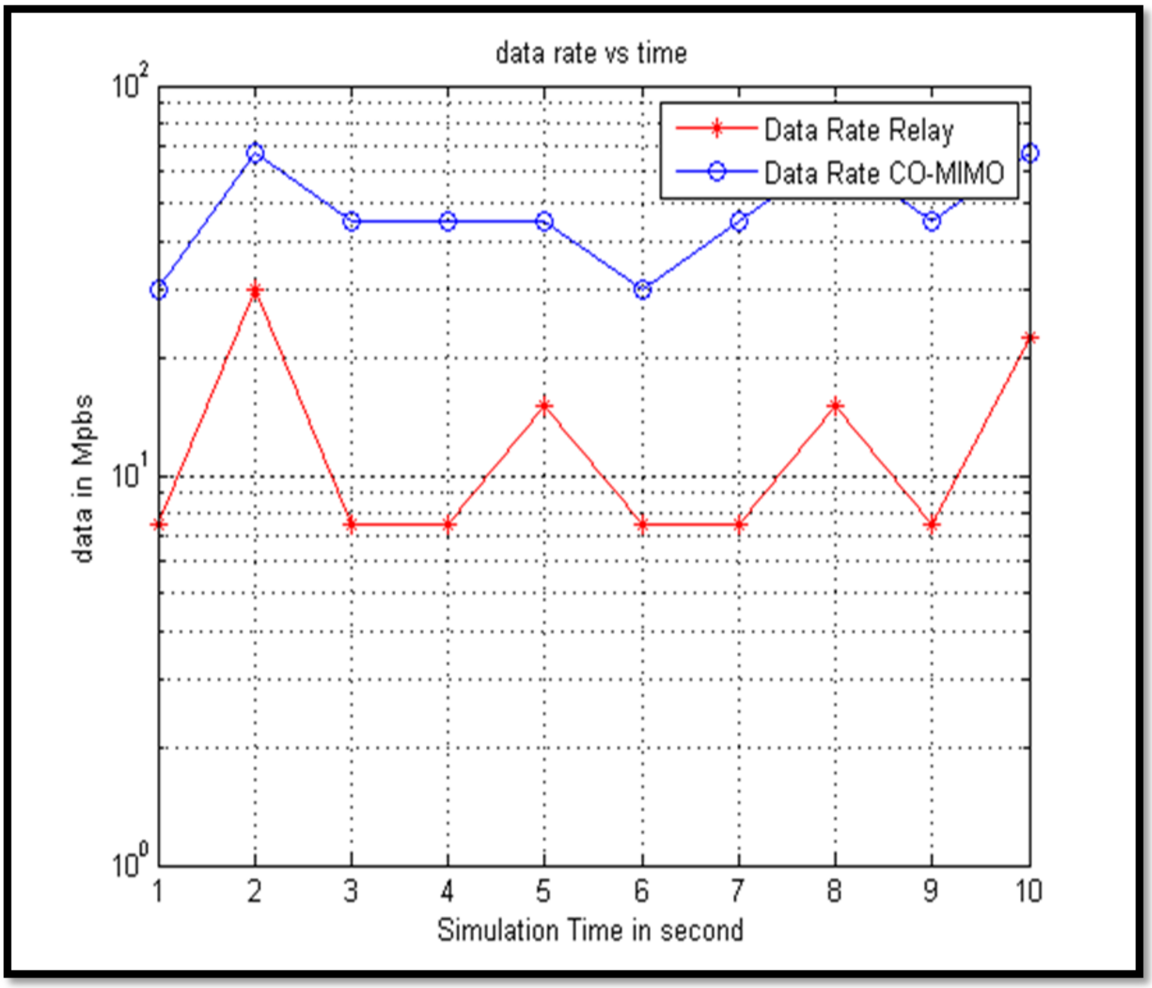

Figure (4.2) Instantaneous Data Rate

4.2.3 Accumulated Throughput

Figure 4.3 shows accumulated throughput performance and change in it for Relay method and cooperative MIMO versus time for mobile, the increasing happen in data rate by 164.07% due to increase in throughput by 335.29%, it's very clear that the accumulated throughput has been increased with cooperative virtual MIMO if it compared with the Relay signal throughput, and that due to increase of instantaneous data rate, Modulation, code rate been used and high SINR.

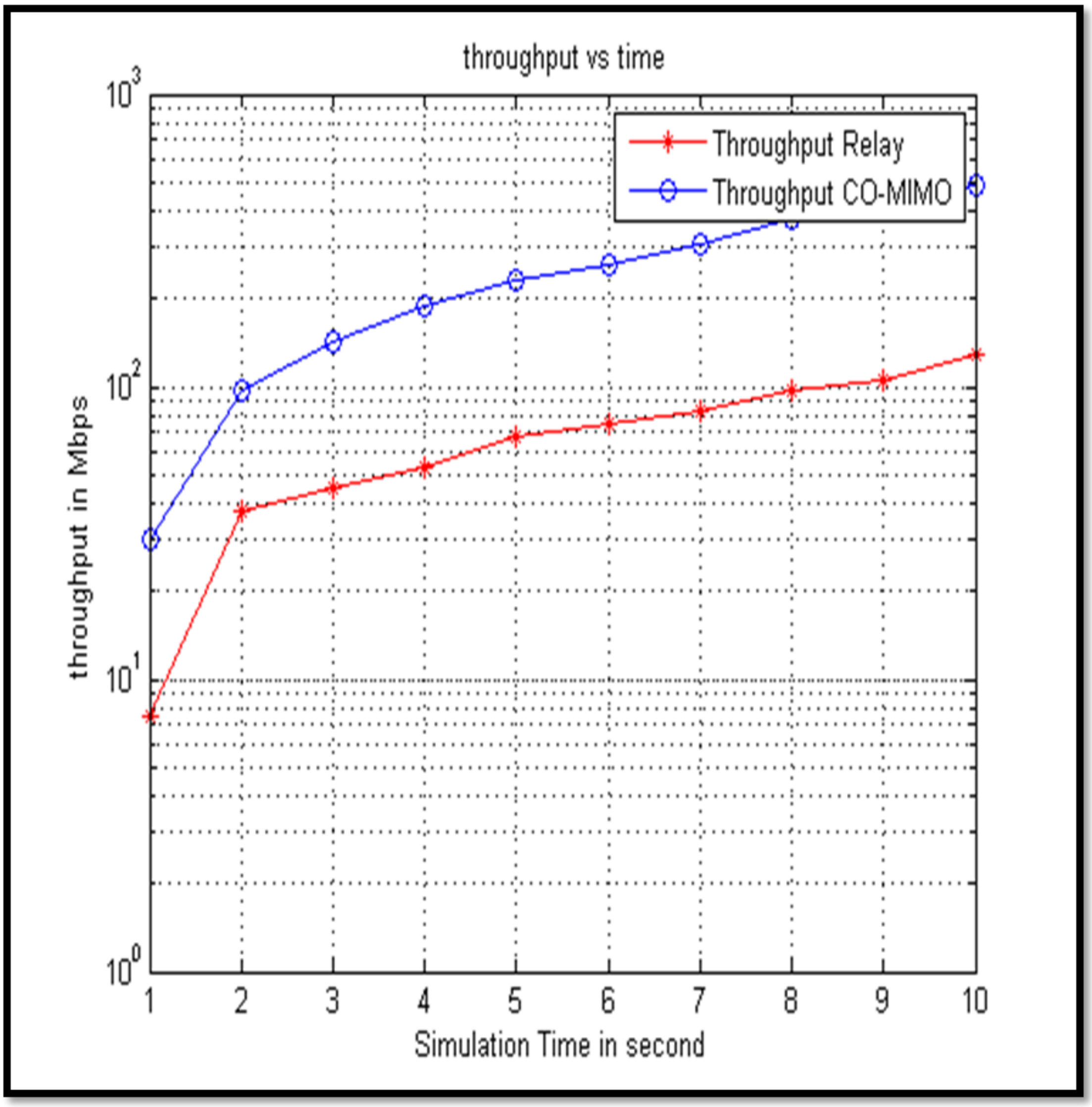

Figure (4.3) Accumulated throughputs.

4.2.4 Spectral Efficiency

Figure 4.4 shows the spectral efficiency with for Relay method and cooperative MIMO, it's very clear that the spectral efficiency has been improved and increased by 332.2% and that due to the increase in data rate and bandwidth. When data rate increases spectral efficiency will increase too.

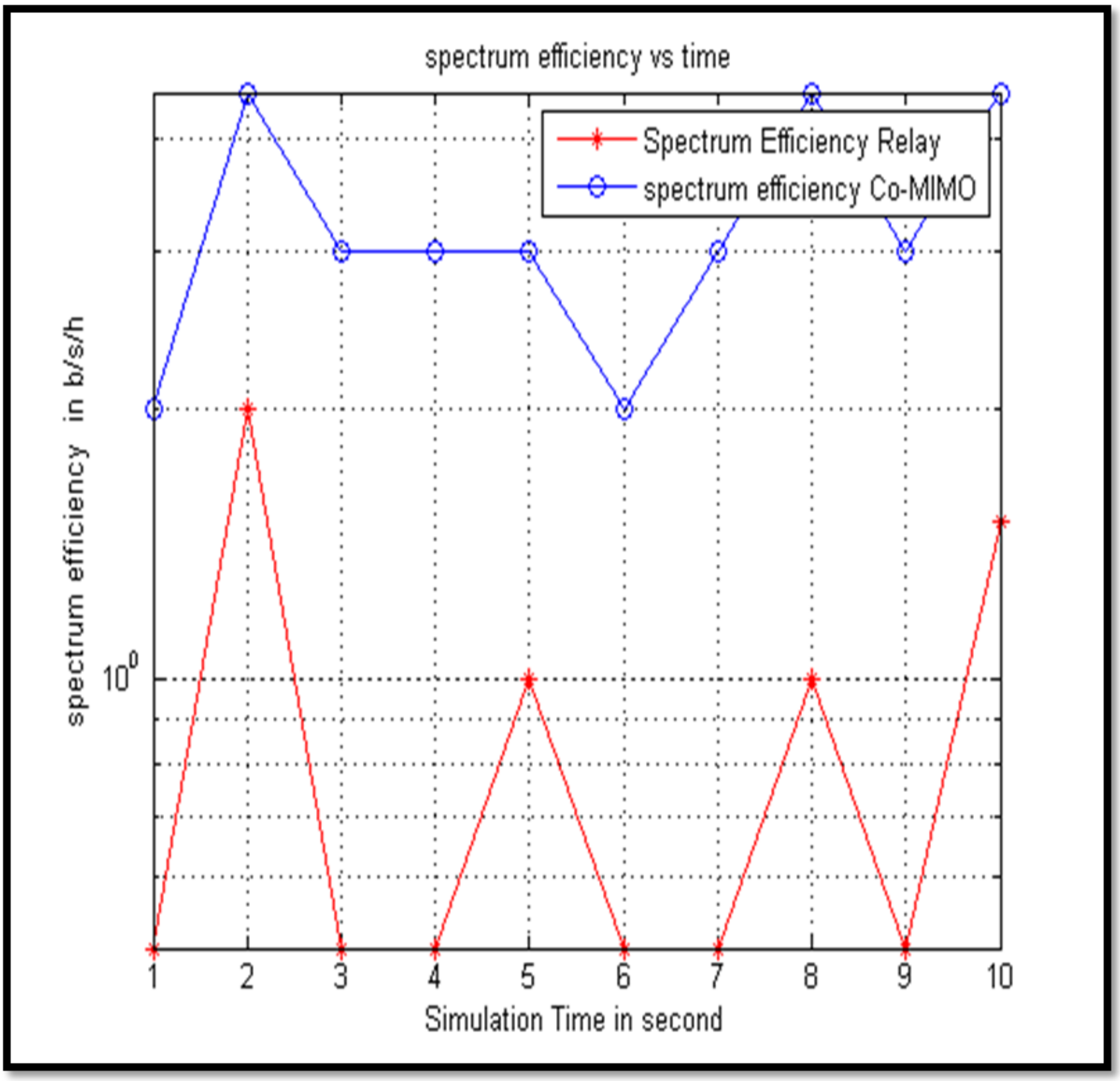

Figure (4.4) spectral efficiency

4.2.5 Delay Transition

Figure 4.5 displays the change of delay Transition for Relay method and cooperative MIMO verses time, and very clear that after applying the cooperative virtual MIMO process for user, the delay decreased in user and enhancement the QOS by 277.2% if compared to Relay Signal and that due to the increasing of data rate due to high data rate in co-operative.

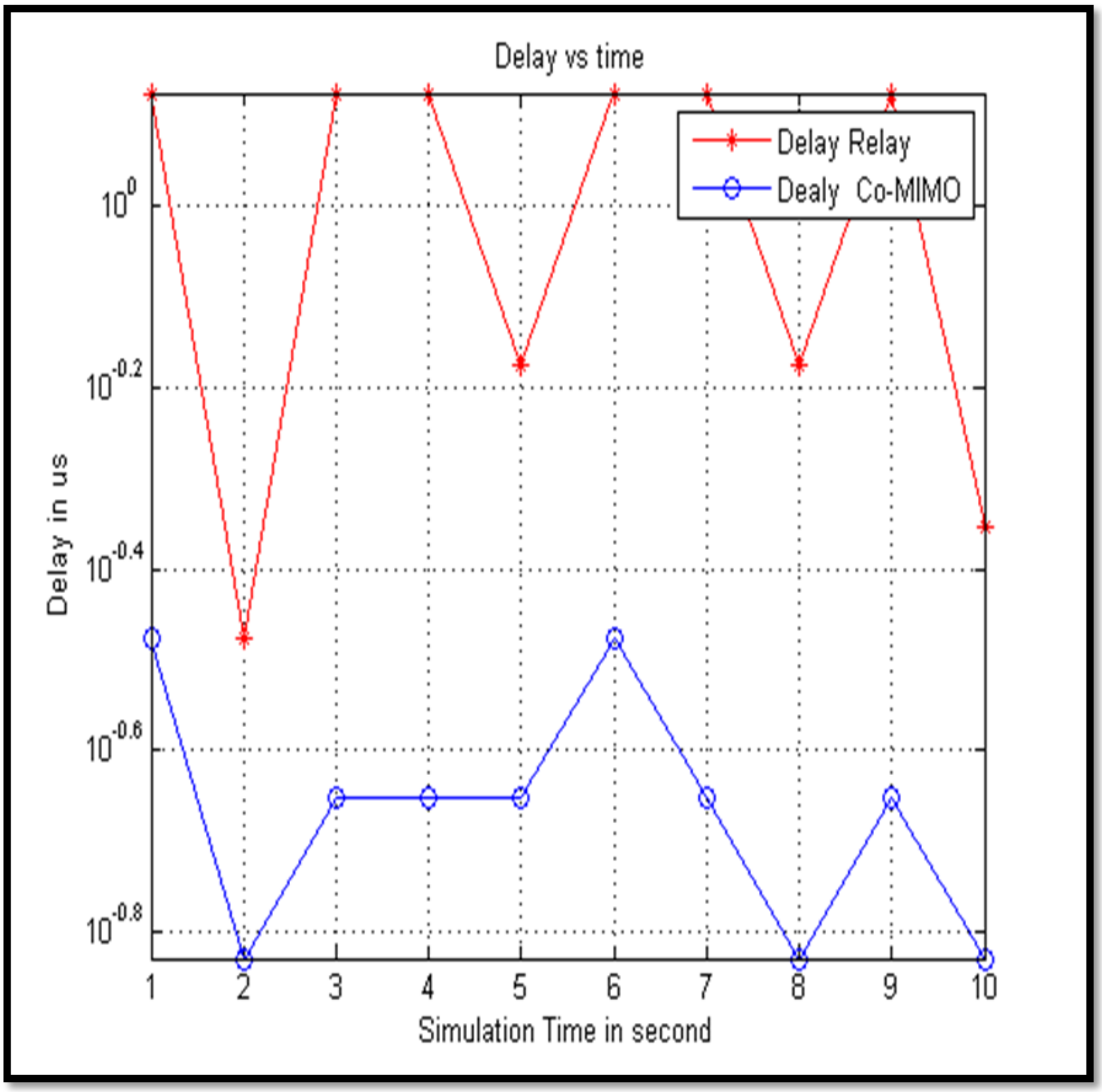

Figure (4.5) delay transition.

4.3 Simulation GUI

Graphical user interface (GUI) used in this project ,its tool that embedded in MATLAB program that facilitates data and helps user to change parameters ,the Changes in this parameter depend on allowable range of network quality and the values that used in code ,this parameters select depend on parameter used in the simulation code.

In the simulation GUI used power transmit , gain transmit ,gain received and distance (location) that used in relay1 ,relay2and relay3,this values can be changeable, the bandwidth and frequency are constant in the range network quality.

In the GUI tool named the parameters of the simulation result depend on simulation code (SINR, data rate, accumulated throughputs, spectral efficiency and delay transition, after that select switch tool to run figure by test button.

The simulations GUI are shown in the following in the form.

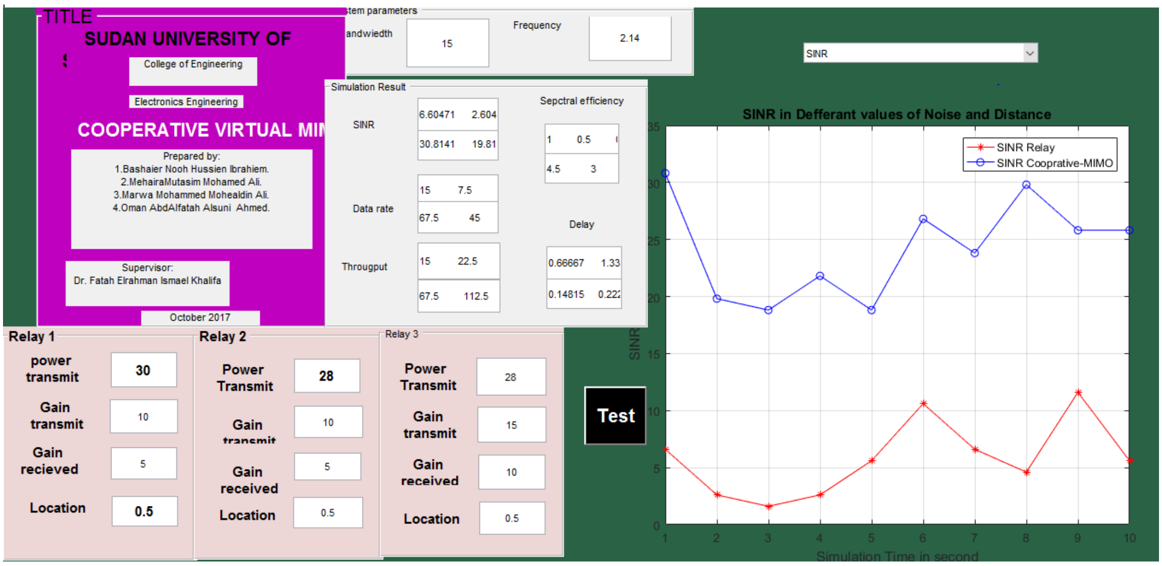

Figure (4.6) SINR GUI

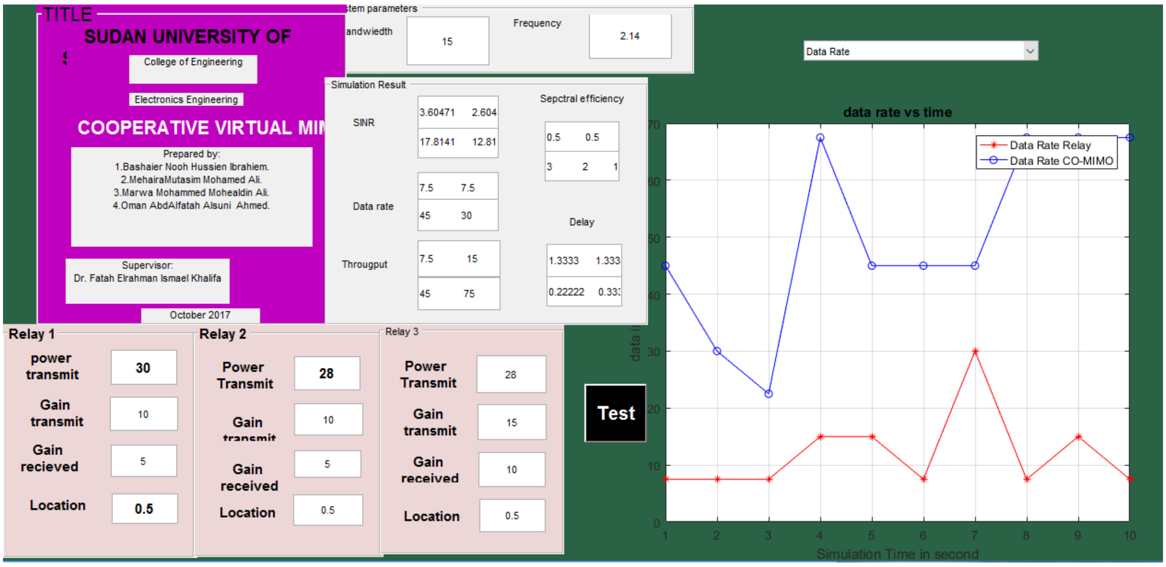

Figure (4.7) Instantaneous Data Rate GUI

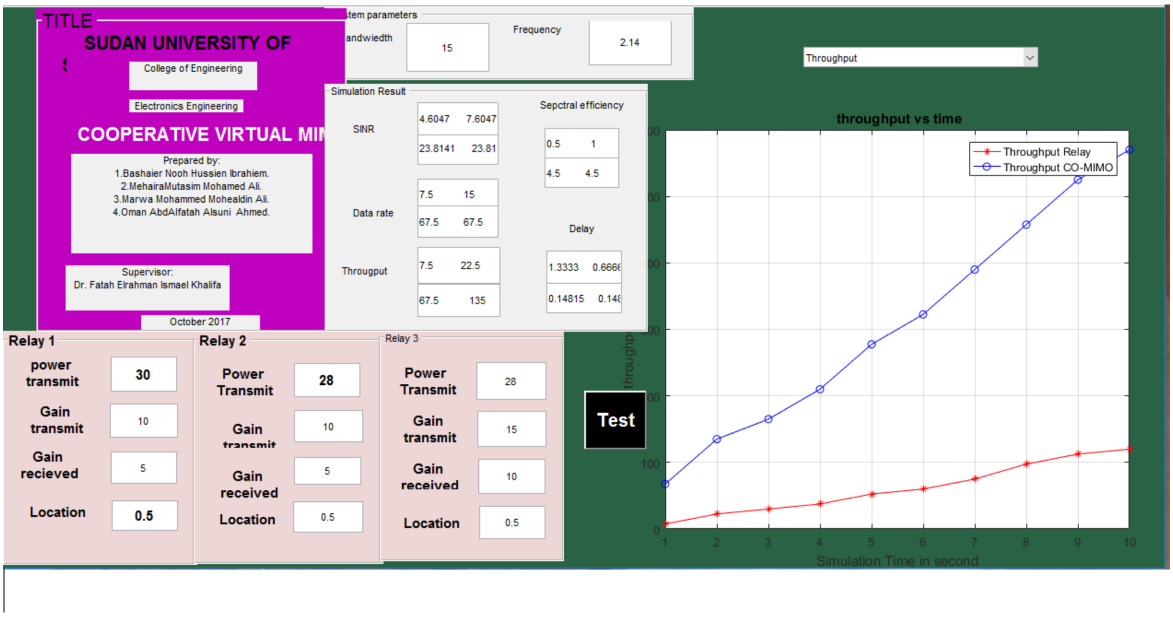

Figure (4.8) Accumulated through GUI

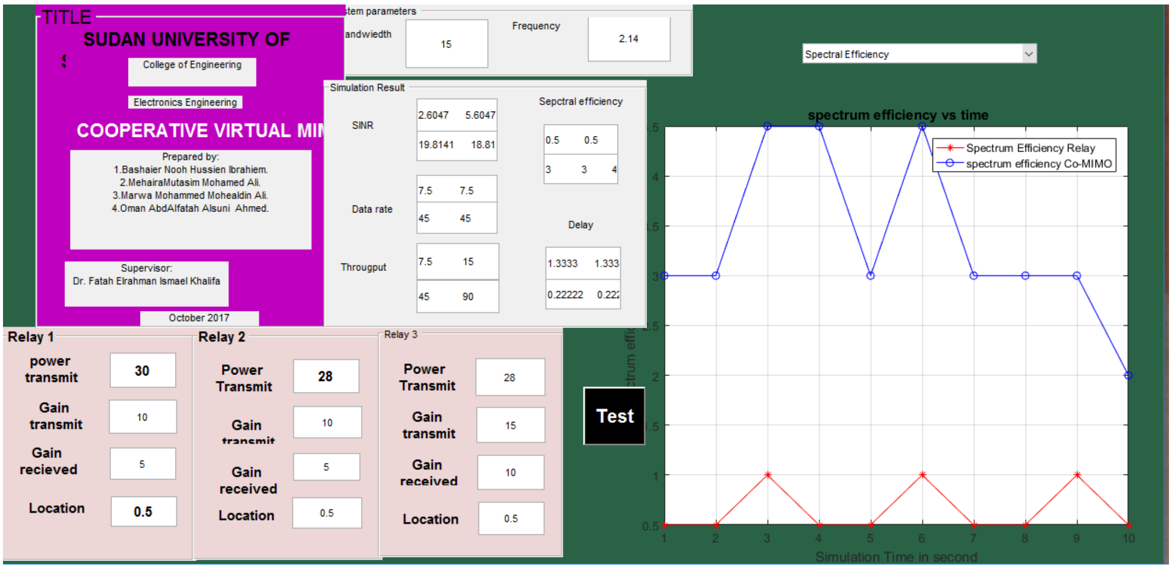

Figure (4.9) spectral efficiency

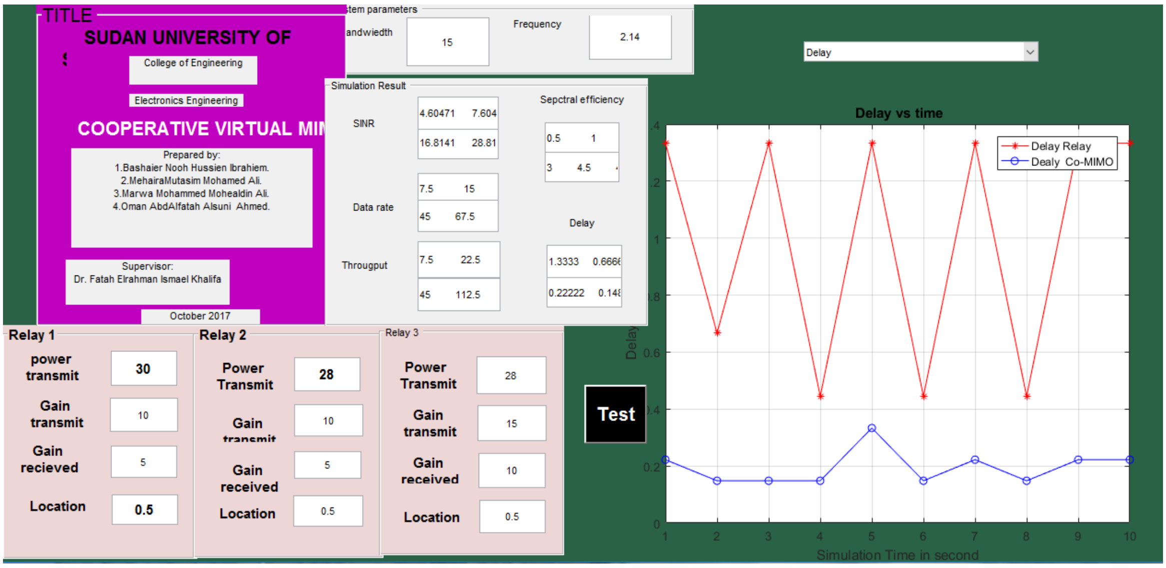

Figure (4.10) delay transition.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1Conclusion

A study is used LTE advanced in the 4G networks using a Co-operative virtual MIMO technique, This technique improved the quality of the signal to the user compared to the previously used the relay technique, The Co-operative virtual MIMO technique provides high signal performance and the network used compared to the signal quality in the relay technique, Explaining the parameter improvement and presenting the results, The idea of the project comparison between the normal Relay and the CO-operative Virtual MIMO technique, where this technique combines the number of three Relay and support one user so that this user receives signal from each Relay (receive three signal) and compared with the normal Relay and found that the new technology is the best, The Data and Frequency, and system bandwidth is constant value in simulation code.. Used MATLAB program to calculate the improvement in specific parameter and the results were as follows: an increase by 251.69 % in SINR single, an increase performance 164.07% in Data rate, high throughput by 332.2%, decrease in Delay by 277.2% . Used graphical user interface (GUI) program that works with MATLAB that facilitates data and helps to change the number of parameter, Changes in the allowable range of network quality are permitted entered in the MATLAB code.

5.2 Recommendations

After finishing this research works there are still some open issues can be considered for future research:

1-first, a complete simulation could not be developed, more algorithms could be implemented in the future like using of different channel to simulate and get result.

2- Future work might improve on the results obtained; by doing this more realistic and reliable simulation data could be achieved and presented.

3- Apply network protocol support cooperative MIMO and studied and simulated like COOPERATIVE AND CLUSTERING PROTOCOL CCP in WSN.

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Appendix: simulation code

```
clc, clear all , close all
Bw=15; %Mhs
data=10; %the data 10k Byte
%Relay one
%SINR1
PT_BS=30;
GT_BS=10;
GR_ST1=5;
%PL_SINR1=20log (d) +20log (f)-174.55
distance1=.5 %Km
Frequency=2.14 %GHz
PL_SINR1=abs (20*log(distance1*1000)+20*log(frequency)-174.55);
%PR_SINR1=PT_BS+GT_BS+GR_ST1_PL_SINR1
PR_SINR1=PT_BS+GT_BS+GR_ST1-PL_SINR1
Iterferanc_SINR1=randi ([1 20],[1 10]); %in dB
Noise_SINR1=randi([1 6],[1 10]); %in dB
SINR1=PR_SINR1-Iterferanc_SINR1-Noise_SINR1;
PTST1=SINR1
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%
%SINR2
PT_ST1=SINR1;
GT_ST1=10;
GR_UE1=5;
%PL_SINR2=20log(d)+20log(f)-174.55
distance2=.6 %Km
```

```
frequncy=2.14 %GHz
PL_SINR2=abs(20*log(distance2*1000)+20*log(frequncy)-174.55);
%PR_SINR2=PT_BS+GT_BS+GR_UE1_PL_SINR2
PR_SINR2=PT_BS+GT_BS+GR_UE1-PL_SINR2
Iterferanc_SINR2=randi([1 8],[1 10]); %in dB
Noise_SINR2=randi([1 6],[1 10]); %in dB
SINR2=PR_SINR2-Iterferanc_SINR2-Noise_SINR2
PR_Relay_one=SINR2
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%
%Relay Two
%SINR1
PT_BS=26;
GT_BS=10;
GR_ST2=5;
%PL_SINR1=20log(d)+20log(f)-174.55
distance1=.5 %Km
frequncy=2.14 %GHz
PL_SINR1=abs(20*log(distance1*1000)+20*log(frequncy)-174.55);
%PR_SINR1=PT_BS+GT_BS+GR_ST1_PL_SINR1
PR_SINR1=PT_BS+GT_BS+GR_ST1-PL_SINR1
Iterferanc_SINR1=randi([1 20],[1 10]); %in dB
Noise_SINR1=randi([1 6],[1 10]); %in dB
SINR1=PR_SINR1-Iterferanc_SINR1-Noise_SINR1;
PTST2=SINR1
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%
%SINR2
PT_ST1=SINR1;
GT_ST2=10;
GR_UE1=5;
%PL_SINR2=20log(d)+20log(f)-174.55
distance2=.6 %Km
frequency=2.14 %GHz
PL_SINR2=abs(20*log(distance2*1000)+20*log(frequncy)-174.55);
%PR_SINR2=PT_BS+GT_BS+GR_UE1_PL_SINR2
PR_SINR2=PT_BS+GT_BS+GR_UE1-PL_SINR2
Iterferanc_SINR2=randi([1 8],[1 10]); %in dB
Noise_SINR2=randi([1 6],[1 10]); %in dB
SINR2=PR_SINR2-Iterferanc_SINR2-Noise_SINR2
PR_Relay_two=SINR2
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%
%Relay Three
%SINR1
PT_BS=28;
GT_BS=15;
GR_ST3=10;
```

```
%PL_SINR1=20log(d)+20log(f)-174.55
distance1=.5 %Km
frequncy=2.14 %GHz
PL_SINR1=abs(20*log(distance1*1000)+20*log(frequncy)-174.55);
%PR_SINR1=PT_BS+GT_BS+GR_ST1_PL_SINR1
PR_SINR1=PT_BS+GT_BS+GR_ST1-PL_SINR1
Iterferanc_SINR1=randi([1 20],[1 10]); %in dB
Noise_SINR1=randi([1 6],[1 10]); %in dB
SINR1=PR_SINR1-Iterferanc_SINR1-Noise_SINR1;
PTST3=SINR1
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%SINR2
PT_ST1=SINR1;
GT_ST3=15;
GR_UE1=10;
%PL_SINR2=20log(d)+20log(f)-174.55
distance2=.6 %Km
frequncy=2.14 %GHz
PL_SINR2=abs(20*log(distance2*1000)+20*log(frequncy)-174.55);
%PR_SINR2=PT_BS+GT_BS+GR_UE1_PL_SINR2
PR_SINR2=PT_BS+GT_BS+GR_UE1-PL_SINR2
Iterferanc_SINR2=randi([1 8],[1 10]); %in dB
Noise_SINR2=randi([1 6],[1 10]); %in dB
SINR2=PR_SINR2-Iterferanc_SINR2-Noise_SINR2
PR_Relay_three=SINR2
```

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

Alpha=1  %same Fase
Coopr ative_MIMO=Alpha*(PR_Relay_one+PR_Relay_two+PR_Relay_
three)  %Mobile Relay

MIMO=  PR_Relay_one   %Non Coopr ative_MIMO

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%
%Plot
%Figure
figure
plot(PR_Relay_one,'r*-')
hold on
plot(Coopr ative_MIMO,'bo-')
grid
xlabel('Simulation Time in second')
ylabel('SINR IN dB')
title('SINR in Defferant values of Noise and Distance')
legend('SINR Relay','SINR Coopr ative-MIMO')
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%
for n=1:10

    if   ( PR_Relay_one(n) >=-10 & PR_Relay_one(n) <= 6.4)
    M1(n)=1;
    C1(n)=1/2;
    elseif ( PR_Relay_one(n) >6.4 & PR_Relay_one(n) <= 9.4 )
    M1(n)=2;
    C1(n)=1/2;
    elseif ( PR_Relay_one(n) >9.4 & PR_Relay_one(n) <= 11.2)
    M1(n)=2;
    C1(n)=3/4;
    elseif ( PR_Relay_one(n) >11.2 & PR_Relay_one(n) <= 16.4  )
    M1(n)=4;
    C1(n)=1/2;
    elseif ( PR_Relay_one(n) >16.4 & PR_Relay_one(n) <=18.2 )
    M1(n)=4;
    C1(n)=3 /4;
    elseif ( PR_Relay_one(n) >18.2 & PR_Relay_one(n) <= 22.7 )
    M1(n)=6;
    C1(n)=1/2;
    elseif ( PR_Relay_one(n) >22.7 & PR_Relay_one(n) <= 24.4  )
    M1(n)=6;
    C1(n)=3/4;

end;
```

```
DR1(n)=Bw*M1(n)*C1(n);
%DR2
    if  ( Cooprative_MIMO(n) <=-10 & Cooprative_MIMO(n) <= 6.4)
  M2(n)=1;
  C2(n)=1/2;
  elseif ( Cooprative_MIMO(n) >6.4 & Cooprative_MIMO(n) <= 9.4)
  M2(n)=2;
  C2(n)=1/2;
  elseif ( Cooprative_MIMO(n) >9.4 & Cooprative_MIMO(n) <= 11.2 )
  M2(n)=2;
  C2(n)=3/4;
  elseif ( Cooprative_MIMO(n) >11.2 & Cooprative_MIMO(n) <=16.4
)
  M2(n)=4;
  C2(n)=1/2;
  elseif ( Cooprative_MIMO(n) >16.4 & Cooprative_MIMO(n) <=18.2
)
  M2(n)=4;
  C2(n)=3/4;
  elseif ( Cooprative_MIMO(n) >18.2 & Cooprative_MIMO(n) <= 22.7
)
  M2(n)=6;
  C2(n)=1/2;
  elseif ( Cooprative_MIMO(n) >22.7 & Cooprative_MIMO(n) <= 35 )
  M2(n)=6;
  C2(n)=3/4;
 end;
DR2(n)=Bw*M2(n)*C2(n);
```

```
%caculate TH
TH1(1)=DR1(1)
TH2(1)=DR2(1)
if n >= 2
TH1(n)=TH1(n-1)+DR1(n)
TH2(n)=TH2(n-1)+DR2(n)
end
%Delay
Delay1(n)= data/(DR1(n))
Delay2(n)= data/(DR2(n))
%SE
 SE1(n)=DR1(n)/Bw
 SE2(n)=DR2(n)/Bw
end;

figure
semilogy(DR1,'r*-')
hold on
semilogy(DR2,'bo-')
grid
xlabel('Simulation Time in second')
ylabel('data in Mpbs')
title('data rate vs time')
legend('Data Rate Relay','Data Rate CO-MIMO')
%Through put
figure
semilogy(TH1,'r*-')
hold on
```

```
semilogy(TH2,'bo-')
grid
xlabel('Simulation Time in second')
ylabel('throughput in Mbps')
title(' throughput vs time')
legend('Throughput Relay','Throughput CO-MIMO')
%delay
figure
semilogy((Delay1),'r*-')
hold on
semilogy((Delay2),'bo-')
grid
xlabel('Simulation Time in second')
ylabel('Delay in us ')
title(' Delay vs time')
legend('Delay Relay','Dealy  Co-MIMO')
%specral efency
figure
semilogy(SE1,'r*-')
hold on
semilogy(SE2,'bo-')
grid
xlabel('Simulation Time in second')
ylabel('spectrum efficiency  in b/s/h')
title(' spectrum efficiency vs time')
legend('Spectrum Efficiency Relay','spectrum efficiency Co-MIMO')
```