Energy Efficient Antenna Selection for Downlink Massive MIMO System

Bonsa Bedaso Tuchi

A Thesis Submitted to

The Department of Electronics and Communication Engineering

School of Electrical Engineering and Computing

Presented in Partial Fulfillment of the Requirement for the Master of Science Degree in Electronics and Communication Engineering

Office of Graduate Studies

Adama Science and Technology University

February, 2021

Adama, Ethiopia

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Advisor: Dr. Rajaveerappa Devadas (PhD)

Co-Advisor: Mr. Shanko Chura

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APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the final open defense by Bonsa Bedaso Tuchi have read and evaluated his thesis entitled "Energy Efficient Antenna Selection for Down Link Massive MIMO System" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Masters in Electronics and Communication.

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DECLARATION

I hereby declare that this MSc thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been fully acknowledged.

Name: Bonsa Bedaso Tuchi

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This MSc thesis has been submitted for examination with my approval as a thesis advisor.

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Signature: ______________________________

Date of Submission: February 1, 2021

ADVISOR APPROVAL SHEET

To: Department of Electronics and Communication Engineering (ECE). This is to certify that the thesis entitled "Energy Efficient Antenna Selection for Downlink Massive MIMO" submitted in partial fulfillment of the requirements of the Master of Science Degree in Electronics and Communication Engineering, and has been carried out by Bonsa Bedaso Tuchi Id No. PGR/18074/11 under my supervision. Therefore, I recommend that the student has fulfilled the requirements and hereby he can submit the thesis to the department.

Dr. Rajaveerappa Devadas (PhD)	______________	February 1, 2021
Name of Advisor	Signature	Date

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ABSTRACT

Through utilizing large numbers of antennas, massive MIMO systems offer high data speeds, which also increases the system's power consumption as a consequence. The primary concept of massive MIMO is that terminals are supported by the base station (BS) equipped with a large number of antenna components over the same time-frequency resources. For current and next generation wireless communication systems, the massive multiple-input multiple-output (MIMO) system implementing vast quantities of antennas is a promising technique to increase energy efficiency. With the exponential growth and need for high-speed wireless communications, the needed quality of service is supported by more and more energy consumption. Thus, under restricted energy resource transmission schemes, energy efficient or green communication has become a very hot topic. The power consumption of radio frequency (RF) chains can, however, be enormous, which poses major challenges. Multiple antennas often include multiple RF chains, consisting of amplifiers, mixers, ADC, filters, etc. Thus, the expense and hardware complexity of the device is improved due to numerous RF chains. In this thesis, the issue of transmitting RF chain configuration with the objective of optimizing energy efficiency in large MIMO systems under total power constraints is considered here. In order to work with optimum energy efficiency, this generates an optimization problem that determines how many antennas the device can use. The main goal is to select a fixed number of antennas in order to enable the device to work with a smaller subset of antennas, depending on the number of active user terminals that may differ over time. Thus, by applying antenna selection methods, the RF chain configuration can be determined and a minimum number of transmission antenna elements are chosen to achieve energy efficiency. The simulation results show the effect of antenna selection (random antenna selection) on the energy efficiency of a massive MIMO system using NOMA and modulation schemes in order to achieve power reduction due to the selection of antennas. This NOMA and modulation scheme used to maximize the capacity that reduced due to antenna selection.

Key words: *massive MIMO, NOMA, Antenna selection, Modulation scheme, Energy Efficiency, RF (Radio Frequency)*

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LIST OF ACRONYMS

5G	Fifth Generation
ADC	Analog to Digital Converter
ATP	Area Transmission Power
AWGN	Additive White Gaussian Noise
BS	Base Station
BW	Bandwidth
CP	Circuit Power Consumption
CSI	Channel State Information
CSIT	Channel State Information at Transmitter
DL	Downlink
EE	Energy Efficiency
FDD	Frequency Division Duplexing
HCRAN	Heterogeneous Cloud Radio Access Network
HetNets	Heterogeneous Networks
IC	Interference Cancellation
IEEE	Institute of Electrical and Electronic Engineering
LOS	Line of Site
LTE	Long Term Evolution
MATLAB	Math's Laboratory
MIMO	Multiple Input Multiple Output
M-MIMO	Massive Multiple Input Multiple Output
MRC	Maximum Ratio Converging
MU-MIMO	Multiuser Multiple Input Multiple Output
NOMA	Non Orthogonal Multiple Access
OFDMA	Orthogonal Frequency Division Multiple Access
OMA	Orthogonal Multiple Access
PA	Power Amplifier
RF	Radio Frequency
RRHs	Remote Radio Heads
SE	Spectral Efficiency

SIC	Successive Interference Cancellation
SINR	Signal to Interference and Noise Ratio
SISO	Single Input Single Output
SNR	Signal to Noise Ratio
TAS	Transmit Antenna Selection
TDD	Time Division Duplexing
UE	User Equipment
UL	Uplink
UT	User Terminal
ZF	Zero Forcing

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

MIMO technology relies on multiple antennas to simultaneously transmit multiple data streams in wireless communication systems. It has already been used in commercial LTE wireless communication system and inevitable be used in current and next generation wireless communication system with its great potential of high spectral efficiency, reliability and other strengths. The development of MIMO technology has gone through point-to-point MIMO, Multi-user MIMO and large scale MIMO [1].

Multi-user MIMO offers tremendous advantages over conventional point-to-point MIMO: it works with inexpensive single-antenna terminals, there is no need for a rich scatting propagation environment, and the distribution of resources is versatile and streamlined since all active terminals use frequency bins all the time. But multi-user MIMO also has drawbacks: it needs approximately equal quantities of service-antennas and terminals and duplex operation of frequency division. It is not a technology which is scalable. Big scale MIMO (also referred to as huge MIMO or MIMO scaling) [2], provides a large advantage over traditional point-to-point MIMO and multi-user MIMO by the use of a large excess of s with current practice through the use of a large excess of service-antennas over terminals and time division duplex operation. Conventional wireless system designs primarily concentrate on system throughput.

Today, the energy efficiency of wireless systems, especially in systems with large-scale antennas, has become extremely important. The research path for the design of high energy efficiency of wireless systems is becoming urgent in line with the intent of the Green Touch organization dedicated to reducing power consumption in communication networks.

In current and future wideband wireless communication systems, large-scale MIMO is a promising core technology that has generated significant interest in both the telecommunication industry and academia. In [2, 3], which considers a single-cell time-division duplex (TDD) model, multi-user operation with large scale base station antennas is advocated. In [4], a further extension of large-scale MIMO systems is implemented that analyzes a model of the cellular system with Multi-cellular and offers a derivation of the cell's sum-capacity as antennas of the base station go limitless.

A Massive MIMO Network is a cellular multi-carrier network with L cells operating under a synchronous TDD protocol. From the Massive MIMO viewpoint, the significant thing is not which multicarrier modulation method is used, but which splits the frequency resources into flat-fading subcarriers. Coherence bandwidth describes the frequency interval over which the channel responses are approximately constant. One or more subcarriers fit into the coherence bandwidth, since the channel observed on adjacent subcarriers is either approximately identical or closely related through a deterministic transformation. Therefore, on any subcarrier, there is generally no need to estimate the channel. Similarly, between neighboring samples, the time variations of the channels are small and the coherence time represents the time period over which the channel responses are roughly constant. By using arrays of a hundred or more antennas, each transmitting with a comparatively large antenna, Massive MIMO aims to develop the coverage tier BSs and Low power rating.

Massive MIMO is a modern type of MIMO technology, because of its many benefits that will improve wireless communications, has yet to be used in the next generation of wireless systems. The name of this technology refers to the idea of equipping the BS with a very large number of antennas. The exponential increase of data traffic is going to be an important solution to deal with. It was viewed as an updated and scalable version of the multi-user MIMO when this technology was introduced. In order to add orders of magnitude of improvement to energy efficiency, basic linear processing is enough for massive MIMO. By taking steps to ensure that operations do not exceed Shannon limit, Massive MIMO avoid this issue, but achieve an output that overtakes any traditional multiuser MIMO system [5].

The massive MIMO architecture was developed by Marzetta, where the main concept was to scale up MU MIMO systems by installing a large number of antennas at BS, which greatly exceeded the number of active terminals. Thus, it is almost desirable to use simple linear processing. The base station serves all participating users at the same time, at the same time and at the same frequency, as is the case with MU MIMO. The massive MIMO system operates in both uplink and downlink modes. Since the number of BS antennas is high, the channel becomes almost deterministic, and thus the effects of small-scale fading and frequency dependency disappear. This is known as channel hardening [6, 7].

Due to microscopic changes in the propagation environment, the hardening of the channel allows a fading channel to act as deterministic, so that the random variations in the channel become negligible. This property alleviates the need to combat small-scale fading and increases the downlink channel profit estimate. Favorable propagation means that various users' channel vectors are almost orthogonal. Due to desirable propagation, the directions of the two UE canals are asymptotically orthogonal. This property makes minimizing interference between these UEs simpler for the BS, which generally enhances the SE and makes it sufficient for linear combining and precoding to be used.

The cost of radio frequency (RF) chains, consisting of power amplifier (PA), analog-to-digital converter (ADC), mixer and filter, is great, one of the key limiting factors. Large-scale base station antennas mean large-scale RF chains, but there is nothing to sneeze at about the overall power consumption of RF chains. Prior work on the selection of antennas focuses primarily on conventional MIMO systems with a few antennas in base station. Methods of antenna selection are typically classified based on criteria for selection.

The most common criterion is power maximization and maximization of the signal post equalization to interference plus noise ratio. As the selection criteria, the transmit antenna selection in the downlink of large MIMO systems and the maximization of capacity/sum-rate are used. By assuming that over all the antennas, the base station has perfect channel state information (CSI) acknowledged.

This is focused on the premise that a less complicated and less expensive system can be used to perform channel estimation on an antenna than a complete transceiver. Here, when the number of BS antennas becomes considerably greater than the number of terminal users in the cell, in the sense of massive MIMOs. The benefits of massive MIMO are improvements in throughput and radiated energy quality, interference suppression among users, and more efficient linear signal processing at BS. However, the benefits are followed by some concerns, such as pilot contamination and unfavorable spread. Here, they include an outline, including some preliminary and significant concepts, of the massive MIMO theory in this chapter.

For the sake of simplicity, let us restrict our discussion to single-cell systems and, thus, consider interference from neighboring cells to be negligible [7 8 9]. The capacity benefits of NOMA have made it a promising multiple access system for 5G networks. When the difference in the channel gain of the multiplexed UEs is significant, NOMA is highly effective at increasing device capability and energy efficiency. A multiplexing advantage is converted into this discrepancy.

There are many benefits beyond higher data rates for the implementation of NOMA in mobile networks, one of the most promising being higher spectral and energy efficiency. With NOMA, it is possible to accommodate more UEs in the same resources as with OMA, which is particularly interesting for highly anticipated overloaded scenarios in 5G networks. Another benefit of using NOMA is providing support for huge networking. The number of scheduled UEs is not strictly restricted by the number of available resources through the implementation of NOMA, which means that NOMA can assign more UEs than OMA within the same time period, thus raising the number of UEs served within a sub-frame without needing more resources [13].

1.2. Statement of the Problem

This usually means that wireless networks with hundreds of antennas support tens of users simultaneously in large scale MIMO systems. To mitigate the computational complexity problem in multiple antenna systems, simple signal detectors are suggested and show that when the Base Station (BS) has perfect channel state information (CSI) it can decrease the transmission power of each consumer proportionally to 1/M when the number of BS antennas M grows without bound. However, the related difficulty arising from the use of a separate radio frequency (RF) chain for each employed antenna is one of the drawbacks of using multiple antennas, which will significantly restrict the practical implementation of large-scale MIMO technology [14].

The cost of energy is problematic; overcoming this involves upgrading wireless networks to meet the rising demand for EE. Because of a higher number of radio frequency (RF) chains, an increase in the number of antenna arrays at a base station (BS) results in higher power consumption. In addition, in the digital-to-analog converter, power amplifier, multiplexer, and filter, higher numbers of RF chains in both BS and UE consume more power due to processing activities. As well as, all the BS antennas need to attach to the RF chains. The large number of antennas is used in massive MIMO and it is important to attach RF chains for all antennas, which causes more and more power consumption. Therefore, the rise in power consumption results in a decrease in the system's energy efficiency.

In order to increase the energy efficiency of the system, simple approach is reduction of power consumption. In massive MIMO system the number of base station antenna is very large and each antenna contains RF chains in both BS and UE, this makes the power consumption become more and more. The power reduction approach controls the RF chain in both BS and UE by limiting number of antenna at the base station. This limiting of number of antenna at the base station, called antenna selection techniques. This antenna selection technique at the base station only allow number of active antenna at the base station.

1.3. Objective

1.3.1. General Objective

The main objective of this thesis is to improve energy efficiency using antenna selection in massive MIMO for downlink system.

1.3.2. Specific Objectives

- To analyze the effects in a massive MIMO downlink system with different antenna selection techniques
- Calculate of energy efficiency to analyze the effect of antenna selection in massive MIMO downlink system over capacity.
- Calculation of total power consumed by the radio frequency connected to the antenna.

1.4. Significance of Study

Considering the amount of power consumption used in RF connected to the BS antenna it saves, and the power consumption savings due to RF connected to the BS antenna have the following advantages:

- ✓ Capacity has been improved with regard to power consumption.

- ✓ As the system's capacity is improved, energy efficiency has also increased with regard to base station antenna, since energy efficiency and power consumption are inversely proportional to each other.

1.5. Scope

With a massive MIMO system, the antenna selection technique has an advantage. In the large MIMO system, the benefit of antenna selection includes: reducing hardware complexity, improving spectral performance, enhancing capacity, improving energy efficiency, etc. But, this proposed thesis work only on the improvement of energy efficiency at the down link only. In this proposed thesis there is some mathematical model of capacity and power consumption due to RF of antenna for the calculation of energy efficiency. Finally, the designed and modeled proposed system is simulated through Matlab software only.

1.6. Main Contributions

This thesis aims to enhance the energy efficiency and practicality of large-scale antenna selection systems by implementing new transmission schemes and developing the literature's current approaches. The following list highlights the key contributions to this study and summarizes them:

- A Massive-MIMO framework is presented using antenna selection. The method was extracted from a user's achievable rate system and expressions of Energy Efficiency performance. Via the antenna selection system, the M-MIMO achieves better energy efficiency. In this work, channel state data at the transmitter (CSIT) is assumed to be perfect.
- Here, the system consider only antenna selection at downlink system since number of base station antenna is typically much larger than number of user terminals in massive MIMO.
- Production of an effective computational antenna selection algorithm for a large MIMO downlink transmission to decrease the transmission capacity. Analytical and numerical findings show that the proposed metric allows massive MIMO to dramatically reduce both hardware and computational complexity, especially when

compared to large-scale systems where current AS systems from the literature are used.

- The energy efficiency for M-MIMO with given target of capacity of the system (capacity targeted with SINR) using antenna selection with respect to OMA and NOMA are compared.

1.7. Thesis Organization

This thesis organizes into the following five chapters. Chapter 1: Presents introduction of the research work, statement of the problems, objectives, significance, and scope of the research. Chapter 2: Includes a literature review on the introduction of Massive MIMO system, Energy efficiency, Antenna selection, Power consumption, NOMA in Massive MIMO and also it introduces the massive MIMO technology and discusses its potential advantages and the possible challenges that must to be dealt with. Chapter 3: Describes the methodology followed in this research thesis. Chapter 4: Presents the proposed results and discussions. Chapter 5: Discusses the conclusions and recommendations.

CHAPTER TWO

2. LITERATURE REVIEW

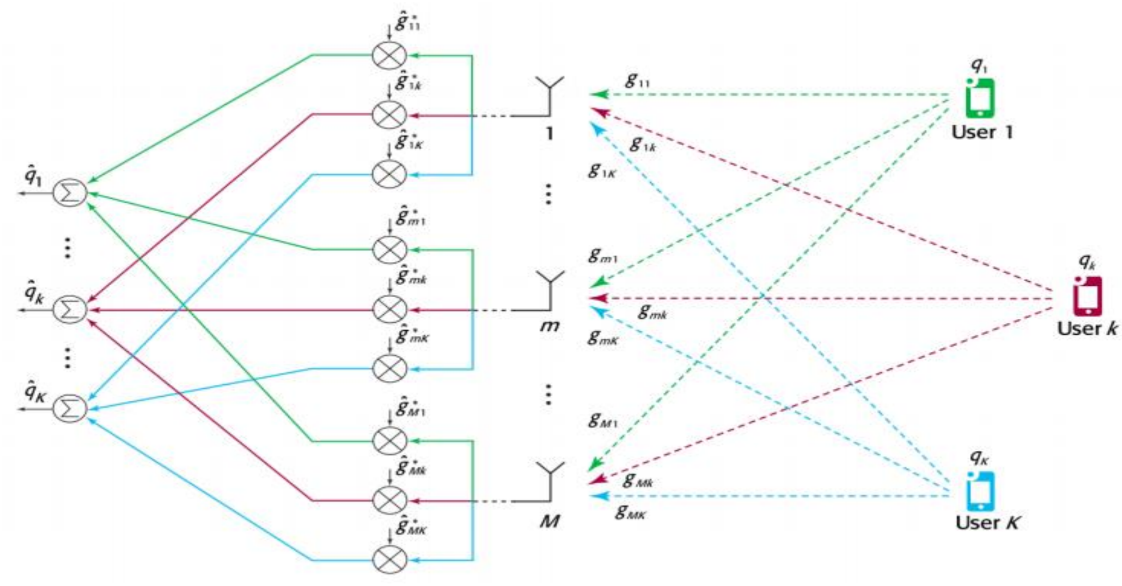
2.1. Introduction of Massive MIMO

In massive MIMO, hundreds of terminals can be simultaneously served with a BS equipped with hundreds of antennas over the same time/frequency resources. Some key enabling characteristics for this technology are: Time Division Duplex The overhead needed to estimate the channel does not depend on the number of BS antennas M under the time division duplex (TDD) protocol, unlike the frequency division duplex (FDD).

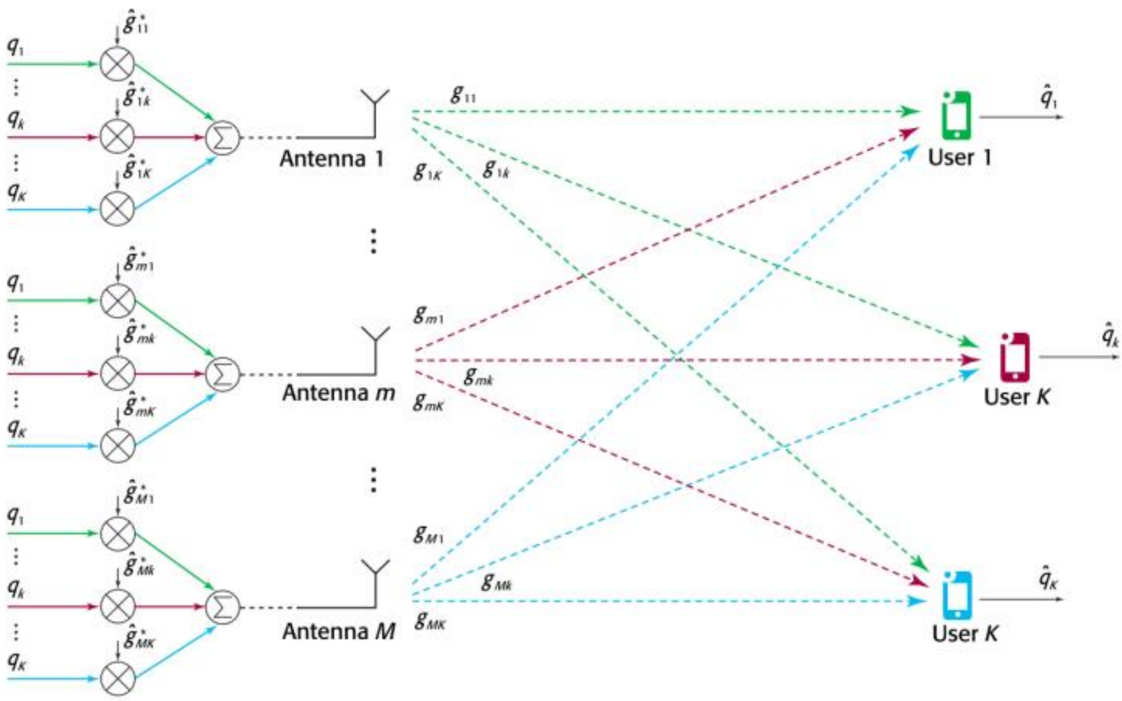
Therefore, the use of the TDD protocol in huge MIMO is favored. Exploiting the reciprocity of the channel will dramatically reduce the overhead needed for the acquisition of CSI [17, 18]. It shows that the potential (M, K) dimensions where K is number of user in TDD is much more than FDD. Therefore, by the number of BS antennas when TDD is used, the resources required for channel estimation are not affected. For example, when the coherence interval T is 200 symbols, the constraint for the number of users and BS antennas is $M+K < 200$ in FDD system, while the constraint for TDD systems is $2K<200$.

2.1.1. Linear Processing

Linear processing: Large dimensional channels need to be able to manage signal processing at terminals in Massive MIMOs. Linear encoding and precoding is also one of the benefits of large scale Massive MIMO. UL data transmission, for example, can be decoded with a simple matched filter and DL data transmission can be pre-coded in the figure below with conjugate beamforming.



(a)



(b)

Figure 2. 1: Linear processing of Massive MIMO: (a) uplink and (b) downlink [34]

2.1.2. Favorable Propagation

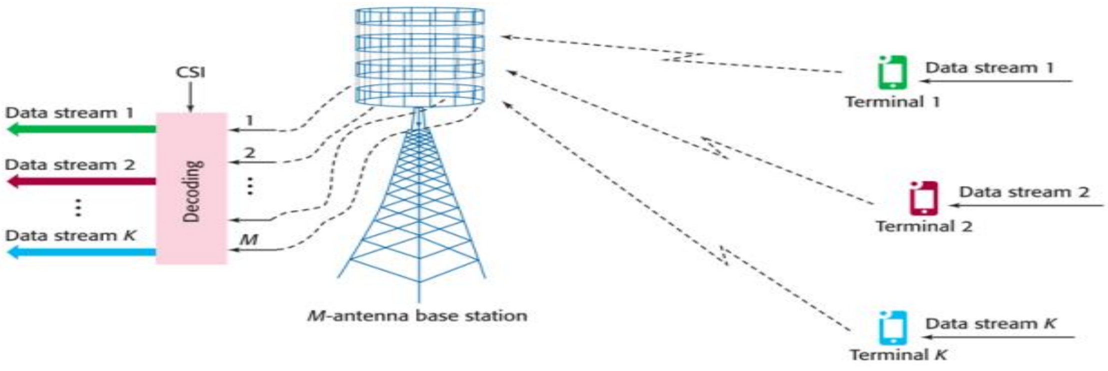
The channel between the terminals and the BS can be well conditioned due to the law of large numbers. Hence, the presumption that the channel vectors are almost orthogonal is abused by massive MIMO. This phenomenon is called favorable propagation, where optimal output involves only linear processing. The above figure shows that the interference and noise on the UL can be canceled using simple linear detectors such as the matched ones, while the BS can use linear beamforming techniques without mutual interference to beam different data streams to multiple users.

2.1.3. Array Size

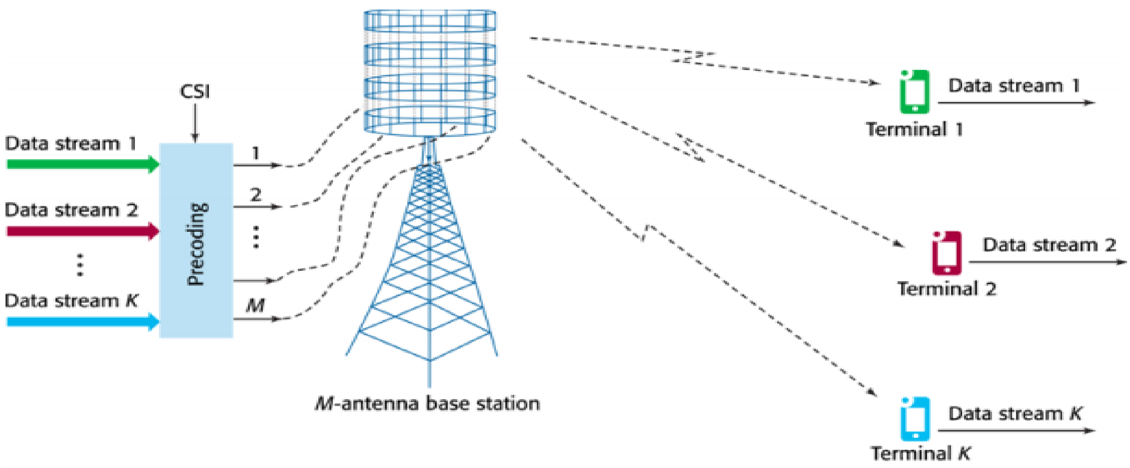
One of the features of massive MIMO is that the antenna array does not occupy a large room because they are physically thin. The distance between antennas, for example, is around 6 cm at 2.6 GHz. Therefore, 128 antennas occupy a cylindrical array of just 28cm to 29cm in size. The array that is designed for the 3.7 GHz carrier frequency comprises 160 dual-polarized patch antennas. The size of the panel is 60*120 cm and the distance between the antenna elements is 4 cm, leaving plenty of room for additional antenna elements to be installed. For such a panel, one of the potential deployment scenarios could be on building facades.

2.1.4. Scalability

Massive MIMO is a scalable technology: because when working in the TDD protocol, the BS acquires the channel via the UL pilot, the time spent on channel estimation does not depend on the number of BS antennas. Thus, without adding more time to the estimating process, the number of BS antennas can be increased. Furthermore, since multiplexing and demultiplexing are not necessary at the ends of the user, signal processing is independent of the other users on each terminal.



(a)



(b)

Figure 2. 2: Massive MIMO. (a) Uplink operation. (b) Downlink operation [34]

How Does Massive MIMO Operate?

Massive MIMO UL and DL operations are shown in Figure 2.2. This configuration could represent a single cell site or a cell taken from a network. A large number of UE Ks are served by an array of antennas in the BS within the cell. Usually, each terminal has a single antenna. Various BSs that do not cooperate with each other except for pilot allocation and power control, support other cells. For UL/DL transmissions, both terminals use the maximum frequency-time tools simultaneously. On the UL, at the BS, the individual signal transmitted by the terminals is retrieved. The BS, on the DL, makes sure that only the signal intended for it is received by any UE. Because of the CSI information available, multiplexing/demultiplexing processing at the BS is feasible.

The BS produces an arrow beam under the Line of Sight (LOS) propagation environment in the direction of the terminal. When the number of antennas is raised, the concentration of these beams becomes more precise (i.e. they become narrower). The signal obtained at any UE consists of the superposition of several independent components as a result of scattering and reflections that can add up destructively or constructively in the event of a local scattering. If the transmitted waveforms are perfectly chosen, these components add up constructively exactly at the user's position. By adding more antennas to the BS, the accuracy of the power concentration at a certain terminal can be improved. It is therefore very important to have a sufficiently accurate CSI at the BS to concentrate the power [24].

2.1.5. Channel Estimation

The identification of the user's transmitted signals on the UL and precoding of the DL signals are one of the most important tasks of the BS. Therefore, the CSI that can be obtained using the UL training is required by the BS. These pilots are sent to the BS by terminals that are each given an orthogonal pilot signal. The BS already knows the pilot sequences transmitted from all terminals. The BS will then estimate the channel using these pilot signals.

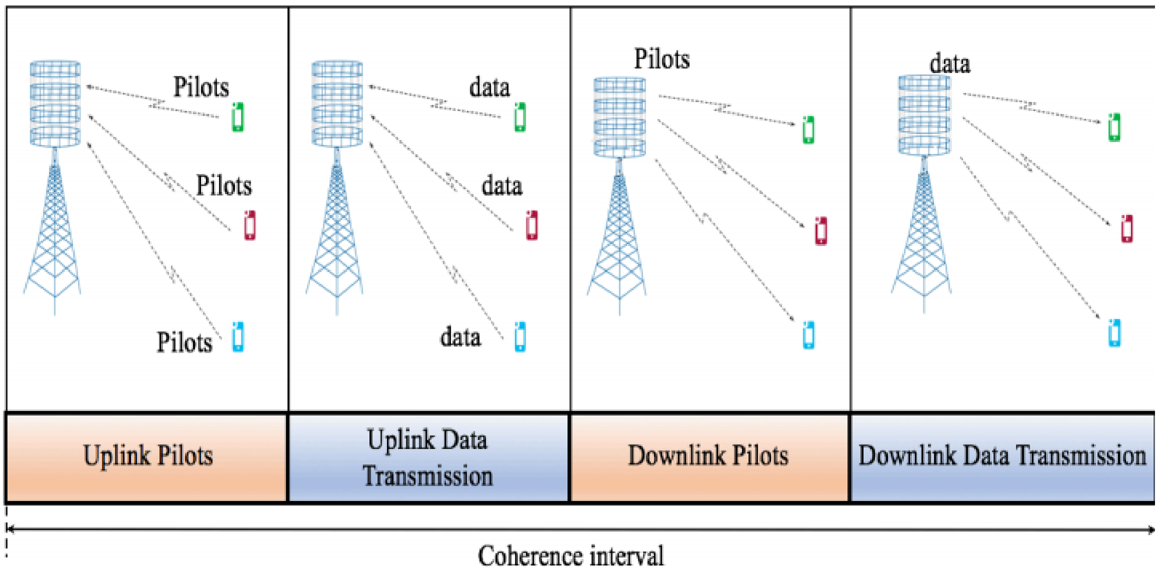


Figure 2. 3: TDD protocol of Massive MIMO transmission [34]

In addition, for coherent detection of the transmitted signals from the BS, partial knowledge of CSI could be needed at each terminal. Either using DL training or through some algorithm that can blindly estimate the channel, this partial information can be obtained. To detect its intended signal, the terminal only requires the effective gain of the channel because the signals performing is conducted using linear precoding techniques at the BS.

2.1.6. Uplink (UL) Data Transmission

Part of the coherence interval is filled by UL data transmission. In the UL, the BS receives the transmitted data from the same frequency-time resource from all K terminals. The BS defines the signals sent from all terminals using channel estimates and linear combination techniques.

2.1.7. Downlink (DL) Data Transmission

The BS transmits the DL data from the same frequency or time resource to all terminals. In particular, the BS produces the pre-coded M signal and feeds it to the M antennas. The approximate channel and the symbol intended for the user of Kth can be used to do this.

2.2. Benefits of Massive MIMO

It will always increase the need for more efficient communications and the need for wireless throughput. Therefore, new technologies are needed to support multiple users with a very high throughput simultaneously. With Massive MIMO, these demands can be met. Favorable propagation conditions and Optimal processing at the BS are necessary to get the array and the multiplexing gain. Instead of the usual low dimensional point to point MIMO with very complicated processing schemes, these gains can also be achieved using linear processing with massive MIMO. In fact, if the number of BS antennas in massive MIMO is increased to a very large number, the channel becomes favorable because of the low number of large numbers. Therefore, for massive MIMO, linear processing is deemed almost optimal. Array and multiplexing gains can therefore be accomplished using simple linear processing. Also, by increasing the number of users and the BS antennas, the throughput can always be improved [24].

2.3. Challenges of Massive MIMO

Although massive MIMO have great advantages, many challenges still need to be dealt with. The most important issues are listed below [24]:

2.3.1. Unfavorable Propagation

Massive MIMO is believed to work under favorable conditions of propagation. There are, however, several factors in practice that make the propagation of the channel unfavorable. For example, when the number of users is much greater than the number of scatters, the propagation environment, or if the scatters are normal between the BS and the channels of different users. One potential solution to this problem is the interference of the BS antennas over a wide area.

2.3.2. Pilot Contamination

In reality, cellular networks consist of a large number of cells. Frequency resources are shared by several cells due to the shortage of the frequency spectrum. Thus, because of the restricted channel coherence duration, it is difficult to assign orthogonal pilots for all users. These orthogonal sequences between the various cells are normally reused. Hence, the process of channel estimation in a certain cell can be affected with the pilot sequences transmitted on the other cells. The system performance can be reduced by this phenomena known as "pilot contamination". One of the major issues that imposes limitations on the efficiency of large MIMO systems is pilot contamination. This effect cannot be reduced even though the number of BS antennas expands to a very large number.

2.4. Non Orthogonal Multiple Access (NOMA)

The technique of non-orthogonal multiple access (NOMA) is widely regarded as a promising technology to enhance the device capability of future wireless communication systems. NOMA's basic concept is to support multiple users by transmitter power domain multiplexing and successive interference cancellation (SIC) at the receiver, which can meet the downlink addictive white Gaussian noise channel capacity region and substantially outperform the orthogonal noise channel. Multiple (OMA) schemes for entry. Early work on the system of NOMA focuses primarily on the case of the transmitter comprises a single antenna. Other authors discuss the system level assessment step by step with some functional aspects, such as multiuser power allocation, overhead signaling, Propagation of SIC errors and high mobility. Some attempts have recently been made to combine multiple-input and multiple-output (MIMO) NOMA to achieve high performance, energy efficiency and spectral efficiency [25].

In the transmission section of NOMA, for each user, signals emitted from the BS are superimposed on top of every other one. More power is allocated to user located farther from the BS. Everything in a network, all in a network, the same signal that includes the information for all users is processed by users. Every consumer is decoding the First, it's the best signal and decodes from the received signal. A power domain multiplexing scheme is NOMA. In NOMA, however, there are many difficulties in transmitting the signal in efficient ways. One of them is to deal efficiently with the power allocation of various users; this work concentrated on NOMA's power allocation technique. And in NOMA, like OFDMA, the frequency spectrum is not broken. Instead, the frequency is the same, but the power for different users in the wireless communication system based on NOMA is different.

NOMA's key concept is to leverage the power domain for multiple access, meaning that multiple users can be served simultaneously at the same time, frequency, and code distributed. NOMA allocates more power to users with weaker channel conditions, instead of using water-filling power allocation methods, in order to promote a balanced tradeoff between system throughput and user fairness. The power ratio assigned to an allocated UE will depend on its channel conditions; the lower the channel gain, the higher the power ratio. Figure 2.4, shows a resource allocation comparison between OMA and NOMA for two UEs. In the receiver, interference cancellation (IC) techniques are used [13].

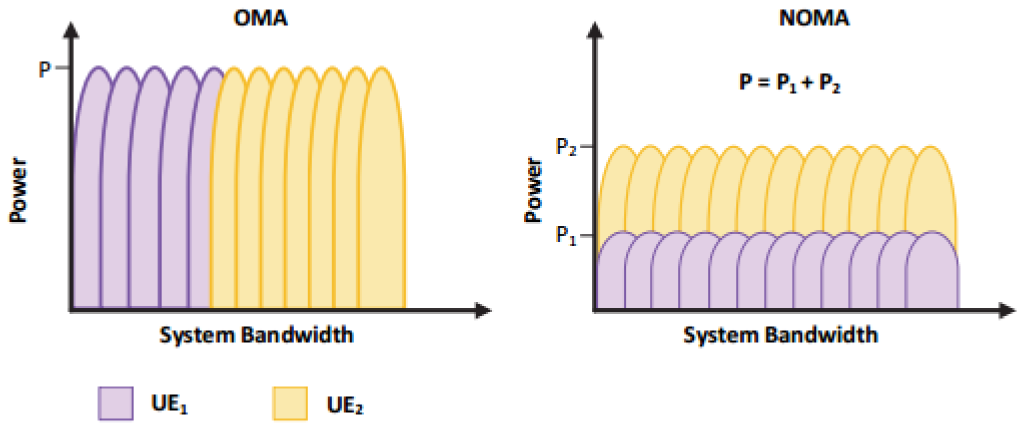


Figure 2. 4: Resource allocation comparison for OMA and NOMA for two UEs [13]

The power allocation introduced by superposition transmission systems is implemented in NOMA. Transmission of superposition is a physical layer technique which allows the transmitter to send independent signals to different UEs simultaneously. Depending on the device configuration, the number of UEs selected to be assigned to the same time/frequency resources can differ.

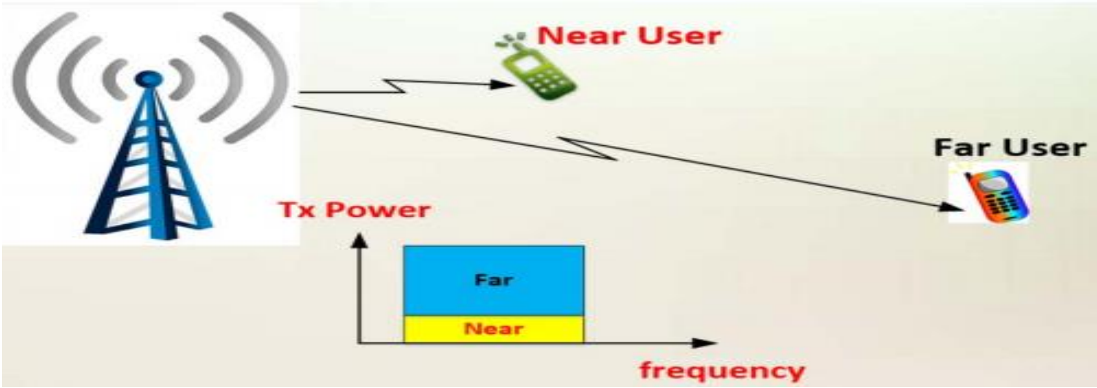


Figure 2. 5: Downlink MIMO NOMA systems [25]

The base station selects two users that are ideal for pairing. Which means served at the same time and frequency by near-user (strong channel gain) and far-user (weak channel gain). The split power of transmission between high share of power to far user and low share of power to close user. The far-user signal has minimal interference from the near-user signal; the far-user usually decodes its signal and suffers from minor additional interference, while the near-user signal has significant interference from the far-user; the near-user first decodes the far-user signal; Subtracts from the composite NOMA signal this interference; Far-user interference is therefore cancelled and Near-user decodes from the cleaned signal its data. Notice that Far-user is unable to cancel Near-user interference because it is too weak to be decoded.

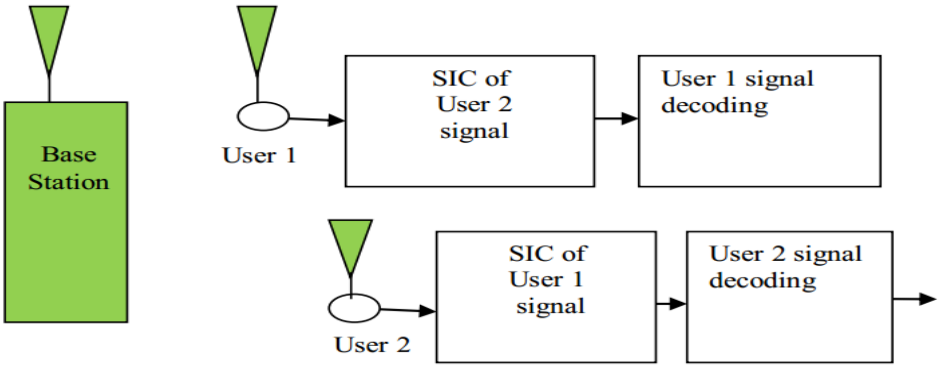


Figure 2. 6: Reception section of NOMA [36]

Figure 2. 7: Far user processing [25]

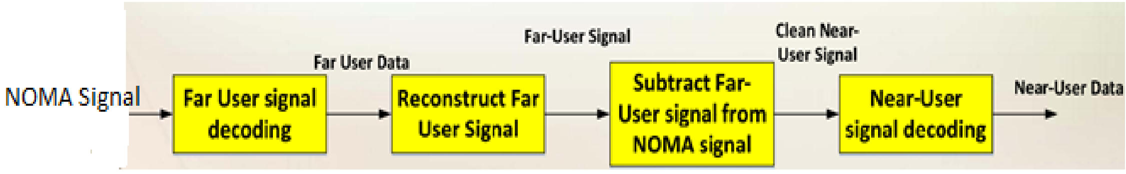


Figure 2. 8: Near user processing [25]

2.5. NOMA in Massive MIMO

Massive MIMO with NOMA will greatly enhance NOMA H-CRANs' EE and SE while requiring only basic approaches to linear signal processing. In addition, multi-user detection (e.g. SIC for power domain NOMA, a message passing algorithm for code domain NOMA) can be transferred into the BBU pool, unlike traditional NOMA HetNets, which significantly simplifies the structure of RRHs and makes it possible to deploy RRHs in a large-scale region cost-effectively. In addition, massive NOMA MIMOs can have a large number of degrees of freedom and suppress intercellular interference by precoding UE signals in various cells [23]. In the transmission section of NOMA, for each user, signals emitted from the BS are superimposed on top of each other. A consumer placed further away from the BS is allocated with more power. Both users generate the same signal on the network that holds the data for all users. Each consumer first decodes the strongest signal and it decode from the received signal.

2.6. Antenna Selection

In theory, massive MIMO systems provide a notable performance increase compared to single-input single-output (SISO) counterparts in terms of connection reliability, data rate and radiated-energy efficiency due to the large number of BS-antennas Unfortunately, increasing the number of antennas at BS in practice could result in undesired costs. To have M RF chains on the transmitter, MIMO systems with M BS-antennas require low-noise amplifiers, downconverters and digital-to-analog converters. This schemes in which the most suitable subset of antenna (S) is selected to be active from the total transmit antenna (M) have been proposed to reduce the number of RF chains needed from the total transmit antenna (M) to the antenna sub-set (S). The methods of antenna selection lead to substantial savings, but there is loss of performance compared to the full system [9].

2.7. Transmit Power Consumption

The area transmission power (ATP), which is defined as the network average power consumption for data transmission per unit area, is a metric used to calculate the transmission power consumed by a wireless network [15].

2.8. Energy Efficiency

EE refers to how much energy it takes for a certain amount of work to be done. Unlike many fields in which the concept of "work" is clear, it is not easy to define what exactly one unit of "work" is in a cellular network. The network provides connectivity and transports bits to and from UEs over a certain region. Massive MIMO's energy efficiency (EE) is based on a model of practical circuit power (CP) consumption. For potential cellular networks, power consumption (PC) is a serious concern. Massive MIMO can theoretically enhance the performance of the region while offering considerable power savings. As the amount of BS antennas grows to infinity, the transmit power's asymptotic behavior is also studied and a power-scaling rule is established, showing how easily the transmit power can be reduced with the number of antennas while achieving a non-zero asymptotic SE [15].

2.9. Related Works

An energy-efficient antenna selection algorithm based on convex optimization was given in [1] for the Massive MIMO system. Maximizing energy efficiency is included in the selection criteria. For that one condition is given, that is, if the cell's channel capacity is greater than a certain threshold, then the number of transmit antennas is optimized jointly to maximize energy efficiency, the subset of transmit antennas and serviceable mobile terminals.

For the selection of antennas in the Massive MIMO system, one system model is given in [2]. This device model utilizes the channel capacity equation to scan for only the first optimum antenna, and does not require an exhaustive search to locate the remaining optimum antennas. As part of the model requirement, channel state information (CSI) about the selected column vectors of the channel must be sent from the receiver to the transmitter. This approach greatly decreases the difficulty of rigorous searching. For two selected antennas, the given device model shows optimum results and very good results if the number of selected antennas is three or more.

An energy efficient antenna selection for large scale green MIMO systems.is given in [3]. In this transmission antenna selection, two types of large antenna array are implemented, one is a compact cylindrical array and the second is a large linear array. The selection of the antenna subset that maximizes capacity in the downlink is used in this convex optimization. The efficiency of the cylindrical array is greatly improved with the selection of the antenna, which shows lower performance than the linear array without this option of antenna.

Antenna selection strategies for MIMO-OFDM wireless systems in [5], an energy-efficiency perspective. Energy-efficiency investigation of MIMO-OFDM systems with various approaches to antenna selection. Several significant energy-efficiency considerations have been investigated, including the contrast between the real transmitted power and the power consumed by the transceiver circuits, the types of selection parameters, the number of antennas, and the spatial correlation between the antennas. To deal with this problem, an adaptive antenna selection method has been proposed. This algorithm, which is critical when the number of antennas is high, can achieve near-optimal efficiency. This work was not done for MIMO-OFDMA multi-user systems, but only for MIMO-OFDMA single-user systems.

In paper [7], employing antenna selection to improve energy efficiency in massive MIMO systems, was suggested to enable the system to work with a subset of antennas to be lower than the total antennas to optimize the EE. They derived a closed-form approximation for the EE formulation to reduce the mathematical complexity by using a practical power consumption model for massive MIMO, which is shown to be very tight with optimal performance. Simulation results showed that the use of antenna selection increases the EE significantly, especially when the number of UEs is relatively small in terms of the number of antennas available. In addition, it has been shown that the ideal number of antennas is slightly higher than the number of UEs, while the relationship depends on the data rate needed. Finally, if the number of antennas used and the average data rate for users are both optimized.

Antenna Selection in Massive MIMO based on Matching Pursuit is given in [8] for the Massive MIMO process. This takes the effect of spatial correlation and imperfect channel estimation into account. The fundamental aim is to minimize the effective number of antennas without weakening the efficiency of the device. Using the orthogonal matching pursuit algorithm, the antenna selection vector is computed. The outcome of the simulation shows that this system has closely approached the same efficiency as the well-adopted MRC system, but needs less antennas. Thus, by using this method, the cost of and the system's hardware complexity is minimized. One drawback here is that for a single user system, the provided scheme is not for a multi user system.

In [9] Energy Efficiency of Large-Scale Multiple Antenna Systems with Transmit Antenna Selection: it perform a transmit antenna selection to improve the energy efficiency of multiuser large scale MIMO systems. Under such a scenario, it establish a new power consumption model as the addition of the transmit power and the circuit power consumption, and based on this model, analyze the effects of the number of transmitting antennas at the base station and the number of users at the receiver on the total power consumption and the energy efficiency respectively. It focus on the multiuser scenario where the zero-forcing (ZF) precoding is used to reduce inter-user interference, and analytically derive the optimal number of selected antennas which can maximize the energy efficiency in this case. Based on the optimal number of transmit antenna, and compare the energy efficiency improvement by antenna selection with using all of the given transmit antennas.

In paper [16] Energy efficient antenna selection scheme for downlink massive MIMO systems: optimize energy efficiency by solving the optimal number of fixed transmit power antennas. Here, first consider the downlink of a single cell massive MIMO system, and derive the closed form lower bounds of the achievable sum-rate with the maximum ratio transmission (MRT) precoding. Then, formulate the maximization of energy efficiency as an optimization problem under the consideration of the circuit power consumption and transmit power. A fixed transmit power convert the maximization of energy efficiency to the optimization of a quasi-concave function, and then the closed form of the optimal number of transmit antennas is solved to maximize energy efficiency.

CHAPTER THREE

3. METHODOLOGY

3.1. Introduction

In this thesis, related secondary sources of data such as different books in LTE, previous researcher's studies, different Institute of Electrical and Electronics Engineers (IEEE) articles, development in 5G cellular technology in general and basics of massive MIMO in particular were revised. Based on the inputs retrieved from review of related literatures and the statement of the problem in mind, the methodology of this study is designed as follows;

3.2. Materials

In this research work, software such as MATLAB/R2017a, is used. MATLAB is the computing software which consists of technical toolboxes and Simulink.

3.3. Methods

3.3.1. System Design

- Outline of work flows of energy efficiency of the system;
- Prepare a mathematical model for calculating the capacity and Energy Efficiency of the system;
- Prepare a mathematical model for power consumption.
    - ✓ Generating channel,
    - ✓ Calculating the capacity of each user and calculating the energy efficiency each user;
    - ✓ Calculating total capacity of all users and calculating total energy efficiency of all user;
- Identify all input parameters for simulation.

3.3.2. Simulation Methods

- Outline of simulations work flow,
- Perform capacity and energy efficiency prediction simulations;
- Simulation for evaluation energy efficiency.
- Perform energy efficiency evaluation analysis whether the target requirement achieved or not.

3.4. The Proposed Block Diagram of Antenna Selection

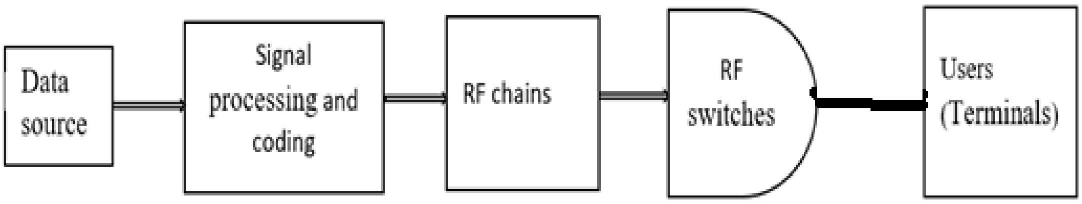


Figure 3. 1: Block diagram of the overall system

The proposed system block diagram of Antenna selection for improvement of Energy Efficiency is shown in figure 3.1. Consider the downlink of a single-cell Massive MIMO system; the base station is equipped with M antennas and S RF chains, and is simultaneously serving K single-antenna users ($K \leq S \leq M$). Perfect CSI over all the antennas is assumed to be known here. Based on the CSI, the “best” S are selected out of the M antennas according to some criterion. These S antennas are then connected to the S RF chains through the RF switch.

3.5. Antenna selection in massive MIMO

Due to the large number of BS-antennas, massive MIMO systems provide a remarkable performance improvement compared to single-input single-output (SISO) counterparts in terms of connection reliability, data rate and radiated-energy quality. Unfortunately, in practice, raising the number of antennas at BS can result in undesired costs. MIMO systems with M BS-antennas need low-noise amplifiers, downconverters and digital-to-analog converters to have M RF chains on the transmitter. In order to reduce the number of necessary RF chains from M to S [8], schemes in which the most acceptable S out of M antennas are selected to be active have therefore been proposed. Strategies for antenna selection contribute to considerable savings, but when compared to the complete device, an output loss is observed. The main objective is to pick a subset of antennas that maintain the efficiency of the device at a certain level. Here, the issue of selecting S from M BS antennas in the downlink of single-cell massive MIMO system was added, as shown in Figure 3.2.

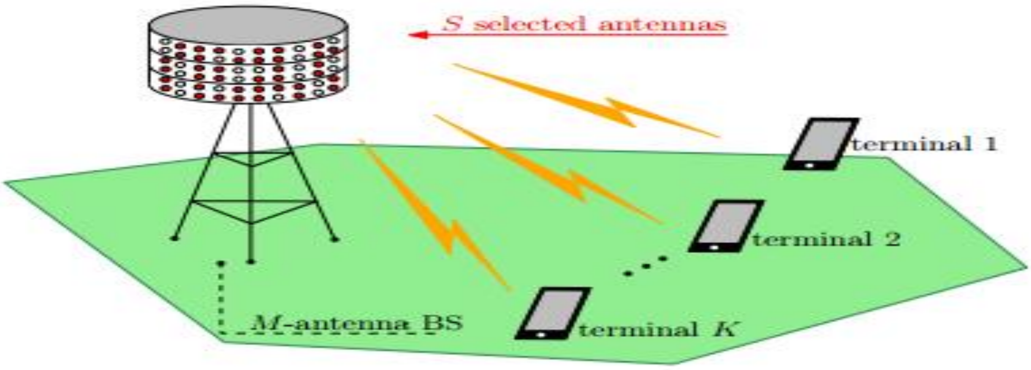


Figure 3. 2: Downlink massive MIMO with only S selected BS-antennas [8]

Let's add a new step to BS processing to model the selection of a subset of S antennas to transmit the data. This phase, shown in Figure 3.3, includes the algorithm for antenna selection that generates matrix $H_S \varepsilon C^{S\times K}$. The subscript S in matrix H_S represents that S rows are selected out of M in the full channel matrix **H**. In general, the antenna selection algorithms have as input only the approximate channel matrix, so that the switch is opened in Figure 3.3. This implies that the procedure for selecting the antenna is only necessary when the channel matrix changes. However, the so-called intended/desired vector q is also required as input by some antenna selection strategies, so the switch in Figure 3.3 is closed. In this case, whenever a new intended vector q is created, the antenna selection procedure has to be performed.

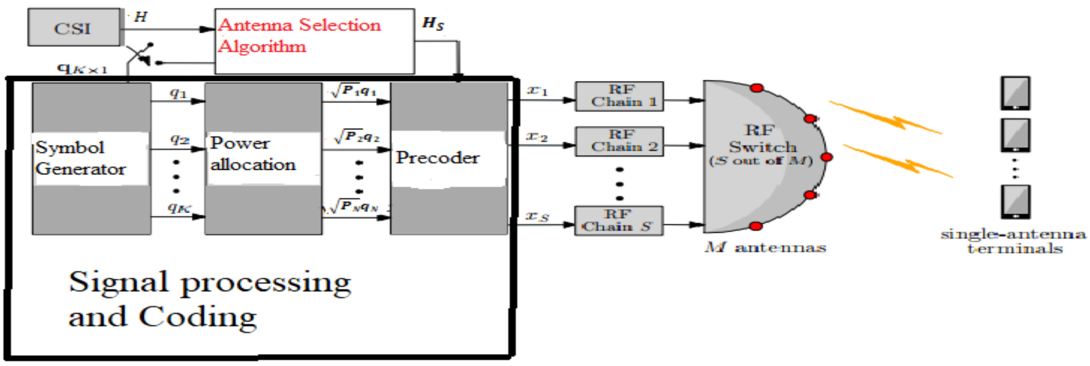


Figure 3. 3: Antenna selection process in the downlink of a massive MIMO system [8]

Depending on some selection criterion, the algorithms of antenna selection produce the selection vector [8]:

$$z = [z_1, z_2, z_3, \ldots \ldots \ldots \ldots \ldots . z_M]^T \varepsilon \{0,1\}^M \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (1)$$

In which $z_t = 0$ represents that the antenna with index t was not selected and $z_t = 1$ represents that the antenna with index t was selected. Moreover, the selection vector must satisfy.

$$1^T z = S, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2)$$

where S is the number of antennas to be selected; here, let form the S-selected channel matrix,

$$H_S = Z^T H, hence\ Z^T = rem\big(diag(z)\big) \ldots \ldots \ldots \ldots \ldots (3)$$

where Z is a matrix of antenna selection. Matrix Z can be obtained by the elimination of the Zero columns of the diagonal matrix $diag(z)$. The rem $(\cdot)$ operator literally represents the diagonal matrix $diag(z)$column.

The message $x_S \varepsilon C^{S\times 1}$ defined by:

$$x_S = diag\sqrt{P}q, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (4)$$

Is transmit signal transmitted by the S active BS antennas, the received signal in the kth terminal is given as:

$$y_k = {h_{Sk}}^T x_S + n_K \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (5)$$

where h_{Sk} is the kth column of H_S.

A typical OMA system: consider the downlink of a large-scale (massive) MIMO system with one terminal for BS and K. The BS is fitted with M transmitting antennas and only one receiving antenna is required for each terminal, which is typical for a mobile phone. Here assume that M is large and $M * K$. It is impractical to use all the antennas to achieve high rate due to the expensive RF chains and high hardware complexity. Thus, let perform transmit antenna selection to choose the best S antennas from all the available M ones. Here, assume perfect CSI at the transmitter. For multiuser MIMO, the signal for a user is interference for the others and it is generally difficult to cooperate between recipient sides in the downlink of massive MIMO, so the achievable rate of each user is reduced by multi-user interference (MUI) and noise. So, let consider the zero-forcing (ZF) precoding scheme to reduce MUI. The receive signal vector at terminals can be written as [9]:

$$y = \sqrt{\frac{P_{tx}M}{K}} HWx + \text{n}, \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (6)$$

where y is the K×1 received vector for each terminal, x is the transmit signal vector, P_{tx} is total transmit power, $H \in C^{K\times M}$ is the channel matrix between M BS antennas and K terminals, n is K×1 noise (AWGN) vector, W is the Zero Forcing Precoding and $W = H^H(HH^H)^{-1}$. Then the receive signal of K_{th} user is:

$$y_K = \sqrt{\frac{P_{tx}M}{K}} H_K W_K x_S + \sqrt{\frac{P_{tx}M}{K}} \sum_{i=1, j\neq K}^{K} H_K W_i\, x_i + n_K \dots \dots \dots \dots \dots \dots \dots (7)$$

where the second term on the right side is Multi User Interference, H_K, W_K, x_S are the channel matrix, precoding matrix and transmitted signal corresponding to user k, respectively. The achievable sum rate can be represented as:

$$C = B * \log_2[1 + SINR] \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (8)$$

$$SINR = E\left[\frac{\frac{P_{tx}M}{K}|H_K W_K|^2}{\frac{P_{tx}M}{K}\left|\sum_{i=1, i\neq 1}^{K} H_K W_i x_i\right|^2 + N_o B}\right] \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (9)$$

where B is Bandwidth, SINR is signal to interference and noise ratio, $N_o B$ is Noise power in the given bandwidth *B*. so in massive MIMO system the simplified form of the above equation is given as:

$$C_{approx} \approx BK * \log_2\left[1 + \frac{P_{tx}M}{(I + N_o B)K}\right], \text{ hence,} SINR = \frac{P_{tx}}{(I + N_o B)K} \dots \dots \dots \dots \dots (10)$$

where *I* is the MUI term, which can be not regarded in the case of ZF precoding.

$$\text{Therefore,} C_{approx} \approx BK * \log_2\left[1 + \frac{P_{tx}M}{(N_o B)K}\right] \text{ hence, } SNR = \frac{P_{tx}}{(N_o B)K} \dots \dots \dots \dots \dots \dots \dots (11)$$

where SNR is signal to noise ratio, if the SNR have fixed value the capacity is given by:

$$Capacity = \text{B}\log_2\left(det\left(I_K + \frac{SNR}{M}H' diag(z)H\right)\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

The EE of the system defined as:

$$EE = \frac{Capacity}{p_{total}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (13)$$

where, EE is Energy Efficiency of the system is, p_{total} is Total power consumption and p_{total} is the total power consumption which includes the transmit power (P_{tx}) and the circuit power consumption at transmitter and user (receiver side) (P_{circ} and P_{crx}) in this model, i.e., $p_{total} = \frac{P_{tx}}{\eta} + P_{circ} + P_{crx}, PA = \frac{P_{tx}}{\eta}.$ Where, η is the power amplifier efficiency, P_{circ} represents dynamic power consumption proportional to the number of transmission antennas and the circuit power of the RF chains. P_{crx} Represents dynamic power consumption due to circuit at the user of the RF chains. Therefore, the circuit power consumption is modeled as:

$$P_{circ} = P_B + P_{syn} + M(P_{DAC} + P_{mix} + P_{filt}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

$$P_{crx} = P_{syn} + K(P_{ADC} + P_{mix} + P_{filt}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

$$p_{total} = \frac{P_{tx}}{\eta} + P_{circ} + P_{crx} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (16)$$

where P_B is Baseband power consumption, P_{syn} is power consumption of frequency synthesizer, P_{DAC} is power consumption of Digital to Analog Converter, P_{ADC} is power consumption of Analog to Digital Converter, P_{mix} is power consumption due to mixer and P_{filt} is power consumption due to filter at the transmitter or base station side and receiver or user terminal side.

Depending on the achievable rate (capacity) and the above total power consumption model, the Energy Efficiency was written as:

$$EE = \frac{Capacity}{p_{total}}$$
$$\approx \frac{\mathrm{B}\log_2\left(det\left(I_K + \frac{SNR}{M} H^H diag(z) H\right)\right)}{\frac{P_{tx}}{\eta} + P_{circ} + P_{crx}} \dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots (17)$$

There are tradeoff between achievable rate and power consumption. The Energy Efficiency increases as increasing number of base station antennas, while the power consumption increases at the same time, resulting in concave shape of energy efficiency. In this model here investigate an appropriate number of selected transmit antenna S for Energy Efficiency maximization and the optimization problem can be defined as [9]:

$$S = arg \max_{M} \frac{Capacity}{p_{total}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (18)$$

As the energy efficiency function is concave, then, the optimal number of selected transmit antennas can be derived, S, which should satisfy the following equation.

$$\frac{\partial(EE)}{\partial M} \approx \frac{\partial}{\partial M}\left(\frac{C_{approx}}{p_{total}}\right) = 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (19)$$

Then, S can be written as:

$$S \approx \frac{N_o BK}{P_{tx}}\left(\mathrm{e}^{1+w(\Gamma)} - 1\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots. (20)$$

$$\Gamma = \frac{M \, {P_{tx}}^2/\eta - N_o B P_{circ} P_{crx}}{N_o B K P_{circ} P_{crx}.\mathrm{e}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (21)$$

where $w(\Gamma) = \ln w(\Gamma) - (\ln(\ln w(\Gamma) - \ln(\ln w(\Gamma) - \ln(\ln w(\Gamma))) \dots\dots\dots (22)$

and W is the lambert W function, here, easily obtain the optimal selected antenna number S from equation (20) And now the problem is how to select the S antennas from the total transmit antennas. When S is fixed, $p_{total}$is independent of antenna selection, so the antenna selection for energy efficiency equals the antenna selection for channel capacity. For the optimal antenna selection, here, need to choose S columns of $\mathbf{H}$ to maximize the energy efficiency.

NOMA with Antenna Selection: A corresponding number of parallel radio frequency (RF) chains at the front end are necessary for the concurrent use of multiple antennas on the transmitter side. As such, with an increase in the number of antennas, this increases device complexity, power consumption, and expense. The best antenna from multiple antennas is opportunistically selected by an efficient TAS technique and uses a subset of transmission RF chain. Eventually, at the expense of reasonable performance loss, this reduces device complexity, power consumption, and cost, as well as scale. Research into finding a new TAS-NOMA scheme for downlink communications from a base station equipped with multiple antennas to multiple users, each equipped with a single antenna, should be carried out in this regard. The aim of the scheme should ultimately improve the achievable rate, considering the targeted user rate is allocated opportunistically based on channel conditions.

A typical NOMA scheme: This scheme considers a single-cell downlink scenario where there is a single base station (BS) and $user\ U_j$, with i ε N = {1, 2……..K}. Subject to constraint of total power, the BS always sends data to all users simultaneously. The wireless connections are believed to encounter independently and identically distributed (i.i.d) additive white Gaussian noise (AWGN). The channels are sorted as $0 < |h_1|^2 \leq |h_2|^2 \leq \cdots \leq \left|h_j\right|^2 \ldots . \leq |h_N|^2$, which indicates that user always holds the weakest instantaneous channel. The NOMA scheme allows simultaneous serving of all users by using the entire system bandwidth (BW) to transmit data with the help of SC at the BS and SIC decoding techniques at the users. The BS transmits a linear superposition of K users' data by allocating a fraction β_i of the total power to each $user\ U_j$, i.e., the power allocated for the j_{th} user is $P_j = \beta_j P$. On the receiving end, each user decodes the signals of a weaker $user\ U_j$, i.e., it can decode the signals for each $user\ U_t$ with $t < j$. The signals for a weaker users are then subtracted from the received signal to decode the signal of user U_j, itself dealing with the signals of a stronger users U_t, with $t > j$, as interference. The received signal at user U_j can be represented as [25]:

$$y_i = h_j x + n_j \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (23)$$

Where $x = \sum_{j=1}^{K} \sqrt{P\beta_j}\, G_j$ is the superposed signal transmitted by the BS, with G_j being the signal for user U_j. Also, n_j is the AWGN of user with zero mean and variance σ_n^2. If signal superposition at the BS, and SIC at U_j, are carried out perfectly, the data rate achievable for user U_j of system bandwidth B is given by [25]:

$$R_j = \mathrm{B} * \log_2\left(1 + \frac{P\beta_j |h_j|^2}{P|h_j|^2 \sum_{k=j+1}^{N} \beta_k + \sigma_n^2}\right) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (24)$$

Notice that a better channel condition is encountered by a strong user, but that does not mean that the signal intensity is higher. In reality, a strong user is allocated lower transmission power, and more power is assigned to a weak user. The weak signal from the user is getting stronger. So, NOMA does not contradict the basic principle of SIC that the strongest signal should first be decoded. The aforementioned NOMA scheme with two users is illustrated in Figure 3.4, as shown below. User 2 first performs SIC in NOMA to decode the signal for user 1, since user 2's channel gain is higher than that of user 1. The decoded signal would then be subtracted from user 2's received signal. Eventually, this resulting signal is used to decode the signal for user 2. SIC is not executed for User 1, and the signal is decoded directly. Thus, the achievable data rate for near and far user are given by:

$$R_1 = B\log_2\left(1 + \frac{P_1|h_1|^2}{P_2|h_1|^2 + \sigma_n^2}\right) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (25)$$

$$R_2 = B\log_2\left(1 + \frac{P_2|h_2|^2}{\sigma_n^2}\right) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (26)$$

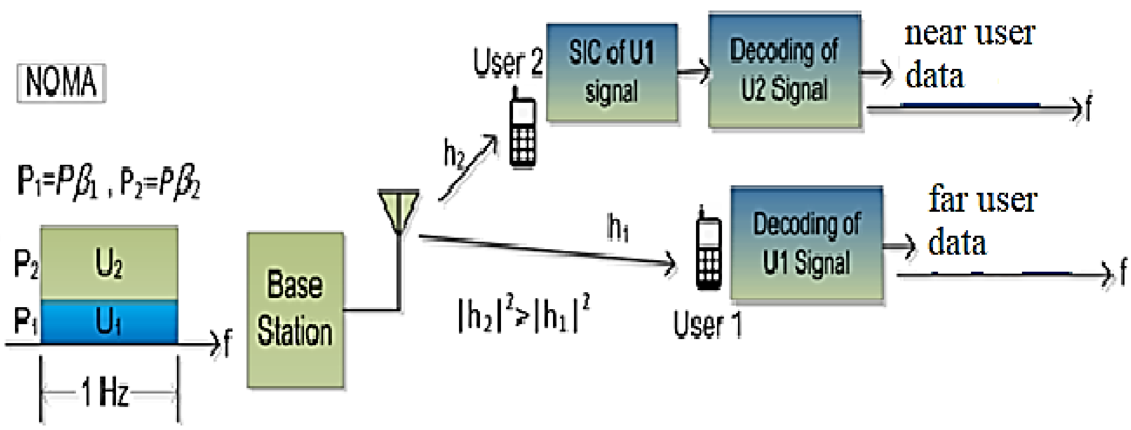


Figure 3. 4: Multiple access schemes for a two-user scenario of NOMA [25]

Energy Efficiency: The energy efficiency of the system defined as:

$$EE = \frac{Capacity}{p_{total}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots\dots (27)$$

$$P_{total} = P_1 + P_2 \dots\dots\dots\dots\dots\dots.\dots\dots..\dots\dots\dots\dots (28)$$

where P_1 *and* P_2 is power consumption due to near and far user.

$$P_1 = PA + P_{circ} + P_{crxnear} \dots\dots\dots.\dots\dots\dots\dots\dots\dots (29)$$

$$P_2 = PA + P_{circ} + P_{crxfar} \dots\dots\dots.\dots\dots\dots\dots\dots\dots\dots (30)$$

$$P_{circ} = P_B + P_{syn} + M(P_{DAC} + P_{mix} + P_{filt}) \dots\dots..\dots\dots\dots\dots (31)$$

$$P_{crxnear} = P_{syn} + K_{near}(P_{ADC} + P_{mix} + P_{filt}) \dots\dots\dots..\dots\dots (32)$$

$$P_{crxfar} = P_{syn} + K_{far}(P_{ADC} + P_{mix} + P_{filt}) \dots\dots\dots\dots.\dots (33)$$

where $P_{crxnear}$ *and* P_{crxfar} are circuit power consumption due to near and far user respectively; K_{near} and K_{far} are near and far user respectively.

Energy Efficiency due to near and far user are defined as:

$$R_{total} = R_1 + R_2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (34)$$

$$EE = \frac{R_{total}}{P_{total}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (35)$$

where R_1*and* R_2 are capacity due to near and far users.

So, finally the capacity of the system and energy efficiency are defined by:

$$R_1 = B \log_2\left(1 + \frac{SNR * H_1 H_1{}'}{M}\right) \dots\dots\dots\dots\dots\dots\dots\dots (36)$$

$$R_2 = B \log_2\left(1 + \frac{SNR * H_2 H_2{}'}{M}\right) \dots\dots\dots\dots\dots\dots\dots\dots (37)$$

$$R_{total} = R_1 + R_2 \dots\dots..\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (38)$$

Hence H_1 and H_2 are channel matrices due to near and far users; $M$is total number of transmit antenna.

$$EE = \frac{R_{total}}{P_{total}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (39)$$

The number of antenna selected to maximize the energy efficiency is given by [9]

$$S = arg \max_{M} EE \dots\dots\dots\dots.\dots\dots\dots\dots\dots\dots\dots\dots (40)$$

Digital Modulation techniques: the digital modulation provides high information capacity and quicker system availability with great quality communication, that's why, the applications of various digital modulation techniques continue to grow, with the growth and evolvement of the digital communications industry. In recent times, the growth of multimedia facilities for mobile wireless communication has contributed to a great advancement in the field of wireless communication. Digital modulation technology is one of the commonly used techniques that enables digitized data to be transmitted or transmitted through analog radio frequency (RF) channels. For uninterruptible communication, the data transmission rate should be maximal. But with high rates, the risk of error is higher.

Modern modulation techniques exploit the fact that digital baseband data can be transmitted by varying both the envelope and the phase/frequency of a carrier wave. Since two degrees of freedom are provided by the envelope and the phase, such modulation techniques map baseband data into four or more possible carrier signals in [27]. For transmission over the channel, digital modulation consists of mapping the information bits into an analog signal. These bits of information are extracted from the source of the information, which may be a digital source or an analog source passed through an A/D converter. To obtain the data bit sequences, both digital and A/D converted analog sources can be compressed.

Mathematical formula for capacity for this modulation techniques are given by

$$Capacity = B \log_2 \left(1 + \frac{L * SNR * HH'}{M}\right) \dots\dots\dots\dots\dots\dots\dots\dots. (41)$$

$L = \log_2 m$, where m is array of modulation and L is number of bits.

$$EE = \frac{Capacity}{P_{total}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (42)$$

$$S = arg \max_{M} EE \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (43)$$

Table 3. 1: Input parameters

List	Input Parameters	Value
1	Transmit power	3 watts
2	Power amplifier coefficient	0.38
3	Power due to mixer	0.03 watts
4	Power due to Digital to Analog Converter	0.015 watts
5	Base band power	0.025 watts
6	Power due to synthesizer	0.05 watts
7	Power due to filter	0.02 watts
8	Bandwidth	10 MHz
9	Signal to Noise Ratio	10 dB
10	Noise signal	$9 * 10^{-8} J/s$
11	Number of users	20
12	Number of transmit antenna	100

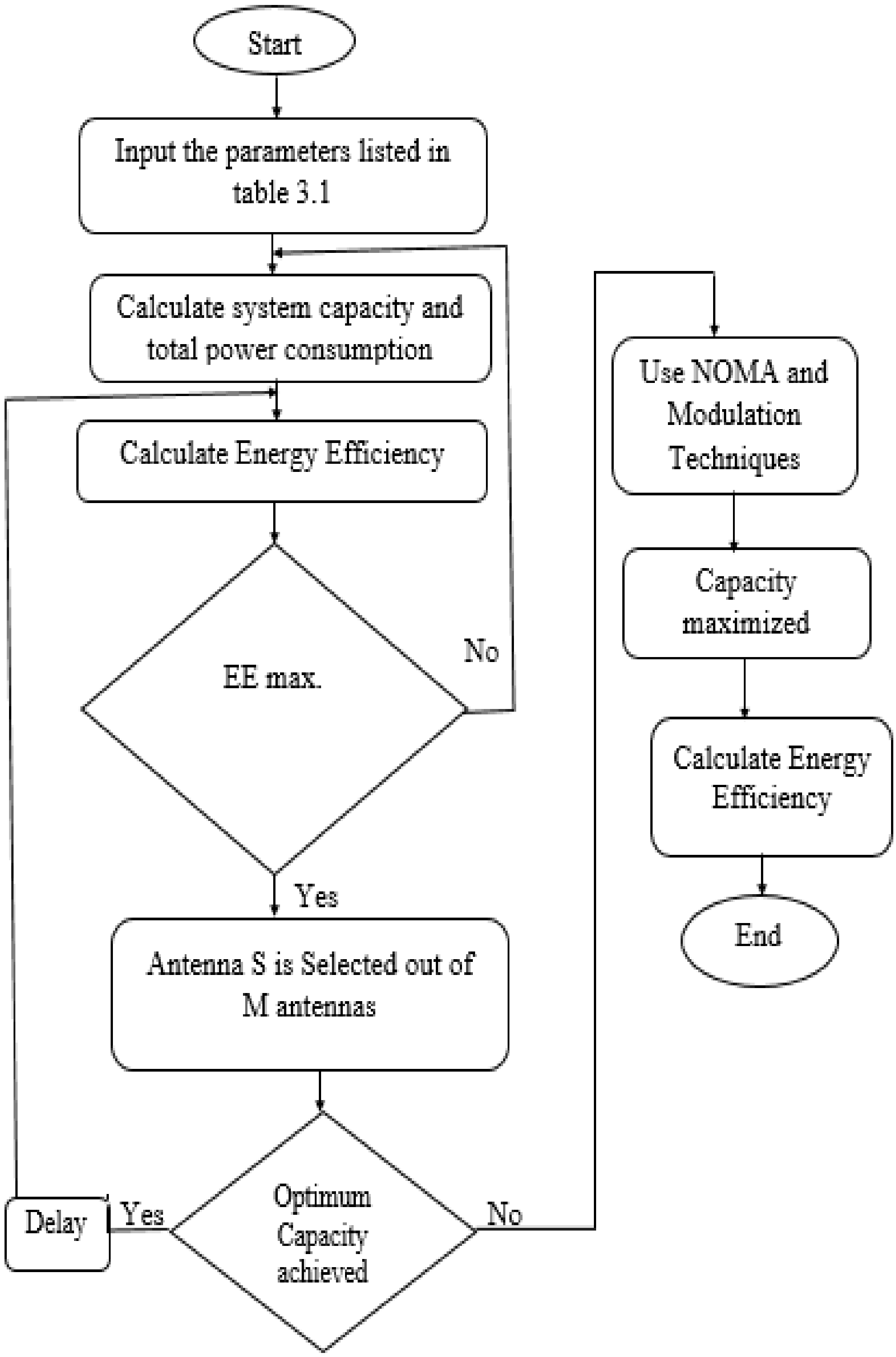
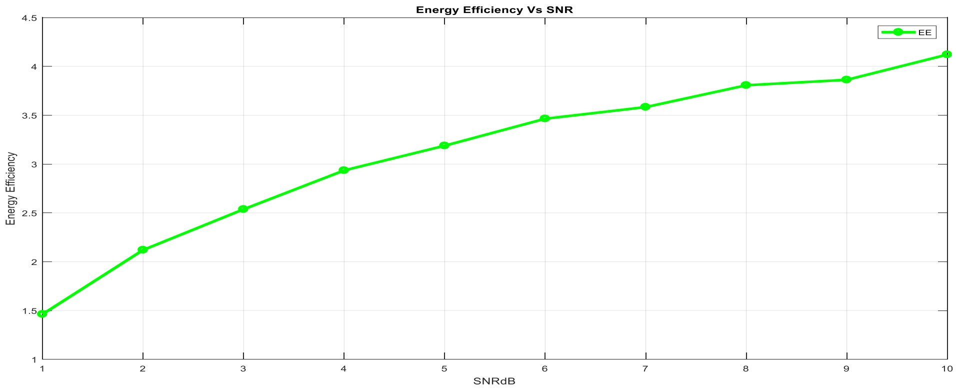


Figure 3. 5: Flow chart of the overall system

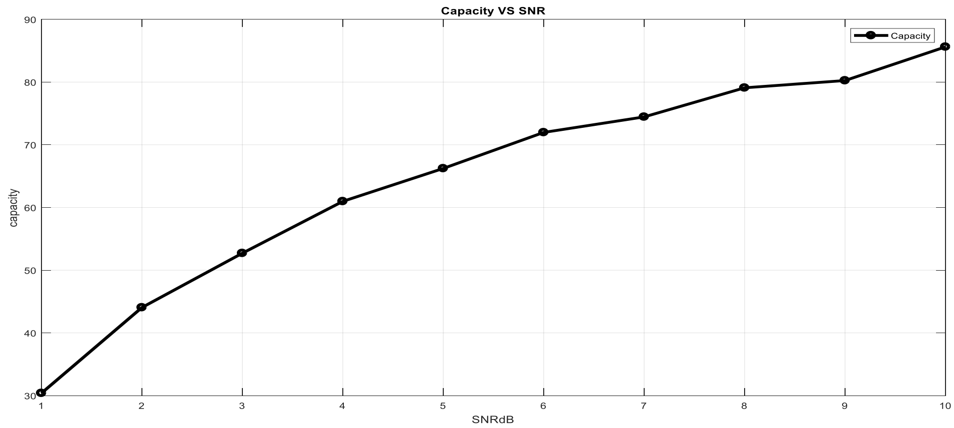
CHAPTER FOUR

4. RESULT AND DISCUSSION

The simulation results of the proposed system is compared with the related works in the literature to fulfill the specific objectives of the research. The simulation results explained in this chapter are performed for the same values of the system parameters with transmit antenna M=100, number of user K=20 and SNR=10dB. Numerical results are provided under both presumed perfect CSI and ZF forcing precoding for inter user interference cancellation, in the single cell. Analytical closed-form equations for the EE-maximizing parameters from Chapter 3 are computed to simulate energy efficiency.



(a)



(b)

Figure 4. 1: (a) Energy efficiency vs. SNR and (b) capacity vs. SNR

Figure 4.1 shows the energy efficiency vs. SNR and capacity vs. SNR, and from the simulation results the total power consumption is 20.78 W when SNR is 10dB. The effect of the SNR on the capacity, and energy efficiency in a Massive MIMO system with fixed number of user K=20 and fixed number of transmit antenna M=100 shown on the figure 4.1. As SNR increases the capacity grows logarithmically, as well as the energy efficiency also increases logarithmically. So, from this result, the capacity with respect to (SNR) and the SNR depends on the fixed value of power consumption improves the energy efficiency of the system.

Table 4. 1: Comparison of capacity, energy efficiency and power for M=25, 50, 100 and K=20

Number of user K=20			
Number of antenna (M)	Capacity	Energy Efficiency	Power
25	75.62	4.89	15.68
50	80.93	4.66	17.38
100	85.10	4.10	20.78

Where capacity in bit/second, energy efficiency in bit/joule and power in Watt

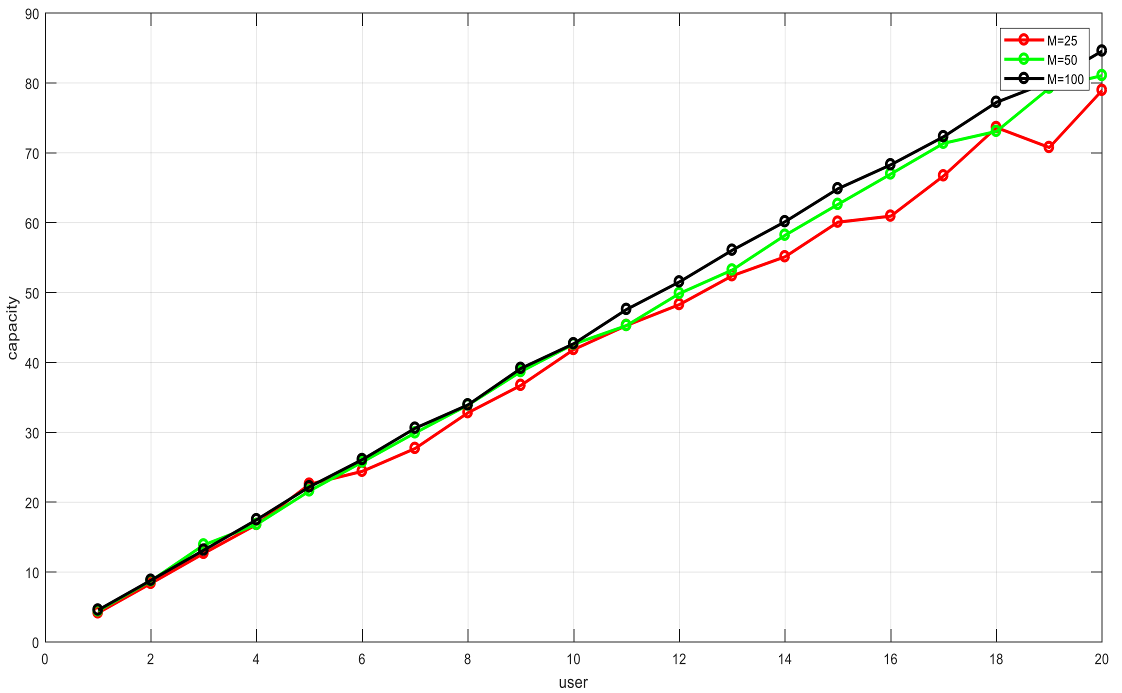


Figure 4. 2: Capacity vs. user at number of transmit antennas are 25, 50,100

Figure 4.2 show that, the capacity in the function of the number of user's for different fixed number of transmit antenna. So, for a fixed value of transmit antenna the total power consumption calculated using this transmit antenna also have fixed value. As the number of fixed number of antenna increases the power consumption also increases and the optimal number of users that maximize the capacity can be observed for different values of transmit antenna at the BS which is shown on table 4.1. From a given different value of transmit antenna, the antenna with a larger value has a good capacity as compared to those transmit antenna with a small value. Finally, as the number of a user increases the system capacity also increases with the increment of the different fixed value of transmit antenna.

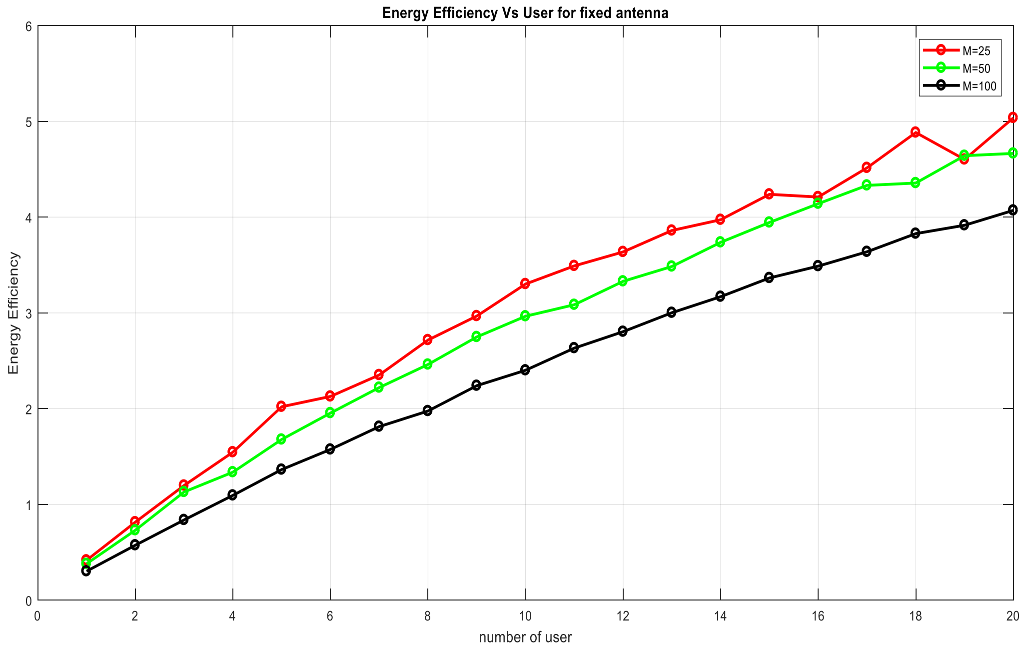


Figure 4. 3: Energy efficiency vs. user at transmit antennas=25, 50,100

Figure 4.3 indicates the energy efficiency with regard to number of user under different value of transmit antenna. In the wireless communication system, the number of users has high effect on the capacity of the system and the increment of user causes inter user interference. But, in this thesis, this inter user interference can be cancelled using ZF precoding. Therefore, as the number of user increases the energy efficiency increases logarithmically. Because, the capacity of the system can be increases as the user increases. From the figure 4.3 as the fixed value of transmit antenna increases the energy efficiency with larger value of transmit antenna at the bottom of the smallest value of transmit antenna shown on table 4.1. This is, because the value of transmit antenna increases the total power consumption become increases. While, energy efficiency decreased as the power consumption increased.

Table 4. 2: comparison of capacity, energy efficiency and power for K=5, 10, 15, 20 and M=100

Number of antenna M=100			
Number of user K	Capacity (bit/s)	Energy efficiency (bits/j)	Power
5	21.98	1.35	16.28
10	42.77	2.41	17.78
15	64.10	3.32	19.28
20	85.10	4.1	20.78

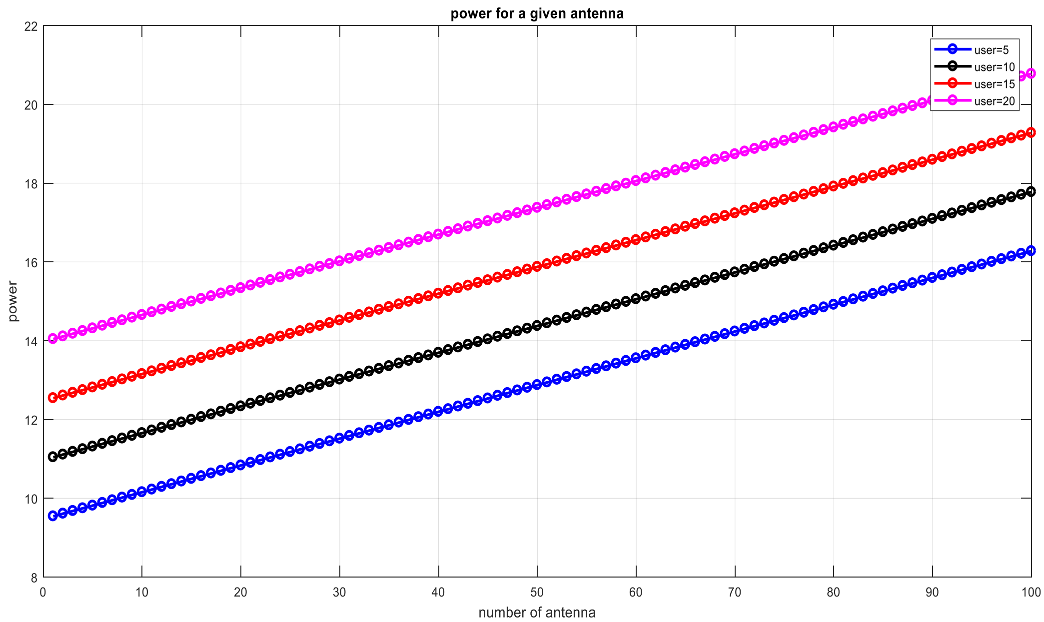


Figure 4. 4: Power Vs number antenna at user K=5, 10, 15, and 20

Depending on the new power consumption, the effects of increasing transmit antenna on the total power consumption for different value of users are shown in Figure 4.4, Since the circuit power consumption from digital to analog converter, filter, mixer, synthesizer, power amplifier and baseband power are considered, the total power consumption is gradually increasing. In addition as the fixed value of user increases the total power consumption also increases with keeping the increment of number of transmit antenna which is shown on table 4.2. In the aspect of energy efficiency, the increase in the total power consumption affects the tendency of energy efficiency critically.

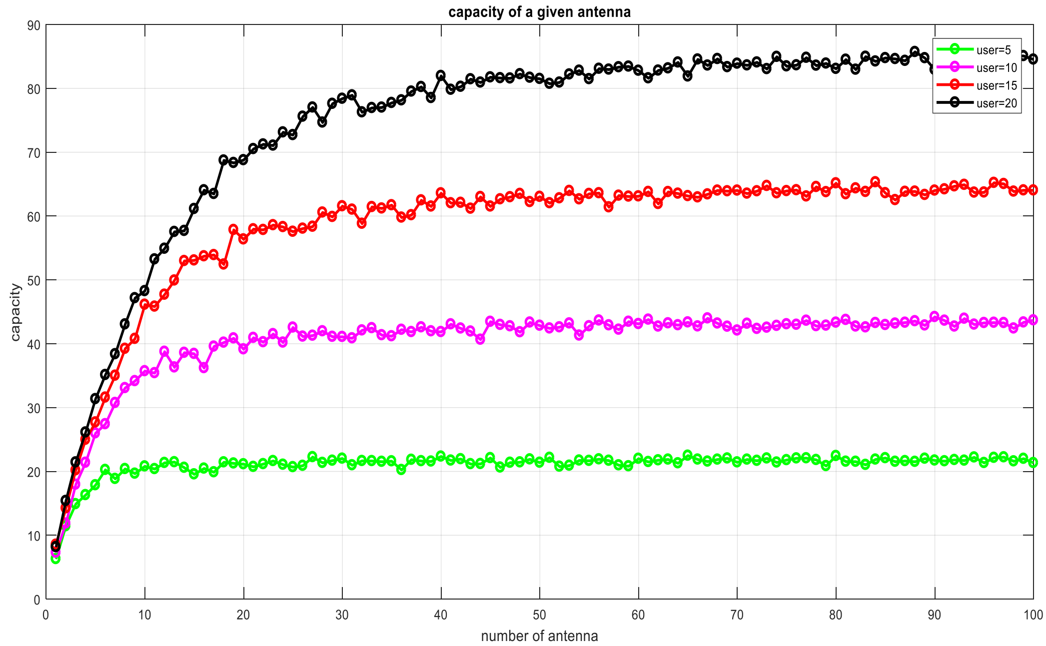


Figure 4. 5: Capacity Vs number of antenna at user K=5, 10, 15, and 20

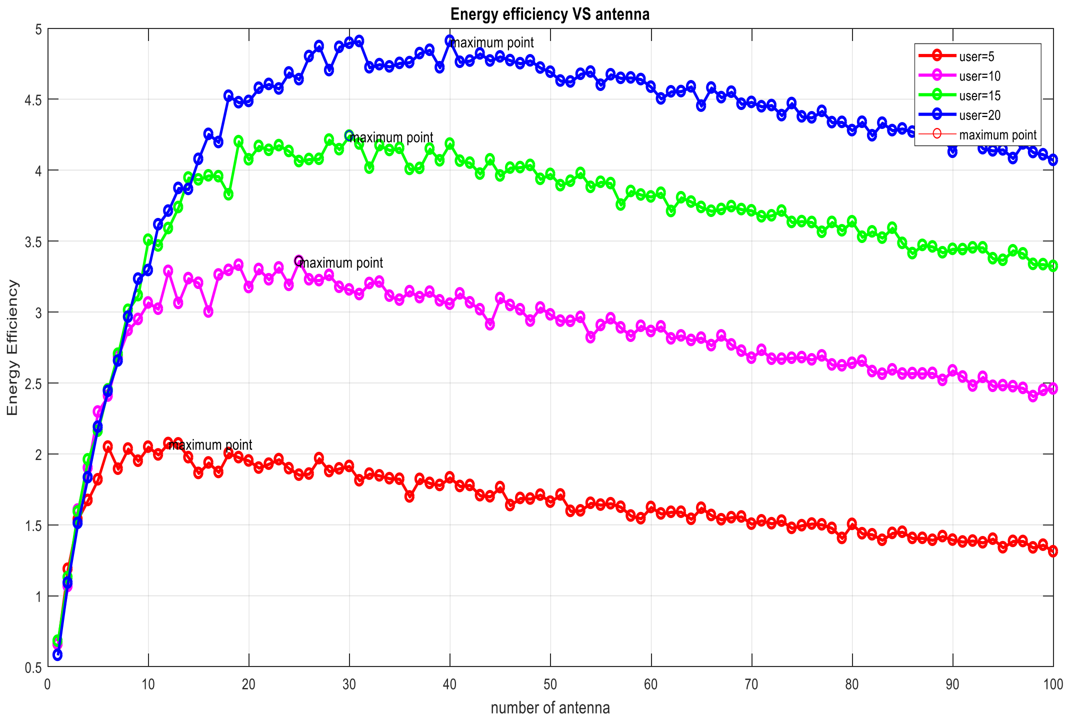


Figure 4. 6: Energy efficiency Vs number of antenna at user K=5, 10, 15, and 20

The simulation result was considered from the energy efficiency viewpoints, the relation between energy efficiency, and the total transmit antennas is shown in a figure 4.6. It can be seen that, in four different values of users, the energy efficiency increases when the number of transmit antenna increases which is shown on table 4.2. However, these energy efficiency values become saturated as the value of transmit antenna very large. This is because of capacity in the antenna selection system is logarithmically increasing function with respect to total number of transmit antenna shown in Figure 4.5 and the capacity increases as the fixed number of users increases.

This is because, the number of users enhances the capacity of the system. Meanwhile, in each value of users, the energy efficiency first increases, and then decreases. This behavior can be explained by the fact that, when the number of transmit antenna become large, the increased power consumption due to RF chains has more impacts on the energy efficiency than the capacity improvement does, which reduces energy efficiency value.

Table 4. 3: Comparison of capacity and energy efficiency using OMA and NOMA schemes for M=100

Number of antenna M=100					
Capacity of OMA	Capacity of NOMA	Energy efficiency of OMA	Energy efficiency of NOMA	Power of OMA	Power of OMA
85.1	169.7	4.1	8.13	20.78	20.78

Figure 4.7, indicates that the comparison among NOMA and OMA with respect to capacity vs. number transmit antenna. However, as the number of transmit antenna increases the capacity increases logarithmically for both NOMA and OMA. But here, from the simulation result the capacity of NOMA scheme have better result as compared to the capacity due to OMA schemes shown on table 4.3.

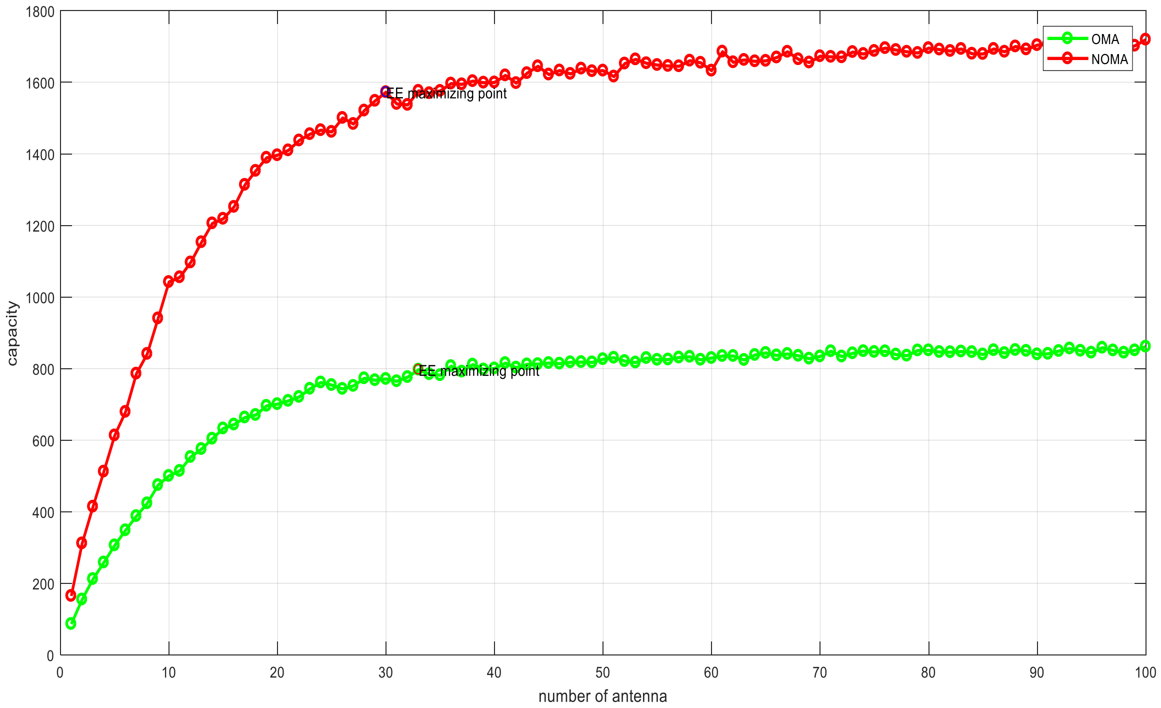


Figure 4. 7: Capacity Vs number of antenna for OMA and NOMA

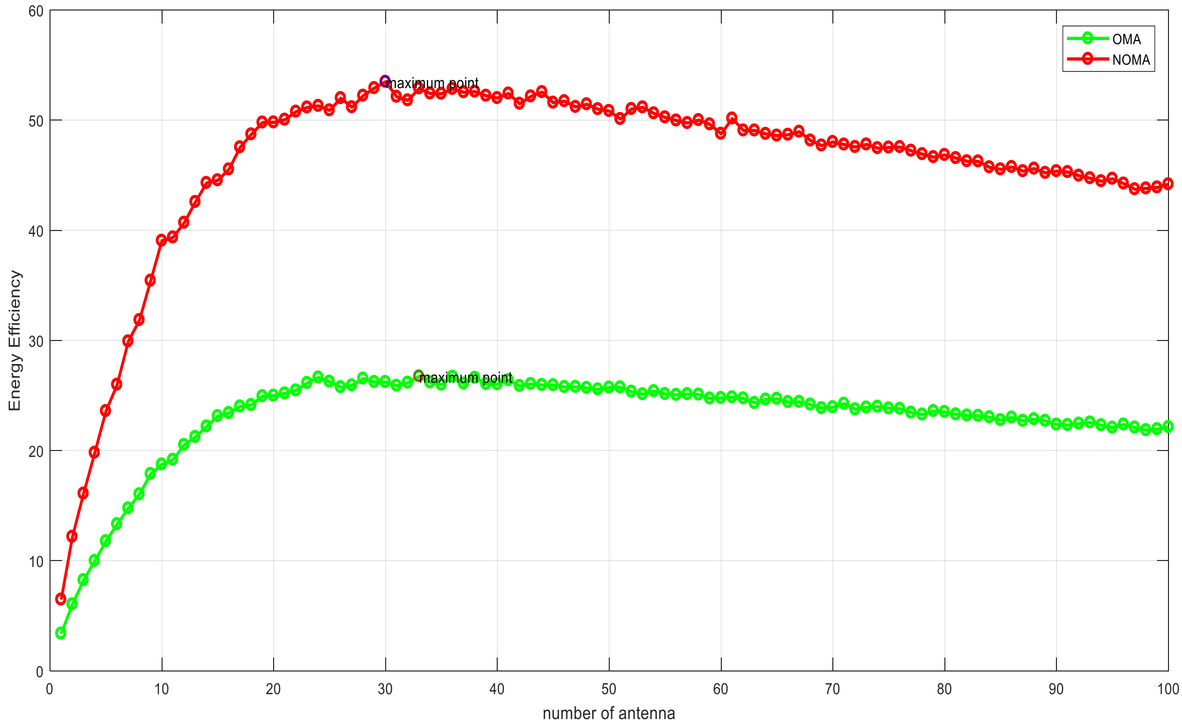


Figure 4. 8: Energy efficiency Vs number of antenna for OMA and NOMA

Figure. 4.8 shows a performance comparison between OMA and NOMA with respect to energy efficiency and different numbers of transmit antenna. Here, two power allocation schemes (i.e. for near and far users) are used, and the overall bandwidth used for near and far users in NOMA. While, in the OMA, half of bandwidth used for each near and far users. As a result, NOMA achieves better energy efficiency than that of OMA shown on table 4.3.

Figure 4.9 and figure 4.10 are showing that, the capacity and energy efficiency with respect to number of transmit antenna using modulation and without modulation. Here, as the number of array modulation increases the number of bit to be sent also increases. As well as, the capacity of the system increases as the number of bit to be sent increases. So, the increment of capacity of the system has an effect on the energy efficiency, and this means as the capacity increases the energy efficiency also increase up to they reach optimal point and then decreases. This is because of the increment of circuit power due to the number of transmit antenna connected to RF chains become larger. Finally, modulation technique enhances the capacity of the system as well as energy efficiency. In addition the energy efficiency due to modulation is got better value than that of energy efficiency without modulation (OMA) which is shown on table 4.4.

Table 4. 4: comparison of capacity and energy efficiency using OMA, NOMA and modulation schemes for M=100

Number of antenna M=100								
Capacity			Energy efficiency			Power		
OMA	NOMA	Modul-Ation	OMA	NOMA	Modul-Ation	OMA	NOMA	Modul-Ation
85.10	169.70	134	4.10	8.13	6.45	20.78	20.78	20.78

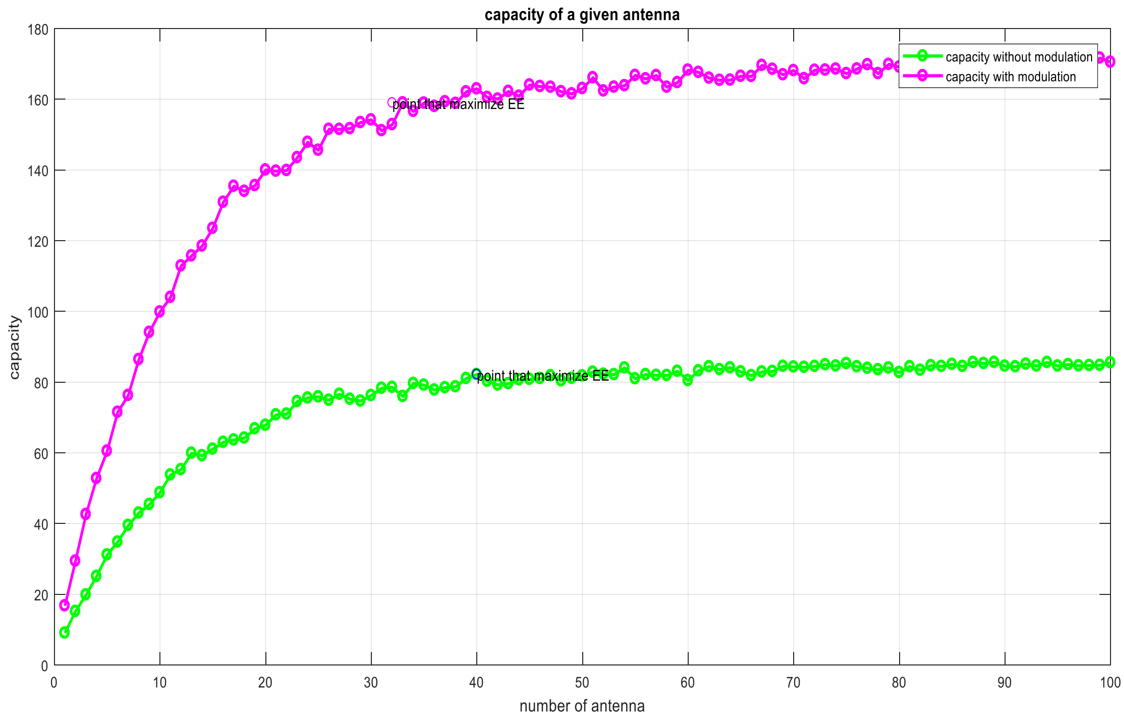


Figure 4. 9: Capacity Vs Number of antenna with modulation and without modulation

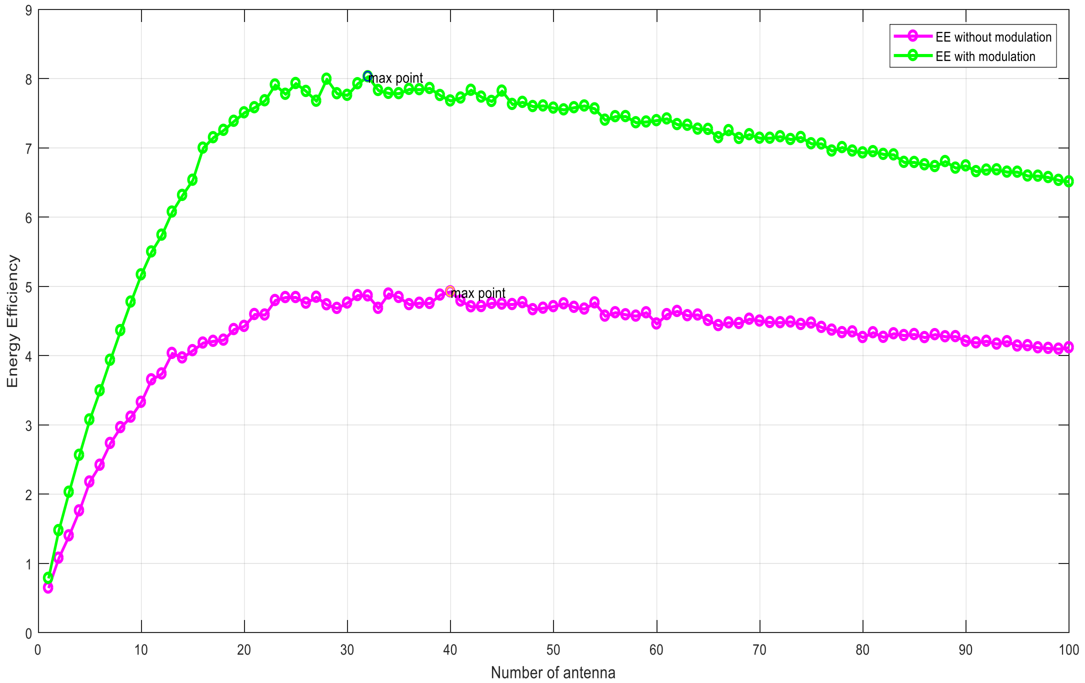


Figure 4. 10: Energy efficiency Vs number of antenna with modulation and without modulation

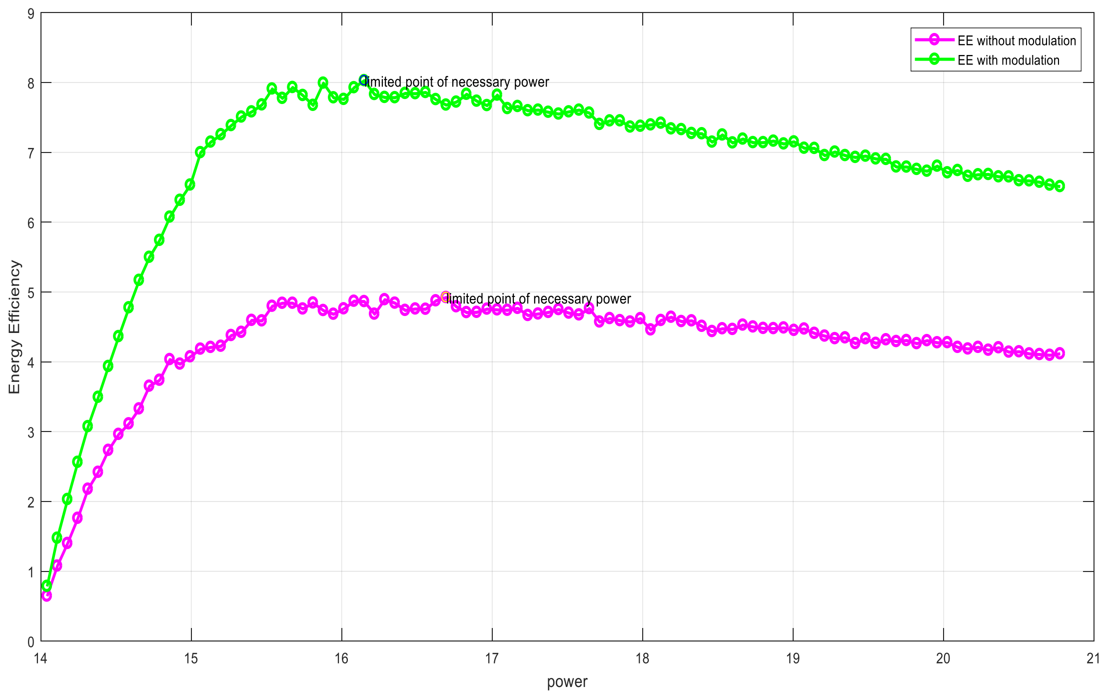


Figure 4. 11: Energy Efficiency Vs power with modulation and without modulation

Figure 4.11 shows that the energy efficiency with respect to the total power consumption and maximal energy efficiency was achieved at the limited necessary power with keeping the increasing of total transmission power. Furthermore, after obtaining maximum points, energy efficiency began to decrease due to an increase in total power consumption. However, energy efficiency still increased with transmit power. This shows that maximum energy efficiency could be achieved with the desired transmit power with minimized circuit power consumption. Alternatively, when the transmission power increased slowly, the total circuit power consumption increased, which decreased energy efficiency, as shown in Figure 4.11.

The modulation techniques enhances the energy efficiency of the system, and as well as the NOMA with power allocation also enhances the energy efficiency of the system. Figure 4.12 compares that, the energy efficiency among NOMA, modulation and without modulation (OMA) schemes with respect to number of transmit antenna. Here, the result shows that, as the number of transmit antenna increases energy efficiency increases until they reach maximum point and then decreases. The comparison of energy efficiency using three option (i.e. NOMA, modulation and without modulation (OMA) schemes) and the energy efficiency with regard to number of transmit antenna of NOMA techniques better than the other two option (i.e. modulation and OMA) schemes, which is shown on table 4.4.

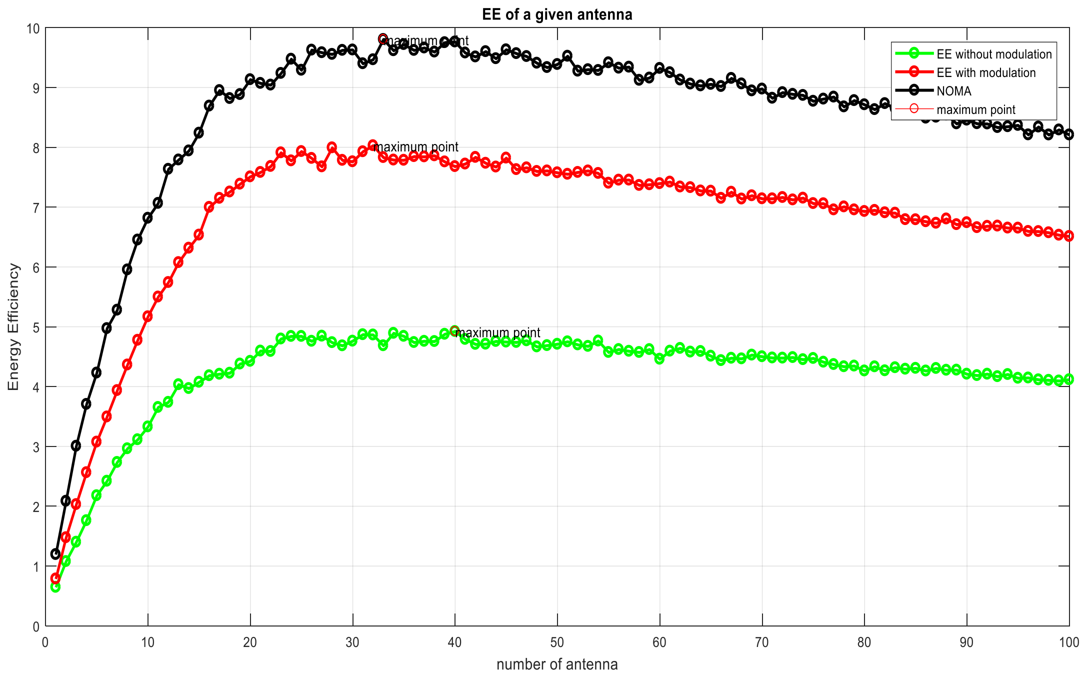


Figure 4. 12: Energy efficiency Vs number of antenna for NOMA, with and without modulation

Table 4. 5: comparison of capacity and energy efficiency using OMA, NOMA and modulation schemes for number of selected antenna S=30

Number of selected antenna S=30								
Capacity			Energy efficiency			Power		
OMA	NOMA	Modul-Ation	OMA	NOMA	Modul-Ation	OMA	NOMA	Modul-Ation
76.23	153.28	125	4.89	9.57	7.81	16.01	16.01	16.01

The effect of antenna selection in massive MIMO system in order to improve energy efficiency of OMA and NOMA schemes and modulation and without modulation schemes shown in a figure 4.13 and figure 4.14 respectively. Here, from the simulation result the result of Energy efficiency increases up to select number of antenna and it shows the comparison between OMA and NOMA schemes, NOMA scheme have better value than OMA scheme. As well as, the comparison between modulation and without modulation scheme, the energy efficiency with regard to modulation scheme have better result as compared to energy efficiency without modulation scheme, which is shown on table 4.5. Therefore antenna selection improves energy efficiency. This is because of antenna selection control the amount power due the circuit that affects the energy efficiency of the system.

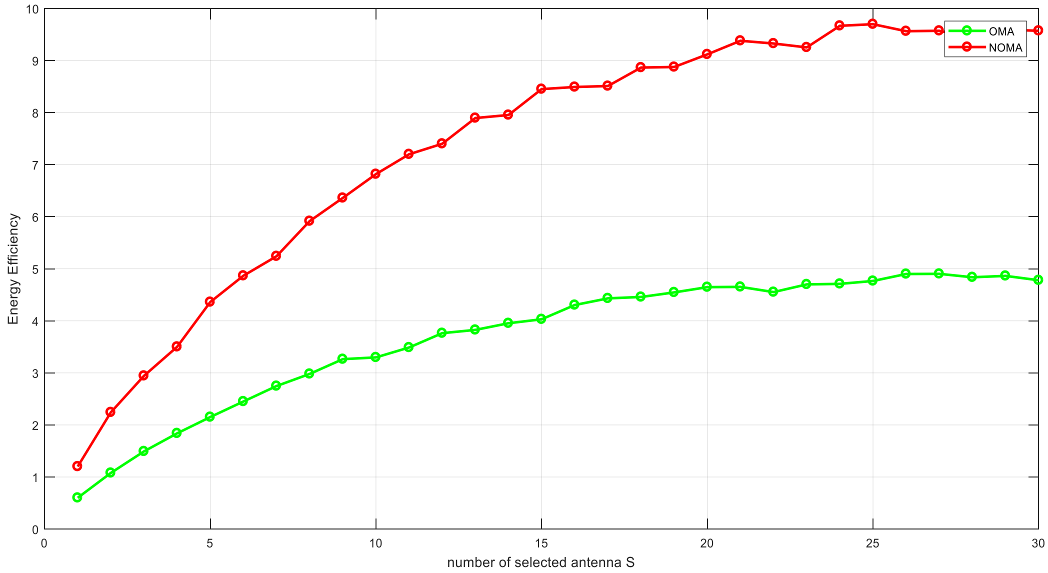


Figure 4. 13: Energy efficiency Vs number of selected antenna S for OMA and NOMA

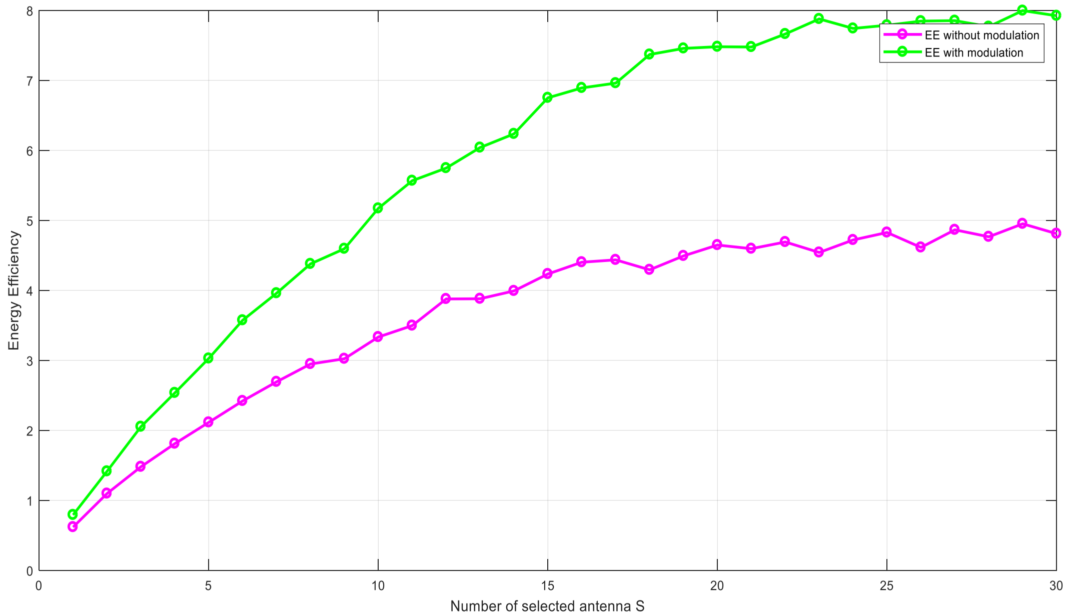


Figure 4. 14: Energy efficiency Vs number of selected antenna S for with and without modulation

Figure 4.15 compares the energy efficiency with respect to number of selected antenna S using NOMA, OMA and modulation schemes. The amount of power consumption due to RF chain or power due ADC (Analog to Digital Converter), amplifier mixer, filter and synthesizer are reduced in antenna selection schemes. From the simulation result the energy efficiency of three schemes (i.e. NOMA, OMA and modulation schemes) increases up to maximum value of selected number of antenna and the NOMA scheme have better performance as compared to OMA (without modulation) and modulation schemes, which is shown on table 4.5.

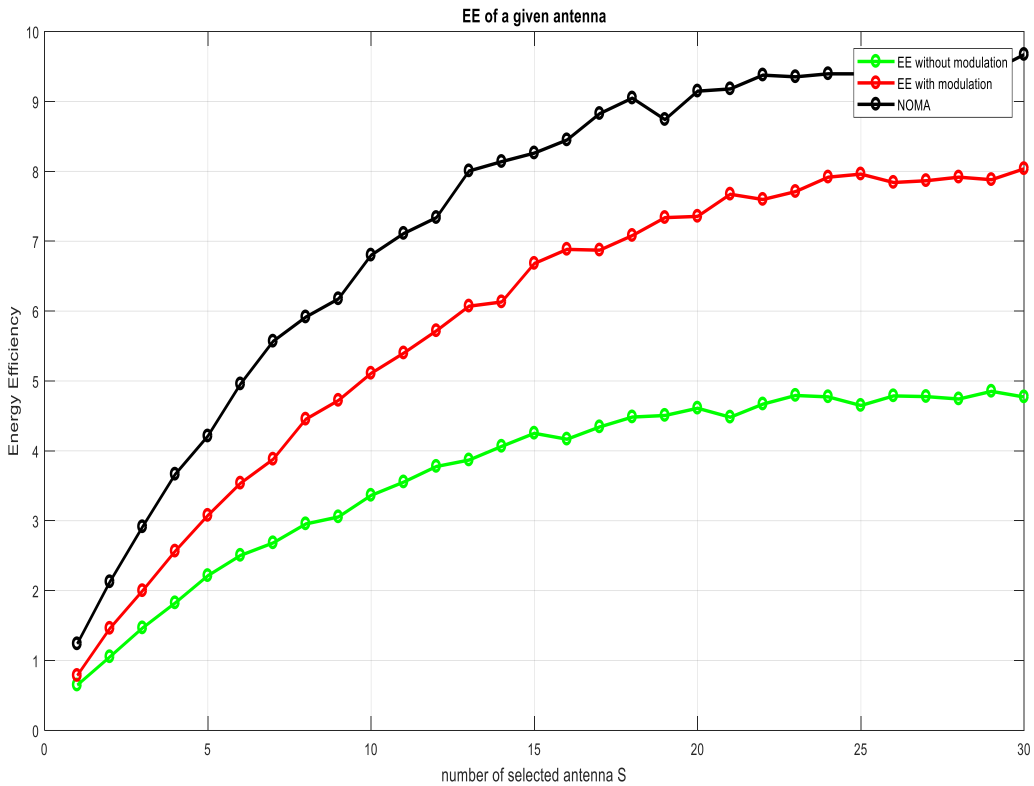


Figure 4. 15: Energy efficiency Vs number of selected antenna S for NOMA, with and without modulation

Table 4. 6: comparison of capacity and energy efficiency using OMA, NOMA and modulating schemes for M=100 and number of selected antenna S=30

	Number of antenna M=100			Number of selected antenna S=30		
Schemes	Capacity	Energy Efficiency	Power	Capacity	Energy Efficiency	Power
OMA	85.1	4.10	20.78	76.23	4.89	16.01
NOMA	169.7	8.13	20.78	154	9.57	16.01
Modulation	134	6.45	20.78	125	7.81	16.01

Table 4.6 shows that the capacity, energy efficiency and power without selection of antenna and with selection of antenna. From the three schemes (i.e. OMA, NOMA and modulation) the energy efficiency of NOMA have better value for antenna selected than without antenna selection and the power consumption is saved from 20.78 to 16.01.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

By employing a very large number of antennas, massive MIMO systems yield high data rates to the user terminal. As a result, however, power consumption also increases with the number of antennas, while energy conservation is a critical concern for wireless systems of the modern generation. This thesis, presented how antenna selection is performed in Massive MIMO system. Massive MIMO offers all the advantages of MIMO system in larger scale. However, due to multiple antennas at the base station, multiple RF chain is required. So cost, hardware complexity and size of the system is much increased. To solve this problem, antenna selection is required in Massive MIMO system.

In this thesis here, consider a multi-user massive MIMO scenario and the proposed antenna selection scheme, so that the system may operates with a subset of $S \leq M$ antennas to maximize the EE.

The results of the simulation show that EE increases with an increase in the SNR value and the number of transmit antennas at the base station. In addition, Energy Efficiency with and without modulation, with NOMA and OMA, with NOMA, OMA and modulation with respect to user and transmit antenna are done. But, as the number of base station transmit antenna increases the energy efficiency increases until they reach the optimal point and then decreases.

Finally, the result of energy efficiency with respect to number of selected antenna have been examined. Here, the capacity with regard to number of selected antenna would be decreased and in order to achieve this capacity NOMA and modulation scheme used in this thesis. The simulation result show that, the comparison of energy efficiency with modulation and without modulation schemes, NOMA and OMA schemes, and comparison of energy efficiency using three schemes (i.e. NOMA, modulation and OMA) has been done. From the comparison of modulation and without modulation, energy efficiency with modulation have better value; from the comparison between NOMA and OMA schemes, energy efficiency of NOMA scheme is the best one and from the comparison among NOMA, OMA and modulation schemes, the NOMA scheme has the better energy efficiency than OMA and modulation schemes.

5.2. Recommendation

Massive MIMO antenna selection schemes developed in this thesis consider only a one single cell wireless network. Further, works can expand these schemes for a system with more than two cell (i.e. expand it to larger networks) which can improve the spectrum utilization efficiency. This thesis work on energy efficiency at downlink system. We recommend that the next work have to include the energy efficiency at uplink system.

In this thesis, the modulation techniques for capacity enhancement were used. But, in theoretical as the number of modulation array increases the error probability also increases in the other sides. We recommend that, it have to consider this problem and prepare the techniques for error probability reduction method.

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Appendix

Code for the comparison between Energy efficiency versus number of antenna using NOMA, OMA, and modulation

```
clc
clear all
close all
NR=20;%number of recieved antenna or user
NT=1:200;%number of transmit antenna
S=30;
No=9*10^-8; %noise signal
BW=10;% bandwidth in Mhz
e=2.71;% constant value
eta=0.38;%power amplifier efficiency
ptx=3;%transmit power
pmix=0.033;% power of mixer
 pfilt= 0.02;%power of filtering
 pbb=0.03;%baseband power consumption
  psyn=0.05;%power of synthesizer
  pdac=0.015;%power of digital to analog converter
  pcrx=0.3;%power circuit of user(receiver)
  pamp=ptx/eta;% power of amplifier

%SNR =round((ptx*NT)/(No*NR*BW))
%SNR=10;

I=eye(NR,NR); % identy vector
SNR_sel=10%signal to noise ratio
cum=0; cum1=0; %initialization of capacity
x=0;
for i=1:length(NT)

    sel=i;
```

```
  %SNR_sel =round(ptx*sel)/(No*NR*BW)
      pcrk=(pbb+psyn)+(sel*(pdac+pmix+pfilt))+(NR*pcrx);%circuit power consumption
  ptotal=pamp+pcrk; % total power

    H = (randn(NR,sel)+j*randn(NR,sel));%channel matrix

    cap=BW*log2(real(det(I+(SNR_sel/i)*H*H')))%capacity calculation

    cpa=cum+cap;
    x=x+1;
  select(i)=sel;
    capacity(i)=cpa;
    power(i)=ptotal;
    EE1=capacity(i)/power(i);% energy efficiency calculation
 EE(i)=EE1;
end
EEmax=max(EE)   %maximuma of energy efficiency
selected=find(EE==EEmax)
NT_max=NT(selected)  % number of optimal selected antenna calculation
selected=find(NT==NT_max) %number selected antenna
powermax=power(selected)% maximum power consumption
capma=capacity(selected)%maxima capacity that maximize EE

display('=====================================================')
%modulation technique
M=input('M value=') % number of array in modulation
  NR1=20; %number of user(receiver)
  I1=eye(NR1,NR1);%identity vector
NT1=1:200;% number transmit antenna
for n=1:length(NT1)
    sel1=n;
```

```
    pcrk=(pbb+psyn)+(sel1*(pdac+pmix+pfilt))+(NR*pcrx);%circuit power
  ptotal=pamp+pcrk;% total power
H1 = (randn(NR,sel1)+j*randn(NR,sel1));%channel matrix
for m=1:length(M)
    L=log2(M)% number of bits
cap1=BW*log2(real(det(I1+(L*SNR_sel/sel1)*H1*H1')))%capacity calculation
cpa1=cum1+cap1;
 select1(n)=sel1
  capacity1(n)=cpa1;
    power1(n)=ptotal;

 EE2=capacity1(n)/power1(n);% Energy efficiency calculation
 EE1(n)=EE2;
end
end
EE1max=max(EE1)%Energy efficiency maxima
selected1=find(EE1==EE1max)
NT1_max=NT(selected1)%number of optimal selected antenna calculation
selected1=find(NT==NT1_max)%number selected antenna
power1max=power(selected1)% maximum power consumption
capma1=capacity1(selected1)%maxima capacity that maximize EE

%===========================================================
NR4=20;
NR3=20;
NT4=1:200;

No=9*10^-8;
BW=10;%inMhz
e=2.71;
eta=0.38;
ptx=3;
pmix=0.033;
```

```
 pfilt= 0.02;
 pbb=0.03;
  psyn=0.05;
  pdac=0.015;
  pcrx=0.3;
  pamp1=ptx/eta;

%SNR =round((ptx*NT)/(No*NR*BW))

I1=eye(NR4,NR4);
I2=eye(NR3,NR3);
SNR_sel=10;
cum=0;
x=0;
for m=1:length(NT4)

    sel3=m;



   %SNR_sel =round(ptx*sel)/(No*NR*BW)
       pcrk1=(pbb+psyn)+(sel3*(pdac+pmix+pfilt))+(NR4*pcrx);
        pcrk2=(pbb+psyn)+(sel3*(pdac+pmix+pfilt))+(NR3*pcrx);
        pcrktotal=pcrk1+pcrk2;
  ptotal=pamp1+pcrktotal;

    H2 = (randn(NR4,sel3)+j*randn(NR4,sel3));
    H3 = (randn(NR3,sel3)+j*randn(NR3,sel3));

    cap1=BW*log2(real(det(I1+(SNR_sel/m)*H2*H2')));
    cap2=BW*log2(real(det(I2+(SNR_sel/m)*H3*H3')));
    captotal=cap1+cap2;
    cpa2=cum+captotal;
```

```
    x=x+1;
  select3(m)=sel3;
    capacity3(m)=cpa2;
    power2(m)=ptotal;
 EE3=capacity3(m)/power(m);
 EE2(m)=EE3;
end
EE2max=max(EE2)%Energy efficiency maxima
selected3=find(EE2==EE2max)
NT3_max=NT(selected3)%number of optimal selected antenna calculation
selected1=find(NT==NT1_max)%number selected antenna
power3max=power(selected3)% maximum power consumption
capma1=capacity3(selected3)%maxima capacity that maximize EE
    figure (1)
 plot(select,capacity,'-go','linewidth',2)
 hold on
  plot(NT1,capacity3,'-mo','linewidth',2)
  hold on
  plot(NT_max,capma,'-bo')
  hold on
 text(NT_max,capma,'point that maximize EE')
 hold on
 plot(NT1_max,capma1,'-mo')
 hold on
 text(NT1_max,capma1,'point that maximize EE')
 xlabel('number of antenna'); ylabel('capacity');
 legend('capacity without modulation','capacity with modulation')
 title('capacity of a given antenna')
 grid on

 figure (2)
 plot(select,EE,'-go','linewidth',2)
 hold on
```

```
plot(NT,EE1,'-ro','linewidth',2)
hold on
plot(NT4,EE2,'-ko','linewidth',2)
xlabel('number of antenna'); ylabel('Energy Efficiency')
hold on
plot(NT_max,EEmax,'-ro')
text(NT_max,EEmax,'maximum point')
hold on
 plot(NT1_max,EE1max,'-ro')
text(NT1_max,EE1max,'maximum point')
hold on
 plot(NT3_max,EE2max,'-ro')
text(NT3_max,EE2max,'maximum point')
title('EE of a given antenna')
legend('EE without modulation','EE with modulation','NOMA','maximum point')
grid on
figure (3)
plot(power,EE,'-mo','linewidth',2)
hold on
plot(power1,EE1,'-go','linewidth',2)
hold on
plot(powermax,EEmax,'-yo')
text(powermax,EEmax,'limited point of necessary power')
hold on
plot(power1max,EE1max,'-bo')
text(power1max,EE1max,'limited point of necessary power')
xlabel('power');ylabel('Energy Efficiency')
legend('EE without modulation','EE with modulation')
grid on
figure (4)
plot(select,EE,'-mo','linewidth',2)
hold on
plot(NT,EE1,'-go','linewidth',2)
```

```
 hold on
 plot(NT_max,EEmax,'-yo')
 text(NT_max,EEmax,'max point')
 hold on
 plot(NT1_max,EE1max,'-bo')
 text(NT1_max,EE1max,'max point')
 xlabel('Number of antenna');ylabel('Energy Efficiency')
 legend('EE without modulation','EE with modulation')
 grid on
```

Code for comparison between Energy Efficiency Versus number of selected antenna using with and without modulation

```
clc
clear all
close all
NR=20;%number of recieved antenna or user
NT=1:30;%number of transmit antenna
S=30;
No=9*10^-8; %noise signal
BW=10;% bandwidth in Mhz
e=2.71;% constant value
eta=0.38;%power amplifier efficiency
ptx=3;%transmit power
pmix=0.033;% power of mixer
 pfilt= 0.02;%power of filtering
 pbb=0.03;%baseband power consumption
  psyn=0.05;%power of synthesizer
  pdac=0.015;%power of digital to analog converter
  pcrx=0.3;%power circuit of user(receiver)
  pamp=ptx/eta;% power of amplifier

%SNR =round((ptx*NT)/(No*NR*BW))
%SNR=10;
```

```
I=eye(NR,NR); % identy vector
SNR_sel=10%signal to noise ratio
cum=0; cum1=0; %initialization of capacity
x=0;
for i=1:length(NT)

    sel=i;

   %SNR_sel =round(ptx*sel)/(No*NR*BW)
       pcrk=(pbb+psyn)+(sel*(pdac+pmix+pfilt))+(NR*pcrx);%circuit power consumption
  ptotal=pamp+pcrk; % total power

    H = (randn(NR,sel)+j*randn(NR,sel));%channel matrix

    cap=BW*log2(real(det(I+(SNR_sel/i)*H*H')))%capacity calculation

    cpa=cum+cap;

    x=x+1;

  select(i)=sel;
    capacity(i)=cpa;

    power(i)=ptotal;
    EE1=capacity(i)/power(i);% energy efficiency calculation
 EE(i)=EE1;
end
EEmax=max(EE)   %maximuma of energy efficiency
selected=find(EE==EEmax)
NT_max=NT(selected)  % number of optimal selected antenna calculation
selected=find(NT==NT_max) %number selected antenna
powermax=power(selected)% maximum power consumption
capma=capacity(selected)%maxima capacity that maximize EE
```

```
display('============================================================')
%modulation technique
M=input('M value=') % number of array in modulation
  NR1=20; %number of user(receiver)
  I1=eye(NR1,NR1);%identity vector
NT1=1:30;% number transmit antenna
for n=1:length(NT1)
    sel1=n;

     pcrk=(pbb+psyn)+(sel1*(pdac+pmix+pfilt))+(NR*pcrx);%circuit power
  ptotal=pamp+pcrk;% total power
H1 = (randn(NR,sel1)+j*randn(NR,sel1));%channel matrix
for m=1:length(M)
    L=log2(M)% number of bits
cap1=BW*log2(real(det(I1+(L*SNR_sel/sel1)*H1*H1')))%capacity calculation
cpa1=cum1+cap1;
 select1(n)=sel1
  capacity1(n)=cpa1;
    power1(n)=ptotal;

 EE2=capacity1(n)/power1(n);% Energy efficiency calculation
 EE1(n)=EE2;
end
end

EE1max=max(EE1)%Energy efficiency maxima
selected1=find(EE1==EE1max)
NT1_max=NT(selected1)%number of optimal selected antenna calculation
selected1=find(NT==NT1_max)%number selected antenna
power1max=power(selected1)% maximum power consumption
capma1=capacity1(selected1)%maxima capacity that maximize EE
```

```
%=========================================================
NR4=20;
NR3=20;
NT4=1:30;
No=9*10^-8;
BW=10;%inMhz
e=2.71;
eta=0.38;
ptx=3;
pmix=0.033;
 pfilt= 0.02;
 pbb=0.03;
  psyn=0.05;
  pdac=0.015;
  pcrx=0.3;
  pamp1=ptx/eta;

%SNR =round((ptx*NT)/(No*NR*BW))

I1=eye(NR4,NR4);
I2=eye(NR3,NR3);
SNR_sel=10;
cum=0;
x=0;
for m=1:length(NT4)


    sel3=m;
   %SNR_sel =round(ptx*sel)/(No*NR*BW)
       pcrk1=(pbb+psyn)+(sel3*(pdac+pmix+pfilt))+(NR4*pcrx);
        pcrk2=(pbb+psyn)+(sel3*(pdac+pmix+pfilt))+(NR3*pcrx);
        pcrktotal=pcrk1+pcrk2;
  ptotal=pamp1+pcrktotal;
```

```
    H2 = (randn(NR4,sel3)+j*randn(NR4,sel3));
    H3 = (randn(NR3,sel3)+j*randn(NR3,sel3));

    cap1=BW*log2(real(det(I1+(SNR_sel/m)*H2*H2')));
    cap2=BW*log2(real(det(I2+(SNR_sel/m)*H3*H3')));
    captotal=cap1+cap2;
    cpa2=cum+captotal;
    x=x+1;

  select3(m)=sel3;
    capacity3(m)=cpa2;
    power2(m)=ptotal;
 EE3=capacity3(m)/power(m);
 EE2(m)=EE3;
end
EE2max=max(EE2)%Energy efficiency maxima
selected3=find(EE2==EE2max)
NT3_max=NT(selected3)%number of optimal selected antenna calculation
selected1=find(NT==NT1_max)%number selected antenna
power3max=power(selected3)% maximum power consumption
capma1=capacity3(selected3)%maxima capacity that maximize EE
    figure (1)
 plot(select,capacity,'-go','linewidth',2)
 hold on
  plot(NT1,capacity3,'-mo','linewidth',2)
%   hold on
%   plot(NT_max,capma,'-bo')
%   hold on
%  text(NT_max,capma,'point that maximize EE')
%  hold on
%  plot(NT1_max,capma1,'-mo')
%  hold on
%  text(NT1_max,capma1,'point that maximize EE')
```

```
xlabel('number of selected antenna S'); ylabel('capacity');
legend('capacity without modulation','capacity with modulation')
title('capacity of a given antenna')
grid on
figure (2)
plot(select,EE,'-go','linewidth',2)
hold on
plot(NT,EE1,'-ro','linewidth',2)
hold on
plot(NT4,EE2,'-ko','linewidth',2)
xlabel('number of selected antenna S'); ylabel('Energy Efficiency')
% hold on
% plot(NT_max,EEmax,'-ro')
% text(NT_max,EEmax,'maximum point')
% hold on
%  plot(NT1_max,EE1max,'-ro')
% text(NT1_max,EE1max,'maximum point')
% hold on
%  plot(NT3_max,EE2max,'-ro')
% text(NT3_max,EE2max,'maximum point')
title('EE of a given antenna')
legend('EE without modulation','EE with modulation','NOMA','maximum point')
grid on
figure (3)
plot(power,EE,'-mo','linewidth',2)
hold on
plot(power1,EE1,'-go','linewidth',2)
% hold on
% plot(powermax,EEmax,'-yo')
% text(powermax,EEmax,'limited point of necessary power')
% hold on
% plot(power1max,EE1max,'-bo')
% text(power1max,EE1max,'limited point of necessary power')
```

```
 xlabel('power');ylabel('Energy Efficiency')
 legend('EE without modulation','EE with modulation')
grid on
figure (4)
 plot(select,EE,'-mo','linewidth',2)
 hold on
 plot(NT,EE1,'-go','linewidth',2)
 %hold on
%  plot(NT_max,EEmax,'-yo')
%  text(NT_max,EEmax,'max point')
%  hold on
%  plot(NT1_max,EE1max,'-bo')
%  text(NT1_max,EE1max,'max point')
 xlabel('Number of selected antenna S');ylabel('Energy Efficiency')
 legend('EE without modulation','EE with modulation')
 grid on
```

Code for comparison between Energy Efficiency Versus number of selected antenna using NOMA and OMA schemes

```
clc
clear all
close all
NR3=20;% number of near user
NR4=20;% number of far user
NT=1:30;% number transmit antenna
No=9*10^-8; %noise signal
BW1=10;% bandwidth In MHz
e=2.71; % constant
eta=0.38;% power efficiency
ptx=3;% transmit power
pmix=0.033;% power due to mixer
 pfilt= 0.02;% power due to filter
```

```
 pbb=0.03;%baseband power
  psyn=0.05; %power due to Synthesizer
  padc=0.015;% power due to analog to digital converter
  pcrx=0.3;% circuit power at user
  pamp=ptx/eta;

%SNR =round((ptx*NT)/(No*NR*BW))

I3=eye(NR3,NR3); %identity vector for near user
I4=eye(NR4,NR4); %identity vector for far user
SNR_sel=10; % signal to noise ratio
cum1=0; %initialization of capacity
x1=0;
for n=1:length(NT)
    sel1=n;
   %SNR_sel =round(ptx*sel)/(No*NR*BW)
       pcrk3=(pbb+psyn)+(sel1*(pdac+pmix+pfilt))+(NR3*pcrx);
       pcrk4=(pbb+psyn)+(sel1*(pdac+pmix+pfilt))+(NR4*pcrx);
       pcrktot=pcrk3+pcrk4;
  ptotal1=pamp+pcrktot;

    H3 = (randn(NR3,sel1)+j*randn(NR3,sel1));
    H4 = (randn(NR4,sel1)+j*randn(NR4,sel1));

    cap3=0.5*BW1*log2(real(det(I3+(SNR_sel/n)*H3*H3')));
     cap4=0.5*BW1*log2(real(det(I4+(SNR_sel/n)*H4*H4')));
     captot=cap3+cap4;
    cpa1=cum1+captot;
    x1=x1+1;
  select1(n)=sel1;
    capacity1(n)=cpa1;
    power1(n)=ptotal1;
 EE2=capacity1(n)/power1(n);
```

```
 EE1(n)=EE2;
end
EE1max=max(EE1)
selected1=find(EE1==EE1max)
NT_max=NT(selected1)
selected1=find(NT==NT_max)
power1max=power1(selected1)
capma1=capacity1(selected1)

%+++++++++++++++++++++++++++++++++++++++++++++++++++++

NR1=20; % number of user for near user
NR2=20;% number of user for far user
NT1=1:30;%number of selected antenna
No=9*10^-8; % noise signal
BW=10;% bandwidth inMhz
e=2.71; %constant
eta=0.38;%power amplifier efficiency
ptx=3; % transmit power
pmix=0.033; %power due to mixer
 pfilt= 0.02; %power due to filter
 pbb=0.03;%base band power
  psyn=0.05;%power due to sysnthesizer
  padc=0.015;% power due to analog to digital converter
  pcrx=0.3; %circuit power at user terminal
  pamp1=ptx/eta;% power amplifier

%SNR =round((ptx*NT)/(No*NR*BW))

I1=eye(NR1,NR1);% identity vector for near user
I2=eye(NR2,NR2);% identity Vector due to far user
SNR_sel=10;% signal to noise ratio
cum=0;% initialization of capacity
```

```
x=0;
for i=1:length(NT1)
    sel=i;
   %SNR_sel =round(ptx*sel)/(No*NR*BW)
       pcrk1=(pbb+psyn)+(sel*(pdac+pmix+pfilt))+(NR1*pcrx);
        pcrk2=(pbb+psyn)+(sel*(pdac+pmix+pfilt))+(NR2*pcrx);
        pcrktotal=pcrk1+pcrk2;
  ptotal=pamp1+pcrktotal;

    H1 = (randn(NR1,sel)+j*randn(NR1,sel));
    H2 = (randn(NR2,sel)+j*randn(NR2,sel));

    cap1=BW*log2(real(det(I1+(SNR_sel/i)*H1*H1')));
    cap2=BW*log2(real(det(I2+(SNR_sel/i)*H2*H2')));
    captotal=cap1+cap2;
    cpa=cum+captotal;
    x=x+1;
  select(i)=sel;
    capacity(i)=cpa;
    power(i)=ptotal;
 EE3=capacity(i)/power(i);
 EE(i)=EE3;
end
EEmax=max(EE) %number of energy efficiency maxima
selected=find(EE==EEmax)
NT1_max=NT1(selected)% calculation of number of selected antenna
selected=find(NT1==NT1_max)% number of selected antenna
powermax=power(selected)% maximum power consumption
capma=capacity(selected)% maximum capacity that maximize EE
figure (1)

plot(NT,capacity1,'-go','linewidth',2)
hold on
```

```
plot(NT1,capacity,'-ro','linewidth',2)
% hold on
% plot(NT_max,capma1,'-ro')
% hold on
% plot(NT1_max,capma,'-bo')
% hold on
% text(NT_max,capma1,'EE maximizing point ')
% hold on
% text(NT1_max,capma,'EE maximizing point')
% hold on
xlabel('number of selected antenna S'); ylabel('capacity');
legend('OMA','NOMA')
grid on
figure (2)
plot(NT,EE1,'-go','linewidth',2)
hold on
plot(NT1,EE,'-ro','linewidth',2)
% hold on
% plot(NT_max,EE1max,'-ro')
% hold on
% plot(NT1_max,EEmax,'-bo')
% hold on
% text(NT_max,EE1max,'maximum point')
% hold on
% text(NT1_max,EEmax,'maximum point')
% hold on
xlabel('number of selected antenna S'); ylabel('Energy Efficiency');
legend('OMA','NOMA')
grid on
```