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Performance Analysis of NOMA for Next Generation Wireless Systems

A project submitted.
in partial fulfillment of the requirements for the degree of
Bachelor of Science in Computer Networks and Communications

by

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Abstract

Several multiple access techniques were used in the first generation of cellular networks, and many techniques are now being introduced. Conversely, NOMA allows multiple users to share the same time and frequency resource blocks increasing the data rate to satisfy the user requirement, connectivity, making it one of the most promising alternative wireless communication techniques. Also, NOMA is different from the traditional multiple access where messages are sent orthogonally in the bandwidth entire with independent time and frequency slots. This paper provides an in-depth study of NOMA's concepts and their relevance to 5G, focusing on NOMA downlinks. The main objective of our project was to analyze the performance of a two-user NOMA downlink system model on a Rayleigh channel with AWGN noise in terms of bit rate, outage probability, and sum rate using MATLAB (v2023). We calculate the achievable speed in relation to the transmitted power in different scenarios. Finally, the simulation results showed that NOMA outperformed OMA in all parameters and achieved superior performance incorporation with 2×2 MIMO.

UNDERTAKING

This is to declare that the project entitled “performance analysis of Noma for next generation wireless systems” is an original work done by undersigned, in partial fulfillment of the requirements for the degree “bachelor’s degree” at Computer Network and Communications, College of Computer Sciences and Information Technology, King Faisal University.

All the analysis, design and system development have been accomplished by the undersigned. Moreover, this project has not been submitted to any other college or university.

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Table of Contents

Acronyms and Abbreviations

NOMA	Non-Orthogonal Multiple Access
1G	first generation
2G	second generation
3G	third generation
4G	fourth generation
5G	fifth generation of cellular communications
(OMA)	orthogonal multiple access
OFDMA	orthogonal frequency division multiple access
QOS	quality of service
MIMO	multiple-input multiple-output
SIC	successive interference cancellation
BS	base station
UE	user equipment
SNR	signal -noise ratio
SCFDE	single carrier with frequency domain equalization
IOT	internet of things
MRC	maximum ratio combiner
SDR	software defined radio
LLR	log likelihood ratio
OP	outage probability
SER	symbol error rate
MATLAB	matrix laboratory
AWGN	additive white gaussian noise
RF	radio frequency
DSCH	downlink shared channel
QPSK	quadrature phase shift keying
MRC	maximum ratio combining
BER	bit error rate

List of Table

List of Figure

List of Equations

1 Introduction

Wireless networks are computer networks that connect without the use of cables. For communication between network nodes, they typically use radio waves. There is also Wi-Fi, is a family of wireless network protocols. Wi-Fi is the radio signal that a wireless router transmits to a device in the area, which then converts the signal into information you can see and use. A radio signal is sent from the device back to the router, which has a wired or wireless connection to the internet. is also a wireless technology that links computers, tablets, cell phones, and other devices to the internet. there are also a generation which are 1G, 2G, 3G, 4G, 5G and 6G as showing below in Fig 1. The NOMA is a multiple access technique is to serve multiple users on same time/frequency resources.

Our project purpose is to evaluate the performance of Noma with and without cooperation of Noma using MATLAB software which will offer spectral efficiency and increase the QoS.

This report will include the following main sections: First, the problem statement will describe the issues and the motivation why we are interested in NOMA. Second, project scope, Third, comprehensive analysis of related work, find other projects like our project. Fourth Alternative Solutions, Sixth, expected outcomes, Tools for Proposal and implementation, appropriate analysis, proposal design ,then simulate different Noma scenario in MATLAB finally analysis the results . [1]

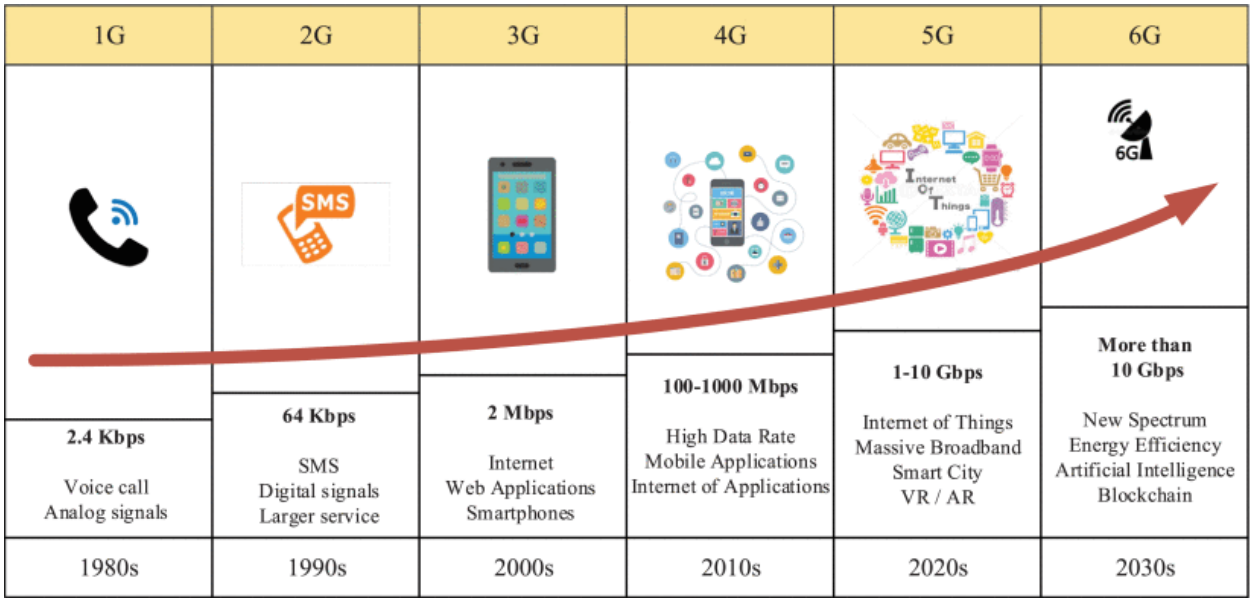


Figure 1 Shows Evolution of Wireless Networks

1.1 Background

Multiple access techniques allow multiple users to access a communications medium and provide service to a specified number of users simultaneously connected to the same medium, where multiple accesses can share resources over time, frequency, or code. The classification of multiple access technologies is shown below

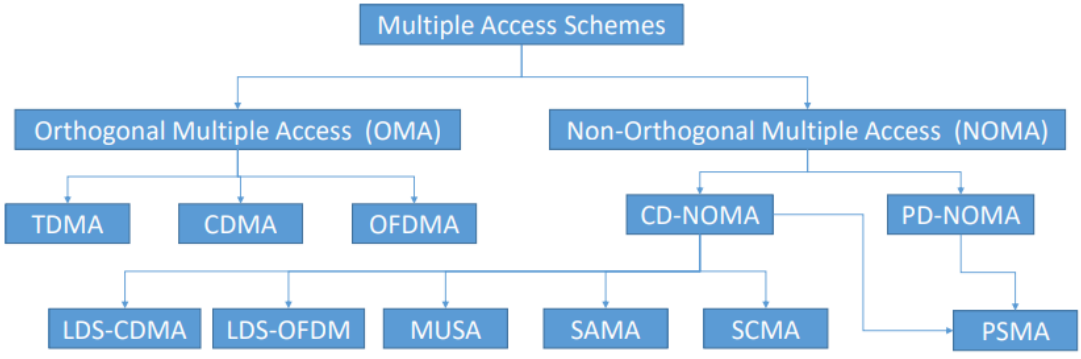


Figure 2 Classifications of Multiple Access Technologies

Among these technologies that have been used with 5G,4G (OFDMA which can allow to a one user in each orthogonal resource block .There is promising radio access methods for next wireless generation communications is NOMA, where 2 or more user are allowed to serve in each orthogonal resource block according to the figure [3 and its offers a number of benefits over OFDMA, the current de facto standard OMA technology, including increased spectrum efficiency, decreased latency with excellent dependability, and huge connection. [4]

The NOMA classified into two types.

1. PD-NOMA (multiplex in power domain)
2. CD-NOMA (multiplex in code domain). and our project will focus on power-domain NOMA [2][3]

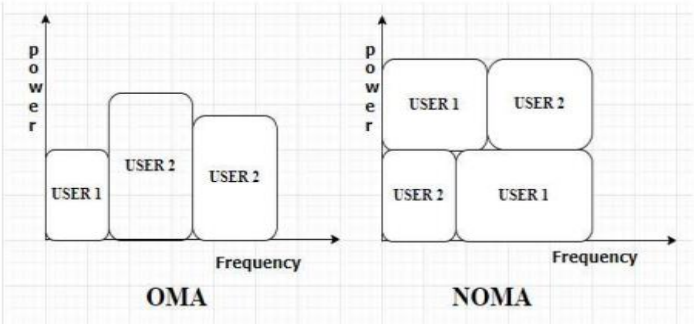


Figure 3 Spectrum Sharing OMA and NOMA

1.1.1 What is NOMA?

NOMA is one of hopeful multiple access technologies that supply user to the work in the same band and time were.

1.1.2 Advantage of NOMA

1. Allow multiple users use same frequency resource at same time (higher spectral efficiency).
2. the NOMA serving more uses simultaneously at the same time (massive connectivity)
3. simultaneous transmission all the time (lower latency)
4. All users using flexible power control algorithms will help increase cell edge productivity and improve cell edge user experience.

5. NOMA can work with MIMO to increase performance.[5]

1.1.3 How NOMA works?

Suppose there BS will choose among two users to pair, strong and weak users will use time and frequency (same) as shown in figure [2].

1. transmit Power is divide between them:
    1. More power for far user(U1)
    2. Less power for near user (U2)

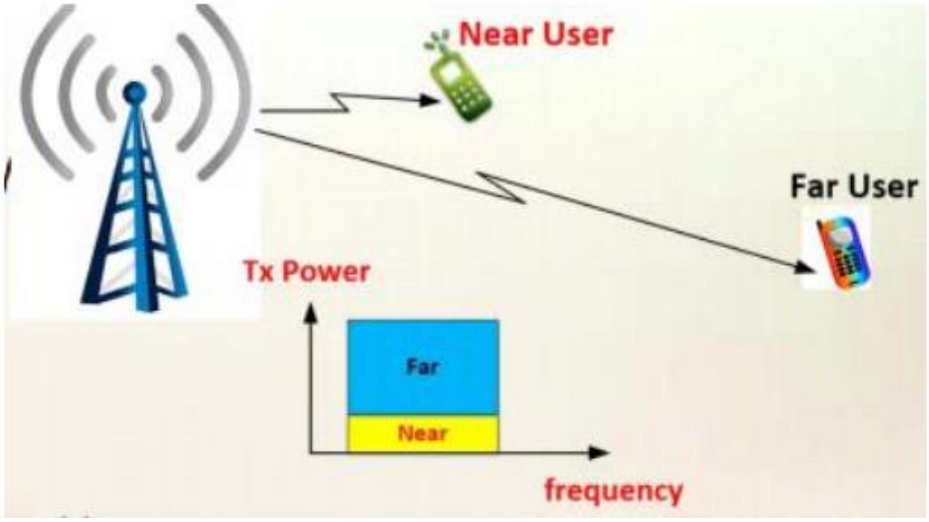


Figure 4 Near and Far User Connectivity

U1 will decodes the signal directly suffer from some interference but near to BS signal has large interference from U1.

U2 decodes the U2 signal and first minimizes this interference from the NOMA composite signal. U1 interference is removed when the user decodes their data from the clean signal [6].

Figure [3] describes the processing of user signals U1 and U2.

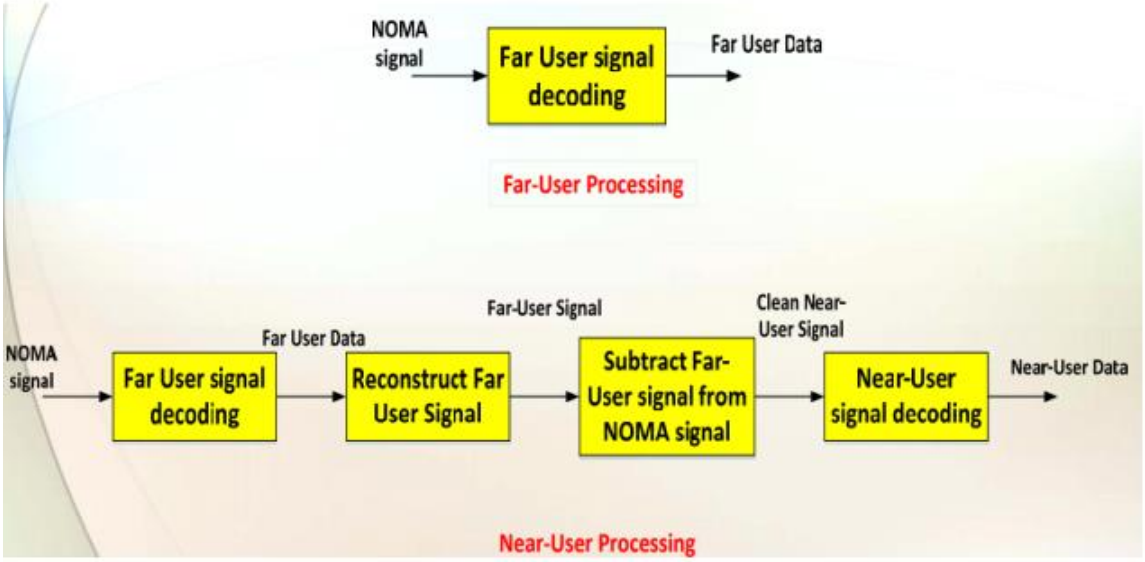


Figure 5 U1 and U2 Signal Processing

1.1.4 PD NOMA Downlink

The PD-NOMA is a type of NOMA by allocating a new dimension (power) for each user. the main techniques in this are SC and SIC. [7]

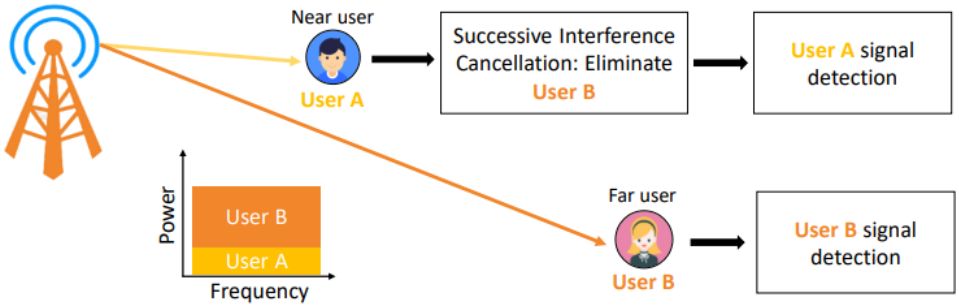


Figure 6 Downlink Noma, One Bs and Two Users [8]

1.1.5 Performance of NOMA

The Performance of NOMA is always calculated using Shannon channel capacity formula as in equation below.

$$\boldsymbol{C = W * log2(1 + SNR)}$$

• Shannon capacity calculate the achievable data rate in term of BW and SNR

• the bandwidth impact on capacity more than SNR.

1.1.6 Drawbacks of NOMA Systems

- All users in the group is required to decrypt the data of every other user, including the one with the weakest channel gains. The receiver becomes more complicated as a result. Additionally, energy use has increased.

- Each of the other users' data will be incorrectly decoded if SIC mistake only affects one user. This restricts by maximum num of users that may be serviced by every one of the cell's groups.[9]

1.2 Motivation

NOMA is a promising solution to break orthogonality, which is occurs in the past multiple access methods it can share the same spectrum resource synchronously, NOMA meet the need of increasing the number of served users and improve the fairness of users.

1.3 Problem Statement

The issue of need increasing the data rate to satisfy the user requirement, connectivity, we need a new technique that can keep up with these requirements.

NOMA is a promising technique to the achieved all the above requirement because of high throughput, spectral efficiency, and energy efficiency of the wireless system. NOMA is different from the traditional multiple access where messages are sent orthogonally in the bandwidth entire with independent time and frequency slots.

In this project, we will try to analyse the signal outage, sum rate, capacity and bit error rate for NOMA system and MIMO integrating with it for two users in case of downlink NOMA system over AWGN with Rayleigh channel.

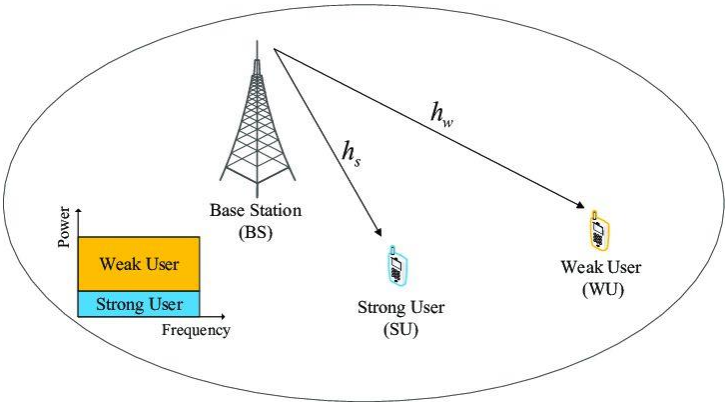
1.4 Innovation and Utility of the Project

The main justification for the proposed NOMA in our project is because due to its high spectral efficiency, this technology can be utilized by future generations. NOMA is higher spectrum efficient and throughput and can serve several users at the same resource block.

1.5 Project Scope

The NOMA allows the BS to allocate one frequency channel to multiple users at the same time in the same cell and offers several advantages, including improved SE, higher throughput compared with OMA.

The project will consider the downlink of PDNOMA showing in figure below which consist of a BS and 2 users through AWGN and Fading Channel .



1 System Model[14]

1.6 Objectives

The main objective for using NOMA in our project is that.

- serving more uses simultaneously at the same time.
- Increases spectral efficiency.
- supports the user-fairness in case of downlink,

We will study the NOMA system and evaluate its performance using MATLAB software under different scenarios.

1.7 Expected Outcomes

After Analyze the Downlink of NOMA with cooperation MIMO for the Network. We expect the results can achieve the required objective in terms of BER, throughput, and outage Propriety.

2 Related work

This section explains the different comparisons between research on the NOMA technology.

2.1 Power NOMA integrated with MIMO for 5G Systems.

Mario marques, Run Dinis, study's goal is to examine conventional and cooperative PDNOMA using the SCFDEblock transfer technique in conjunction with a significant amount of MIMO, demonstrating its extra benefit in terms of the combined scheme's spectral efficiency. In addition to the more traditional centimeter waves and mMIMO technologies, novel approaches like mm wave are used to provide the new services offered by the 5G. Future 5G versions are anticipated to include NOMA since it tends to accomplish a capacity earning, which is crucial for the vast array of IoT devices, to enable an effective recycling of finite spectrum. This study demonstrates that the combination of cooperative and conventional NOMA with m-MIMO and SCFDE, tends to deliver capacity gains while the performance only suffers a mild deterioration, being a suitable choice for future 5G developments. Further evidence suggests that Cooperative NOMA outperforms Conventional NOMA. This study also demonstrates how the MRC receiver is ideally suited to be used with NOMA and m-MIMO since it delivers powerful performance while minimizing receiver challenges. [10][14]

2.2 Software Defend Radio NOMA

Bathula Siva Kumar Reddy, Kiran Mannem Since NOMA has been identified as an important effective tool for 5G wireless networks, the objective of this paper is to analyze the implementation of NOMA systems on SDR platforms. This paper provides an in-depth analysis of NOMA's historical development, as well as the latest trends and future research initiatives. Mathematical analysis is offered specifically for several receivers, including the ideal receiver, symbol-level SIC receiver, codeword-level SIC receiver,and log-likelihood (LLR)
based receivers. In addition, the Noma system is used with and without GNU radio software to study the bit error rate of multiple individuals.In addition, the pairs of coefficients (bandwidth), spectral efficiency and
energy efficiency of the systems Oma and Noma were compared. The conclusion of the research is that Noma systems perform better than OMA systems and it is emphasized that SDR is a flexible framework a flexible framework for the implementation and testing of future communication technologies. [11]

2.3 Performance Analysis of Noma Techniques For 5g Networks

Sivasankari Sundaram was overviewing the concept and advantages of NOMA techniques, as the promising technologies for future 5G systems, to increase the efficient usage of limited network resources. A NOMA for 5G system contains numbers of users sharing the same subcarrier served by a BS and using the same frequency on different level of transmit power. All these users will receive a combined signal for all users. On the NOMA, SIC is applied on the many users who receive a powerful transmitted signal. The transmitted signal is a linear combination of the two messages for these users where SIC is applied at the receiver side with users, SNR value is increased to get exact data, then get the desired results: best users experience for data transmission and less noise. [12]

2.4 Performance Analysis of NOMA in MIMO Setup

At Sankeerth Pooja, services have been proposed to meet the growing demands for higher data rates in 5G radio networks of wireless communication systems that support the number of users through a combination of NOMA and MIMO. NOMA allows different users to efficiently share the same resources at different power levels, so that a user with lower channel gain is served with higher power and vice versa. Multi-user MIMO technology uses tens or even hundreds of antennas in the base station, increasing bandwidth and spectrum efficiency. The performance of the NOMA and MIMO system in terms of OP, SER in the energy domain in MATLAB was also analyzed. The probability of arrival and the symbol errors in various parameters, such as e.g. B. the variation of the number of antennas at the source and users, various parameters for acquisition and the spectrum of allocation factors . The conclusion of the investigation is that as the number of antennas increased, downtime for both users was significantly reduced and performance increased. [13]

2.5 Comparative Study between the Related Works

This section compares the related work section according to main specified features (as shown in Table 1).

Table 1 Comparison between All Related Work

Ref #	Objective	Metric	Direction (Uplink or Downlink)	Channel	M(Modulation)	N(user)	Receiver
3.1	• Cooperate PD-NOMA +MIMO	• BER	Downlink	• Rayleigh fading channel	• QPSK	• Two users	• SIC • MCE • ZF
3.2	• Implement NOMA systems on SDR platforms	• throughput • spectral efficiency • energy efficiency	Downlink	• AWGN Channel • Rayleigh Channel • Rician Channel	• QPSK	• Two users	• SIC
3.3	• Compare NOMA with OMA	• RATE • energy efficiency • Spectrum efficiency • Throughputs	Downlink	• DSCH channel		• more users	• SIC
3.4	• analyze the performance of NOMA-MIMO system	• OP • SER		• Fading Channel	• PSK	• Two users or more	• M RC • SC

3 Alternative Solutions

This section describes the alternative solutions for the NOMA Systems. These alternative solutions are derived from the work that had been done in related Works.

3.1 Alternative Solutions for Multiple Access Techniques

OMA Techniques:

In FDMA Techniques, frequency is shared between the users. As shown in figure 7 part from frequency to user 1 and the reaming for 2

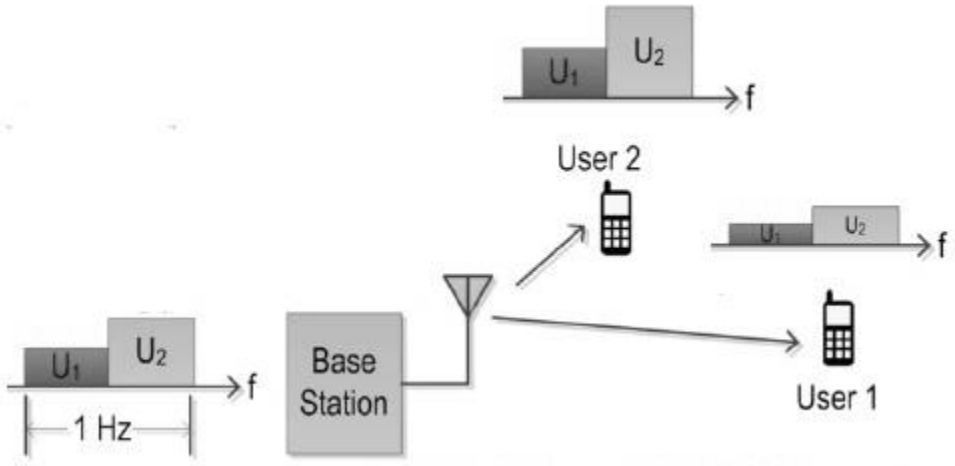


Figure 7 OMA Orthogonal Multiple Access

3.2 Alternative Solutions to Improve the Spectral Efficiency

Massive MIMO techniques

Wireless communication known as MIMO uses multiple antennas in the transmitter andreceiver as shown in Figure 7. To enable the simultaneous flow of data over multiple signal paths, antennas are combined at both ends of the communication circuits to reduce errors, increase transmission speed and increase the capacity of radio transmissions. When numerous copies of the same signal are made, the data has a better chance of reaching the receiving antenna without being affected by fading. As a result, they improves SNR and error rate. MIMO improves the performance of the radio frequency system, resulting in a more reliable connection and less congestion. [10]

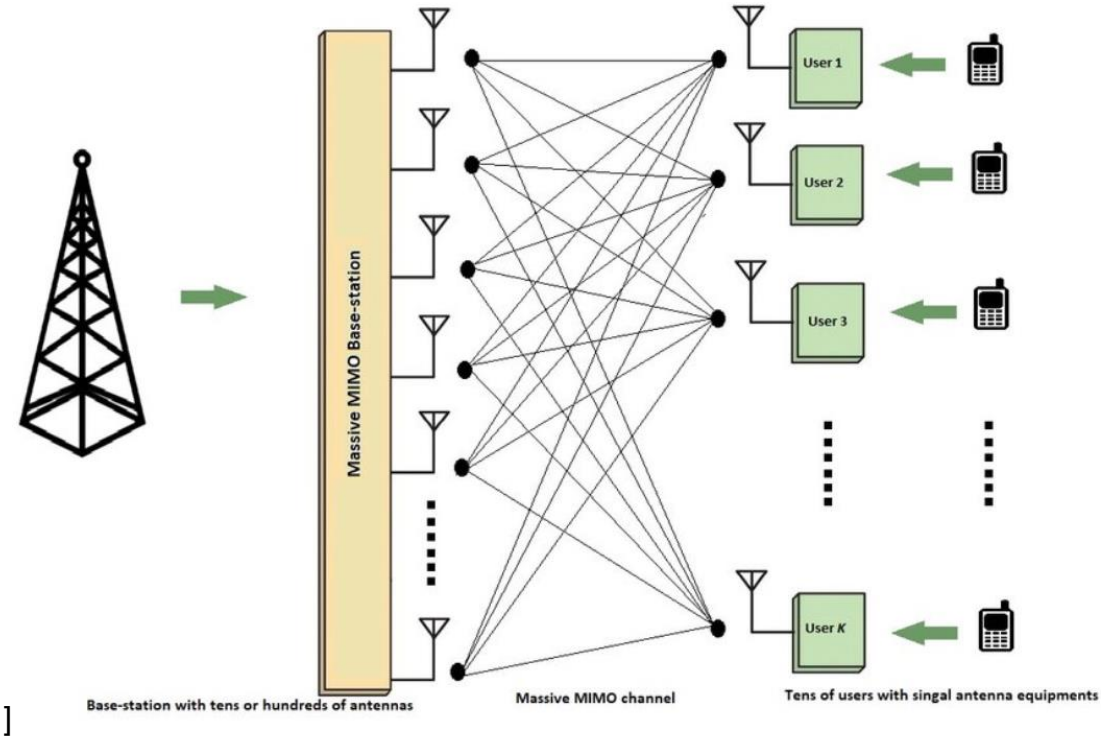


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Figure 8 Massive MIMO Architecture

4 Project Requirement

This section describes the requirements of the project.

4.1 Software

MATLAB

A high-quality application, characterized by an interactive environment for developing algorithms and performing data analysis, creating applications and models, while providing the user with a set of tools and mathematical functions that help in finding amazingly fast solutions based on spreadsheets or even traditional programming languages.

4.2 Hardware

A personal computer is needed to download the software.

5 Appropriate Analysis

The power NOMA achieves better spectrum usage for cooperative downlink networks. Below the typical downlink system model which will used in the analysis

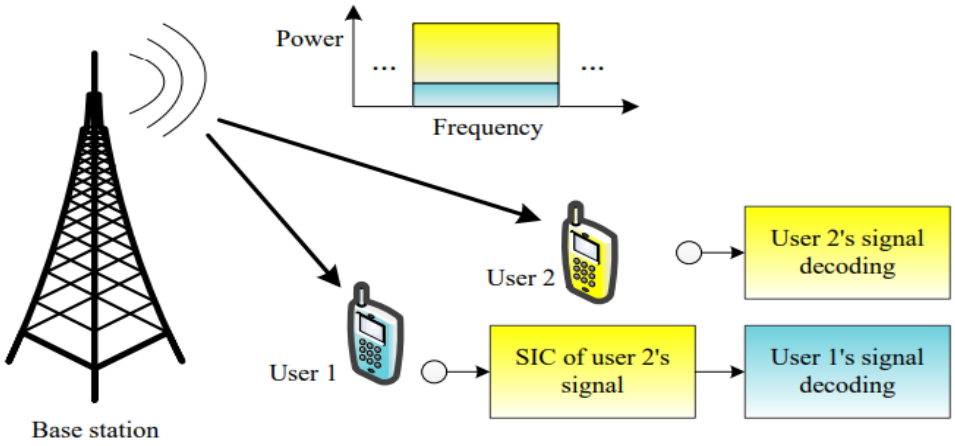

Figure 9 A downlink NOMA model with one base station and two users.

Let's assume two users and one channel h1 greater than h2 (user 2 as far user and user 1 as near user). User 1 runs a SIC with allocated low power to decode User 2's signal and then aborts it so that it can finally decode its signal. User 2, on the other hand, has a higher level of performance and does not need to perform SIC and decode its signal directly through User 1's processing.

BS forwards messages from user 1 and user 2, e.g., m1 and m2, each with different transmission powers a1 and a2 in the same frequency band. The corresponding transmitted signal is represented by .

$$x = \sqrt{a_1 m_1} + \sqrt{a_2 m_2}$$

Equation 1 The transmitted Signal from BS

here transmits power is constrained by a1 + a2 = 1. The received signal at user i is given by.

$$R_i = h_i x + v_i$$

Equation 2 The Received Signal at user i

Where hi is the coefficient of the composite channel that includes the fading effect. Variable Ri denotes the AWGN noise [16].

for user 1 (far)

$$R_1NOMA = \sqrt{a}\big(\underbrace{\sqrt{a_1}m_1}_{\text{desired and dominating}} + \underbrace{\sqrt{a_2}m_2}_{\text{interference}}\big)h_1 + v_1$$

Equation 3 Decoding signal of user 1

$$\boldsymbol{R_1NOMA = \frac{a_1 a|h_1|^2}{a_2 P|h_2|^2 + \sigma^2}}$$

Equation 4 the SNR at user 2

Allocate higher power for user 1 and depend on that user 1 will directly decode user 1 message, then perform SIC to remove it from R2, NOMA.

the resulting signal would be.

$$R_2NOMA = \sqrt{p}\big(\underbrace{\sqrt{a_1}m_1}_{\text{undesired and dominating}} + \underbrace{\sqrt{a_2}m_2}_{\text{desired}}\big)h_2 + v_2$$

Equation 5 Decoding signal of user 1

User 2 can directly decode his message from R2, NOMA by treating all the remaining users' messages as interference.

At end the SNR at user 2 to decode his own message calculated by,

$$R_2NOMA = \frac{a_2 P|h_2|^2}{\sigma^2}$$

Equation 6 the SINR at user 2

In general, for any user i, the SNR to decode his own signal is given by,

Based on Shannon's capacity formula, user1 and user2 data rates is represented as

$$\mathrm{C1} = \mathrm{B}\log_2\left(1 + \frac{a_1|h_1|}{\sigma^2}\right)$$

$$\mathrm{C2} = \mathrm{B}\log_2\left(1 + \frac{a_2|h_2|}{\mathrm{a}|h_1| + \sigma^2}\right)$$

Equation 7 User1 and User2 Data Rates

Then we can calculate capacity of downlink NOMA system with two users by the sum of users of the data rates in the system as follows:

$$\mathrm{RNOMA} = \mathrm{C1} + \mathrm{C2}$$

Equation 8, the Capacity of Downlink NOMA

And for OMA system, the bandwidth divided in half between the two users

They achieved data rates of users given as:

$$C_{1\,OMA} = \frac{B}{2}\log_2\left(1 + \frac{a_1|h_1|}{\sigma^2}\right)$$

$$C_{2\,OMA} = \frac{\mathrm{B}}{2}\log_2\left(1 + \frac{a_2|h_2|}{\sigma^2}\right)$$

Equation 9 OMA Achieved Data Rates

System's capacity of OMA system is calculated by:

$$\mathrm{R_{OMA}} = \mathrm{C_{1\,OMA}} + \mathrm{C_{2\,OMA}}$$

Equation 10 Capacity of OM

6 Details of Project Implementation Conforming to Project Proposal

The performance of NOMA, MIMO-NOMA and OMA techniques were evaluated, analyzed, and compared with each other with the input transmit power and SNR for both AWGN and Rayleigh fading channel.

6.1 AWGN and Rayleigh Fading channel.

In our simulation we consider two types of channels:

1. AWGN is the simplest channel model, which does not take any fade into account and only takes care of the linear addition of the white noise floor.
2. The Rayleigh model applies to scattered or reflected paths.

6.2 Simulation Parameters

In this section we will discuss the main parameters which will be considered in our evaluation.

6.2.1 Outage Probability

Outage probability is defined as the probability that the information rate is less than the required target rate of. We can calculate it from equation 11 [21]

Pout(R) = Pr [AR<R]

Equation 11 Outage Probability Condition

AR is the user achievable rate and R is the target rate or threshold.

To calculate the probability of outage, count the number of times the rate fell below the target.

CooperatewithMIMO, the probability of failure decreases with increasing directiv ity gain since MIMO-NOMA uses more antennas to increase directivity gain.

6.2.2 Bit Error Rate

BER is the number of bit errors divided by the total number of bits transmitted in the time interval and the error of each bit in the communication channel, which is affected by transmission channel noise, interference, distortion, bit synchronization problems, attenuation, etc. and wireless multipath loss [22]

$$\textbf{Bit Error Rate} = \frac{\textbf{Errors received}}{\textbf{Total no. of bits}}$$

Equation 12 Bit Error Rate Equation

We can improve the BER by choosing a strong signal strength, a slow and robust modulation scheme and line coding scheme [23]

6.2.3 Channel Capacity

Is the maximum rate at which data can be transmitted over a communication path or channel or it the summation of individual achievable rates of each user.

Channel capacity = R1 + R2

The channel capacity depends on four factors (data rate (bps), bandwidth (Hz), noise (dB) and error rate).

We can also calculate the average sum of all the user rates in a network which is called the sum rate.

It is given by the formula.

Sum rate=mean (R1+R2+R3+…..+Rn)

Where Ri =user rate i=1, 2, 3….., n.

6.3 The Simulated System Parameters

The Parameters are used in our system to evaluate the performance are shown in the bellow table.

Table 2 The Simulation Parameter

Parameter	Specifications
Techniques	NOMA, OMA,NOMA-MIMO, MIMO ,OMA
P1	0.75
P2	0.25
D1	5000
D2	2000
N	10^5
N0	No = -174 + 10*log10(BW)
BW	10^6
R	1
eta	4
Channel Type	AWGN, Rayleigh
Modulation	BPSK
Tx	-30:5:30(dbm)

7 Mastery of Tools and Techniques Used in Project Implementation.

This section equips a list of tools and techniques that were used during the implementation phase of project, in addition, some of the tools and techniques that were used in the proposal phase.

7.1 MATLAB (Matrix Laboratory)

MATLAB is a powerful technical computing language that integrates computer programming and visualization in an easy-to-use environment and is built on an advanced matrix software foundation in which a dimensionless matrix is the central building block. [20]

7.1.1 The Uses of MATLAB

1. Math and computation
2. Algorithm development
3. Modeling, simulation, and prototyping
4. Data analysis, exploration, and visualization
5. Scientific and engineering graphics
6. Application development, including Graphical User Interface building [20]

7.1.2 The MATLAB Features

1. Advanced algorithm for high performance numerical computation.

2. have A large collection of predefined mathematical functions and you can define own functions.

3. for plotting and displaying data, MATLAB have Two-and three-dimensional graphics

4. have online help system

5. high-level programming language for individual applications.

6. Number of Toolboxes available to solving advanced problems in several application areas.[20]

7.1.3 The MATLAB System

The MATLAB system consists of five main parts:

1. **The MATLAB language**.

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features.

2. **The MATLAB working environment.**

set of tools and facilities that you work with as the MATLAB user or programmer (managing the variables in your workspace, importing and exporting data, developing, managing, debugging, and profiling M-files, MATLAB's applications.)

3. Support graphics.

MATLAB contains high-level commands for 2D and 3D data visualization, image processing, animation, and presentation graphics.

4. MATLAB Math Function Library.

is a large collection of arithmetic algorithms ranging from basic functions such as sum, sine, cosine and complex arithmetic, matrix inverse, matrix eigenvalues, Bessel functions and fast Fourier transforms.

5. MATLAB Application Program Interface (API).

This is a library that allows you to write C and Fortran programs that interact with MATLAB. [20]

7.2 Other Tools and Techniques

The table below contains a list of other tools and techniques used during the project.

Table 3 Tools and Techniques Used During Project Implementation

Tool / Technique	Description
Software	
 Google Chrome	Google Chrome is a proprietary web browser developed by Google, and it works on most operating systems. Used for search.
Microsoft Office Word 	Word is one of set programs for Microsoft Office. Used to prepare a formal report.
 Microsoft Office PowerPoint	PowerPoint is one of set programs for Microsoft Office. Used to prepare a professional presentation.
 Dropbox	Dropbox is a cloud storage service, even if you're using a different device. so that we use it for writing reports cooperatively.
Google Scholar 	Google Scholar is a public Internet search engine. It helps in finding articles, paper, or search, and more. We use it in searching for the related search for our project.

KFU Saudia Digital Library	Saudia Digital Library is one of services that KFU provider for get reliable scientific research sources.
Grammarly	The Grammarly software helps in the grammatical correctness of a text. Grammarly premium was used in our project to double-check reports.
 Personal Computer	A personal computer is needed to download the software

8 Overall Project Results

This section describes the Result from the Simulation under different scenarios as shown below.

8.1 The Sum Rate of MIMO _NOMA, NOMA & OMA

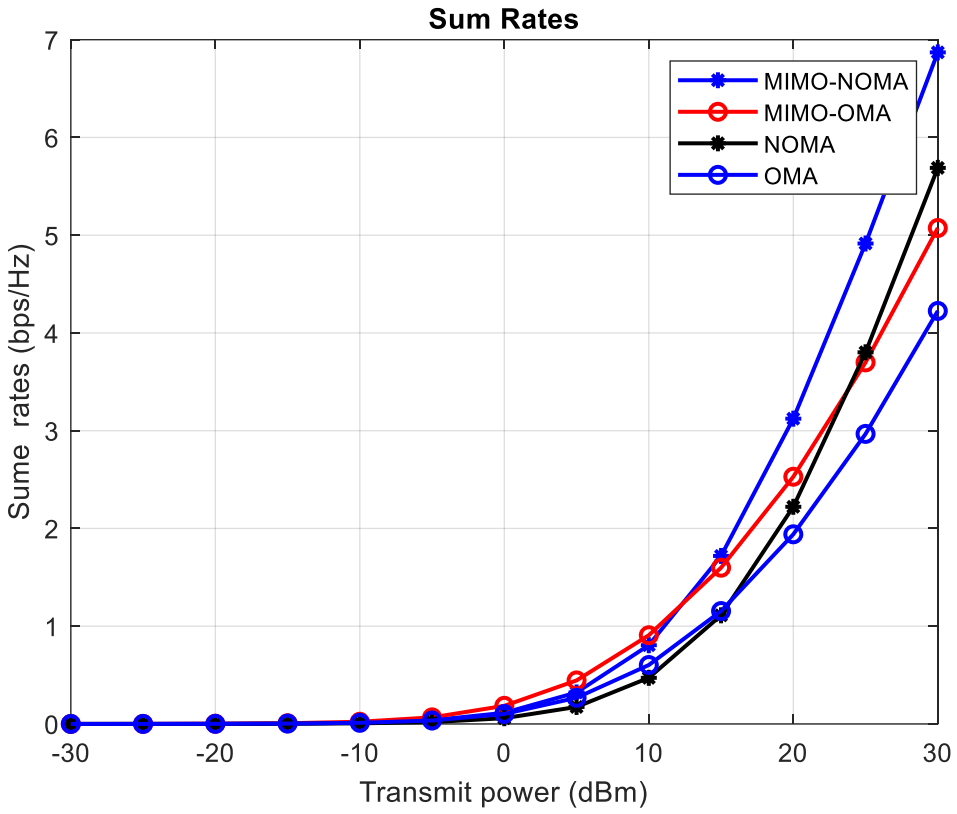

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Figure 10: Sum Rate of MIMO_NOMA, MIMO_OMA, NOMA and OMA at d1=5000,d2=2000, a1=0.75, a2=0.25

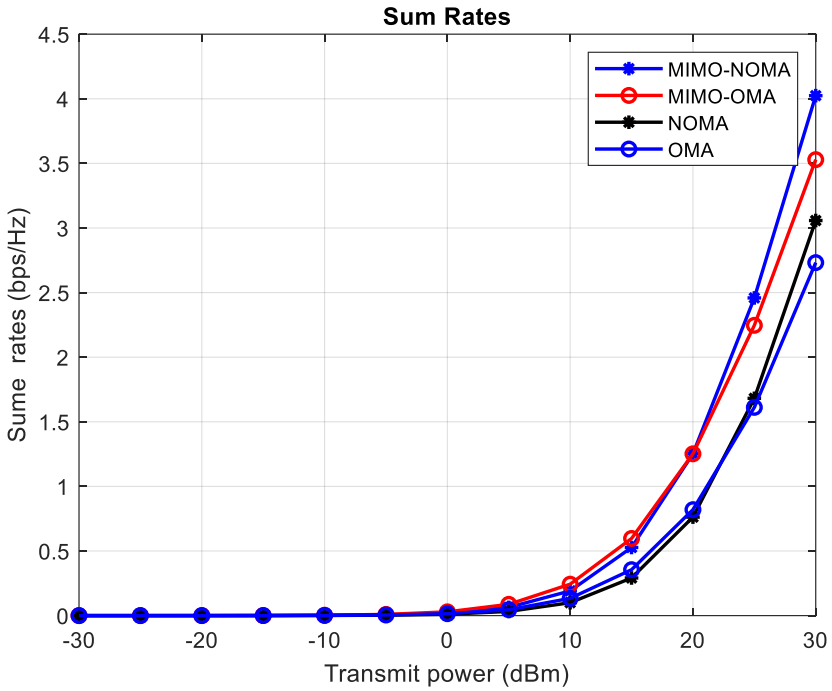

Figure 11: Sum Rate of MIMO_NOMA, MIMO_OMA, NOMA and OMA at d1=5000, d2=3500

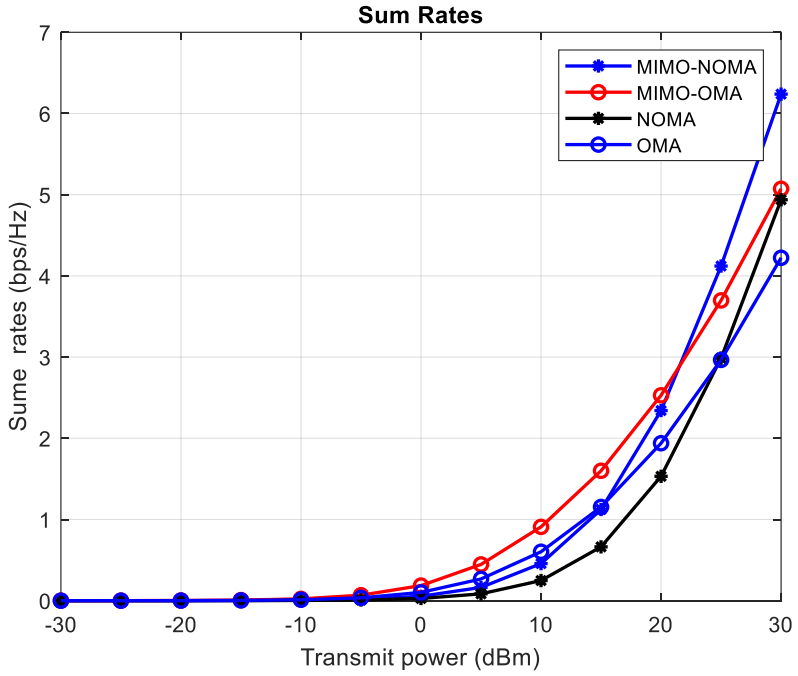

Figure 12: Sum Rate of MIMO-NOMA, MIMO_OMA, NOMA and OMA at a1=0.9,a2=0.1

8.2 The Individual Rate of MIMO_NOMA, MIMO_OMA, NOMA

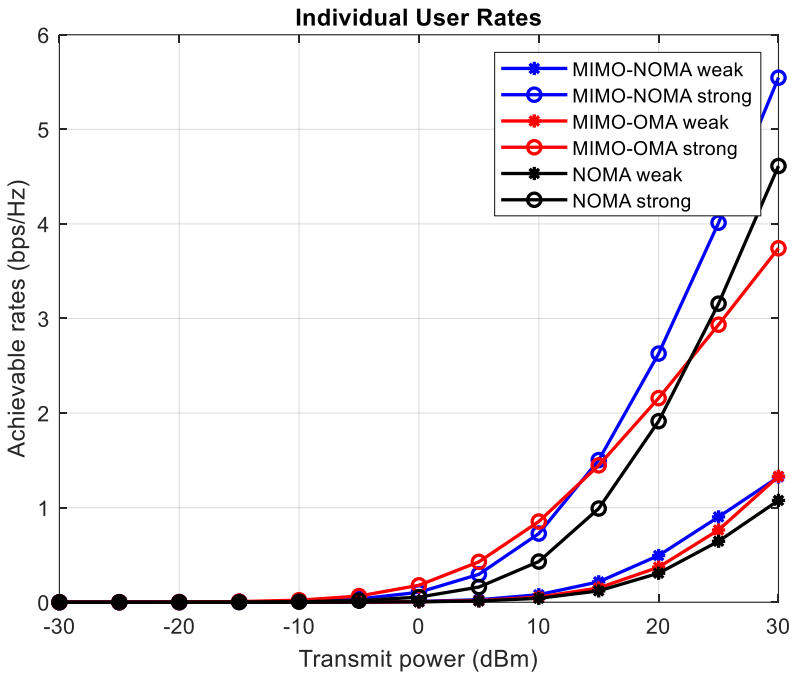

Figure 13: The Individual Rate of MIMO-NOMA, MIMO-OMA, NOMA at d1=5000, d2=2000, a1=0.75, a2=0.25

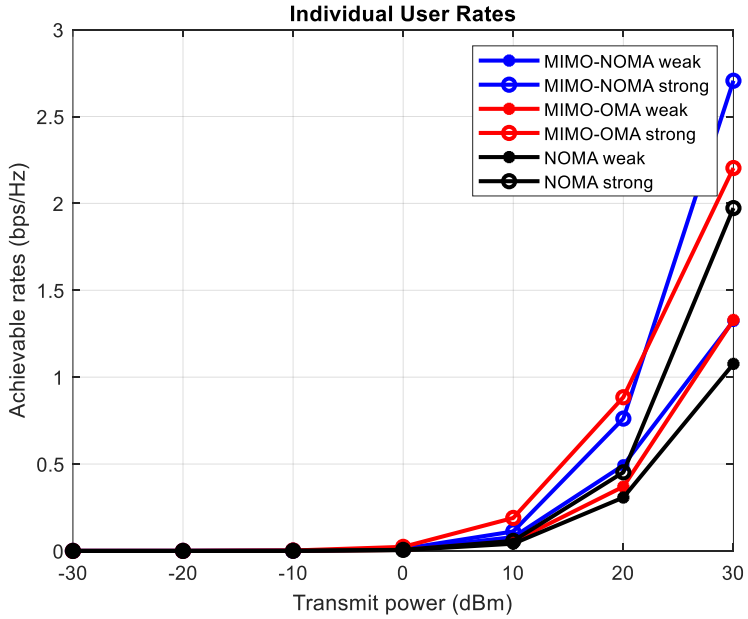

Figure 14: The Individual Rate of of MIMO-NOMA, MIMO-OMA, NOMA at d1=5000, d2=3500

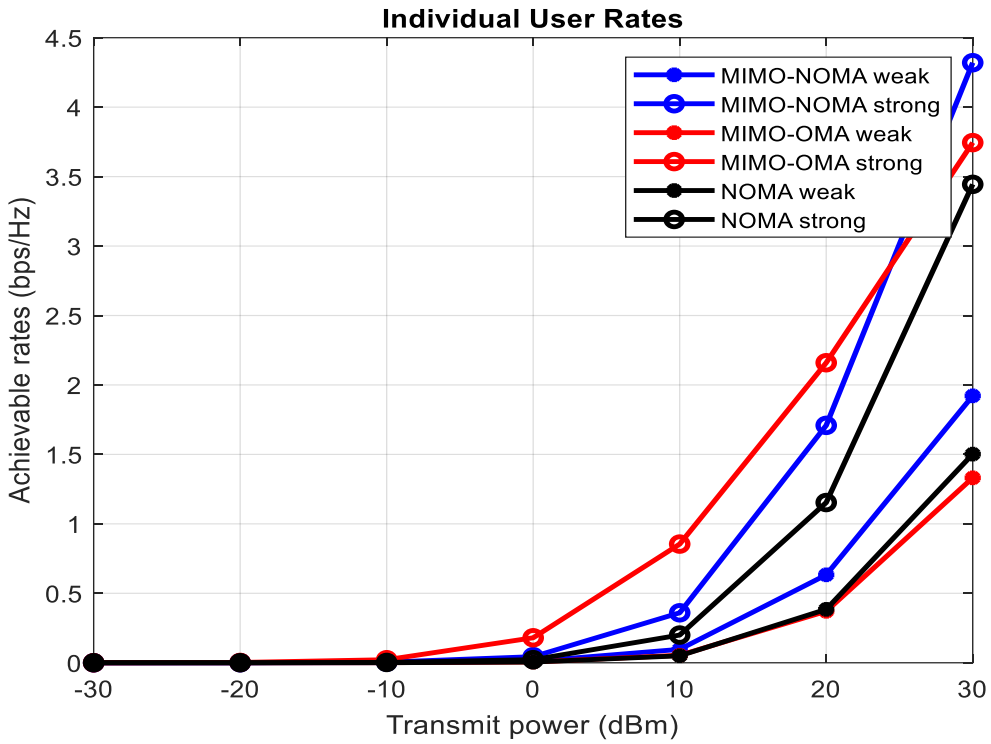

Figure 15: The Individual Rate of MIMO-NOMA, MIMO-OMA, NOMA at a1=0.9, a2=0.1

8.3 The Outage Probability of MIMO _NOMA, MIMO-OMA, NOMA

We plot the outage for MIMO-NOMA, MIMO-OMA and NOMA

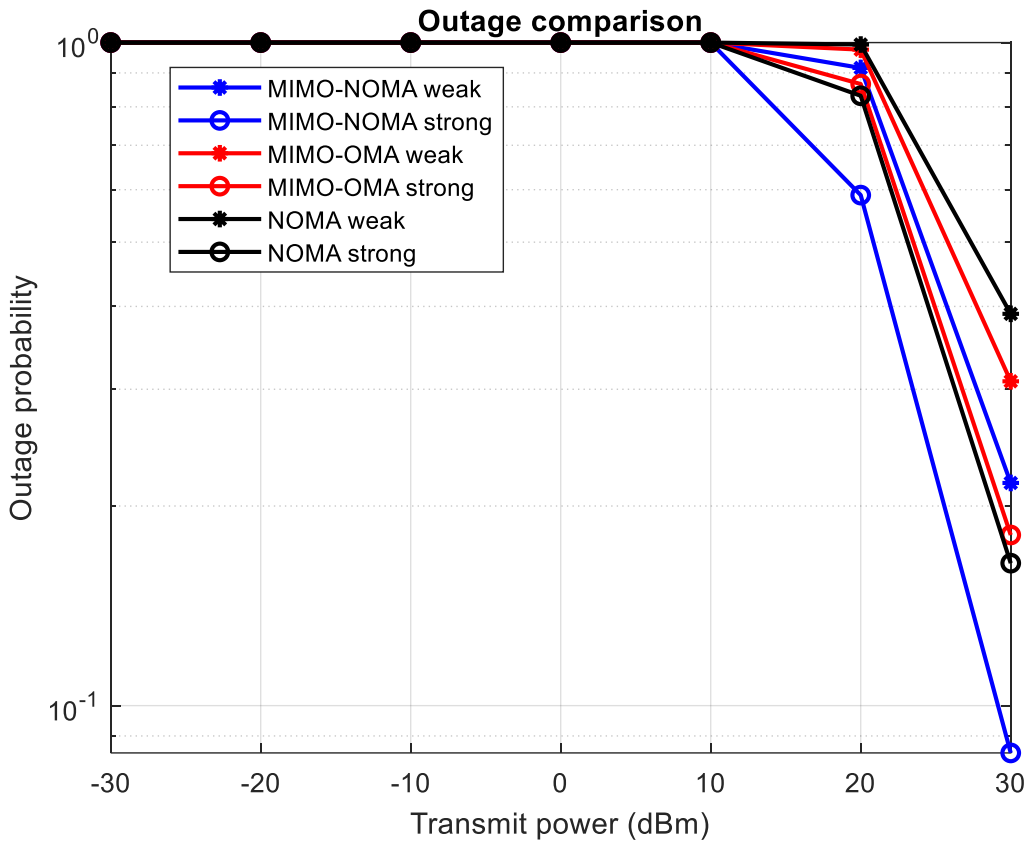

Figure 16: The Outage Probability of of MIMO-NOMA, MIMO-OMA, NOMA at d1=5000, d2=2000, a1=0.75, a2=0.25

8.4 NOMA Bit Error Rate

8.4.1 The First Scenario Simulation for AWGN Channel

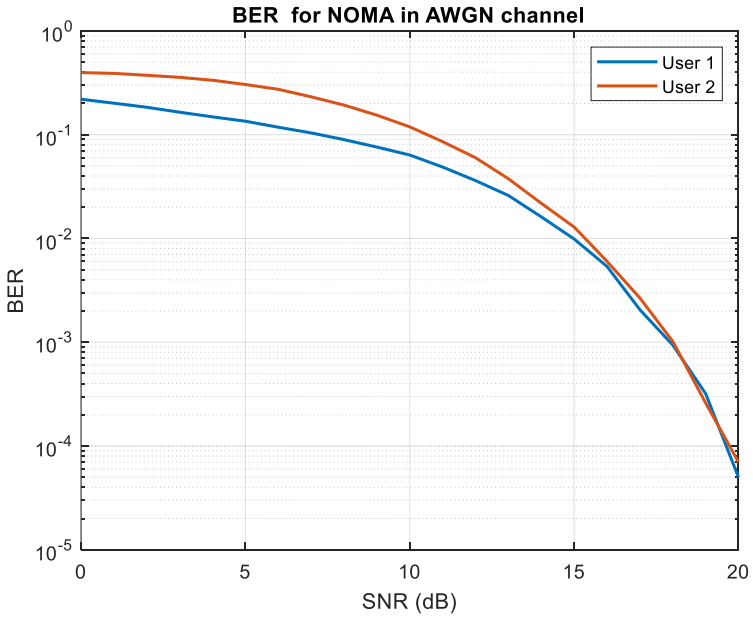

Figure 17 BER for NOMA in AWGN Channel

8.4.2 The Second Scenario Simulation for Rayleigh Fading Channels

We did three changes in the mat lab simulation in term of distance, bandwidth and power coefficient as shown in table below.

Parameter	User 1	User 2
Distance	5000	2000
Power coefficient	0.75	0.25
Bandwidth	10^5 10^6 10^7	

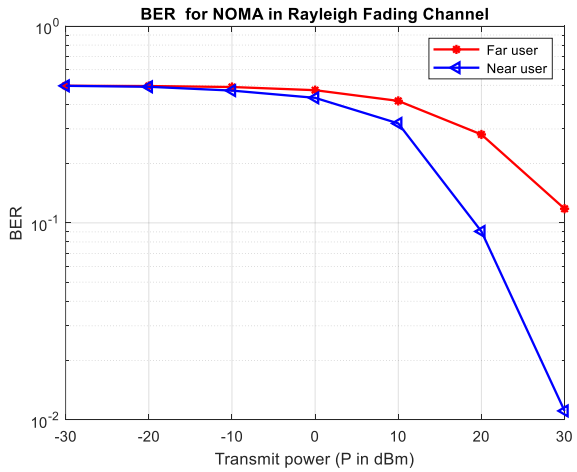

Figure 18 BER for NOMA in Rayleigh Fading Channel at 100KHZ

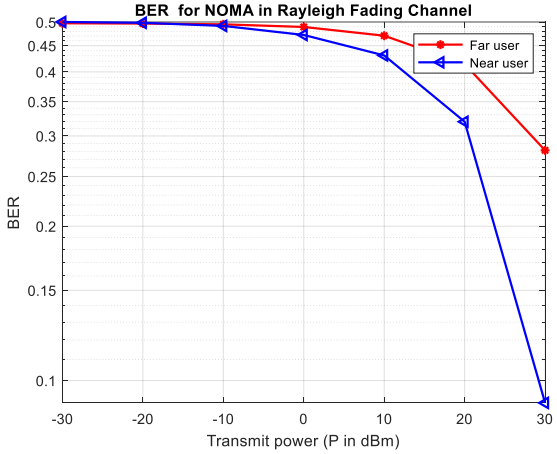

Figure 19 BER for NOMA in Rayleigh Fading Channel at 1MHz.

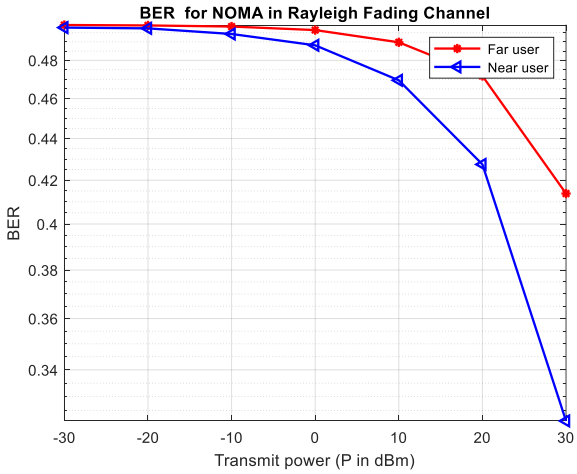

Figure 20 BER for NOMA in Rayleigh Fading Channel at 10MHz

Parameter	User
Distance	7000 ,1500
Power coefficient	0.4
Bandwidth	10^5

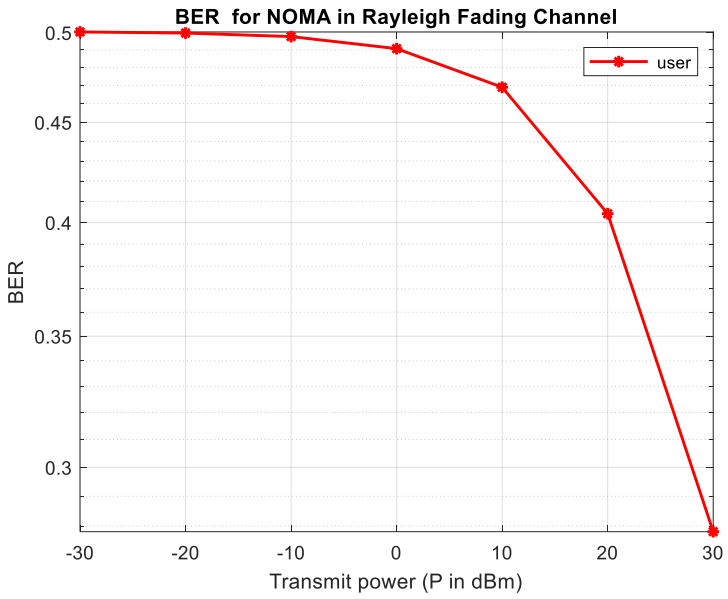

Figure 21 BER for NOMA for one user d=7000

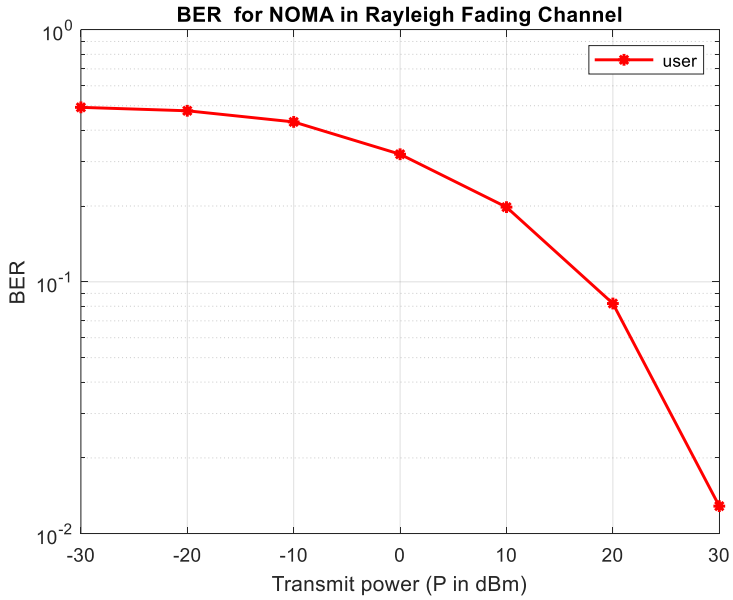

Figure 22 BER for NOMA for one user d=1500

Parameter	User
Distance	1000
Power coefficient	0.75
Bandwidth	100K,10000K

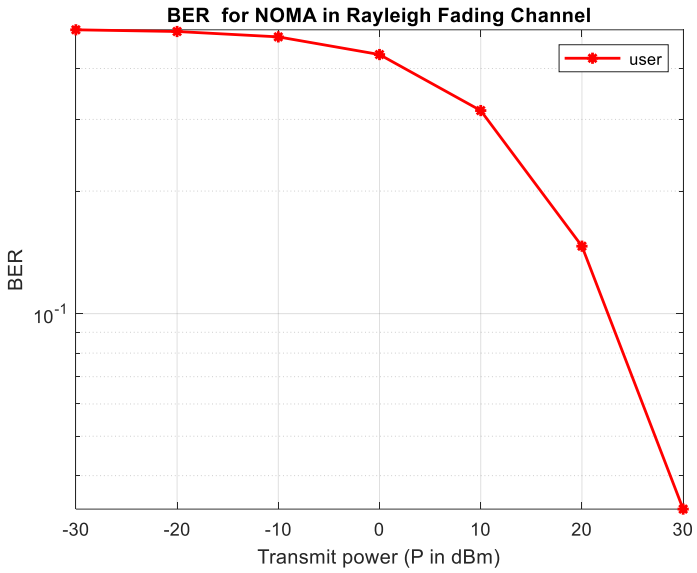

Figure 23 BER for NOMA for one user BW=100KHz

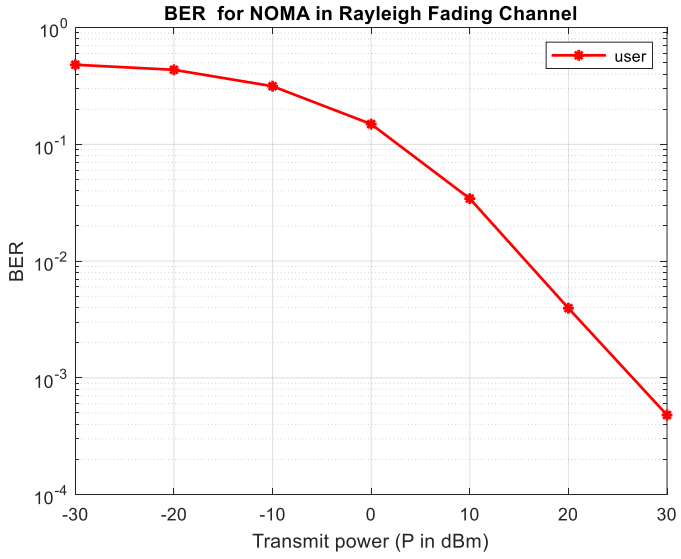

Figure 24 BER for NOMA for one user BW=10MHz

9 Analysis of Finally Result Through Comparison, Validation or Verification

This section intends to check the percentage of completion of each part in the system.

9.1 The Sum Rate Analysis

For an efficient communication system, the capacity should be more.

Completion percentage: 100%

- Referring to figure10 all users with different distance have same sum rate at low transmission power(dBm) from -30 to -10 then from -10 to 10 MIMO-OMA very little higher than others, but at high transmission power MIMO-NOMA is better than other users from 10 to 30.
- Referring to figure11 we can see all user with different distance at low transmission power have same sum rate from -30 to 0, at high transmission power from 0 to 30 MIMO-NOMA is higher.
- Referring to figure12 we can see all user with different power at low transmission power have same sum rate from -30 to -10 then from -10 to 20 OMA is higher, at high transmission power from 21 to 30 MIMO-NOMA is higher.

9.2 Individual Rate Analysis

- Referring to figure13 all user with different distance has same individual rate at low transmission power(dBm) from -30 to -10 then from -10 to 10 MIMO-OMA strong very little high than others, but at high transmission power MIMO-NOMA strong is better than other users from 10 to 30.
- Referring to figure14 all user with different distance has same individual rate at low transmission power(dBm) from -30 to 0 then from 0 to 23 MIMO-OMA strong very little high than others, but at high transmission power MIMO-NOMA strong is better than other users from 20 to 30.
- Referring to figure15 all user with different power has same individual rate at low transmission power(dBm) from -30 to -10 then from -10 to 20 MIMO-OMA strong is higher, but at high transmission power MIMO-NOMA strong is better than other users from 23 to 30.

9.3 Outage Probability Analysis

For efficient communication system outage should be Less.

Completion percentage: 100%

- Referring to figure16 at low transmission power (dBm) from -30 to 10, all users achieve the same outage, after that NOMA weak and MIMO-OMA weak are same from 10 20.it is evident that NOMA receives fewer errors than MIMO-OMA for both users.

9.4 Bit Error Rate Analysis

Completion percentage: 100%

For an efficient communication system it should be less.

1. AWGN Channel

Referring to figure 17 we can observe that User2 has a higher BER than User1 especially when the SNR is low, also the results show that the BER performance decreases as SNR increases and if there any error in decoding will impact its BER.

2. Raleigh Channel

1. Figures (18, 19 and 20) show that BER efficiency decreases with increasing power and the effects of distance and power factor are clearly visible. User 1 has the worst BER performance due to User 2's interference.
2. After increasing the bandwidth from 100 kHz to 10 MHz in figure (20) for the same distance and power factor values as in figure (16), the result shows that the BER from user 2 to all users 1 has improved.
3. Figure 21,22 appears the BER for one user at BW (100K), power 0.4 and different distance and the effect appear with increasing the Power.
4. Figure 23,24 appears the BER for one user fixed distance 1000 and power 0.75 and different BW and the results show as BW increase the BER increase means BER improve when the BW Decrease

10 Conclusion

Technology has simplified and improved our lives in many ways. In this project, we examine the core concept of NOMA, which promises multiple next-generation network access techniques that allow multiple users to share the same time and frequency blocks of resources.

This project evaluates PD-NOMA integrated with MIMO technology. To increase reliability and improve the system performance, and observed the performance and it is compared with OMA techniques.

The performance is evaluated for the parameters (outage probability, achievable channel capacity, bit error rate and sum rate) for both AWGN and Rayleigh Channel and outputs were observed from simulation results when these parameters are plotted against the transmit power in NOMA with cooperation than NOMA without cooperation and OMA techniques.

System performance changes significantly when settings are changed. First, the overall performance of the Capacity is assessed. The result shows that all users have the same speed at low power, but at high transmit power, MIMO-NOMA is better than other users.

Second, the outage is assessed. The result shows that with low transmit power (dBm) from -30 to 10, all users have the same outage, after that low NOMA and low MIMO OMA from 10 to 20 are the same. NOMA receives fewer errors than MIMO-OMA for both users.

Third, the bit error rate performance is evaluated. The result for the AWGN channel shows that the performance of the BER decreases with increasing SNR and the BER is degraded when a decoding error occurs. And under the Raleigh channel, the result shows that BER performance decreases with increasing power and the effects of distance and power factor are clearly visible when bandwidth is increased for the same distance and factor values of power that improved BER. And as BW increases, a BER increase of means that BER improves as BW decreases.

11 Future Work

In this project, we focused on evaluating the performance of downlink two user NOMA system. In future this work can be extended by increasing the number of users for other performances parameter and, we can consider other types of channels, modulation type and Noma can cooperate with other technology to enhance the performance.

Surely there are still challenges and open issues that need to be considered for future research like Delta NOMA.

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