PERFORMANCE EVALUATION OF MIMO-NOMA FOR THE NEXT GENERATION WIRELESS COMMUNICATIONS

A Project report submitted in partial fulfilment of the requirements

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BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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CERTIFICATE

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ABSTRACT

In 4G, the using of Orthogonal Multiple Access techniques (OMA) which does not fulfill the massive increase in Mobile networks and also Increasing Technology like IOT. It was limiting the number of users that can be supported by the number of orthogonal resources available, as it was not fulfilling the exponential growth in Mobile network like low latency, massive connectivity and energy efficiency etc.

So to overcome the problems with OMA in 4G, In 5G NOMA was implemented which overcomes problems to some extent. Like it uses the same resource block. It transmit multiple users' signals from the transmitter to the receiver. By allowing multiple users to share the same resource elements, be it in the time, frequency, space, or code domain. The main advantage of NOMA is it uses power domain technique for transmission of signals.

As NOMA is versatile technique. we can combine it with MIMO to increase throughput as well as to increase spatial multiplexing to increase achievable rates and diversity gain to decrease BER.

Our main aim of this project is to show the performance evaluation of Multi-Input Multi-Output Non-Orthogonal Multiple Access (MIMO-NOMA) for Next Generation Wireless Communication Systems. The efficiency of the MIMO-NOMA technique over Non-Orthogonal Multiple Access (NOMA) and Orthogonal Multiple Access (OMA) is examined by using distinct parameters, in particular, Power Allocation (PA), Bit Error Rate (BER), Outage Probability (OP), and Channel Capacity (CC).

A system model for MIMO is assumed for the two-user scenario. A Rayleigh fading channel is assumed between the Transmitter and the receiver. By using Rayleigh fading channel coefficients, calculated the achievable rates and SNR equations for all techniques and then compared each parameter with others.

Finally, the simulation results are provided to facilitate the performance analysis of MIMO-NOMA for a next-generation wireless communication system and also demonstrate the accuracy of the developed analytical results.

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LIST OF ABBREVATIONS:

- OMA - Orthogonal Multiple Access
- NOMA - Non - Orthogonal Multiple Access
- MIMO-NOMA - Multiple Input Multiple Output Non - Orthogonal Multiple Access
- SIC - Successive Interference Cancellation
- SNR - Signal to Noise Ratio
- BER - Bit Error Rate
- PA - Power Allocation
- CC - Channel Capacity
- OP - Outage Probability
- BEP - Bit Error Probability
- BS - Base Station

CHAPTER-1

INTRODUCTION

CHAPTER-1

INTRODUCTION

Different multiple access schemes are acquired from First Generation (1G) to Fourth Generation (4G). All the proposed schemes from 1G to 4G are common in one particular subject. That is the signals that are transmitted from the transmitter to the receiver must be orthogonal to each other.

OMA is one of the multiple access schemes which uses orthogonal resource allocation among individual users to avoid intra-cell interference. This technique also helps in the dissociation of respective user data in which time and frequency resources are split for multiple receivers in current broadcasting systems. But the number of users that can be supported through this OMA method is then limited by the number of orthogonal resources available.

As 4G, uses the OMA approach, that cannot satisfy high-speed communication or with low latency, etc. The main disadvantages of 4G networks are, they don't accomplish the exponential growth in capacity demands, low latency, massive connectivity, high throughput, and energy efficiency.

A lot of investigations have been done to satisfy various requirements in practical systems in the history of broadband multimedia communications and broadcasting. Among all, 5G technology comes with a better solution. Since it uses Non-Orthogonal Multiple Access (NOMA). NOMA uses the same resource blocks to transmit multiple user's signals from the transmitter to the receiver. This will reduce delays, accommodate larger population satisfy traffic demands and reduces the time lag in communication.

NOMA adopts super-position coding at the transmitter and successive interference cancellation at the receiver.

During the transmission of signal in NOMA, at the transmitter side, it performs super position-coding technique and at the receiver side, it introduces some controllable interference like Successive Interference Cancellation (SIC), thus allows multiplexing users in the power domain.

MIMO communications send similar data as multiple signals through multiple antennas simultaneously, utilizing a single radio channel. MIMO system is incorporated with NOMA multiple access schemes to provide spatial multiplexing to increase achievable rates and diversity gain to decrease BER.

1.1 MOTIVATION:

Different multiple access schemes are acquired from First Generation (1G) to Fourth Generation (4G). All the proposed schemes from 1G to 4G are common in one particular subject. That is the signals that are transmitted from the transmitter to the receiver must be orthogonal to each other. OMA is one of the multiple access schemes which uses orthogonal resource allocation among individual users to avoid intra-cell interference. Using of Orthogonal Multiple Access techniques (OMA) which does not fulfill the massive increase in Mobile networks and also Increasing Technology like IOT. It was limiting the number of users that can be supported by the number of orthogonal resources available.

As it was not fulfilling the exponential growth in Mobile network like low latency, massive connectivity and energy efficiency, NOMA technique is introduced. It uses same resource block for transmission of different users signals from transmitter to the receiver. So, it can increase the number of connections at a time and increase the speed of communication.

In order to get good achievable rates and SNR rates MIMO system is incorporated with NOMA multiple access schemes.

Our main motivation is to compare each technique with others in different aspects. That is all techniques are compared using different parameters like power allocation, channel capacity, outage probability and bit error rate. By comparing each technique with others, we can know which technique outperforms the other techniques in that particular parameter, using MATLAB.

1.2 PROJECT OBJECTIVE:

The main objective of this project is to observe and analyse the performance of MIMO-NOMA for next generation wireless communications and how it overcomes the NOMA and MIMO-OMA.

These MIMO-NOMA, NOMA, MIMO-OMA performance was analysed by considering the parameters like power allocation, outage probability, channel capacity and BER.

1.3 PROJECT OUTLINE:

This document is presented over the four remaining chapters. Chapter 2 gives an overview of coding techniques of communication systems. Chapter 3 describes briefly about the system model of NOMA, MIMO-OMA, MIMO-NOMA used in this project. Chapter 4 describes the performance analysis of the parameters taken in the project. Chapter 5 describes the features and uses of MATLAB. Chapter 6 portrays the parameters specifications and techniques values for two different users and Chapter 7 follows with the conclusion.

CHAPTER-2

CODING TECHNIQUES

CHAPTER-2

CODING TECHNIQUES

2.1 NOMA

Non-orthogonal multiple access (NOMA) principle emerges as a solution to improve the spectral efficiency while allowing some degree of multiple access interference at receivers. In NOMA, multiple users can utilize non-orthogonal resources concurrently by yielding a high spectral efficiency while allowing some degree of multiple access interference at receivers.

NOMA uses superposition coding at the transmitter, to combine the all user's signals into a single signal. Successive interference cancellation (SIC) receiver can separate the respective user's signal both in the uplink and in the downlink channels.

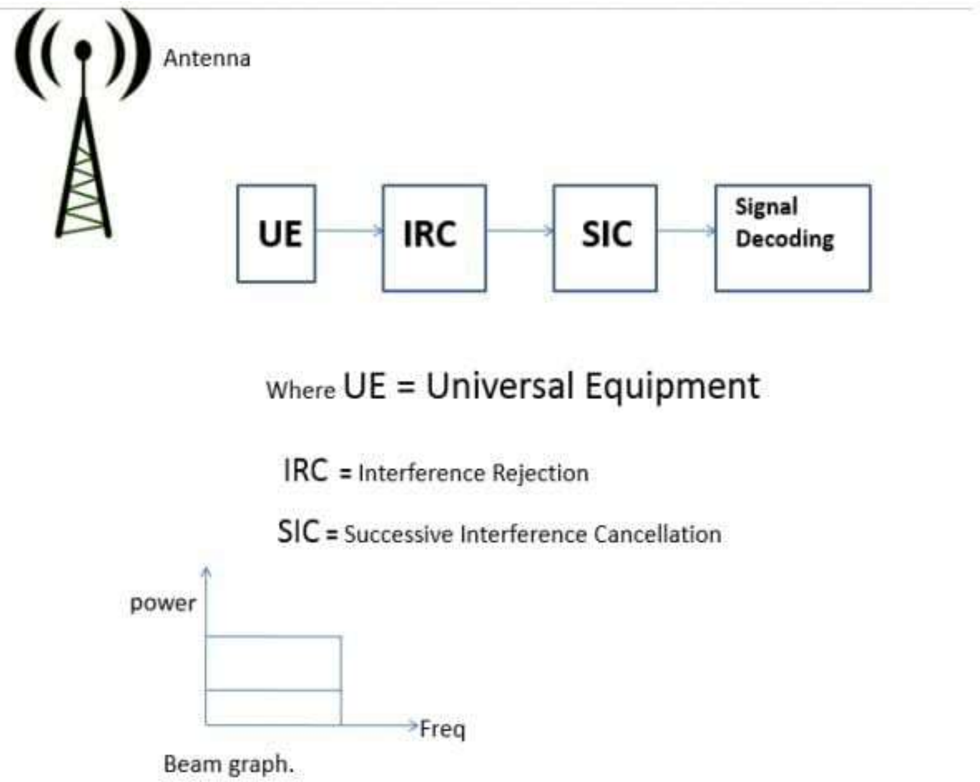


Fig 1: Block Diagram showing NOMA transmission in DL mode

Superposition coding at the transmitter and successive interference cancellation (SIC) at the receiver makes it possible to utilize the same spectrum for all users. At the transmitter site, all the individual information signals are superimposed into a single waveform, while at the receiver, SIC decodes the signals one by one until it finds the desired signal.

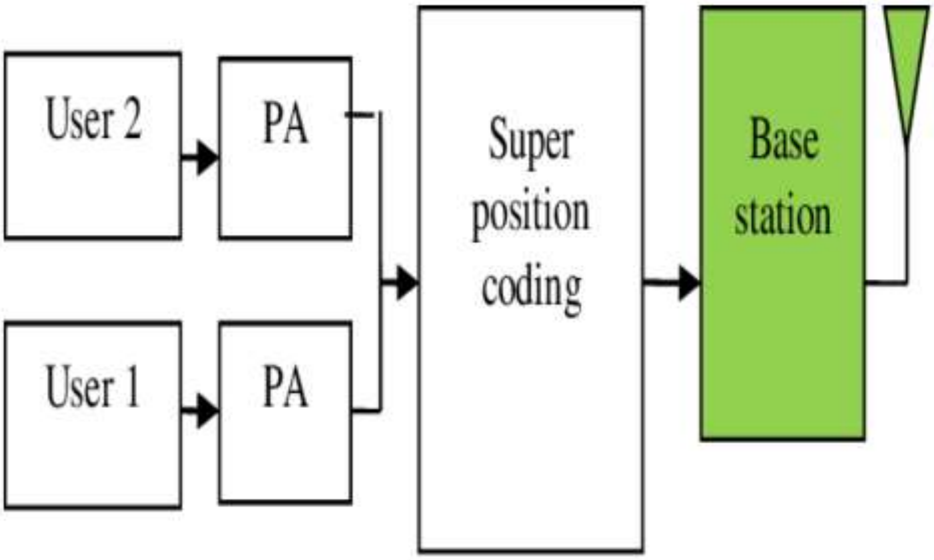


Fig. 1. Block diagram of NOMA in transmission section

At the transmitter side, each users signal is allocated with different power allocation coefficients and then it send the signals to the super position coding block to combine all the signals to a single signal and it is transmitted to base station.

At the receiver side, the signal is sorted according to SNR. Based on dominant power allocation coefficient among users,decoding takes place. The user with dominant power coefficient will decode first and then second dominant user decode next and so on till the last user.

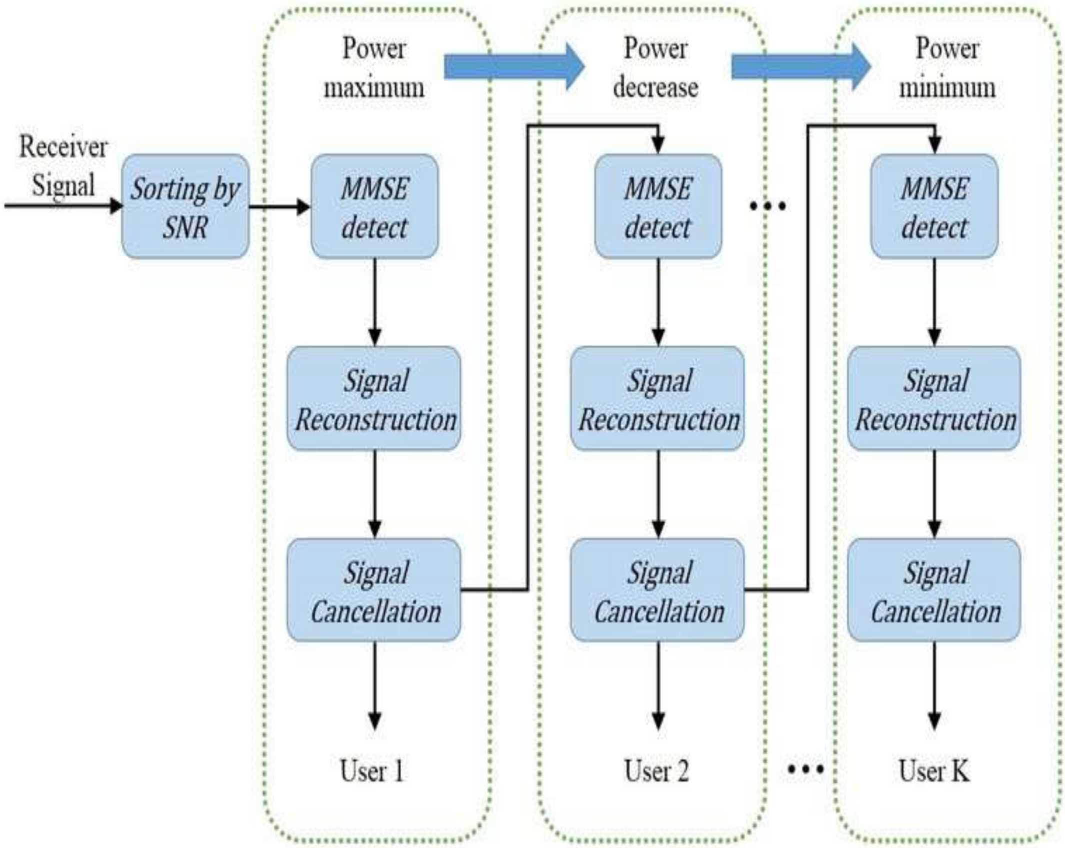


Fig. Decoding at receiver

In general, NOMA schemes can be classified into two types: power-domain multiplexing and code-domain multiplexing. In power-domain multiplexing, different users are allocated different power coefficients according to their channel conditions in order to achieve a high system performance. In particular, multiple user's information signals are superimposed at the transmitter side. At the receiver side successive interference cancellation (SIC) is applied for decoding the signals one by one until the desired user’s signal is obtained, providing a good trade-off between the throughput of the system and the user fairness.

In code-domain multiplexing, different users are allocated different codes and multiplexed over the same time-frequency resources.

In addition to power-domain multiplexing and code-domain multiplexing, there are other NOMA schemes such as pattern division multiple access (PDMA) and bit division multiplexing (BDM). Although code-domain multiplexing has a potential to enhance spectral efficiency, it requires a high transmission bandwidth and is not easily applicable to the current systems. On the other hand, power-domain multiplexing has a simple implementation as considerable changes are not required on the existing networks. Also, it does not require additional bandwidth in order to improve spectral efficiency.

In NOMA the same frequency resource is assigned to multiple mobile users, with good and bad channel conditions, at the same time. Hence, the resource assigned for the weak user is also used by the strong user, and the interference can be mitigated through SIC processes at user's receivers. Therefore, the probability of having improved spectral efficiency and a high throughput will be considerably increased.

NOMA can serve multiple users with different channel conditions simultaneously; therefore, it can provide improved user fairness, lower latency, and higher massive connectivity. And NOMA is also compatible with the current and future communication systems since it does not require significant modifications on the existing architecture.

2.2 MIMO-OMA

Different multiple access schemes are acquired from First Generation (1G) to Fourth Generation (4G). All the proposed schemes from 1G to 4G are common in one particular subject. That is the signals that are transmitted from the transmitter to the receiver must be orthogonal to each other. OMA uses orthogonal resource allocation so that only single user can use the resource block. When OMA is incorporated with MIMO system to get high diversity gain and less BER. In MIMO-OMA resource block is divided based on number of user's. Let us consider time division, then total time is equally divided into number of users and in first time slot, all the transmitter antennas transmits the first user signal and then in second time slot all the transmitter antennas transmits the second user signal to the second user and it continues till the last user respectively.

In MIMO-OMA the message passes from the transmitted to the receiver in different time slots, Like in a certain time slot a particular message will be travelled. Likewise the remaining message will be travelled. In terms of sum-rate the MIMO-OMA is low compared to the MIMO-NOMA for a simple two user scenario.

2.3 MIMO-NOMA

MIMO technologies have a significant capability of increasing capacity as well as improving error probability of wireless communication systems.

In order to achieve a balance between the maximum number of mobile users and the optimal achievable sum rate in MIMO-NOMA systems, sum rate has been represented through two ways. The first approach targets the optimization of power partition among the user clusters. Another approach is to group the users in different clusters such that each cluster can be allocated with orthogonal spectrum resources according to the selected user grouping algorithms.

The application of multiple-input multiple-output (MIMO) technologies to NOMA is important since the use of MIMO provides additional degrees of freedom for further performance improvement. MIMO can be used for either spatial multiplexing (increase achievable rate) or diversity gain (decrease BER).

As multiple techniques can achieve multi-stream beamforming coding diversity, the use of MIMO techniques brings flexible dimension for performance improvements. There are two techniques in MIMO-NOMA Zero forcing and block diagonalization based on zero-forcing (ZF) technique, low complexity linear precoding scheme can reduce inter-interference when channel transmission occurs. Block diagonalization (BD) is typical linear precoding technique with implemented in the downlink of multiuser MIMO systems.

The performance of downlink MIMO-NOMA network for a simple case of two users, that is, one cluster, is introduced. In this case, MIMO-NOMA provides a better performance than MIMO-OMA in terms of both the sum rate and ergodic sum rate. Also, it is shown that for a more practical case of multiple users, with two users allocated into a cluster and sharing the same transmit beamforming vector. MIMO-NOMA can achieve better outage performance than conventional MIMO-OMA, even for users that suffer strong co-channel interference.

CHAPTER-3

SYSTEM MODEL

CHAPTER-3

SYSTEM MODEL

3.1 SYSTEM MODEL OF NOMA

Consider a 2 x 1 downlink NOMA system. Let US1 and US2 be the user 1 and user 2 respectively. US1 be the far user or weak user and US2 be the near user or strong user. Let D1 and D2 denotes the distances of US1 and US2 respectively from transmitter. We assume, D1>D2. Let B1 and B2 be the information intended for both users. Let us consider the Rayleigh fading channel between the transmitter antenna and receiver antenna. Following are the notations of NOMA, let C_n denote the fading channel between the transmitter antenna and near user and Cf denote the fading channel between the transmitter and the far user receiver antenna. At the transmitter side super position coding takes place to get the total signal transmitted, with different power allocation coefficients. Let TP be the total power for transmission of signals from transmitter to respective receiver antenna or user. The total signal transmitted by transmitter antennas for 2 x1 NOMA is given by,

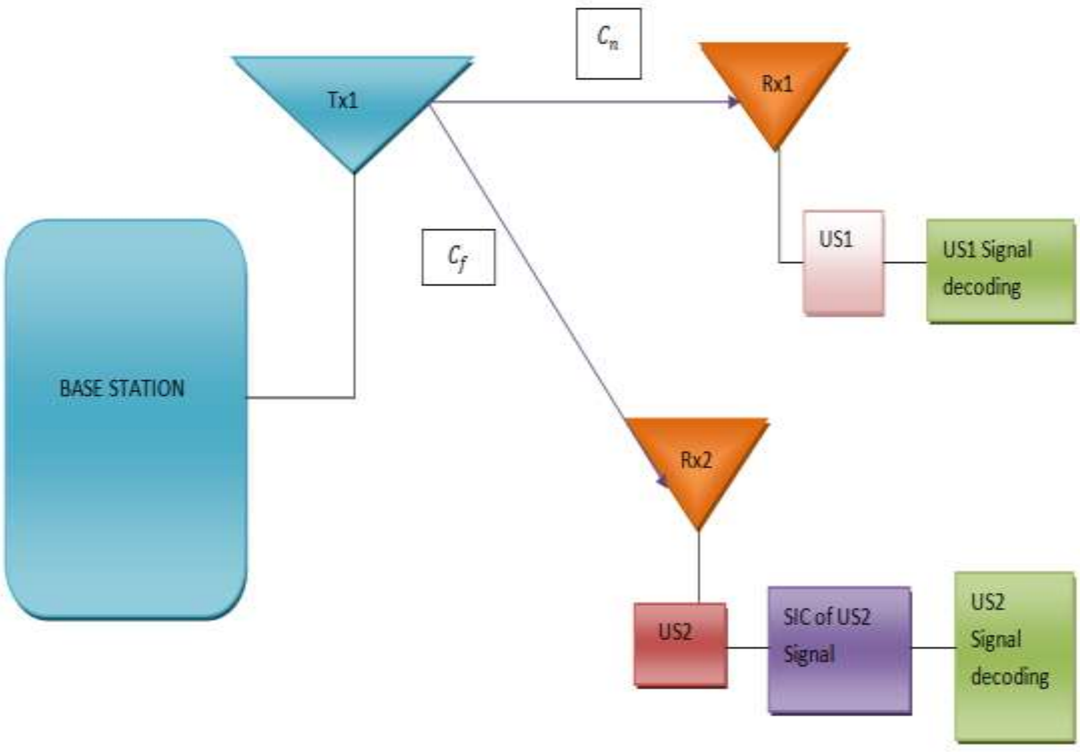


Fig 3.2 Showing NOMA Downlink system model with one BS and two distinct users.

In NOMA superposition coding is performed at the transmitter side and then the signal is transmitted to the receiver through the Rayleigh fading channel.

$$Y_{NOMA=}\sqrt{TP}(\sqrt{p_1} * B1 + \sqrt{p_2} * B2) \quad (1)$$

Then, at the receiver end, SIC is performed. After that, respective user information decoding takes place. In NOMA, the transmitter at the transmitter side transmits the total signal to all the receivers simultaneously. The signal received by the US1 receiver is given by,

$$Y_{1,NOMA} = Y_{NOMA} * C_f + N_1 \quad (2)$$

Similarly, the signal received by US2 at the receiver side is given by,

$$Y_{2,NOMA} = Y_{NOMA} * C_n + N_2 \quad (3)$$

Where C_f is the Rayleigh fading channel coefficient between transmitter and US1, C_n is the Rayleigh fading channel coefficient between transmitter and US2 receiver.

3.2.1 Decoding at User 1

Now, US1 has to decode B1 from the signal received by the US1 receiver. Since US1 is the weak signal, B1 is allocated with more power. Therefore, US1 can directly decode B1 from Y_{NOMA}, treating B2 as interference. The SNR 1-NOMA equation is given by,

$$SNR_{1,NOMA} = \frac{TP * p_1 |C_f|^2}{TP * p_2 |C_f|^2 + \sigma^2} \quad (4)$$

Therefore, US1 achievable rate is given by,

$$AR_{1,NOMA} = log_2(1 + SNR_{1,NOMA}) \quad (5)$$

3.2.2 Decoding at User 2

User 2 must decode B2 from $Y_{2\text{-}NOMA}$. Since US2 is a strong user, B2 is allocated with less power. Therefore, in $Y_{2\text{-}NOMA}$, the power allocated to B1 is dominating. So, US2 will first perform direct decoding on $Y_{2\text{-}NOMA}$ to obtain B1. Then SIC is carried out to remove B1. Then B2 is decoded. The SNR equation for US2 [1] is given by,

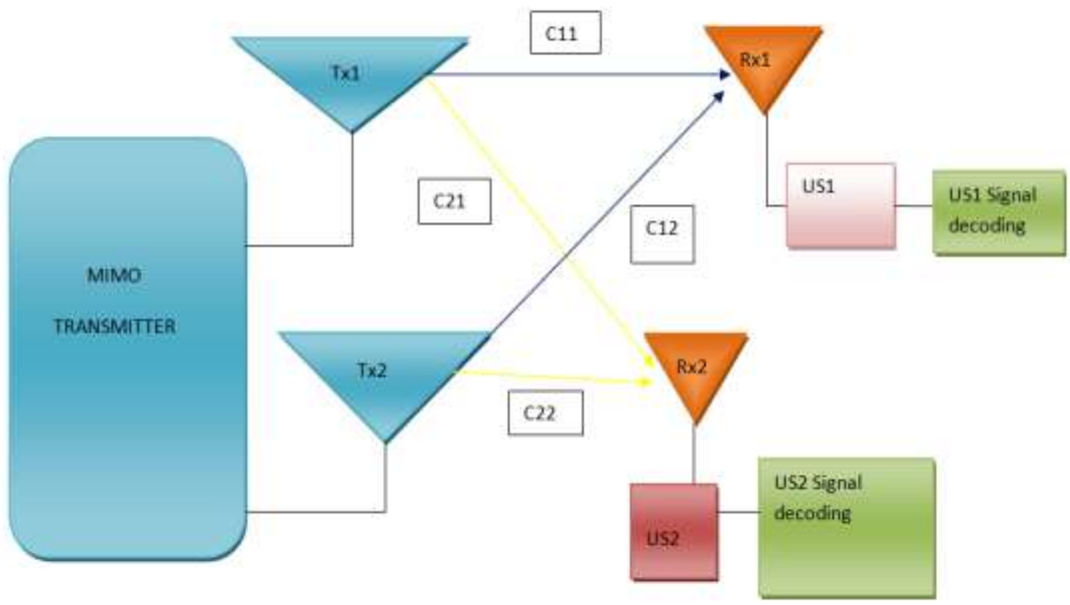
$$SNR_{2,NOMA} = \frac{TP * p_2 |C_n|^2}{\sigma^2} \tag{6}$$

Therefore, the achievable rate for US2 [1] is given by,

$$AR2, NOMA = \log 2(1 + SNR2, NOMA) \tag{7}$$

3.2 SYSTEM MODEL OF MIMO-OMA

Consider a 2 x 1 MIMO downlink system. Let us consider US1 and US2 to be user 1 and user 2 respectively. A far user or weak user is denoted by US1 and the near user or strong user is denoted by US2. Let D1 and D2 denote the distances of US1 and US2 respectively, from the MIMO transmitter. We assume, D1>D2. Let B1 and B2 be the information intended for both users. The notations of the MIMO system are as follows, fading channel between t^{th} transmitter antenna and r^{th} receiver antenna is given by C_{rt}. Superposition coding takes place to get the total signal transmitted with different power allocation coefficients, at the transmitter side. The total PA coefficients must be equal to 1. Let us consider, TP to be the total power for the transmission of signals from the transmitter to the respective receiver antenna or user. Here in MIMO-OMA time is divided between the users. Both the transmitting antennas transmit the signal for user 1 in first time slot and then to the next user, thus time is divided among the users.



C_{rt}=Channel from t^{th} transmit antenna to r^{th} receiver antenna

Fig3.1 Showing MIMO-OMA Downlink system model having one BS and two distinct users

To know how MIMO-NOMA performs well, we are going to compare MIMO-NOMA with MIMO-OMA and NOMA. In MIMO-OMA, suppose we consider 2 users then the transmission time is divided into two slots. In the first time slot, both transmitter antennas transmit to the US1 signal and in the second time slot, both the transmitter antennas transmit the US2 signal. The signal transmitted by both the transmitter antennas at the first time slot is TP*B1. The signal received by US1 in the first time slot is given by,

$$Y_{1,OMA} = \sqrt{TP} * B1(C_{11} + C_{12}) + N_1 \quad (8)$$

Similarly, the signal transmitted by both the antennas in the second time slot to US2 is TP*B2 and the signal received by US2 is given by,

$$Y_{2,OMA} = \sqrt{TP} * B2(C_{21} + C_{22}) + N_2 \quad (9)$$

The SNR at US1 and US2 are given by,

$$SNR_{1,OMA} = \frac{TP|C_{11}+C_{12}|^2}{\sigma^2} \quad (10)$$

$$SNR_{2,OMA} = \frac{TP|C_{21}+C_{22}|^2}{\sigma^2} \quad (11)$$

US1 and US2 achievable rates for MIMO-OMA are given by,

$$AR_{1,OMA} = \frac{1}{2} log_2(1 + SNR_{1,OMA}) \quad (12)$$

$$AR_{2,OMA} = \frac{1}{2}\log_2\left(1 + SNR_{2,OMA}\right) \quad (13)$$

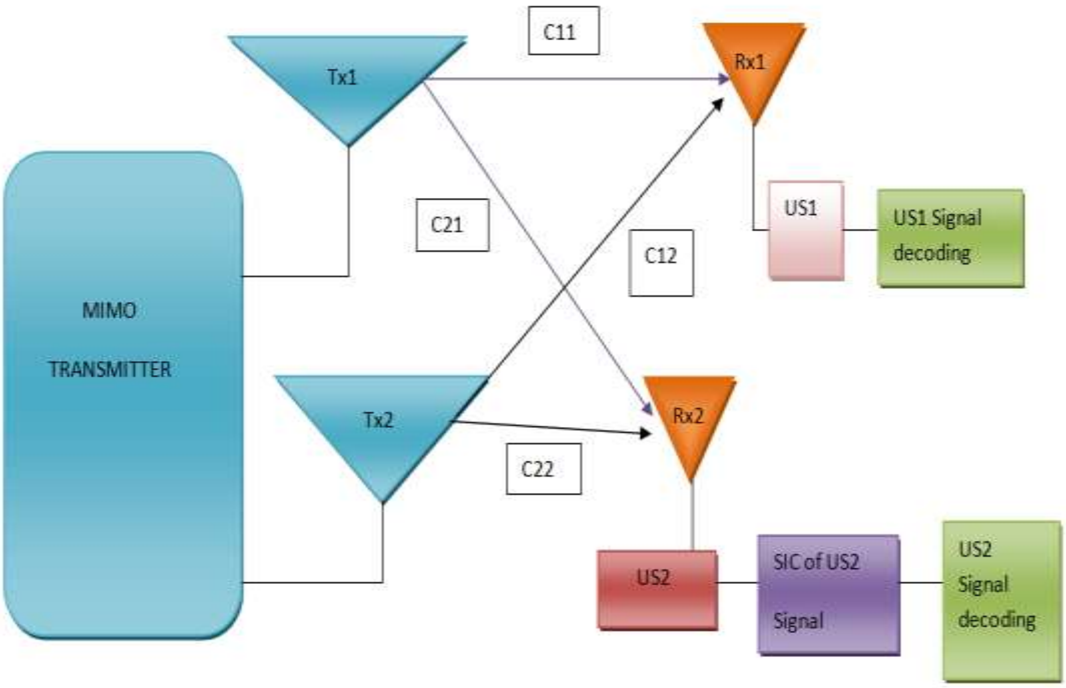
3.3 SYSTEM MODEL OF MIMO-NOMA

Consider a 2 x 1 MIMO downlink system. Let us consider US1 and US2 to be user 1 and user 2 respectively [2]. A far user or weak user is denoted by US1 and the near user or strong user is denoted by US2. Let D1 and D2 denote the distances of US1 and US2 respectively, from the MIMO transmitter. We assume, D1>D2. Let B1 and B2 be the information intended for both users. The notations of the MIMO system are as follows, fading channel between t^{th} transmitter antenna and r^{th} receiver antenna is given by C_{rt}.

Superposition coding takes place to get the total signal transmitted with different power allocation coefficients, at the transmitter side. The total PA coefficients must be equal to 1. Let us consider, TP to be the total power for the transmission of signals from the transmitter to the respective receiver antenna or user. The total signal transmitted by transmitter antennas for 2 x1 MIMO systems is given by

$$Y = \sqrt{TP}\left(\sqrt{p_1} * B1 + \sqrt{p_2} * B2\right) \tag{14}$$

Where p1 and p2 are the NOMA power allocation coefficients. $p_1 > p_2$, because US1 is a distant user or weak user.



C_{rt}=Channel from t^{th} transmit antenna to r^{th} receiver antenna

Fig 3.3 Showing MIMO Downlink system model having one BS and two distinct users.

The total signal is transmitted to each receiver in multiple paths by each transmitter. At the receiver end, the same signal is received by both the antennas. Therefore, the received signal at US1 is given by,

$$Y_{1,MIMO} = YC_{11} + YC_{12} + N_1 = Y(C_{11} + C_{12}) + N_1 \tag{15}$$

Similarly, the signal received by US2 is given by,

$$Y_{2,MIMO} = YC_{21} + YC_{22} + N_2 = Y(C_{21} + C_{22}) + N_2 \quad (16)$$

Where N_1 and N_2 are the noise samples of AWGN with zero mean and variance σ^2

3.3.1 Decoding at User1

At US1, the intended data for the US1 signal has the dominating PA coefficient, so direct decoding of the US1 signal takes place. The information intended for US2 is treated as interference at the US1 receiver. The SNR of a signal is given by the ratio of the original signal intended for the respective user, to the interference. Then SNR1 for US1 in decoding B1 is given by,

$$SNR_{1,MIMO} = \frac{(TP*p_1|C_{11}+C_{12}|^2)}{(TP*p_2|C_{11}+C_{12}|^2)+\sigma^2} \quad (17)$$

Therefore, the achievable rate for US1 is given by, $AR_{1,MIMO} = \log_2(1 + SNR_{1,MIMO})$

$$AR_{1,MIMO} = \log_2(1 + SNR_{1,MIMO}) \quad (18)$$

3.3.2 Decoding at User2

Whereas at US2, US1 signal information is allocated with more power, so decoding of US1 signal takes place directly by treating US2 signal as interference. The SNR at the US1 for direct decoding of B1is given by,

$$SNR_{12,MIMO} = \frac{TP*p_1|C_{21}+C_{22}|^2}{TP*p_2|C_{21}+C_{22}|^2+\sigma^2} \quad (19)$$

After performing SIC (successive interference cancellation), the US1 data is removed from Y, and then the remaining signal is decoded to get the US2 signal. The SNR equation for US2 to decode its signal is given by,

$$SNR_{2,MIMO} = \frac{TP*p_2|C_{21}+C_{22}|^2}{\sigma^2} \quad (20)$$

The achievable rates at US2 for decoding B1 and B2 are given by,

$$AR_{12,MIMO} = log_2(1 + SNR_{12,MIMO}) \tag{21}$$

$$AR_{2,MIMO} = \log_2\left(1 + SNR_{2,MIMO}\right) \tag{22}$$

CHAPTER-4

PERFORMANCE ANALYSIS

CHAPTER-4

PERFORMANCE ANALYSIS

4.1 POWER ALLOCATION

Wireless data networks are increasingly becoming an important part of next generation network infrastructure. The objective of these networks is to provide with anytime, anywhere data access. The computing and storage capabilities of these devices cover a wide spectrum. Power consumption has become an important concern when it comes to the implementation phase of wireless devices. Therefore, power management is one of the challenging problems in wireless communications.

In wireless networks, power allocation is an effective technique for prolonging the lifetime of network terminals. Generally optimum power allocation improves the efficiency of wireless systems. When power allocation is properly done, source information can reach the destination efficiently. The problem of power allocation in relay assisted wireless system is investigated here with Maximal Ratio Combining (MRC) at the destination terminal. Based on the SNR and BER, power is allocated to the network terminals using water filling power allocation scheme. It is observed that water filling power allocation scheme allocates more power for the network terminals with less noise. Also based on the users channel capacity optimized power allocation is done. Hence the channel serves good enough in transmitting the source information to the destination.

The amount of power that is allocated to the user data to transmit the respective signal from the transmitter to the receiver is called power allocation. By implementing the optimum power allocation process, the efficiency of the wireless communications system has been improved. To transmit the signal from the transmitter antenna to the receiver antenna, power allocation coefficients are required, as NOMA is based on a power domain technique. The user which is distant from the transmitter antenna is allocated with high power and the user which is close to the transmitter is allocated with less power coefficient. The summation of all power allocation coefficients must be 1. In the MIMO system, NOMA is included to achieve effective sum rates which come up with greater performance. Here we use fixed power allocation coefficients and determine the achievable sum rates for both the users. The achievable rates for respective users are calculated. The performance analysis of MIMONOMA, NOMA, and MIMO-OMA is observed and studied by considering PA as a parameter using MATLAB.

4.2 CHANNEL CAPACITY

The maximum rate at which data can be transmitted over a communication path or channel is called channel capacity. The channel capacity depends upon four factors they are data rate (bps), bandwidth (Hz), noise (dB), error rate (in %).

Wireless channel is prone to multipath propagation and fading. Several channel models are available to capture the effects of fading. Each model deals with a particular scenario. One such model is Rayleigh fading model. Rayleigh fading model can be used when there is no line of sight (LOS) path between the transmitter and the receiver. In other words, all multipath components have undergone small scale fading effects like reflection, scattering, diffraction, shadowing etc. We are going to consider an extreme case of Rayleigh fading where each transmitted bit undergoes a different attenuation and phase shift due to multipath transmission. In other words, the channel changes for every bit.

To calculate channel capacity of each technique first distances for far user and near user should be taken and power allocation coefficients are allocated to each user. Far user must be allocated with more power than near user.

$$\text{Channel capacity} = AR1 + AR2 \quad (23)$$

Where AR1 and AR2 are the achievable rates for user 1 and user 2.

In a mobile communication environment the channel is not time invariant and is slowly varying. This characteristic feature of the channel leads to a phenomenon called Fading. Fading channels induce rapid amplitude fluctuations in the received signal. If they are not compensated for then this will lead to serious performance degradation.

4.3 OUTAGE PROBABILITY

Outage probability is the ratio of the number of samples of the signal below the threshold to the total number of samples. If we increase the threshold power, the outage probability is increased, that is the probability of better detection of signal is decreased. In Information theory, outage probability of a communication channel is the probability that a given information rate is not supported, because of variable channel capacity. Outage probability is defined as the probability that information rate is less than the required threshold information rate. It is the probability that an outage will occur within a specified time period. Mathematically, the outage probability can be represented as the CDF of the SNR and is given by,

$$Pout(R) = Pr\ [AR<R] \qquad (24)$$

Where AR is considered as the achievable rate for the respective user and R is the target rate or the threshold value. If R is high blocking rate is more. To get OP below a maximum value, the SNR threshold value should be kept low. If AR is less than the target rate, then the outage occurs. In case the target rate is high then the outage probability reaches the maximum value as noise dominates the original information. To calculate the outage probability for a user, set the target rate and count the number of times that the calculated achievable rates dropped below the target rate and plot them. In MIMO-NOMA outage probability decreases as directivity gain increases, because in MIMO-NOMA multiple antennas are used to increase directivity gain. As it is evident, that the outage probability should be less to get a significant result.

4.4 Bit Error Rate

The number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors. The bit error rate (BER) is the number of bit errors per unit time. The biterror ratio (also BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. Bit error ratio is a unit less performance measure, often expressed as a percentage. The bit error probability p_e is the expectation value of the bit error ratio. The bit error ratio can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors.

The quality of digital wireless transmission is determined by the measurement of BER. If the BER of a system is low then, it provides better performance. Moreover, the different factors like channel noise, interference, distortion, and attenuation affect the BER during the transmission of a signal. Here, in this paper, we calculated BER by comparing the copy of the transmitted signal with the signal that is decoded at the receiver to the total number of bits, and then it is plotted against transmitted power.

$$\text{BER} = \frac{Number\ of\ bit\ errors}{Total\ number\ of\ bits} \tag{25}$$

Bit error rate is a key parameter that is used in assessing systems that transmit digital data from one location to another. BER is applicable to radio data links, Ethernet, as well as fibre optic data systems. When data is transmitted over a data link, there is a possibility of errors being introduced into the system. If this is so, the integrity of the system may be compromised. As a result, it is necessary to assess the performance of the system, and BER provides an ideal way in which this can be achieved. BER assesses the full end to end performance of a system including the transmitter, receiver and the medium between the two.

CHAPTER-5

MATLAB

CHAPTER-5

MATLAB

5.1 MATLAB INTRODUCTION

MATLAB is a high performance language for technical computing. It integrates computation visualization and programming in an easy to use environment. MATLAB stands for matrix laboratory. It was written originally to provide easy access to matrix software developed by LINPACK (linear system package) and EISPACK (Eigen system package) projects. MATLAB is therefore built on a foundation of sophisticated matrix software in which the basic element is matrix that does not require pre dimensioning. Typical uses of MATLAB

1. Math and computation
2. Algorithm development
3. Data acquisition
4. Data analysis, exploration and visualization
5. Scientific and engineering graphics

The main features of MATLAB

1. Advanced algorithm for high performance numerical computation, especially in the Field matrix algebra
2. A large collection of predefined mathematical functions and the ability to define one's own functions.
3. Two-and three dimensional graphics for plotting and displaying data
4. A complete online help system
5. Powerful matrix or vector oriented high level programming language for individual applications.
6. Toolboxes available for solving advanced problems in several application areas.

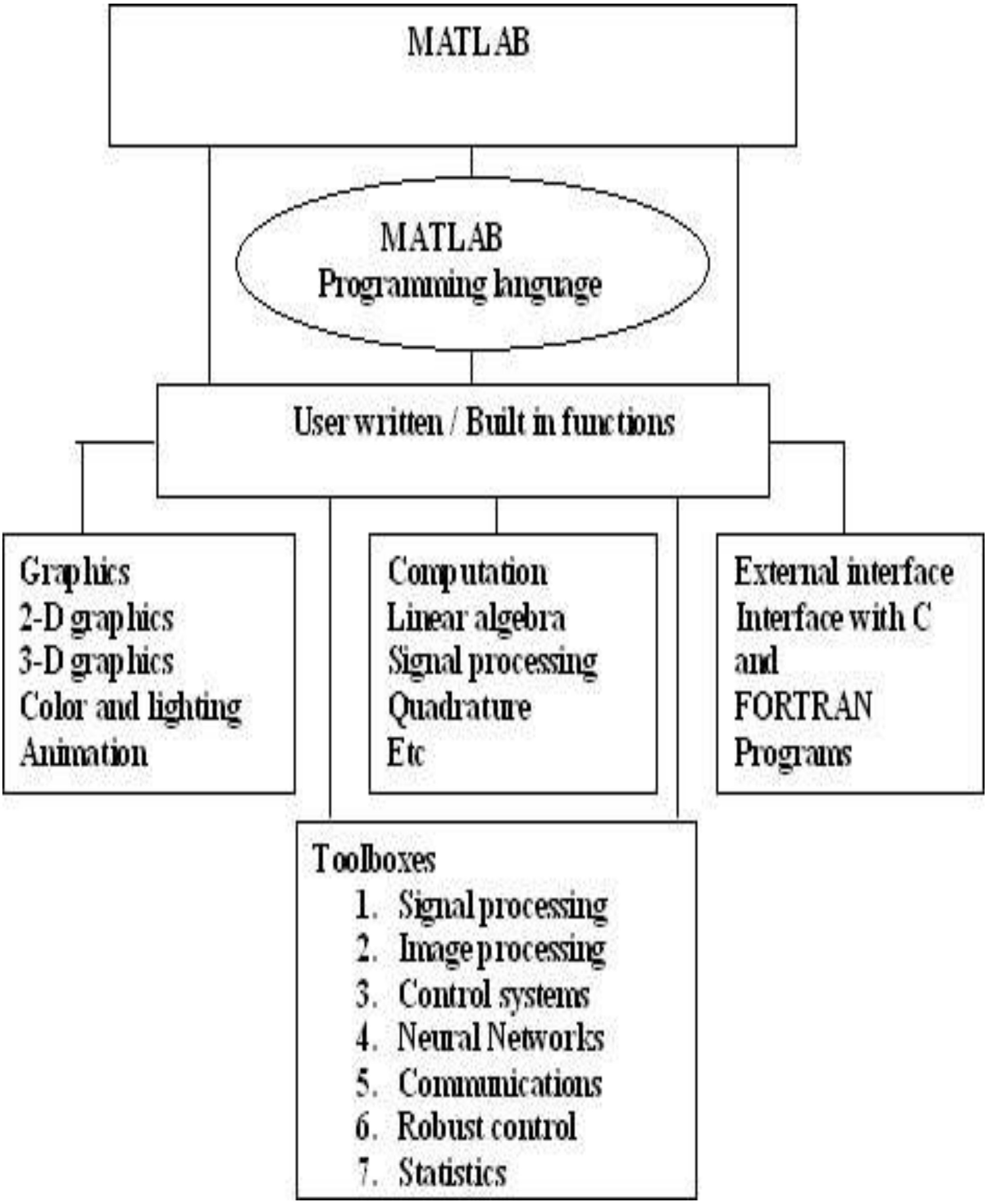


Fig. 5.1 Features and capabilities of MATLAB

5.2 MATLAB INSTALLATION

Installation Procedure for MATLAB Software

Redundant clients-Windows XP-SP2/Vista/Windows 7/Windows 8

Download:

- win32.rar or win64.rar (for 64 bit system)
- PLP
- "license.dat" ***from http://mirror.iitd.ernet.in/matlab*** into Your Desired Folder.

STEPS: Installation of MATLAB Software for window XP/VISTA / Windows 7/8

Get administrator privileges for the system on which you plan to install MATLAB. Use WinRAR to extract RAR file

Step1: Start the installer

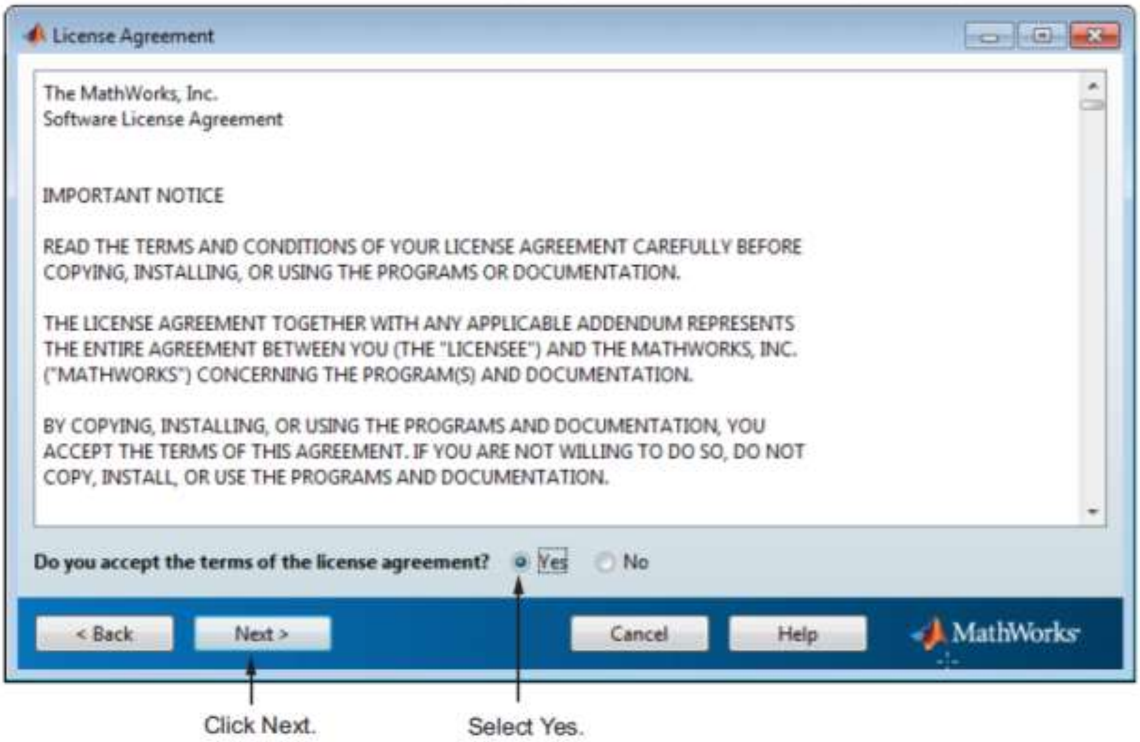
For Windows, double-clicking on setup.exe

Step 2: Choose to Install Without Using the Internet

When it starts, the installer displays the following dialog box. Select the Install without using the Internet option and Click OK to proceed with installation.

Step 3: Review the License Agreement

Review the software licensing agreement and, if you agree to its terms, click Yes.



Step 4: Enter the File Installation Key

Enter your File Installation Key and Click OK.

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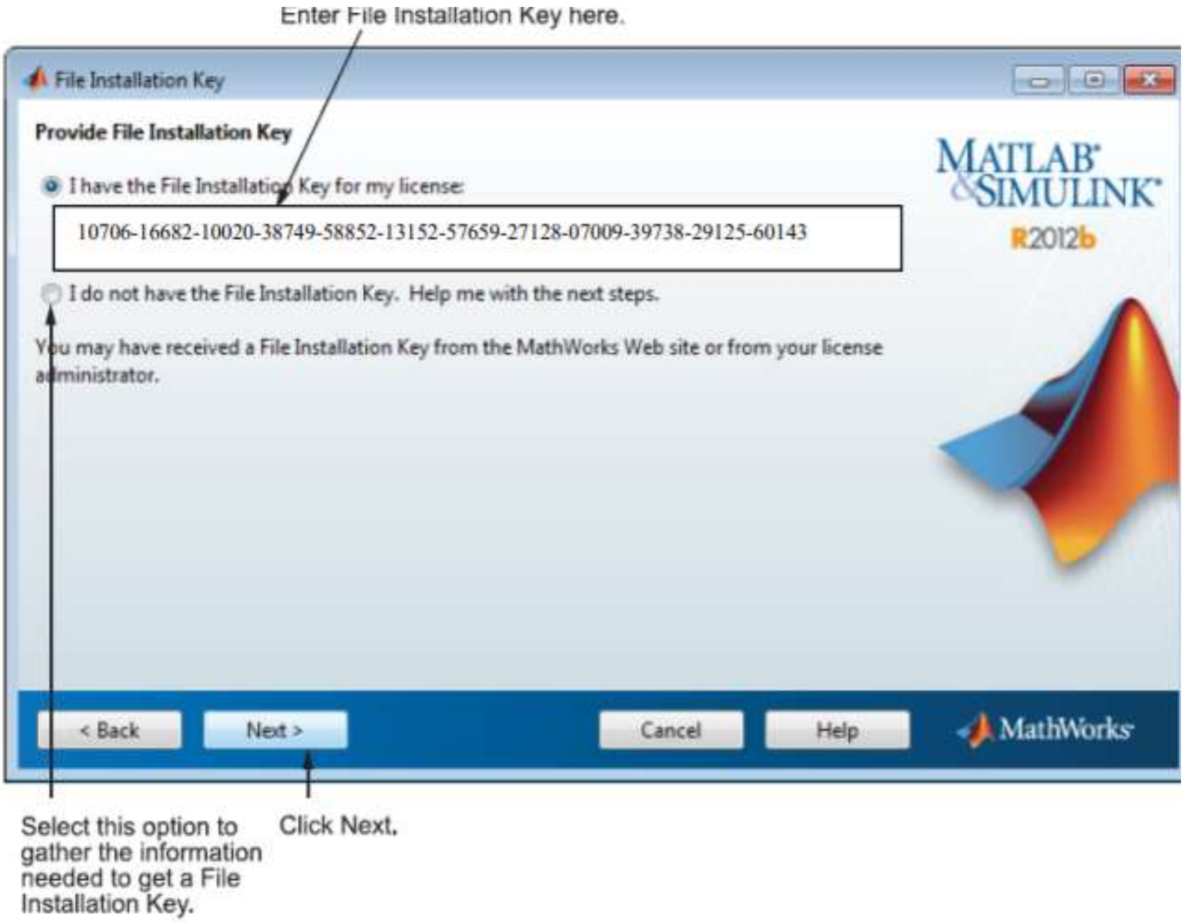
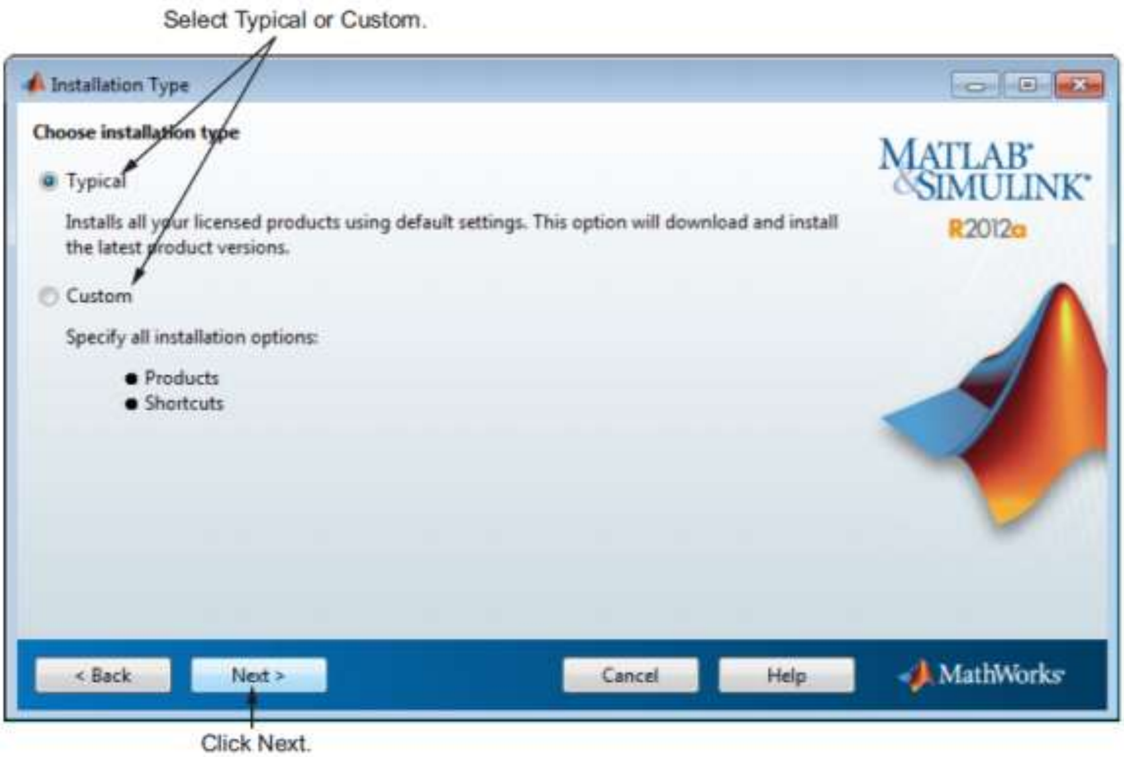


Step 5: Choose the Installation Type

In the Installation Type dialog box, specify whether you want to perform a Custom installation and click Next.



Step 6: Specify the Installation Folder

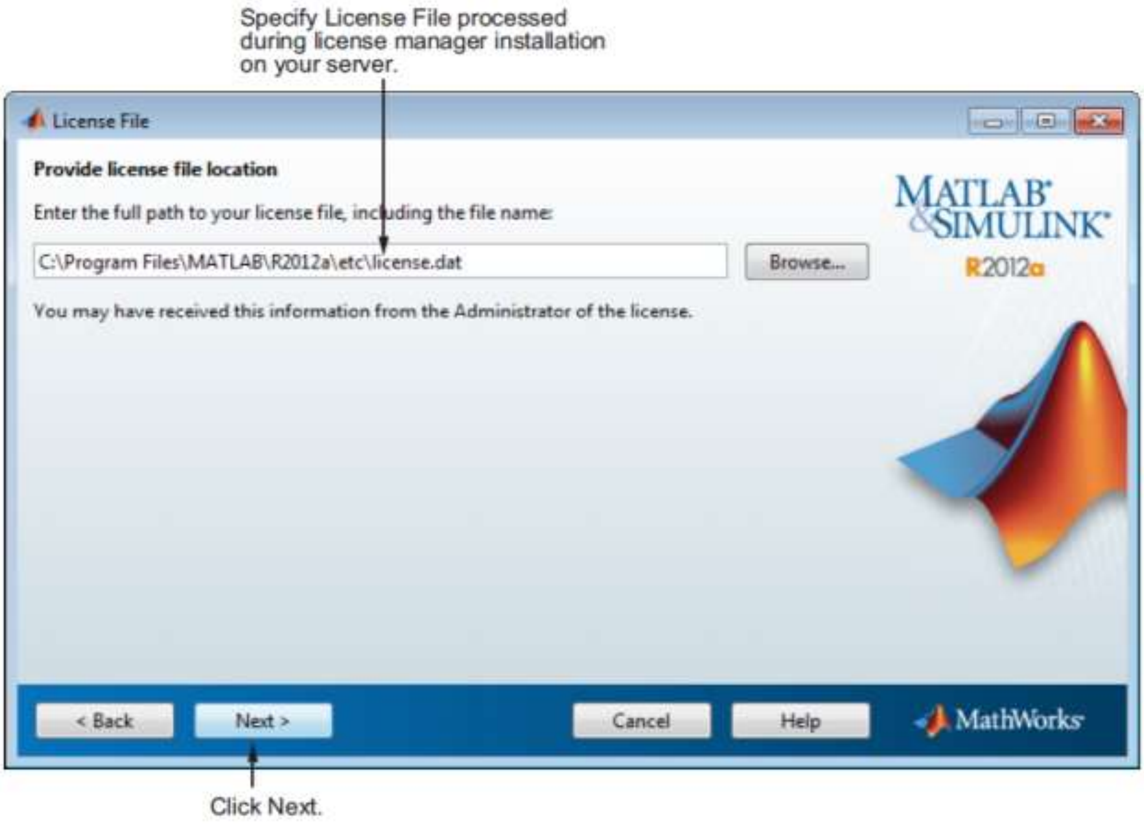
Specify the name of the folder where you want to install MathWorks products. Accept the default installation folder or click Browse to select a different one. If the folder doesn't exist, the installer creates it.

Step 7: Specify Products to Install (Custom Only)

Leave it by default and continue.

Step 8: Specify the Location of the License File

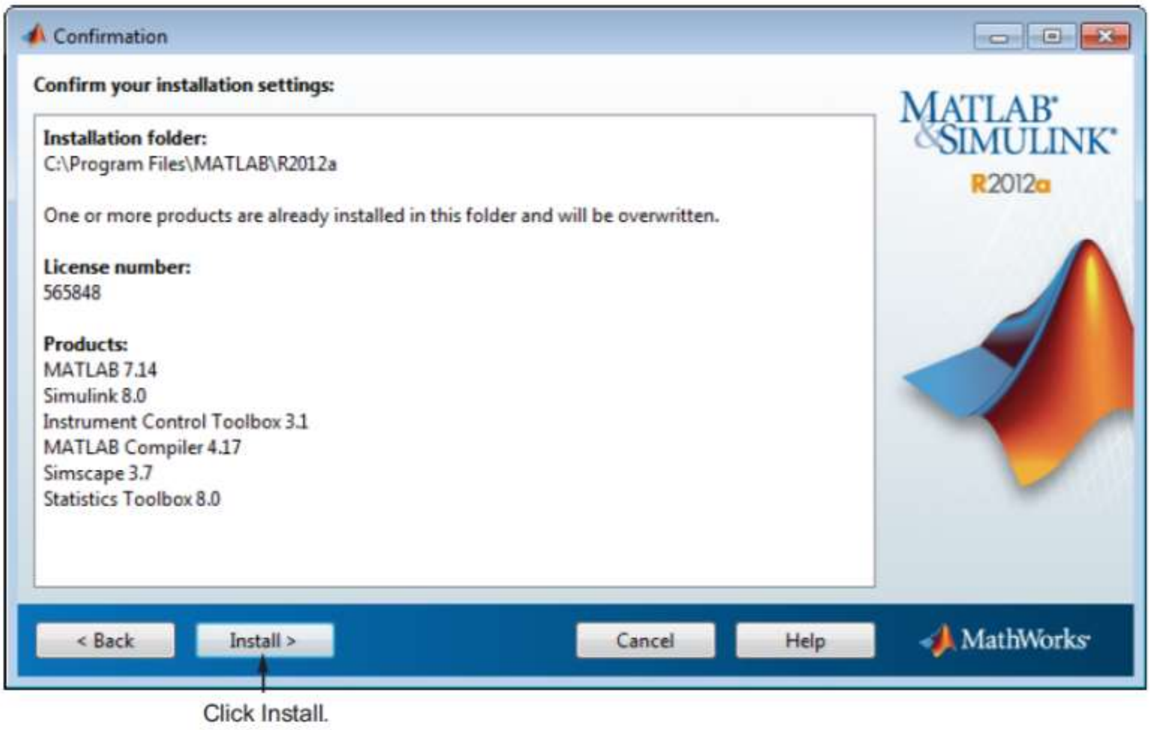
Enter the full path of your License File in the text box (or drag and drop the file) and click Next.



Step 9: Specify Installation Options (Custom Only)

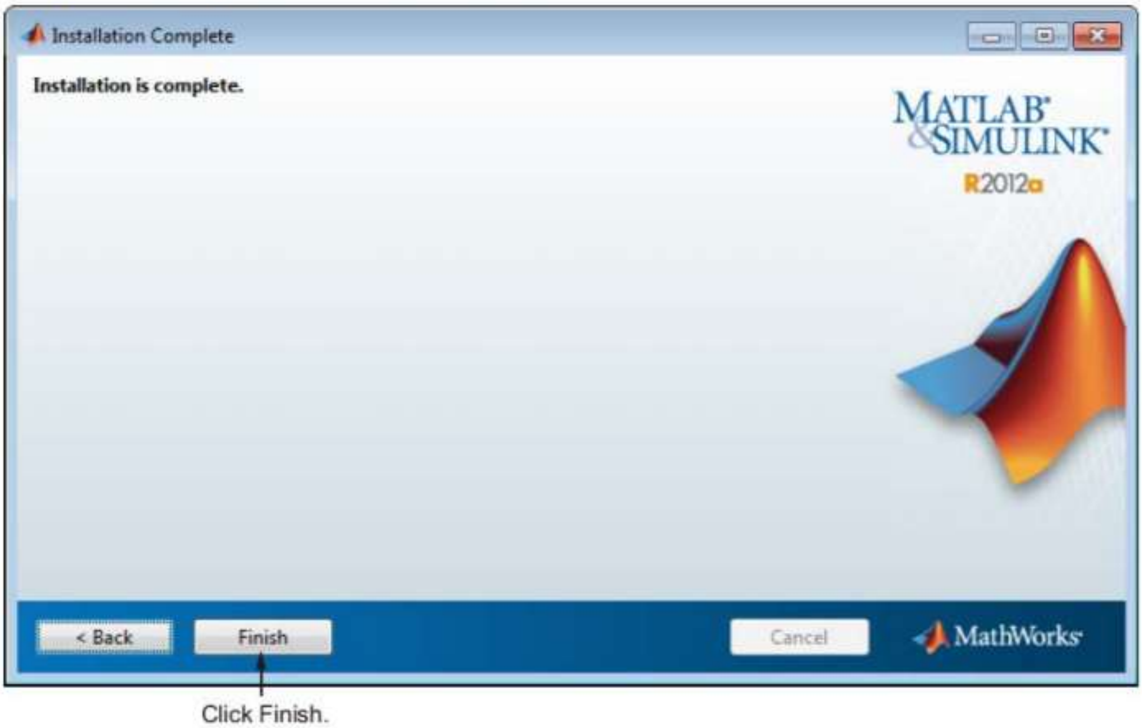
After selecting installation options, click Next to proceed with the installation.

Step 10: Confirm Your Choices and Begin Copying Files Before it begins copying files to your hard disk, the installer displays a summary of your installation choices. To change a setting, click Back. To proceed with the installation, click Install. As it copies files to your hard drive, the installer displays a status dialog box to show the progress of the installation.



Step 11: Complete the Installation

Step 11: Complete the Installation



Step 12: Set Environment Variables

Click right Button on My Computer

Select Properties……..>Advanced System settings ……>Environment

Variables…>New

The environment variable that should be added is as follows:

Variable_ name: MLM_LICENSE_FILE

Variable_value:27000@licmngr1.iitd.ernet.in, 27000@licmngr2.iitd.ernet.in, 27000@ licmanager.cse.iitd.ernet.in.

5.3 The MATLAB SYSTEM

The MATLAB System consists of five main parts

- Development Environment:

This is the set of tools and facilities that help you use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, command history an editor and debugger, and browsers for viewing help the workspace, files, and the search path.

• The MATLAB Mathematical Function Library:

This is a vast collection of computational algorithms ranging from elementary functions, like sum sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

• 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. It allows both programming in the small to rapidly create quickly programs, and "programming in the large" to create large and complex application programs.

• Graphics:

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three dimensional data visualization, video processing, animation, and presentation graphics. It also includes low-level functions that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on your MATLAB applications

• The MATLAB Application Program Interface (API):

This is a library that allows you to write C and Fortran programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files .

5.4 Starting MATLAB

On Windows platforms, start MATLAB by double-clicking the MATLAB shortcut icon on your Windows desktop. On UNIX platforms, start MATLAB by typing mat lab at the operating system prompt. You can customize MATLAB start-up. For example, you can change the directory in which MATLAB starts or automatically execute MATLAB statements in a script file named start-ups.

5.5 MATLAB Desktop

When you start MATLAB, the MATLAB desktop appears, containing tools (graphical user interfaces) for managing files, variables, and applications associated with MATLAB. The following illustration shows the default desktop. You can customize the arrangement of tools and documents to suit your needs.

5.6 MATLAB Working Environment

• MATLAB Desktop:

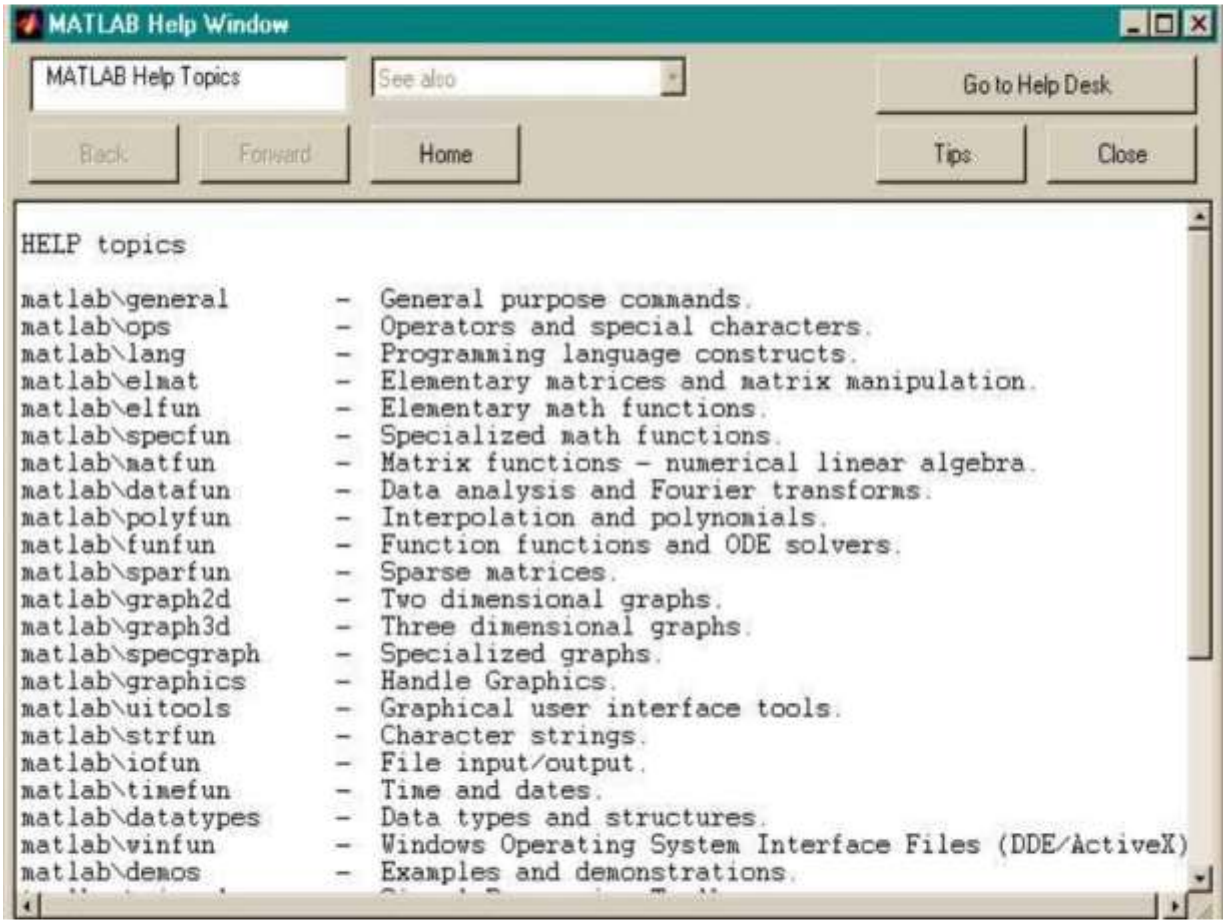
MATLAB Desktop is the main MATLAB application window. The desktop contains five sub windows the command window, the workspace browser the current directory window, the command history window, and one or more figure windows, which are shown only when the user displays a graphic. The command window is where the user types MATLAB commands and expressions at the prompt(>>) and where the output of those commands is displayed. MATLAB defines as the workspace as the set of variables that the user creates in a work session. The workspace browser shows these variables and some information about them. Double clicking on a variable in the workspace browser launches the Array Editor, which can be used to obtain information and income instances edit certain properties of the variable. The current Directory tab above the workspace tab shows the contents of the current directory, whose path is shown in the current directory window. For example, in the windows operating system the path might be as follows: C-MATLAB Work, indicating that directory "work" is a subdirectory of the main directory MATLAB WHICH IS INSTALLED IN DRIVE C. clicking on the arrow in the current directory window shows a list of recently used paths. Clicking on the button to the right of the window allows the user to change the current directory. MATLAB uses a search path to find M-files and other MATLAB related files, which are organize in directories in the computer file system. Any file run in MATLAB must reside in the current directory or in a directory that is on search path. By default, the files supplied with MATLAB and math works toolboxes are included in the search path. The easiest way to see which directories is on the search path. The easiest way to see which directories are soon the search paths, or to add or modify a search path, is to select set path from the File menu the desktop, and then use the set path dialog box. It is good practice to add any commonly used directories to the search path to avoid repeatedly having the change the current directory. The Command History Window contains a record of the command window, including both current and previous MATLAB sessions. Previously entered MATLAB commands can be selected and re-executed from the command History window by right clicking on a command or sequence of commands. This action launches a menu from which to select various options in addition to executing the commands. This is a use to select various options in addition to executing the commands. This is useful feature when experimenting with various commands in a work session.

• Using the MATLAB Editor to create M-Files:

The MATLAB editor is both a text editor specialized for creating M-files and graphical MATLAB debugger. The editor can appear in a window by itself, or it can be a sub window in the desktop, M-files are denoted by the extension m The MATLAB editor window has numerous pull-down menus for tasks such as saving viewing, and debugging files. Because it performs some simple checks and also uses colour to differentiate between various elements of code, this text editor is recommended as the tool of choice for writing and editing M functions. To open the editor, type edit at the prompt opens the M-file filenames in an editor window ready for editing. As noted earlier the file must be in the current directory, or in a directory in the search path.

• GettingHelp:

The principle way to get help online is lo use the MATLAB help browser, opened as a separate window either by clicking on the question mark symbol (?) on the desktop toolbar, or by typing help browser at the prompt in the command window. The help Browser is a web browser integrated into the MATLAB desktop that displays a Hypertext Markup Language (HTML) documents. The Help Browser consists of two panes, the help navigator pane, used to find information, and the display pane, used to view the information. Self explanatory tabs other navigator pane are used to perform a scratch. For example, help on a specific function is obtained by selecting the search tab, selecting Function Name as the Search Type, and then typing in the function name in the Search for field. It is good practice to open the Help Browser at the beginning of a MATLAB session to have help readily available during code development or other MATLAB task.



Another way to obtain for a specific function is by typing doc followed by the function name at the command prompt. For example, typing doc format displays documentation for the function called format in the display pane of the Help Browser. This command opens the browser if it is not already open.

M-functions have two types of information that can be displayed by the user The first is called the HI line, which contains the function name and alone line description the second is a block of explanation called the Help text block. Typing help at the prompt followed by a function name displays both the HI line and the Help text for that function in there command window.

Typically look for followed by a keyword displays all the HI lines that contain that keyword. This function is useful when looking for a particular topic without knowing the names of applicable functions. For example, typing look for edge at the prompt displays the HI lines containing that keyword. Because the HI line contains the function name, it then becomes possible to look at specific functions using the other help methods. Typing look for edge-all at the prompt displays the HI line of all functions that contain the word edge in cither the HI line or the Help text block. Words that contain the characters edge also are detected. For example, the HI line of a function containing the word poly edge in the H1 line or Help text would also be displayed.

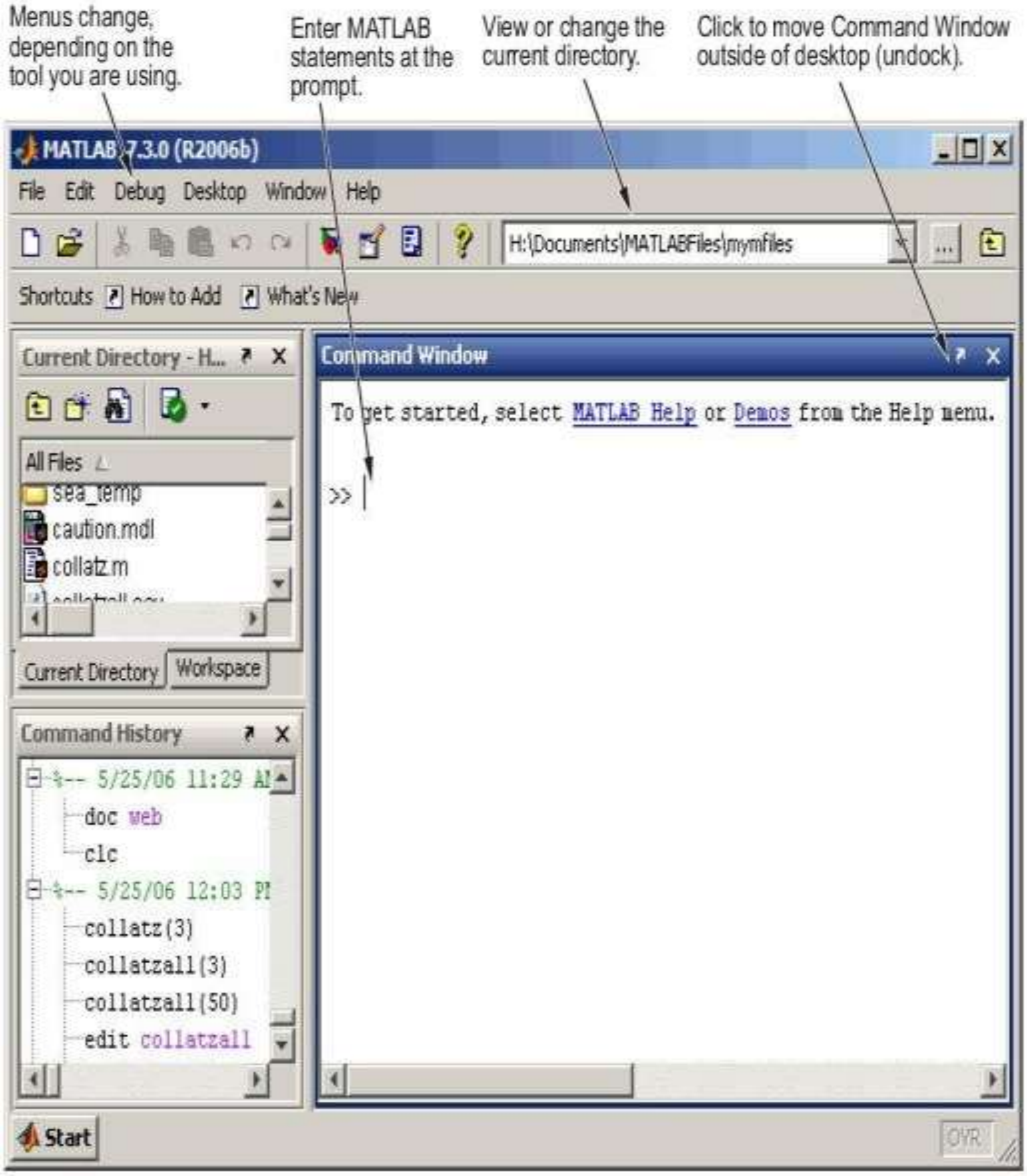
5.7 Saving and Retrieving a Work Session

There are several ways to save and load an entire work session or selected workspace variables in MATLAB. The simplest is as follows.

To save the entire workspace, simply right-click on any blank space in the workspace Browser window and select Save Workspace as from the menu that appears. This opens a directory window that allows naming the file and selecting any folder in the system in which to save it. Then simply click Save. To save a selected variable from the workspace, select the variable with a left click and then right-click on the highlighted area. Then select Save Selection As from the menu that appears. This again opens a window from which a folder can be selected to save the variable.

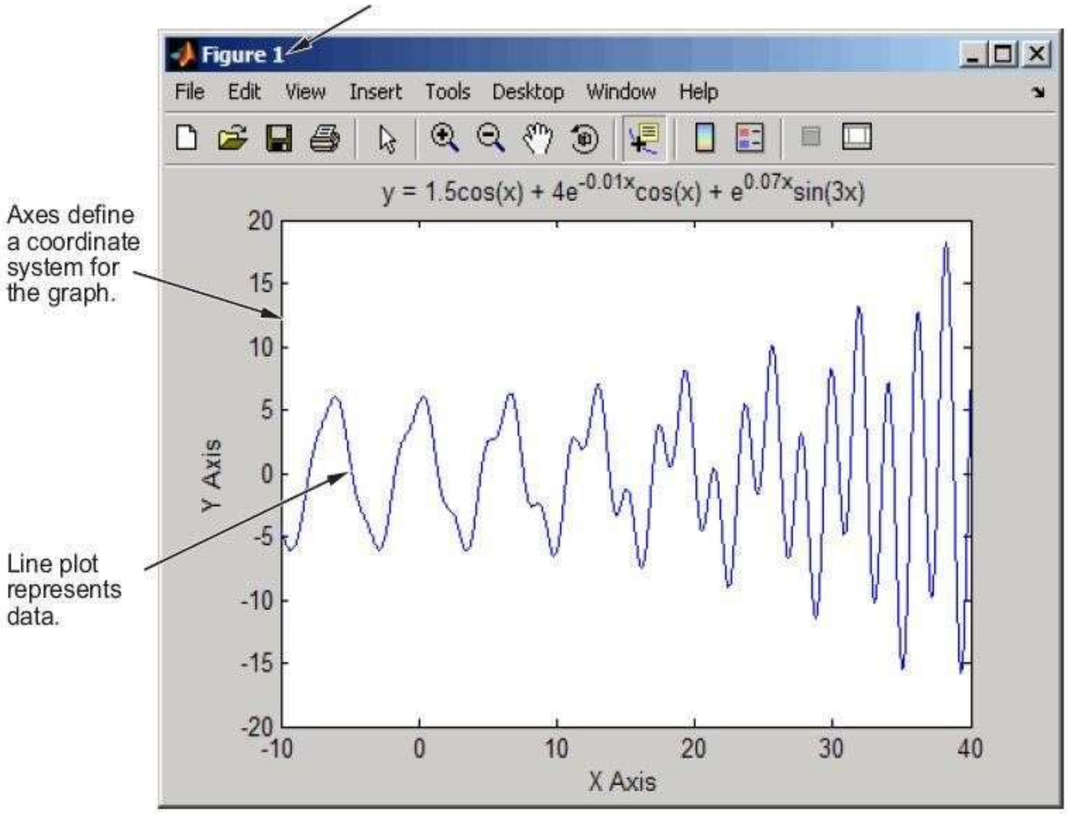
To select multiple variables, use shift click or control click in the familiar manner, and then use the procedure just described for a single variable. All files are saved in the double-precision, binary format with the extension mat. These saved files commonly are referred to as MAT-files. For example, a session named, says mywork_2012-02-10, and would appear as the MAT-file mywork_2012_02_10.mat when saved. Similarly, a saved video called final video will appear when saved as final_ video.mat.

To load saved workspaces and/or variables, left-click on the folder icon on the toolbar of the workspace Browser window. This causes a window to open from which a folder containing MAT-file or selecting open causes the contents of the file to be restored in the workspace Browser window. It is possible to achieve the same results described in the preceding paragraphs by typing save and load at the prompt with the appropriate file names and path information. This approach is not as convenient, but it is used when formats other than those available in the menu method are required.



• Graph Components:

MATLAB displays graphs in a special window known as a figure. To create a graph, you need to define a coordinate system. Therefore every graph is placed within Axes, which are contained by the figure. The actual visual representation of the data is achieved with graphics objects like lines and surfaces. These objects are drawn within the coordinate system defined by the axes, which MATLAB automatically creates specifically to accommodate the range of the data. The actual data is stored as properties of the graphics objects.



• Plotting Tools

Plotting tools are attached to figures and create an environment for creating Graphs.

These tools enable you to do the following:

• Select from a wide variety of graph types

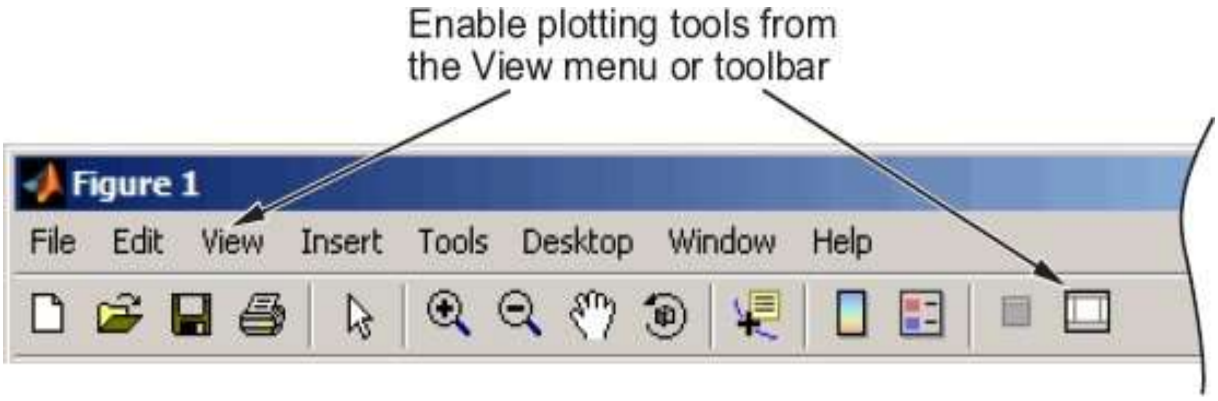
• Change the type of graph that represents a variable

• See and set the properties of graphics objects

• Annotate graphs with text, arrows, etc.

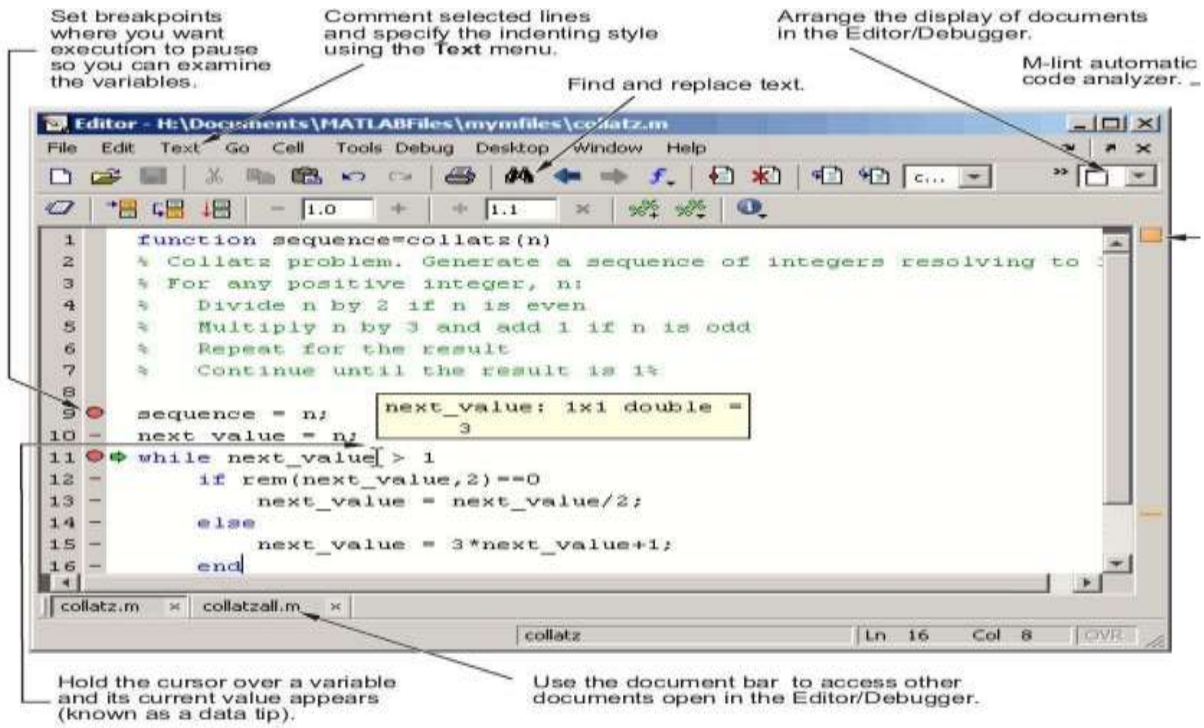
• Drag and drop data into graphs

Display the plotting tools from the View menu or by clicking the plotting tools icon in the figure toolbar, as shown in the following picture.



• Editor/Debugger

Use the Editor/Debugger to create and debug M-files, which are programs you write to run MATLAB functions. The Editor/Debugger provides a graphical user interface for text editing, as well as for M-file debugging. To create or edit an M-file use File > New or File > Open, or use the edit function.



CHAPTER-6

SIMULATION RESULTS

CHAPTER-6

SIMULATION RESULTS

This project focuses on how MIMO-NOMA outperforms remaining techniques like NOMA and OMA w.r.t each parameter. The Simulation results shows a comparison of each parameter w.r.t the three different techniques. For the analysis of Power allocation, Channel capacity, Outage probability, and Bit error rate for three different techniques, MATLAB 2015a is used with the following specifications.

6.1 Parameters Specifications

TABLE 6.1 Following are the specifications that are used

Parameters	Specifications
Techniques used	MIMO-NOMA,NOMA,OMA
p_1	0.75
p_2	0.25
D1	5000
D2	2000
N	10^5
N0	-174 + 10*$\log_{10}$(BW)
BW	10^6
R	1
eta	4
Channel type	Rayleigh fading channel
Modulation type	BPSK
Transmit power range	0:30 (dB)

6.2 Power allocation table at different transmitted powers

TABLE 6.2POWER ALLOCATION VALUES OF MIMO-NOMA, NOMA, OMA AT DIFFERENT TRANSMITTED POWER FOR TWO DIFFERENT USERS

Tx Power (dB)	MIMO-NOMA US1	NOMA US1	MIMO-OMA US1	MIMO-NOMA US2	NOMA US2	MIMO-OMA US2
0	0.000	0.000	0.000	0.0112	0.005	0.021
10	0.008	0.004	0.005	0.1055	0.054	0.18
20	0.079	0.041	0.053	0.7271	0.431	0.854
30	0.492	0.306	0.369	2.632	1.918	2.16

6.3 CHANNEL CAPACITY TABLE OF DIFFERENT TRANSMITTED POWERS

TABLE 6.3CHANNEL CAPACITY VALUES OF MIMO-NOMA, NOMA, OMA AT DIFFERENT TRANSMITTED POWER

TRANSMIT POWER(dB)	MIMO-NOMA	NOMA	MIMO-OMA
0	12.68	7.588	3.348
10	17.31	11.52	5.458
20	20.97	15.06	7.647
30	24.35	18.42	9.858

6.4 OUTAGE PROBABLITY TABLE OF DIFFERENT TRANSMITTED POWERS

TABLE 6.4OUTAGE PROBABILITY VALUES OF MIMO-NOMA, NOMA, OMA AT DIFFERENT TRANSMITTED POWER FOR TWO DIFFERENT USERS

TRANSMIT POWER (dB)	NOMA US1	MIMO-OMA US1	MIMO-NOMA US1	MIMO-OMA US2	NOMA US2	MIMO-NOMA US2
0	0.391	0.312	0.221	0.182	0.163	0.085
10	0.048	0.036	0.024	0.019	0.017	0.008
20	0.004	0.003	0.002	0.001	0.001	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000

6.5 POWER ALLOCATION TABLE OF DIFFERENT TRANSMITTED POWERS

TABLE 6.5BER VALUES OF MIMO-NOMA, NOMA, OMA AT DIFFERENT TRANSMITTED POWER FOR TWO DIFFERENT USERS

TRANSMIT POWER (dB)	NOMA US1	MIMO-NOMA US1	NOMA US2	MIMO-NOMA US2
0	0.3137	0.262	0.220	0.147
10	0.148	0.103	0.040	0.021
20	0.033	0.018	0.004	0.002
30	0.003	0.001	0.000	0.000

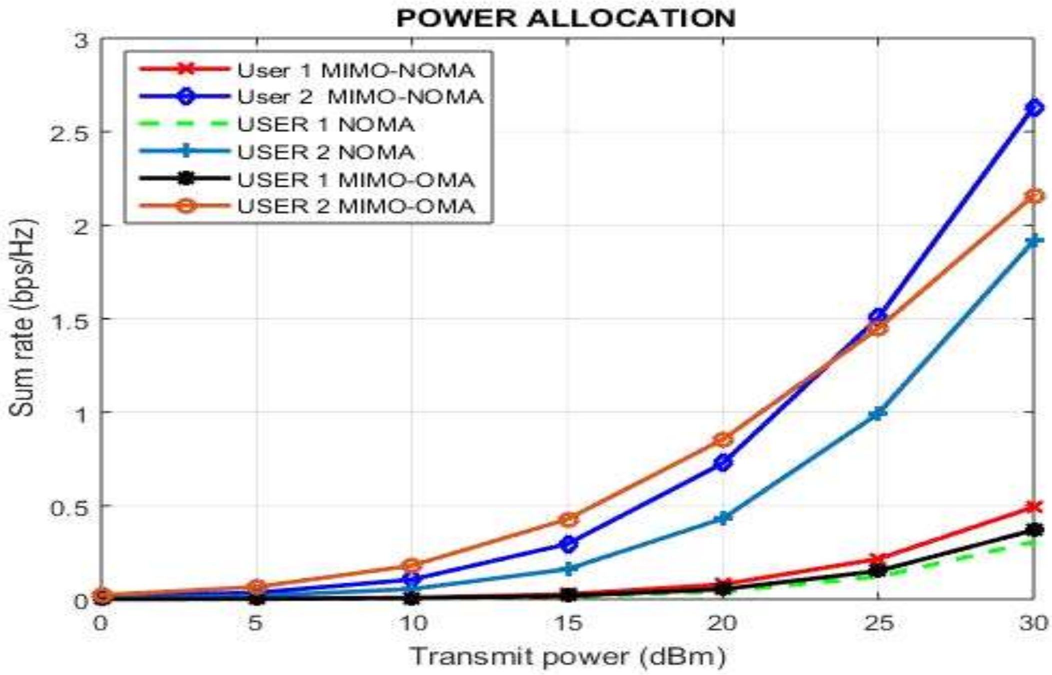


Figure 6.1 Power Allocation of MIMO-NOMA, NOMA, and OMA for two different users

Figure 6.1 llustrates the power allocation of three different techniques -OMA, NOMA, and MIMO-NOMA. The PA of two users-far user and a near user is depicted in the figure. It is evident from the figure that the power allocation of three different techniques-OMA, NOMA, and MIMO-NOMA for two different users are observed and analysed close to each other. For near user which is allocated with less power gives better performance than the far user which is allocated with high power. Among all, MIMO-NOMA outperforms remaining techniques at larger values of transmit power. For both near and far users MIMO-NOMA beat the remaining techniques. For example, from TABLE IIat transmit power (dB) = 20 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.07936, 0.05346, 0.05388, 0.7271, 0.4314 and 0.8545 respectively. From TABLE II at transmitting power (dB) = 30 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.07936, 0.05346, 0.05388, 0.7271, 0.4314 and 0.8545 respectively. From TABLE II at transmitting power (dB) = 30 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.4925, 0.3072, 0.3696, 2.632, 1.917, and 2.16 respectively. From the above two examples, it is clear that as transmitted power increases MIMO-NOMA outperforms all other techniques.

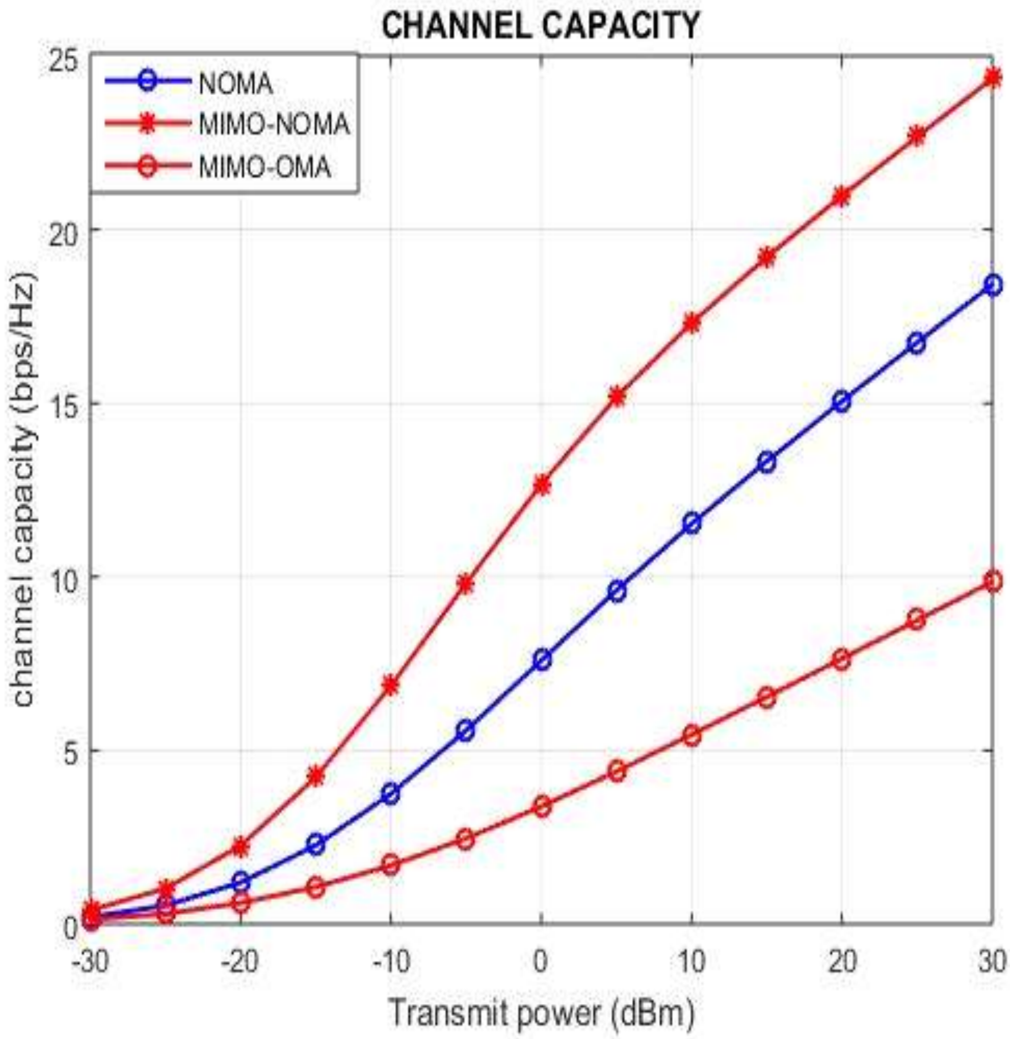


Figure 6.2 Channel Capacity of MIMO-NOMA, NOMA, and OMA for two different users

Figure 6.2 Depicts the effect of channel capacity for three different techniques OMA, NOMA, and MIMO-NOMA. Among all MIMO-NOMA outperforms remaining techniques at all the values of transmit power. For example, from TABLE III at transmitting power (dB) = 20 the obtained values for MIMO-NOMA, NOMA, and MIMO-OMA are 20.97, 15.06, and 7.6460 respectively. From TABLE III at transmitting power (dB) = 30 the obtained values for MIMO-NOMA, NOMA, and MIMOOMA are 24.35, 18.43, and 9.857 respectively. From the above two examples, it is clear that the Channel capacity of MIMO-NOMA outperforms all other techniques at all the values of transmit power..

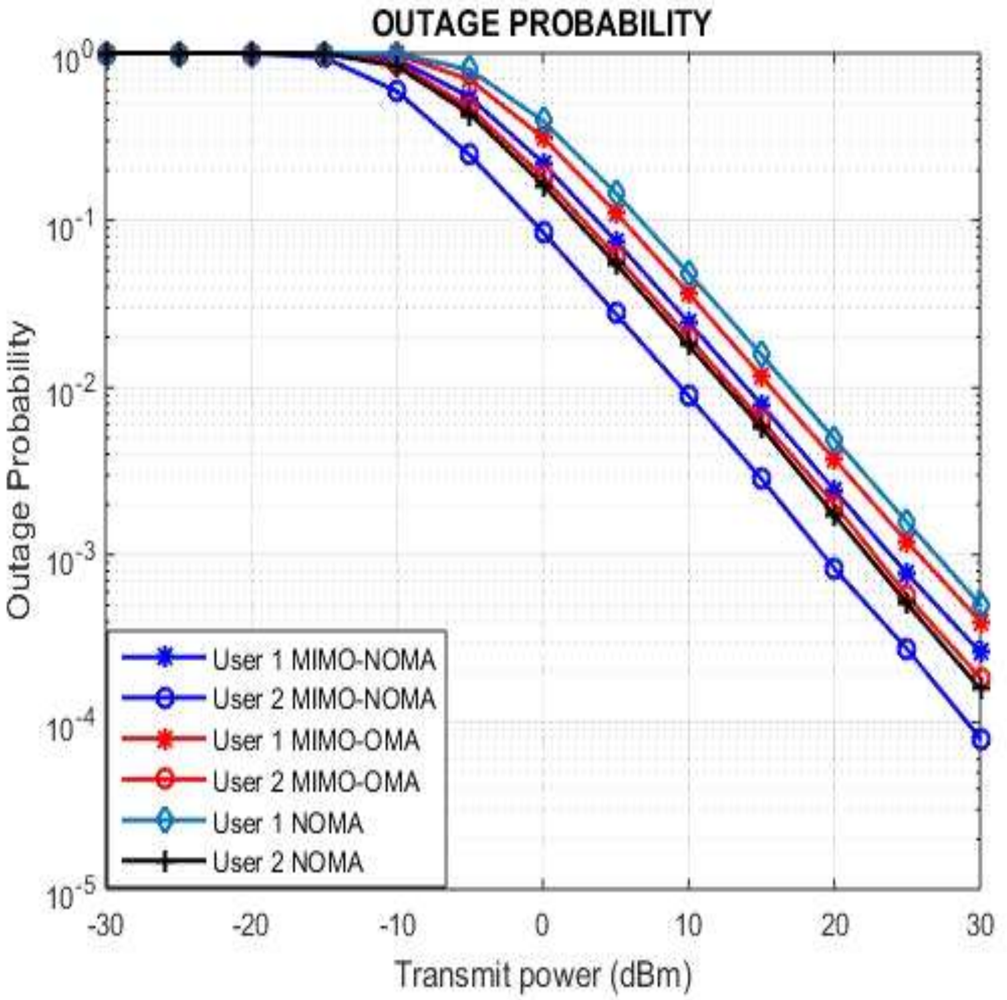


Figure 6.3 Outage Probability of MIMO-NOMA, NOMA, and OMA for two different users.

Figure 6.3 shows the effect of outage probability for three different techniques-OMA, NOMA, and MIMO-NOMA. Among all, MIMO-NOMA outperforms remaining techniques at all the values of transmitting power. For example, from TABLE IV at transmit power (dB) = 20 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2 and MIMO-OMA US2 are 0.002524, 0.005038, 0.003634, 0.000856, 0.001752, and 0.001972 respectively. From TABLE IV at transmit power (dB) = 30 the obtained values for MIMO-NOMA US1, NOMA US1, MIMOOMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.000258, 0.000538, 0.000378, 8.8e-05, 0.000158, and 0.00021 respectively. From the above two examples, it is clear that the Outage probability of MIMO-NOMA is less comparatively. Lesser the outage probability better would be the performance of the system.

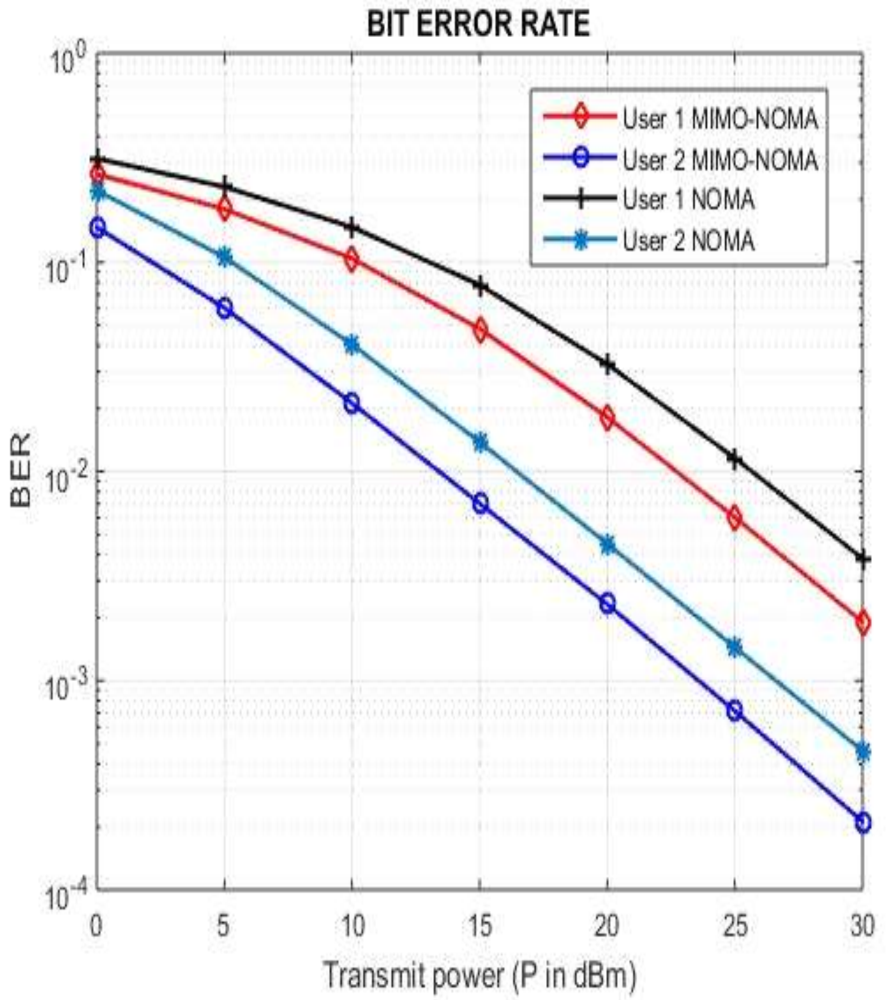


Figure 6.4 Bit Error Rate of MIMO-NOMA and NOMA for two different users.

Figure 6.4 depicts the effect of Bit error rate for three different techniques-OMA, NOMA, and MIMO-NOMA. Among all MIMO-NOMA outperforms remaining techniques at all the values of transmit power. For example, from TABLE V at transmit power (dB) = 20 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO- OMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.01793, 0.03278, x, 0.002231, 0.004442, and y respectively. From TABLE V at transmitting power (dB) = 30 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.002014, 0.003824, x, 0.000225, 0.00046, and y respectively. From the above two examples, it is clear that the BER of MIMO-NOMA is less comparatively. Lesser the bit error rate better would be the performance

CONCLUSION

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In OMA, Orthogonal multiple access techniques are used, because of that it can strict to limited users and it cannot satisfy the number of subscribers day by day, and also it cannot satisfy the low latency, massive connectivity and spectral efficiency. To satisfy the number of increasing subscribers NOMA technique is introduced. The performance of NOMA is better than OMA in latency, spectral efficiency, and massive connectivity because it uses the same resource blocks for different user's data transmission. But Bit error rate and SNR are not upto the mark. A MIMO system is incorporated with the NOMA technique to achieve less BER and good SNR. An individual sum-rate and SNR equations for each user are calculated and compared among MIMO-NOMA, NOMA, and OMA have been investigated and plotted. From that, we conclude that MIMO-NOMA achieves a higher individual rate than NOMA and OMA for a simple two-user scenario. For all four parameters-Power allocation, Channel capacity, Outage probability, and Bit error rate, a comparison has been done among all the three techniques in which MIMO-NOMA provides better performance. In this paper, we provide a complete analysis of how each system performs and are compared each system model with others for a simple two-user scenario. For all four parameters, the Simulation results and performance of each technique are analysed.

Future Scope

In this paper we have used Rayleigh fading channel between the transmitter and the receiver. In future this work can be extended by replacing Rayleigh channel with Rician and AWGN channels and predicting the channel which provides better performance.

CHAPTER-7

BIBLIOGRAPHY

CHAPTER -7

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Performance Evaluation of MIMO-NOMA for the Next Generation Wireless Communications

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***Abstract*—The principal objective of this paper is the performance evaluation of Multi-Input Multi-Output Non-Orthogonal Multiple Access (MIMO-NOMA) for Next Generation Wireless Communication Systems. The efficiency of the MIMO-NOMA technique over Non-Orthogonal Multiple Access (NOMA) and Orthogonal Multiple Access (OMA) is examined by using distinct parameters, in particular, Power Allocation (PA), Bit Error Rate (BER), Outage Probability (OP), and Channel Capacity (CC). A system model for MIMO is assumed for the two-user scenario. A Rayleigh fading channel is assumed between the Transmitter and the receiver. By using Rayleigh fading channel coefficients, calculated the achievable rates and SNR equations for all techniques and then compared each parameter with others. Finally, the simulation results are provided to facilitate the performance analysis of MIMO-NOMA for a next-generation wireless communication system and also demonstrate the accuracy of the developed analytical results.**

Keywords*—Multiple-In and Multiple-Out Non-Orthogonal Multiple Access (MIMO-NOMA), Non-Orthogonal Multiple Access (NOMA), Orthogonal Multiple Access (OMA), Power Allocation (PA), Channel Capacity (CC), Bit Error Rate (BER), Outage Probability (OP), Signal to Noise Ratio (SNR) and Successive Interference Cancellation (SIC).

I. INTRODUCTION

Different multiple access schemes are acquired from First Generation (1G) to Fourth Generation (4G). All the proposed schemes from 1G to 4G are common in one particular subject [1-4]. That is the signals that are transmitted from the transmitter to the receiver must be orthogonal to each other [5]. OMA is one of the multiple access schemes which uses orthogonal resource allocation among individual users to avoid intra-cell interference. This technique also helps in the dissociation of respective user data in which time and frequency resources are split for multiple receivers in current broadcasting systems [6]. But the number of users that can be supported through this OMA method is then limited by the number of orthogonal resources available. As 4G, uses the OMA approach, that cannot satisfy high-speed communication or with low latency, etc. The main disadvantages of 4G networks are, they don't accomplish the exponential growth in capacity demands, low latency, massive connectivity, high throughput, and energy efficiency. A lot of investigations have been done to satisfy various requirements in practical systems in the history of broadband multimedia communications and broadcasting [7-8]. Among all, 5G technology comes with a better solution. Since it uses Non-Orthogonal Multiple Access (NOMA). NOMA uses the same resource blocks to transmit multiple users' signals from the transmitter to the receiver. During the transmission of signal in NOMA, at the transmitter side, it performs super position-coding technique and at the receiver side, it introduces some controllable interference like Successive Interference Cancellation (SIC), thus allows multiplexing users in the power domain [9-12].

MIMO communications send similar data as multiple signals through multiple antennas simultaneously, utilizing a single radio channel. MIMO system is incorporated with NOMA multiple access schemes to provide spatial multiplexing to increase achievable rates and diversity gain to decrease BER. The remainder of this article is presented in the following way: Section 2 Elaborate system model performance, section 3 explains MIMO-OMA and NOMA, section 4 gives an analysis of simulation results in terms of power allocation, BER, channel capacity, and outage probability and section 5 gives concluding remarks.

II. SYSTEM MODEL

Consider a 2 x 1 MIMO downlink system. Let us consider US1 and US2 to be user 1 and user 2 respectively [2]. A far user or weak user is denoted by US1 and the near user or strong user is denoted by US2. Let D1 and D2 denote the distances of US1 and US2 respectively, from the MIMO transmitter. We assume, D1>D2. Let B1 and B2 be the information intended for both users. The notations of the MIMO system are as follows, fading channel between t^{th} transmitter antenna and r^{th} receiver antenna is given by C_{rt}.

Superposition coding takes place to get the total signal transmitted with different power allocation coefficients, at the transmitter side. The total PA coefficients must be equal to 1. Let us consider, TP to be the total power for the transmission of signals from the transmitter to the respective receiver antenna or user. The total signal transmitted by transmitter antennas for 2 x1 MIMO systems is given by

$$Y = \sqrt{TP}\left(\sqrt{p_1} * B1 + \sqrt{p_2} * B2\right) \quad (1)$$

Where p1 and p2 are the NOMA power allocation coefficients. $p_1 > p_2$, because US1 is a distant user or weak user.

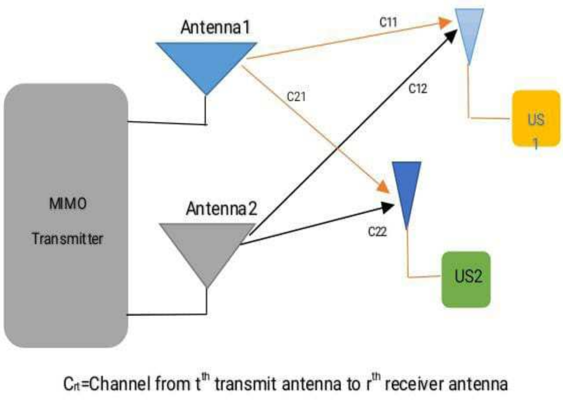

Fig. 1. Showing MIMO Downlink system model having one Base Station and two distinct users.

The total signal is transmitted to each receiver in multiple paths by each transmitter. At the receiver end, the same signal is received by both the antennas. Therefore, the received signal at US1 is given by,

$$Y_{1,MIMO} = YC_{11} + YC_{12} + N_1 = Y(C_{11} + C_{12}) + N_1 \quad (2)$$

Similarly, the signal received by US2 is given by,

$$Y_{2,MIMO} = YC_{21} + YC_{22} + N_2 = Y(C_{21} + C_{22}) + N_2 \quad (3)$$

Where N_1 and N_2 are the noise samples of AWGN with zero mean and variance σ^2

A. Decoding at User 1

At US1, the intended data for the US1 signal has the dominating PA coefficient, so direct decoding of the US1 signal takes place. The information intended for US2 is treated as interference at the US1 receiver. The SNR of a signal is given by the ratio of the original signal intended for the respective user, to the interference. Then SNR1 for US1 in decoding B1 [12] is given by,

$$SNR_{1,MIMO} = \frac{(TP*p_1|C_{11}+C_{12}|^2)}{(TP*p_2|C_{11}+C_{12}|^2)+\sigma^2} \quad (4)$$

Therefore, the achievable rate for US1 is given by,

$$AR_{1,MIMO} = \log_2(1 + SNR_{1,MIMO}) \quad (5)$$

B. Decoding at user 2

Whereas at US2, US1 signal information is allocated with more power, so decoding of US1 signal takes place directly by treating US2 signal as interference. The SNR at the US1 for direct decoding of B1is given by,

$$SNR_{12,MIMO} = \frac{TP*p_1|C_{21}+C_{22}|^2}{TP*p_2|C_{21}+C_{22}|^2+\sigma^2} \quad (6)$$

After performing SIC (successive interference cancellation), the US1 data is removed from Y, and then the remaining signal is decoded to get the US2 signal. The SNR equation for US2 to decode its signal is given by,

$$SNR_{2,MIMO} = \frac{TP*p_2|C_{21}+C_{22}|^2}{\sigma^2} \quad (7)$$

The achievable rates at US2 for decoding B1 and B2 are given by,

$$AR_{12,MIMO} = log_2(1 + SNR_{12,MIMO}) \quad (8)$$

$$AR_{2,MIMO} = \log_2(1 + SNR_{2,MIMO}) \quad (9)$$

III. MIMO-OMA

To know how MIMO-NOMA performs well, we are going to compare MIMO-NOMA with MIMO-OMA and NOMA. In MIMO-OMA, suppose we consider 2 users then the transmission time is divided into two slots. In the first time slot, both transmitter antennas transmit to the US1 signal and in the second time slot, both the transmitter antennas transmit the US2 signal. The signal transmitted by both the transmitter antennas at the first time slot is TP*B1. The signal received by US1 in the first time slot is given by,

$$Y_{1,OMA} = \sqrt{TP} * B1(C_{11} + C_{12}) + N_1 \quad (10)$$

Similarly, the signal transmitted by both the antennas in the second time slot to US2 is TP*B2 and the signal received by US2 is given by,

$$Y_{2,OMA} = \sqrt{TP} * B2(C_{21} + C_{22}) + N_2 \quad (11)$$

The SNR at US1 and US2 are given by,

$$SNR_{1,OMA} = \frac{TP|C_{11}+C_{12}|^2}{\sigma^2} \quad (12)$$

$$SNR_{2,OMA} = \frac{TP|C_{21}+C_{22}|^2}{\sigma^2} \quad (13)$$

US1 and US2 achievable rates for MIMO-OMA are given by,

$$AR_{1,OMA} = \frac{1}{2} log_2(1 + SNR_{1,OMA}) \quad (14)$$

$$AR_{2,OMA} = \frac{1}{2}\log_2(1 + SNR_{2,OMA}) \quad (15)$$

A. NOMA

In NOMA superposition coding is performed at the transmitter side and then the signal is transmitted to the receiver through the Rayleigh fading channel.

$$Y_{NOMA} = \sqrt{TP}(\sqrt{p_1} * B1 + \sqrt{p_2} * B2) \quad (16)$$

Then, at the receiver end, SIC is performed. After that, respective user information decoding takes place. In NOMA, the transmitter at the transmitter side transmits the total signal to all the receivers simultaneously. The signal received by the US1 receiver is given by,

$$Y_{1,NOMA} = Y_{NOMA} * C_f + N_1 \quad (17)$$

Similarly, the signal received by US2 at the receiver side is given by,

$$Y_{2,NOMA} = Y_{NOMA} * C_n + N_2 \quad (18)$$

Where C_f is the Rayleigh fading channel coefficient between transmitter and US1, C_n is the Rayleigh fading channel coefficient between transmitter and US2 receiver.

B. Decoding at user 1

Now, US1 has to decode B1 from the signal received by the US1 receiver. Since US1 is the weak signal, B1 is allocated with more power. Therefore, US1 can directly decode B1 from Y_{NOMA}, treating B2 as interference. The SNR 1-NOMA equation is given by,

$$SNR_{1,NOMA} = \frac{TP * p_1 |C_f|^2}{TP * p_2 |C_f|^2 + \sigma^2} \quad (19)$$

Therefore, US1 achievable rate is given by,

$$AR_{1,NOMA} = log_2(1 + SNR_{1,NOMA}) \quad (20)$$

C. Decoding at user 2

User 2 must decode B2 from $Y_{2\text{-}NOMA}$. Since US2 is a strong user, B2 is allocated with less power. Therefore, in $Y_{2\text{-}NOMA}$, the power allocated to B1 is dominating. So, US2 will first perform direct decoding on $Y_{2\text{-}NOMA}$ to obtain B1. Then SIC is carried out to remove B1. Then B2 is decoded. The SNR equation for US2 [1] is given by,

$$SNR_{2,NOMA} = \frac{TP * p_2 |C_n|^2}{\sigma^2} \quad (21)$$

Therefore, the achievable rate for US2 [1] is given by,

D. Power Allocation

The amount of power that is allocated to the user data to transmit the respective signal from the transmitter to the receiver is called power allocation. By implementing the optimum power allocation process, the efficiency of the wireless communications system has been improved. To transmit the signal from the transmitter antenna to the receiver antenna, power allocation coefficients are required, as NOMA is based on a power domain technique. The user which is distant from the transmitter antenna is allocated with high power and the user which is close to the transmitter is allocated with less power coefficient. The summation of all power allocation coefficients must be 1. In the MIMO system, NOMA is included to achieve effective sum rates which come up with greater performance. Here, in this paper, we use fixed power allocation coefficients and determine the achievable sum rates for both the users. The achievable rates for respective users are calculated from equations (20) and (21). The performance analysis of MIMO-NOMA, NOMA, and MIMO-OMA is observed and studied by considering PA as a parameter using MATLAB. Then, the graph is plotted between Transmitted power (dB) and the respective achievable rates of the respective users.

E. Channel Capacity

The data or a signal that can reliably transmit over a wireless communication channel at the highest rate is known as Channel capacity. Here, in this paper, for the transmission of a signal from the transmitter to the receiver, the Rayleigh fading channel is used. The Channel capacity of MIMO-NOMA is very high because the interference or noise added is very low. Channel capacity of a system is the summation of individual achievable rates of a respective user.

$$\text{Channel capacity} = AR1 + AR2 \quad (22)$$

Where AR1 is the total achievable rates of US1 and AR2 is the total achievable rates of US2.

F. Outage Probability

In Wireless Communication, Outage probability is expressed as the probability that the information rate to the noise, interferences or any disturbances ratio is smaller than the threshold information rate to the noise ratio. Mathematically, the outage probability can be represented as the CDF of the SNR and is given by,

$$\text{Pout}(R) = \Pr[AR < R] \quad (23)$$

Where AR is considered as the achievable rate for the respective user and R is the target rate or the threshold value. If R is high blocking rate is more. To get OP below a maximum value, the SNR threshold value should be kept low. If AR is less than the target rate, then the outage occurs. In case the target rate is high then the outage probability reaches the maximum value as noise dominates the original information. To calculate the outage probability for a user, set the target rate and count the number of times that the calculated achievable rates dropped below the target rate and plot them. In MIMO-NOMA outage probability decreases as directivity gain increases, because in MIMO-NOMA multiple antennas are used to increase directivity gain. As it is evident, that the outage probability should be less to get a significant result.

G. Bit Error Rate

Bit error rate is known as the ratio of the number of errors of bits that occur during the transmission of a signal to the total number of bits taken. The quality of digital wireless transmission is determined by the measurement of BER. If the BER of a system is low then, it provides better performance. Moreover, the different factors like channel noise, interference, distortion, and attenuation affect the BER during the transmission of a signal. Here, in this paper, we calculated BER by comparing the copy of the transmitted signal with the signal that is decoded at the receiver to the total number of bits, and then it is plotted against transmitted power.

$$\text{BEP} = \frac{number\ of\ error\ bits}{total\ number\ of\ bits} \quad (24)$$

IV. SIMULATION RESULTS

For the analysis of Power allocation, Channel capacity, Outage probability, and Bit error rate for three different techniques, MATLAB 2015a is used with the following specifications.

TABLE I. FOLLOWING ARE THE SPECIFICATIONS THAT ARE USED.

Parameters	Specifications
Techniques used	MIMO-NOMA,NOMA,OMA
p_1	0.75
p_2	0.25
D1	5000
D2	2000
N	10^5
N0	$-174 + 10*\log_{10}(BW)$
BW	10^6
R	1
eta	4
Channel type	Rayleigh fading channel
Modulation type	BPSK
Transmit power range	0:30 (dB)

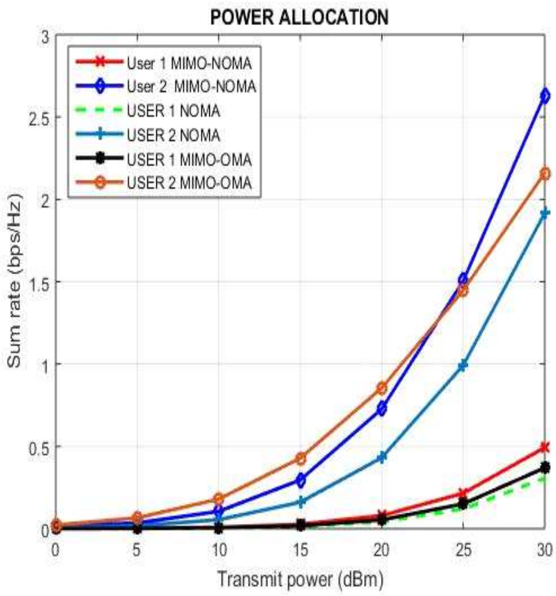

Fig. 2. Power Allocation of MIMO-NOMA, NOMA, and OMA for two different users.

Fig. 2. illustrates the power allocation of three different techniques -OMA,NOMA, and MIMO-NOMA. The PA of two users-far user and a near user is depicted in the figure. It is evident from the figure that the power allocation of three different techniques-OMA,NOMA, and MIMO-NOMA for two different users are observed and analyzed close to each other. For near user which is allocated with less power gives better performance than the far user which is allocated with high power. Among all, MIMO-NOMA outperforms remaining techniques at larger values of transmit power. For both near and far users MIMO-NOMA beat the remaining techniques. For example, from TABLE IIat transmit power (dB) = 20 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.07936, 0.05346, 0.05388, 0.7271, 0.4314 and 0.8545 respectively. From TABLE II at transmitting power (dB) = 30 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.4925, 0.3072, 0.3696, 2.632, 1.917, and 2.16 respectively. From the above two examples, it is clear that as transmitted power increases MIMO-NOMA outperforms all other techniques.

TABLE II. POWER ALLOCATION VALUES OF MIMO-NOMA, NOMA, OMA AT DIFFERENT TRANSMITTED POWER FOR TWO DIFFERENT USERS

Tx Power (dB)	MIMO-NOMA US1	NOMA US1	MIMO-OMA US1	MIMO-NOMA US2	NOMA US2	MIMO-OMA US2
0	0.000	0.000	0.000	0.0112	0.005	0.021
10	0.008	0.004	0.005	0.1055	0.054	0.18
20	0.079	0.041	0.053	0.7271	0.431	0.854
30	0.492	0.306	0.369	2.632	1.918	2.16

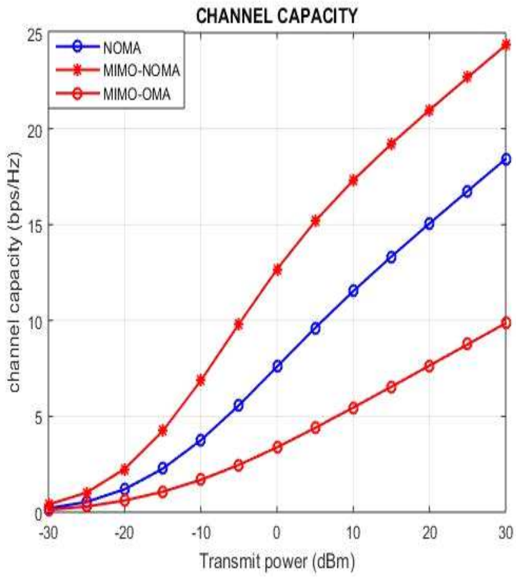

Fig. 3. Channel Capacity of MIMO-NOMA, NOMA, and OMA

Fig. 3. Depicts the effect of channel capacity for three different techniques OMA, NOMA, and MIMO-NOMA. Among all MIMO-NOMA outperforms remaining techniques at all the values of transmit power. For example, from TABLE III at transmitting power (dB) = 20 the obtained values for MIMO-NOMA, NOMA, and MIMO-OMA are 20.97, 15.06, and 7.6460 respectively. From TABLE III at transmitting power (dB) = 30 the obtained values for MIMO-NOMA, NOMA, and MIMO-OMA are 24.35, 18.43, and 9.857 respectively. From the above two examples, it is clear that the Channel capacity of MIMO-NOMA outperforms all other techniques at all the values of transmit power.

TABLE III. CHANNEL CAPACITY VALUES OF MIMO-NOMA, NOMA, OMA AT DIFFERENT TRANSMITTED POWER

TRANSMIT POWER(dB)	MIMO-NOMA	NOMA	MIMO-OMA
0	12.68	7.588	3.348
10	17.31	11.52	5.458
20	20.97	15.06	7.647
30	24.35	18.42	9.858

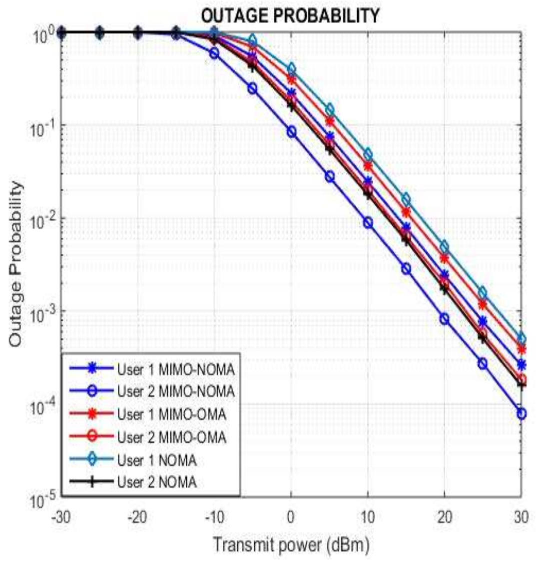

Fig. 4. Outage Probability of MIMO-NOMA, NOMA, and OMA for two different users.

Fig.4. shows the effect of outage probability for three different techniques-OMA, NOMA, and MIMO-NOMA. Among all, MIMO-NOMA outperforms remaining techniques at all the values of transmitting power. For example, from TABLE IV at transmit power (dB) = 20 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2 and MIMO-OMA US2 are 0.002524, 0.005038, 0.003634, 0.000856, 0.001752, and 0.001972 respectively. From TABLE IV at transmit power (dB) = 30 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.000258, 0.000538, 0.000378, 8.8e-05, 0.000158, and 0.00021 respectively. From the above two examples, it is clear that the Outage probability of MIMO-NOMA is less comparatively. Lesser the outage probability better would be the performance of the system.

TABLE IV. OUTAGE PROBABILITY VALUES OF MIMO-NOMA, NOMA, OMA AT DIFFERENT TRANSMITTED POWER FOR TWO DIFFERENT USERS

TRANSMIT POWER (dB)	NOMA US1	MIMO-OMA US1	MIMO-NOMA US1	MIMO-OMA US2	NOMA US2	MIMO-NOMA US2
0	0.391	0.312	0.221	0.182	0.163	0.085
10	0.048	0.036	0.024	0.019	0.017	0.008
20	0.004	0.003	0.002	0.001	0.001	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000

Fig.5. depicts the effect of Bit error rate for three different techniques-OMA, NOMA, and MIMO-NOMA. Among all MIMO-NOMA outperforms remaining techniques at all the values of transmit power. For example, from TABLE V at transmit power (dB) = 20 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.01793, 0.03278, x, 0.002231, 0.004442, and y respectively. From TABLE V at transmitting power (dB) = 30 the obtained values for MIMO-NOMA US1, NOMA US1, MIMO-OMA US1, MIMO-NOMA US2, NOMA US2, and MIMO-OMA US2 are 0.002014, 0.003824, x, 0.000225, 0.00046, and y respectively. From the above two examples, it is clear that the BER of MIMO-NOMA is less comparatively. Lesser the bit error rate better would be the performance.

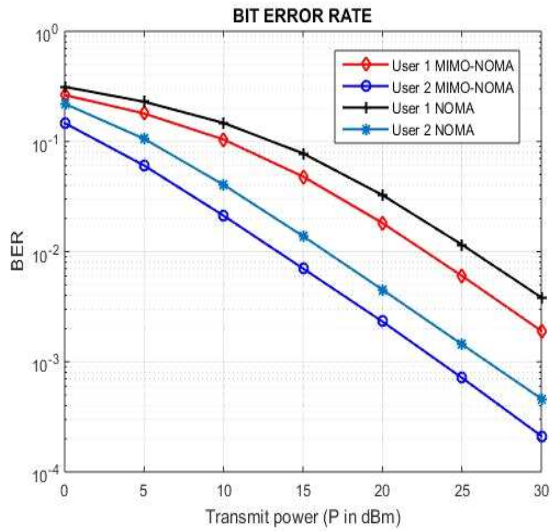

Fig. 5. Bit Error Rate of MIMO-NOMA and NOMA for two different users.

TABLE V. BER VALUES OF MIMO-NOMA, NOMA, OMA AT DIFFERENT TRANSMITTED POWER FOR TWO DIFFERENT USERS

TRANSMIT POWER (dB)	NOMA US1	MIMO-NOMA US1	NOMA US2	MIMO-NOMA US2
0	0.3137	0.262	0.220	0.147
10	0.148	0.103	0.040	0.021
20	0.033	0.018	0.004	0.002
30	0.003	0.001	0.000	0.000

V. CONCLUSION

In OMA, Orthogonal multiple access techniques are used, because of that it can strict to limited users and it cannot satisfy the number of subscribers day by day, and also it cannot satisfy the low latency, massive connectivity and spectral efficiency. To satisfy the number of increasing subscribers NOMA technique is introduced. The performance of NOMA is better than OMA in latency, spectral efficiency, and massive connectivity because it uses the same resource blocks for different user's data transmission. But Bit error rate and SNR are not up to the mark. A MIMO system is incorporated with the NOMA technique to achieve less BER and good SNR. An individual sum-rate and SNR equations for each user are calculated and compared among MIMO-NOMA, NOMA, and OMA have been investigated and plotted. From that, we conclude that MIMO-NOMA achieves a higher individual rate than NOMA and OMA for a simple two-user scenario. For all four parameters-Power allocation, Channel capacity, Outage probability, and Bit error rate, a comparison has been done among all the three techniques in which MIMO-NOMA provides better performance.

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