MIMO System Capacity based on Multiple fading channels and varying numbers of antennas including the comparison of MIMO-NOMA and MIMO-OMA

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Article Info

Article history:

Received Oct 21, 2023
Revised Dec 5, 2023
Accepted Dec 14, 2023

Keyword:

MIMO,
Massive-MIMO,
Fading channels,
SVD,
MIMO-NOMA,
MIMO-OMA

ABSTRACT

Multiput-Input, Multiple-Output (MIMO) systems have greatly improved data speed, connection stability, and spectrum efficiency, revolutionizing wireless communication. In cases where numerous fading channels coexist and the number of antennas at both the transmitter and receiver fluctuates, this paper examined the functionality of MIMO systems. In actual wireless settings, fading channels frequently occur, resulting in time-varying and spatially correlated channel characteristics. In this paper, we used a thorough analysis to investigate the capability of MIMO systems under some difficult circumstances. We considered circumstances with various numbers of antennas, channel correlation, and fading statistics, ranging from Single-Input, Single-Output (SISO) to MIMO setups. We investigated the impact of geographic diversity, Rayleigh, Rician, Nakagami fading models, and correlated fading channels on system performance. The trade-offs between the quantity of antennas, channel correlation, and capacity in MIMO systems are well illustrated by our findings. We presented our evidence in this paper to show that MIMO-NOMA is solely superior to MIMO-OMA in terms of total channel capacity, except in scenarios where communication is limited to one individual, with a power disparity for which MIMO-NOMA can achieve strictly larger rate pairs than MIMO-OMA. This study also explored the outage probability (OP) performance of MIMO-NOMA and MIMO-OMA systems in a massive MIMO communication scenario, including different fading channels. Based on these findings, we demonstrated that MIMO-NOMA can achieve a higher total ergodic capacity than MIMO-OMA.

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1. INTRODUCTION

While several industrialized nations are attempting to introduce 6G communication technologies, the majority of those nations continue to use both 4G and 5G communication systems. For this reason, we are living 5G era. Notably, a series of novel and evolutionary trends have begun to surface lately, aiming at radically altering the landscape for future 6G wireless networks and systems. Specifically, the amalgamation of cutting-edge technology, structures, and strategies will augment the potential and efficiency of forthcoming massive MIMO (mMIMO) systems [1]. Multiple-Input Multiple-Output (MIMO), whether for 5G smartphone terminals or 5G base stations, is a crucial aspect of 5G [2]. Marconi initially put out an antenna technology called MIMO around 1980. By connecting numerous antennas at the transmitter and receiver, the communication system's capacity and data transfer rate are improved. Due to its ability to greatly expand the capacity of the system channel and enhance the quality of wireless connection transmission, MIMO antenna transmission systems have received a lot of attention [3]. It offers a wide range of potential uses in mobile communication systems. MIMO systems can be classified as SISO (Single-Input Single-Output), MISO (Multiple-Input Single-Output), SIMO (Single-Input Multiple-Output), MIMO and more modes depending on the quantity of transmit and receive antennas. Large-scale MIMO is now thought to be a crucial technology to satisfy 5G coverage and capacity needs. Currently, the global mobile network's average speed will increase to 44 Mbps, and 1Gbps or above 5G network speed. Greater quality, greater transmission rate, larger user densities, stronger mobility performance as well as shorter latency, and lower energy usage scenarios, may all be supported by 5G mobile communication. Therefore, MIMO as well as massive MIMO are suitable candidates to meet these demands [4]. Although MIMO technology has been used in 4G communication, its performance gain is significantly constrained by the low number of antennas (often less than 8) in the 4G system's base station (BS). To address the drawbacks of the conventional MIMO technology, Marzetta who is from the United States developed the idea of large-scale MIMO (massive MIMO, mMIMO) in 2010. By expanding the number of antennas in the BS, mMIMO technology may support dozens, hundreds, or even more antenna. The BS can increase network capacity by concurrently sending and receiving signals to several subscribers. In the transition from 4G to 5G, as the frequency rises the size of antennas gets smaller and there are more of them. The mMIMO system may regulate the phase, amplitude of each antenna units sent or received signal, and it creates directed beams by modifying numerous unit antennas. This means that the energy of the wireless transmission can create the electromagnetic waves superimposed at the mobile station (MS) terminal, so strengthening the signal received. There has been a lot of work on mMIMO which has been shown in various works [5-9]. But the expense of mMIMO's implementation cost is still too expensive, which is mostly seen in the price of Radio Frequency (RF) modules and auxiliaries the expensive price of the significant channel estimate overhead, the cost of deploying dense stations, as well as the lengthy estimating process. A point-to-multipoint data transmission from one transmitter to several receivers is involved in wireless broadcasting. Current broadcast technologies employ Orthogonal Multiple Access (OMA) techniques, which divide time or frequency resources among several receivers to achieve user data separation. Non-Orthogonal Multiple Access (NOMA) which superimposed user signals above one another at the transmitter and uses successive interference cancellation (SIC) at the receivers is another method of transmission for wireless broadcast. The maximum efficiency of the sets of possible rates for Additive White Gaussian Noise (AWGN) broadcast channels was demonstrated by Bergmans and Cover discovered sets of obtainable rates for NOMA [10]. Tse concluded in [11] that NOMA is clearly superior than OMA (apart from the two corner locations where just a single individual is being addressed to) for any arte combination in terms of sum rate completed by OMA a power divide exists for which NOMA can obtain strictly higher rate pairings. Tse did not provide a proof for this claim, which is meant for single antenna systems. Noteworthy is the fact that NOMA's capacity advantage over OMA comes at the expense of more difficult decoding requirements for NOMA receivers. It has been investigated how to best maximize ergodic capacity for a Rayleigh fading MIMO-NOMA system with statistical CSI at the transmitter [12]. By utilizing the idea of signal accordance, a universal MIMO-NOMA framework for downlink and uplink transmission has been suggested in [13]. Most MIMO-NOMA studies to far have made assumptions about perfect CSI information at the transmitter, which is challenging to obtain in practice. The flawless CSI presumption can use up enormous amounts of bandwidth resources, especially when mMIMO is used with NOMA [14-15]. The plan outlined does not need CSI at the transmitter, but it does call for a higher number of receive antennas than at the transmitter. Another two more papers have examined a massive MIMO-NOMA downlink mechanism with little feedback [16-17]. A different study has examined the effects of user scheduling on the functionality of two NOMA systems: NOMA with fixed power allocation and NOMA affected by cognitive radio (CR-NOMA) [18]. A comparison of the NOMA and broadcast channel capacity areas has been made in [19]. Ding et al. investigated the use of MIMO in NOMA systems in [20], from which closed-form equations of the rate difference between MIMO-NOMA and MIMO-OMA were produced. Instead of demonstrating implies there is a positive rate gap, simulation data were used to compare the advantages of MIMO-NOMA versus MIMO-OMA. Prominent work is done [21], unveiling the capacity gap between MIMO-NOMA and MIMO-OMA in Multi-User Networks. This work explored the performance of MIMO-NOMA when users are organized into clusters. Using analytical methods, it also demonstrated that MIMO-NOMA outperforms MIMO-OMA in terms of both sum channel capacity and ergodic sum capacity. It has provided [22] a summary of the 3GPP debates on NOMA with some recommendations for ways to increase the effectiveness of NOMA-based transmission for both the uplink and the downlink by reducing implementation complexity and latency. Recently, a work is done [23] and suggested to improve performance and reduce OP, MIMO presents a promising alternative. In the above-mentioned papers, the performance comparison of MIMO-NOMA and MIMO-OMA by considering at a time four fading channels simultaneously is not used. In our work, we have performed this performance by considering all four channels together. Without considering deployment costs, this work investigates the impact channel capacity of a MIMO system and antenna number using MATLAB simulation to examine the performance of the MIMO system including mMIMO in the uplink and downlink with different fading channel environments. This paper also investigates the ergodic capacity comparison of MIMO-NOMA and MIMO-OMA in four different fading channel environments as well as the OP performance in a mMIMO communication scenario.

The remainder of the writing is structured as follows: In the first section, some related paper discussion is included in the Introduction. The second section contains Materials and Methods, the Third section is a Mathematical analysis of MIMO capacity versus Signal-to-Noise Ratio (SNR), the Fourth section includes the capacity analysis using Shanon-Hartely Theorem, the fifth section contains Singular value decomposition including ergodic capacity and OP analysis of MIMO-NOMA and MIMO-OMA, the Sixth section adds Results and Discussion, and the last section contain a conclusion.

2. MATERIALS AND METHOD

2.1. A Basic MIMO System Channel Model

Several antennas both at the receiving end and the transmitting end are specified as $n_t$and n_2, respectively in this work. The transmitted symbol energy of a single antenna is denoted as E_s/n_t, while the average transmitted symbol period is E_s. Zero-mean Additive White Gaussian noise (AWGN) interferes with the channel, and each receiving antenna's noise power is σ^2. The assumption is that the channel is quasi-static flat Rayleigh fading and that the receiving end has perfect knowledge of the state information [24]. Figure 1. depicts a basic MIMO system channel model.

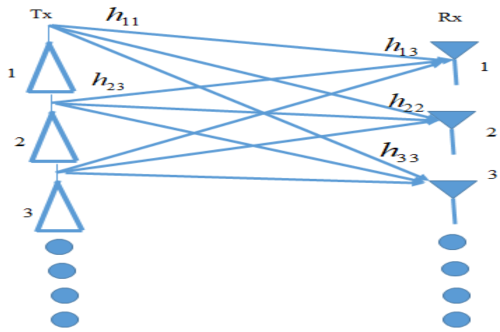

Figure 1. A basic MIMO system channel model [2]

A MIMO channel can be represented as a matrix, where the transmitted signals from each antenna are linearly combined and passed through a channel matrix, and the received signals at the receiver are also combinations of the transmitted signals in linear form. The general MIMO channel model can be written as:

$$Y = HX + N \tag{1}$$

Where, $Y$is the receive signal vector, $X$is the transmitted signal vector, $H$is the channel matrix, which represents the channel gains and phase shifts, $N$is the noise vector. The capacity of the MIMO systems, assuming a Gaussian channel is given by-

$$C = log_2\left(det\left(I + \frac{\rho}{N_t}HH^H\right)\right) \tag{2}$$

where $\rho$is the SNR, and $H^H$is the conjugate transpose of H. The power optimization problem can be formulated as-

$$\text{Maximize } C = log_2\left(det\left(I + \frac{\rho}{N_t}HH^H\right)\right) \tag{3}$$

with power constraint $T_r(P) \le P_{max}$, where $P$is the transmit power matrix, and $P_{max}$is the maximum allowable transmit power.

Power optimization in MIMO systems is fundamental for achieving the full potential of wireless communication technologies. It contributes to increased capacity, improved spectral efficiency, interference mitigation, energy efficiency, adaptation to channel conditions, and the ability to meet diverse quality of service (QoS) requirements. As wireless communication continues to evolve, power optimization remains a critical aspect of designing and operating efficient and high-performance MIMO systems.

2.2. General MIMO Channel Model for Rayleigh Fading

For a MIMO system with Rayleigh fading channels, the received signal at the ithantenna of the receiver can be expressed as:

$$Y_i = \sum_{j=1}^{N_T} H_{ij}\, X_j + Z_i \tag{4}$$

Where, $Y_i$is the receive signal at the ithantenna, $N_T$is the number of transmit antennas, $H_{ij}$is the complex channel coefficient between the ithreceive antenna and jthtransmit antennas which follows a complex Gaussian distribution with zero mean and unit variance $H_{ij} \sim CN(0,1)$, $X_j$is the transmitted signal from the jthtransmit anyenna, $Z_i$is the complex Gaussian noise at the receive antenna, following $CN(0, \sigma^2)$.

2.3. General MIMO Channel Model for Rician Fading

In Rician fading channel, we can model it as a combination of a deterministic line-of-sight (LoS) component and a Rayleigh fading component. The channel model can be expressed as:

$$H_{ij} = \sqrt{K}.H_{LoS} + \sqrt{1-k}.H_{Rayleigh} \quad (5)$$

Where, $K$is the Rician – $k$factor, representing the ratio of the power in the LoS component to the power in the scattered Rayleigh fading component. H_{LoS}follows a complex Gaussian distribution, $H_{Rayleigh}$represents the Rayleigh fading component.

2.4. General MIMO Channel Model for Nakagami Fading

The Nakagami fading channel is characterized by the Nakagami distribution, which is a generalization of the Rayleigh distribution. The Nakagami channel model can be expressed as:

$$H_{ij} \sim CN(0, \Omega) \quad (6)$$

Where, Ωrepresents the shape parameter of the Nakagami distribution which determines the severity of fading. Higher value of Ωindicates less severe fading.

2.5. General MIMO Channel Model for AWGN Fading

The AWGN channel is a special case when there is no fading, and the received signal is only affected by Gaussian noise. The received signal can be simply represented as:

$$Y_i = X_i + Z_i \quad (7)$$

Where, $X_i$is the transmitted signal, $Z_i$is the complex Gaussian noise at the ithreceive antenna, following$CN(0, \sigma^2)$.

2.6. MIMO-NOMA Channel Model

In MIMO-NOMA, non-orthogonal superposition coding is used to transmit signals to multiple users on the same resources. The channel model can be extended to MIMO-NOMA as follows:

$$Y_i = H_i X_i + \sum_{j \neq i} H_{ij} X_j + N_i \quad (8)$$

Where, $Y_i$is the received signal at user i, X_i is the transmitted signal for user i, H_i is the channel matrix for user i, $H_{ij}$is the interference channel matrix between user $i$and user j, and, N_i is the noise vector at user i.

2.7. MIMO-OMA Channel Model

In MIMO-OMA, orthogonal resources are assigned to different users, ensuring that there is no interference between them. The channel model for MIMO-OMA is based on these orthogonal resources: For user i

$$Y_i = H_i X_i + N_i \quad (9)$$

Where, $Y_i$is the received signal at user i, $X_i$is the transmitted signal at user i,$H_i$is the channel matrix for user i, and, N_i is the noise vector at user i.

3. MATHEMATICAL ANALYSIS OF MIMO CAPACITY VERSUS SIGNAL-TO-NOISE RATIO (SNR)

Mathematics analysis of MIMO capacity versus SNR for a 2×1 antenna configuration using Rayleigh, Nakagami, and AWGN fading channels, we can use the Shannon-Hartley theorem and statistical properties of the fading channels. By considering the 2×1 MIMO system, where, Number of transmit antennas (N_t) is 2 and number of receive antennas (N_r) is 1. The capacity analysis are as follows:

For Rayleigh fading channel

The channel coefficients ($h_{11}$and h_{21}) are complex Gaussian random variables with zero mean and unit variance (Independent Identical Distribution, i.i.d. for each realization). The received signal at the receiver is provided by $y = h_{11} * x_1 + h_{21} * x_2 + n$, where $x_1$and $x_2$are the transmitted symbols and $n$is AWGN with power σ^2.

For Nakagami fading channel

We assume Nakagami fading with parameter m. The channel coefficients ($h_{11}$and h_{21}) follow a Nakagami distribution. The received signal is $y = sqrt(h_{11}^2 + h_{21}^2) * x_1 + n$, where $x_1$is the transmitted symbol, and $n$is AWGN with power σ^2.

For AWGN channel

In this case, there is no fading, and the received signal is $y = x_1 + n$.

4. THE CAPACITY ANALYSIS USING THE SHANNON-HARTLEY THEOREM

For Rayleigh fading channel

The channel magnitude ($|h|$)follows a Rayleigh distribution with probability density function (PDF): $f(|h|) = |h| * exp(-|h|^2)$, The capacity in bits per second per Hertz (bps/Hz) is given by: $C_{Rayleigh} = (log_2 1 + SNR * E[|h|^2])$, where SNR is the signal-to-noise ratio, and $E[|h|^2]$is the average channel power.

For Nakagami fading channel

The capacity in bps/Hz for a Nakagami fading channel with parameter $m$is given by: $C_{Nakagami} = log_2(1 + SNR * m/(m-1))$.

For AWGN channel

The capacity in bps/Hz for an AWGN channel is given by: $C_{AWGN} = log_2(1 + SNR)$.

5. SINGULAR VALUE DECOMPOSITION (SVD)

The SVD is a key technique in MIMO communication systems. It is often used to analyze the channel capacity and the eigenvalues (or singular values) of the channel matrix. The normalized probability density function (PDF) of the singular values in MIMO systems can provide insights into the performance and capacity of the system. In a MIMO system with a 5×5 antenna configuration, the channel matrix typically has dimension 5×5, and SVD can be applied to this matrix. The singular values are obtained as the square root of the eigenvalues of the product of the channel matrix and its Hermitian transpose. In another sense, SVD is a matrix factorization technique that breaks down the channel matrix H, into three matrices: U, S, and V. The U and V matrices are unitary matrices, and S is a diagonal matrix containing the singular values. The singular values in the matrix S are positive real values, and they provide information about the channel's capacity and quality. In MIMO systems, the singular values are connected to the eigenvalues of the covariance matrix of the received signals [25-26].

Normalized PDF of Singular Values

The normalized PDF of singular values characterizes the distribution of singular values in the MIMO channel. It describes how the singular values are spread and can help in understanding the channel capacity and performance. To calculate the normalized PDF of singular values for a 5×5 MIMO system, the following steps are followed:
*Compute the channel matrix H based on the specific channel model or measurements.
*Apply SVD to decompose H into U,S, and V.
*Extract the singular values from the diagonal matrix S.
*Normalize the singular values by dividing them by the sum of all singular values.
*Create a histogram or use a kernel density estimation to estimate the PDF of the normalized singular values.

Ergodic capacity in MIMO-NOMA

Users in MIMO-NOMA share the same time and frequency resources, and their signals are divided depending on the power-domain NOMA at the receiver. The ergodic capacity for MIMO-NOMA in a Rayleigh fading channel can be stated as: $C\_NOMA = E[log_2(1 + SNR\_NOMA)]$, where $E[.]$indicates the expectation, and $SNR_NOMA$is the SNR for MIMO-NOMA. The SNR_NOMA for MIMO-NOMA depends on the power allocation, the fading coefficients, and the number of users. For separating the users' signals, it could take into account the superposition coding and successive interference cancellation (SIC) technique.

Ergodic capacity in MIMO-OMA

In MIMO-OMA users are assigned orthogonal resources (time, frequency, or code), and they do not interfere with each other. The ergodic capacity for MIMO-OMA in a Rayleigh fading channel can be written as: $C\_OMA = \sum\left[E\left[log_2(1 + SNR\_OMA\_i)\right]\right]$, where the sum is dominated all users i, and SNR_OMA_i is the signal-to-noise ratio for the i-th user in MIMO-OMA. In MIMO-OMA, each user's capacity depends on the fading coefficient and SNR of their dedicated resources.

MIMO-NOMA and MIMO-OMA OP analysis

In MIMO-NOMA, multiple users share the same time-frequency resources using non-orthogonal codes. The OP is the probability that the instantaneous channel conditions are unfavorable for reliable communication. Outage occurs when the achievable rate falls below a certain threshold. In MIMO-NOMA, the OP can be defined as-

$$P_{out,NOMA} = P_r\left(log_2\left(1 + \frac{\sum_{k=1}^{K} P_k |h_k|^2}{\sigma^2}\right) < R_{th}\right) \quad (10)$$

where, $K$is the number of users, $P_k$is the transmit power allocation to user K, $h_k$is the channel gain for user K, $\sigma^2$is the noise power, $R_{th}$is the target rate threshold. The power allocation factor $P_k$can be determined based on the channel state information (CSI) and user fairness considerations. Commonly, it is proportional to the channel gain $|h_k|^2$of each user.

In MIMO-OMA, users are assigned orthogonal time-frequency resources, meaning that the user's transmissions do not interfere with each other in the time or frequency domain. The OP of MIMO-OMA can be defined as-

$$P_{out,OMA} = P_r\left(log_2\left(1 + \frac{P_t.|h_k|^2}{\sigma^2}\right) < R_{th}\right) \quad (11)$$

where, $P_t$is the total transmit power. In MIMO-OMA, each user is allocated a portion of the total transmit power, and outage occur if at least one user's achievable rate falls below the threshold.

The simulation setup is shown in Table I.

Table I: Simulation Setup

Monte-Carlo Simulation	**Matlab Programming**
Number of Transmitter	1 to Many
Number of Receiver	1 to Many
Number of Simulations	1000, 10000
SNR	-10 dB to 30 dB
Fading Channel Types	Rayleigh, Rician, Nakagami, AWGN

6. RESULTS AND DISCUSSION

MIMO uplink, and downlink capacity versus SNR with different antenna configurations up to 16×16 are shown in Figure 2. and Figure 3. Where the SNR differs from -10 dB to 30 dB. The average capacity of mMIMO system is shown in Figure 4. The results are presented in the form of plot depicting the uplink and downlink capacity against SNR for different antenna configurations. The obtained results reveal insights into the performance of MIMO systems in uplink and downlink communication under diverse antenna configurations. Observations can be drawn regarding the impact of increasing the number of antennas on the system's capacity, and how this capacity changes with varying SNR levels. The presented plot facilitates a visual comparison of the different antenna configurations, aiding in the identification of optimal configurations for specific SNR regimes. Moreover, these results contribute to a deeper understanding of MIMO system behavior and its sensitivity to environmental conditions.

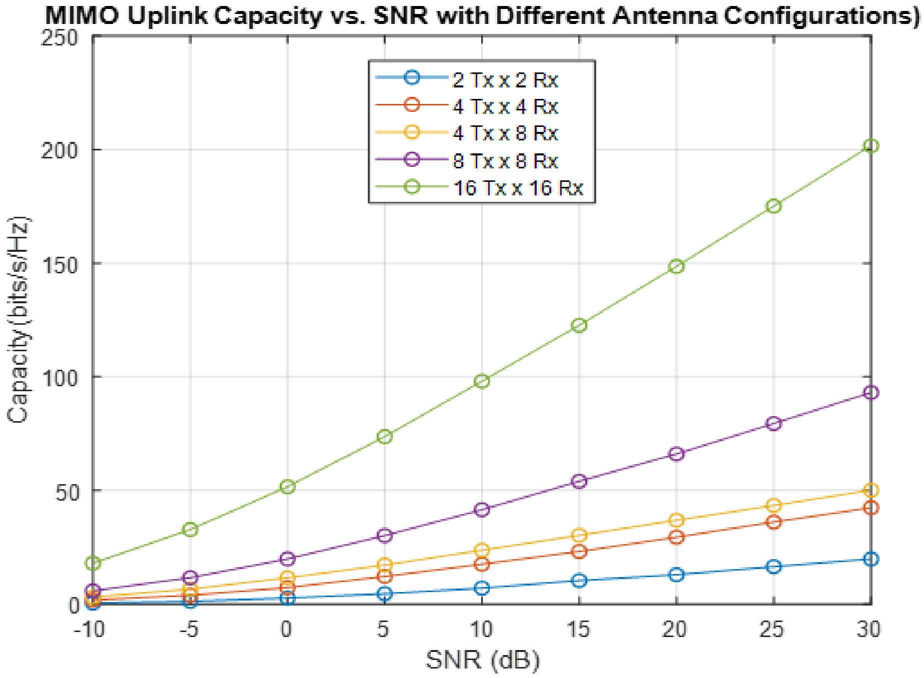

Figure 2. MIMO capacity simulation of uplink

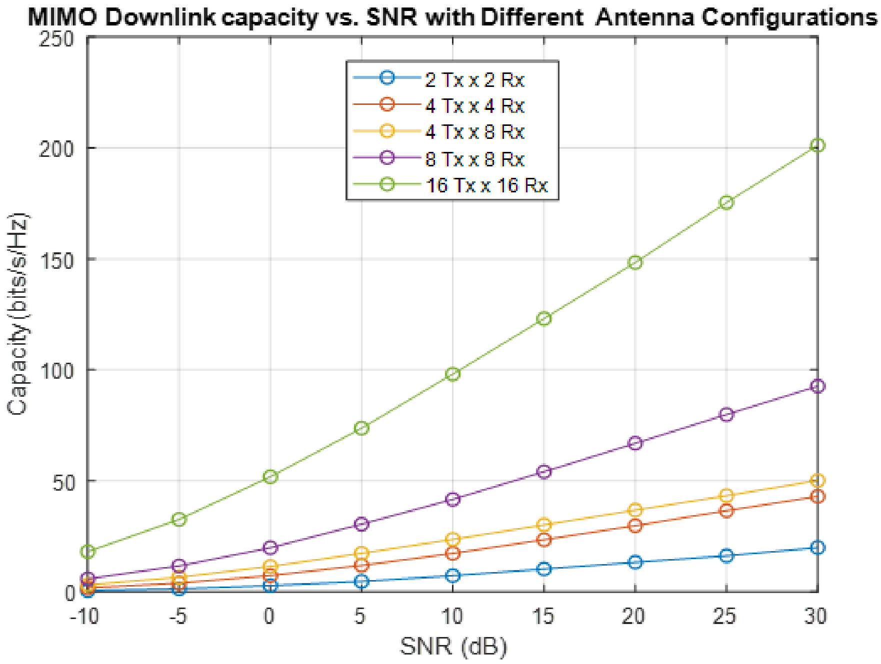

Figure 3. MIMO capacity simulation of downlink

From the simulation results, we notice that the channel capacity rises as SNR rises while the number of antennas at the transmitter and receiver are unchanged. Additionally, if the transmitter or receiver has a fixed number of antennas, upgrading the antenna count at the receiving end can significantly increase the channel capacity. In other words, when the SNR remains constant, the channel capacity increases with an increase in the number of antennas. However, when the SNR is higher, the gain of the channel capacity will increase with the increases of antennas, as is, at high SNR, the channel capacity gain provided by MIMO as well as mMIMO is greatly increased.

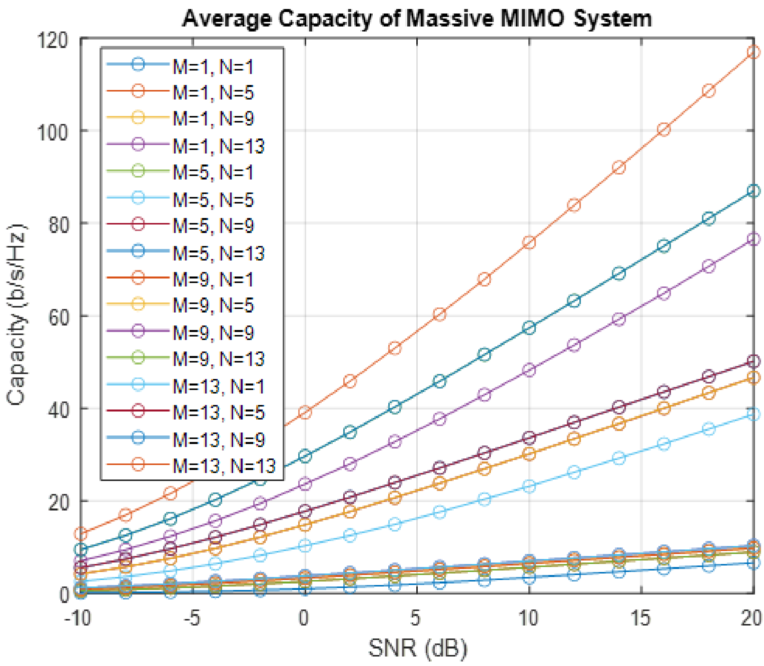

Figure 4. Average capacity of massive MIMO system

MIMO channel capacity performance for different fading channels (Rayleigh, Nakagami, AWGN, and Rician) is shown in Figure 5. In this simulation, we noted that the channel capacity performance for MIMO of the Rayleigh and Rician fading channels is the same that shown in Figure 6.

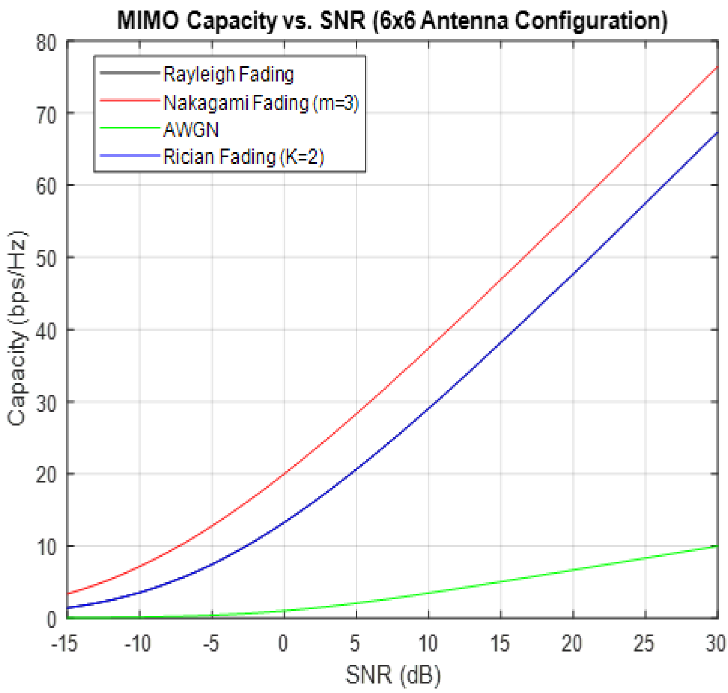

Figure 5. MIMO capacity performance for different fading channels

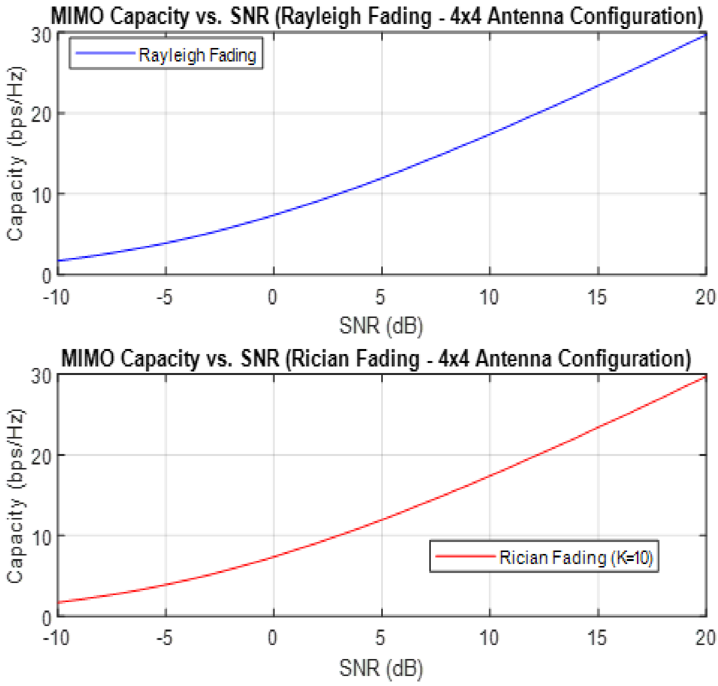

Figure 6. MIMO capacity vs SNR for Rayleigh and Rician fading channels

Figure 7. shows the cumulative distribution function (CDF) of the capacity at a specific SNR value (5 dB in this case). This gives an understanding of the probability of achieving a certain capacity level under the given SNR conditions. Each curve corresponds to a different antenna configuration, demonstrating how the capacity distribution varies across different setups.

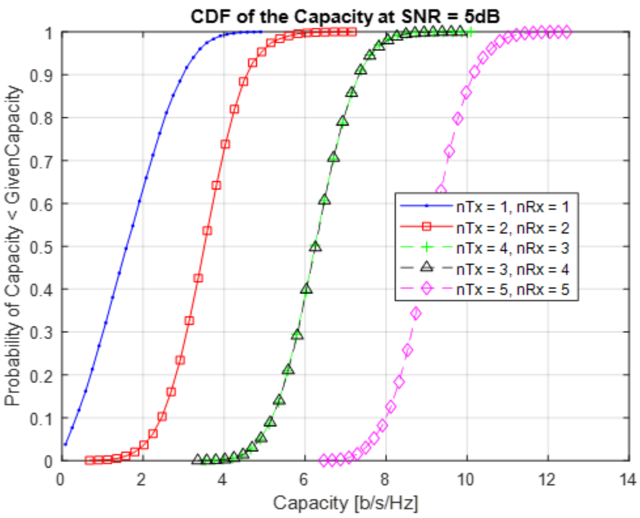

Figure 7. CDF of the MIMO capacity at SNR 5dB

MIMO normalized pdf of SVD values for 5×5 antenna configurations is shown in Figure 8. The shape of the normalized pdf reveals information about the diversity and multiplexing gain of the MIMO system. A pdf with multiple peaks indicates a diversity-rich channel, while a single peak suggests a channel with higher multiplexing gain. It focuses on the singular value distribution at a specific SNR (target SNR dB). The plot includes the PDFs of the singular values for a particular setting of transmitter and receiver antennas. This information is valuable for understanding the characteristics of the channel and the impact of the MIMO configuration on signal decomposition.

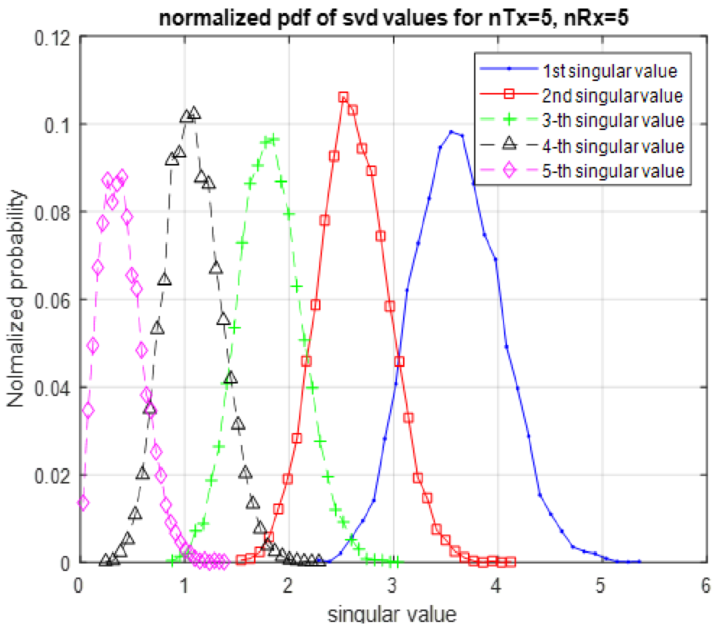

Figure 8. MIMO normalized pdf of SVD values for 5×5 antenna configurations

Figure 9 depicts a comparison of the ergodic capacities of MIMO-NOMA and MIMO-OMA over a Rayleigh fading channel. This comparison showed that MIMO-NOMA outperforms MIMO-OMA in terms of total ergodic capacity.

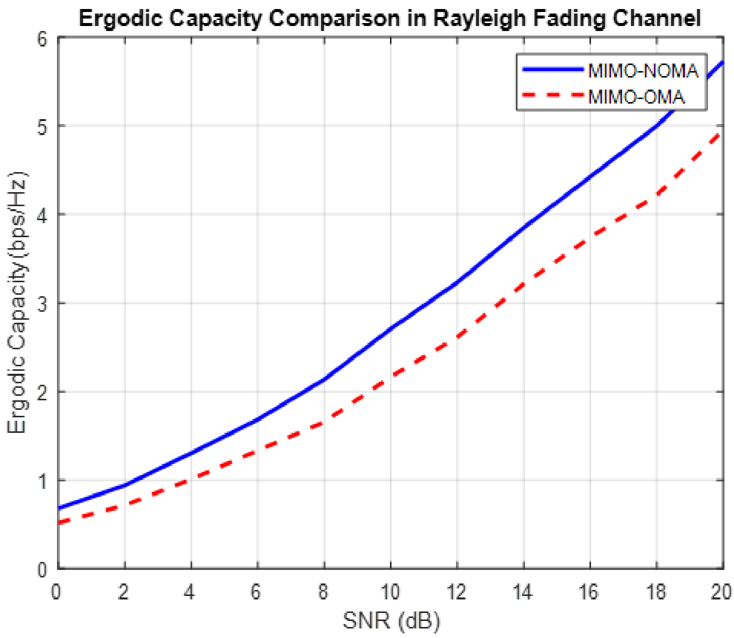

Figure 9. Ergodic capacity comparison of MIMO-NOMA and MIMO-OMA (Rayleigh fading channel)

Figure 10 illustrates a comparison of ergodic capacity for four distinct fading channels (Rayleigh, Nakagami, Rician, and AWGN) between MIMO-NOMA and MIMO-OMA. The ergodic capacities for both MIMO-NOMA and MIMO-OMA vary significantly across different fading channels. Rayleigh fading, characterized by random amplitude and phase, exhibits distinct behavior compared to Rician and Nakagami fading, which introduces different levels of determinism. Additionally, it is evident from these simulation findings that MIMO-NOMA beats MIMO-OMA for each fading channel.

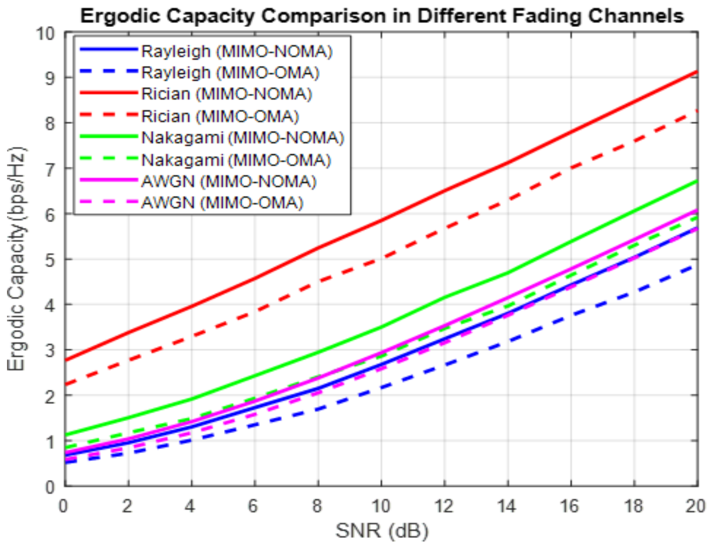

Figure 10. Ergodic capacity comparison of MIMO-NOMA and MIMO-OMA (Four fading channels)

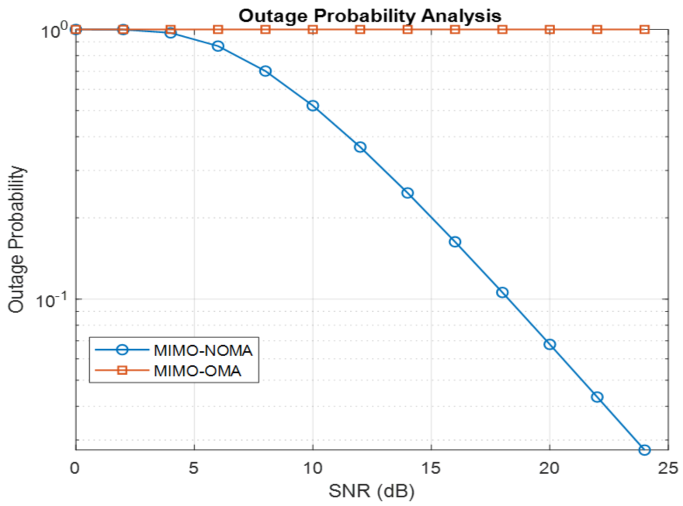

Figure 11. Outage probability for MIMO-NOMA and MIMO-OMA

Figure 11. shows the OP for MIMO-NOMA and MIMO-OMA. The OP analysis for MIMO-NOMA and MIMO-OMA systems under varying SNRs provides valuable insights into their performance in mMIMO communication networks. The simulation parameters include a large-scale network with 1000 users, each equipped with 8 antennas at the transmitter and receiver ends. As observed in the simulation results in MIMO-NOMA, the OP decreases as SNR increases. This behavior aligns with the expectation that higher SNR levels contribute to improved communication reliability. It allows for more efficient utilization of the available spectrum, enabling simultaneous communication among multiple users. This results emphasize the impact of power allocation and resource-sharing strategies on OP in mMIMO systems. MIMO-NOMA and MIMO-OMA OP versus SNR under different fading channels is shown in Fig 12. The key findings from this figure are MIMO-NOMA and MIMO-OMA exhibit similar outage behavior under Rayleigh fading. As SNR increases, the outage probability decreases, which is expected due to the improved signal quality. MIMO-NOMA shows improved performance compared to MIMO-OMA under Rician fading. This improvement is attributed to the NOMA's ability to efficiently allocate power among users, mitigating interference. The OP of both schemes decreases with increasing SNR, but the gap between MIMO-NOMA and MIMO-OMA persists. In all fading scenarios, the OP decreases as SNR increases, highlighting the importance of signal quality in wireless communication systems. NOMA consistently exhibits advantages over OMA in terms of outage probability, especially in scenarios with fading channels.

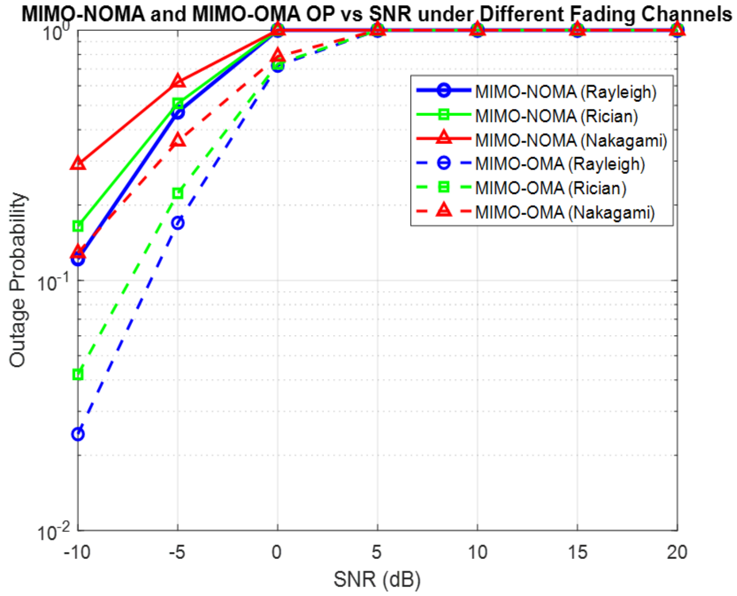

Figure 12. MIMO-NOMA and MIMO-OMA OP for different fading channels

7. CONCLUSION

This study examines several typical system average capacities through simulations using different MIMO systems. The connection between the number of transmitting and receiving antennas and the MIMO system's channel capacity is explored. According to the analysis and simulation results, the independent and various fading channels, the capacity of system channels increases linearly with the increasing number of antennas. A MIMO system's capacity is often an integer multiple of a SISO system with a similar SNR. Aside from the scenario where only one user is being communicated with, we also demonstrate in this paper that MIMO-NOMA is strictly superior to MIMO-OMA in terms of sum channel capacity. In other words, there is a power split for which MIMO-NOMA schemes can achieve rate pairs that are strictly larger than any rate pair achieved by MIMO-OMA schemes. Based on these findings, we also demonstrate that MIMO-NOMA can outperform MIMO-OMA for different fading channels in terms of sum ergodic capacity. Finally, the OP analysis provides valuable insights into the performance of MIMO-NOMA and MIMO-OMA systems in mMIMO networks, aiding in the understanding of their behavior under different SNR conditions and different fading channels. MIMO-NOMA shows promising performance improvement over MIMO-OMA, particularly in challenging fading scenarios. This analysis provides valuable perceptions into the performance trade-offs between MIMO-NOMA and MIMO-OMA under different fading channels, contributing to the understanding of their behavior in realistic wireless communication environments.

ACKNOWLEDGEMENTS

Department of Information and Communication Technology, at Islamic University, Kushtia-7003, Bangladesh, provided funding and other logistics support for this study.

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