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Performance optimization of MIMO-NOMA systems in Nakagami-m fading environments

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ABSTRACT

In this context, the utilization of multiple-input multiple-output (MIMO) and non-orthogonal multiple access (NOMA) technologies is applied to improve wireless communication. This paper is dedicated to the evaluation of the performance in the MIMO-NOMA system under Nakagami-m fading environments, which is a more general scenario for different kinds of fading conditions that occur normally. Our proposed framework is applied to evaluate key performance metrics, including bit error rate (BER), outage probability, spectral efficiency, and ergodic capacity. The results reveal the deep impact of Nakagami-m fading on these key performance metrics, emphasizing an intricate balance between reliability and spectral efficiency that is achieved through power domain multiplexing in conjunction with successive interference cancellation (SIC). Our results are further evidence of the strength and flexibility of MIMO-NOMA, and point to insights and practical guidelines that are new towards the optimization of next-generation wireless networks. This overall analysis not only closes the gap in current literature on the subject but also sets a new benchmark for future research on advanced communication technologies.

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1. INTRODUCTION

Wireless communication technologies have witnessed fast advancements, demanding increasing data rates, improved spectral efficiency, and better connectivity. Among them, multiple-input multiple-output (MIMO) and non-orthogonal multiple access (NOMA) techniques have received great attention in recent years. The MIMO spatial diversity is harnessed by using multiple antennas at the transmitter and receiver ends for the improvement of link reliability and throughput [1]. NOMA, on the other hand, enhances spectral efficiency by allowing more than one user to share the same time-frequency resources through power domain multiplexing [2], [3]. The incorporation of MIMO with NOMA comes up with a great result regarding taking care of the growing requirements in modern wireless communication systems [4], [5].

However, despite these promising benefits that may be accrued from MIMO-NOMA, one of the most critical challenges lies in handling the varying channel conditions experienced by users. The effects of multipath fading, shadowing, and path loss can significantly deteriorate the propagation characteristic of the signal in actual wireless surroundings. These effects have been characterized using the classic Rayleigh and Rician fading models, which can be poor in capturing their environment's complexity under certain situations [6], [7]. The Nakagami-m fading model is able to generalize both Rayleigh and Rician models; it is quite flexible in this regard and can offer a much more appropriate representation [8]. Therefore, this model can be applied to a wide range of fading conditions, making it one of the best choices. Performance of MIMO-NOMA systems under Nakagami-m fading plays an indispensable role in harnessing the resource allocation process and enhancing the overall system reliability [9].

There are two performance analyses of existing literature on MIMO-NOMA systems: Rayleigh and Rician fading conditions. Recent researches have proved the benefits of NOMA over traditional OMA schemes in terms of spectral efficiency and user fairness [10]. For example, it is shown that NOMA can achieve higher throughput by exploiting power domains to multiplex users with different channel gains. Furthermore, MIMO techniques are adapted to further optimize the performance of NOMA systems [11]. However, an important gap exists in this literature review through the comprehensive analysis of MIMO-NOMA systems under Nakagami-m fading channels. From this review, it is inferred how improvements in performance are actually realized with MIMO-NOMA, hence investigating the underlying reasons for these improvement [12].

In MIMO systems, multiple antennas are used on both the transmitting and receiving sides, resulting in many spatial paths through which signals pass [13]-[15]. This spatial diversity helps to mitigate the fading and interference effects, thus improving the signal quality and the overall system capacity. The combination of NOMA with the multiple input multiple output technology is expected to further enhance the spectral efficiency of the system. NOMA achieves this by superimposing signals from multiple users in the power domain and utilizing successive interference cancellation (SIC) at the receiver to separate the signals [16], [17]. Users with relatively better channel conditions first decode their signals, and then the decoded signals of these users are subtracted from the aggregate received signal to aid decoding of the signals of users with worse channel conditions [18].

In real applications, however, the realization of MIMO-NOMA meets several challenges, especially on how to cope with the changing channel conditions that experience wireless users [19]. This is the Nakagami-m fading model in the sense that it gives an excellent versatile way to model the changing conditions. It can also describe a wide range of fading surroundings when one varies the form parameter m, better than the classical Rayleigh and Rician models. As a specific example, for $m=1$ special cases, the Nakagami-m model changes to the Rayleigh model, while, for $m>1$, it approaches the Rician model. Hence, the Nakagami-m model is popular due to the fact that this model can adapt to whatever is presented in the performance analysis of a wireless communication system under various fading conditions [20]-[23].

At this premise, the main objective of the current study is to assess MIMO-NOMA systems' performance over Nakagami-m fading. This study tends to fill the research gap by providing an exhaustive evaluation in terms of key performance metrics, which includes bit error rate (BER), outage probability, spectral efficiency, and ergodic capacity. The above performance metrics are key performance measures that describe the overall effectiveness of a system in various fading environments. This paper enunciates on a mathematical formulation of these performance metrics within a Nakagami-m fading environment. We also employ SIC at the receiver side to decrease inter-user interference, at the cost of more overhead.

Analytically, we consider a system model in which a base station (BS) with a multiplicity of antennas serves a multi-tenant via a power domain multiplexing mechanism. Each of the users is subject to another channel condition, described by the fading Nakagami-m model. The overall transmitted signal from the BS then becomes the superposition of the desired signals from all users, with dissimilar power levels. In the receiver, each user conducts SIC decoding for its intended signal corresponding to the best channel condition. Such a hierarchically decoding scheme allows users' signals with a weaker channel condition to be distinguished after elimination of the dominating users' signal.

The performance of the MIMO-NOMA system is given with a lot of simulation. Many scenarios are considered by taking the Nakagami-m shape parameter m at different values, thereby ensuring the reality of the investigation in portraying the wide scope of fading environments. The corresponding results show how different channel conditions can affect various system performance metrics. For instance, the BER is measured as a function of signal-to-interference-plus-noise ratio (SINR) to reflect how the error rate varies with the received signal quality. The outage probability estimates, up to a given level, how likely it is that the received SINR drops below some predetermined threshold value guaranteeing quality of service. Spectral efficiency is the measure of data rate per unit bandwidth, whereas the ergodic capacity characterizes the long-term average capacity of the channel.

The novelty in this research comes from the fact that MIMO-NOMA systems under Nakagami-m fading were not studied to that length in current literature. By fusing the Nakagami-m fading model, a considerably much wider range of fading environments can be expressed; hence, more general knowledge of how the system performs may be given. For such results, the focus will be to help in achieving more robust and efficient MIMO-NOMA systems that will provide high data rates and reliable connectivity in different wireless environments. Also, the findings of such research can be used to contribute to other studies and design resource allocation optimization strategies within the context of next-generation wireless networks.

In the end, incorporation of MIMO and NOMA technologies becomes a promising solution to the challenges being faced with the demand for higher data rates and improvements in spectral efficiency in any wireless communications system [21]-[25]. With the Nakagami-m fading model being highly flexible, it matches the varying real-world channel conditions with high precision; hence, proving to be appropriate for the performance evaluation of MIMO-NOMA systems. The following, therefore, outlines in more detail some of the important key performance metrics that one can expect from these systems, providing valuable insight into their designs and optimization processes. The proposed method and the obtained results have assisted the increasing research base and further opened ways for the developments in the near future within this wireless communication sector.

The rest of this paper is organized as follows: sections 2 and 3 presents the system model, detailing the MIMO-NOMA framework and Nakagami-m fading channel characteristics. Section 4 outlines the mathematical formulations and derivations for BER, spectral efficiency, outage probability, and ergodic capacity. Section 5 simulation results and discussion on performance analysis of MIMO-NOMA systems; lastly, the paper is concluded in section 6 with potential research directions for the future.

2. SYSTEM MODEL

We consider in this work a MIMO-NOMA system where multiple users are grouped into two clusters which is shown in Figure 1. The base station is equipped with multiple antennas and transmits signals to users in these clusters. This configuration is designed to attain higher spectral efficiency and fit various user requirements using the power domain multiplexing property of NOMA.

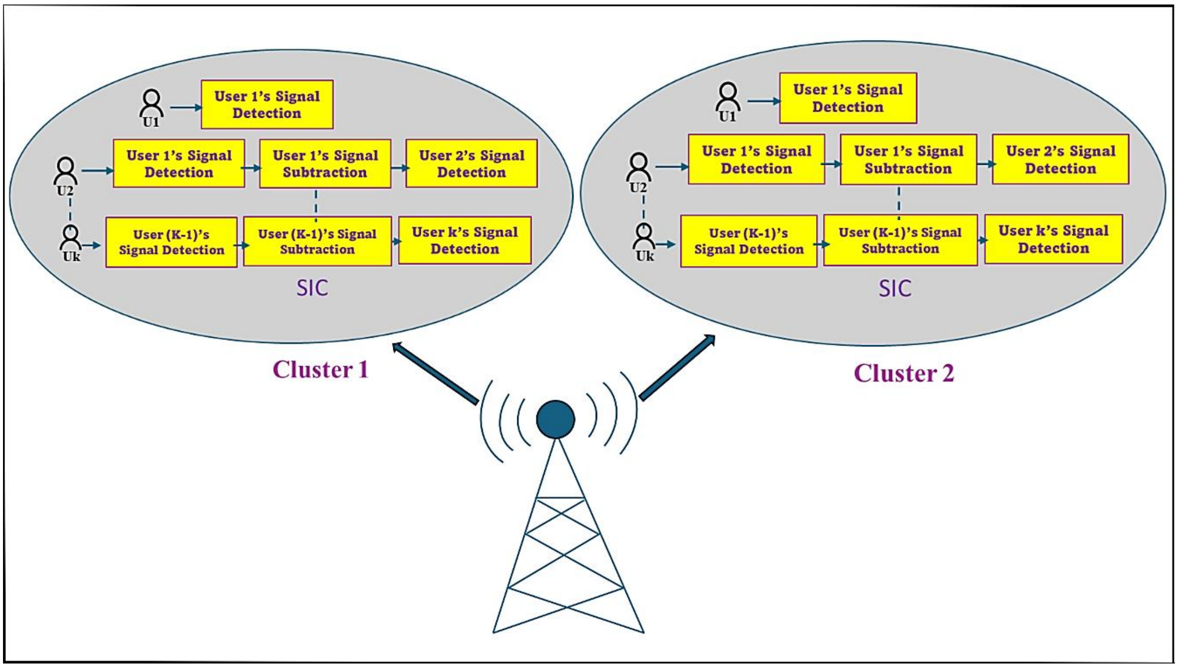

Figure 1. System Design for MIMO-NOMA beamforming

2.1. Multiple-input multiple-output-non-orthogonal multiple access framework

The MIMO-NOMA system, serving two clusters, consists of a BS with N_t transmit antennas and K single-antenna users per cluster. Each cluster uses a unique set of users. It superimposes the signals intended for all users within each cluster with the transmitted signal from the BS. In view of the NOMA operation, the signals are identified based on their power levels. For Cluster 1, the transmitted signal x1x_1x1 can be written as (1):

$$x_1 = \sum_{k=1}^{k} \sqrt{\alpha_k P_2 s_k} \tag{1}$$

$\alpha_k, P_2, and\ s_k$ are defined similarly for Cluster 2. At the receiving end, users in each cluster use SIC to decode their desired signals. The SIC process consists of decoding and subtracting the signals of users with higher power levels (stronger signals) before decoding its own signal. This approach significantly reduces the impact of inter-user interference, thus improving the decoding performance.

2.2. Signal detection and successive interference cancellation

The detection process in each cluster is carried out hierarchically such that the users are ordered through their channel gains. This means that, within a given cluster, the user having the most superior channel gain is decoded first. For instance, Cluster 1 has user 1 with the most superior channel gain, then directly decode user 1 because it experiences the least interference. This is then subtracted from the decoded signal and user 2 may be able to decode its own signal with lesser interference. This process continues further in a chain until the signal for the last user in the cluster can be decoded.

The subsequent signal detection and SIC process can be described mathematically as: Let $h_{k,1}$ be the channel vector for user k in cluster 1 and $y_{k,1}$ be the received signal at user k in cluster 1. The received signal $y_{k,1}$ is:

$$y_{k,1} = h_{k,1}x_1 + n_{k,1} \tag{2}$$

where $n_{k,1}$is the AWGN at user k within Cluster 1. SIC for user k first decodes and subtracts the signals of users in higher channel gains before performing decoding on its own signal.

3. CHANNEL MODEL

In this paper, the Nakagami-m fading is considered to model the wireless communication channel between the BS and the users; it is a versatile fading model that generalizes both Rayleigh and Rician fading models. More precisely, it is a very appropriate fading model for those environments in which the multipath scattering is either less severe than Rayleigh fading or more severe than Rician fading.

3.1. Nakagami-m fading channel characteristics

The Nakagami-m fading model is characterized in terms of the shape parameter m and spread parameter Ω. The shape parameter m shows the extent to which fading is taking place, where m = 1 is a Rayleigh type of fading and m>1 is of less severe. The spread parameter Ω stands for the mean power of the received signal. For a Nakagami-m fading channel, the probability density function (PDF) of the received signal amplitude r can be expressed as (3):

$$f_R(r) = \frac{2m^m r^{2m-1}}{\Omega^m \Gamma(m)} exp(-\frac{mr^2}{\Omega}) \tag{3}$$

where Γ(m) is the Gamma function. The corresponding cumulative distribution function (CDF) is:

$$F_R(r) = 1 - \sum_{k=0}^{m-1} \frac{(\frac{mr^2}{\Omega})^k}{k!} exp(-\frac{mr^2}{\Omega}) \tag{4}$$

3.2. User-specific channel vectors in MIMO-NOMA

In the context of the MIMO-NOMA system, the channel between the BS and each user is modeled as a Nakagami-m fading channel. Let H_1 and H_2 denote the channel matrices for Cluster 1 and Cluster 2, respectively. Each element of H_1 and H_2 represents the channel gain between a transmit antenna at the BS and a receive antenna at the user, modeled as a Nakagami-m distributed random variable.

For user k in Cluster 1, the channel vector $h_{k,1}$can be expressed as:

$$h_{k,1} = [h_{k,1,1}, h_{k,1,2}, \ldots\ldots\ldots, h_{k,1,N_t}]^T$$

where $h_{k,1,j}$ is the Nakagami-m fading coefficient between the j-th transmit antenna at the BS and user k in Cluster 1. Similarly, for user k in Cluster 2, the channel vector $h_{k,2}$ is given by:

$$h_{k,2} = [h_{k,2,1}, h_{k,2,2}, \ldots\ldots\ldots, h_{k,2,N_t}]^T$$

where $h_{k,2,j}$ is the Nakagami-m fading coefficient for Cluster 2.

4. MATHEMATICAL FORMULATIONS
4.1. Signal-to-interference-plus-noise ratio calculation
The SINR is a critical performance metric that determines the quality of the received signal at each user. For user k in Cluster 1, the SINR $SINR_{k,1}$ can be expressed as (5):

$$SINR_{k,1} = \frac{|h_{k,1}w_{k,1}|^2\alpha_k p_1}{\sum_{j=1,j\neq k}^{k}|h_{k,1}w_{k,1}|^2\alpha_k p_1+\sigma^2} \quad (5)$$

where represents the beamforming vector for user k in Cluster 1. The beamforming vectors are designed to maximize the received signal power for the intended user while minimizing the interference to other users.

Similarly, the SINR for user k in Cluster 2, denoted as $SINR_{k,2}$, is given by:

$$SINR_{k,2} = \frac{|h_{k,2}w_{k,2}|^2\alpha_k p_2}{\sum_{j=1,j\neq k}^{k}|h_{k,2}w_{k,2}|^2\alpha_k p_2+\sigma^2} \quad (6)$$

4.2. Performance metrics
The performance of the MIMO-NOMA system is evaluated using key metrics such as BER, outage probability, spectral efficiency, and ergodic capacity. These metrics provide insights into the effectiveness of the power domain multiplexing and SIC techniques in improving system performance under Nakagami-m fading conditions.

4.2.1. Bit error rate
The BER for user k is a function of the SINR and can be expressed using the Q-function:

$$BER_k = Q(\sqrt{2\cdot SINR_k}) \quad (7)$$

for user k in Cluster 1, the BER $BER_{k,1}$ can be represented as (8):

$$BER_{k,1} = Q\left(\sqrt{2\cdot\frac{|h_{k,1}w_{k,1}|^2\alpha_k p_1}{\sum_{j=1,j\neq k}^{k}|h_{k,1}w_{k,1}|^2\alpha_k p_1+\sigma^2}}\right) \quad (8)$$

similiarly for user k in Cluster 2, the BER $BER_{k,2}$ can be expressed as (9).

$$BER_{k,2} = Q\left(\sqrt{2\cdot\frac{|h_{k,2}w_{k,2}|^2\alpha_k p_2}{\sum_{j=1,j\neq k}^{k}|h_{k,2}w_{k,2}|^2\alpha_k p_2+\sigma^2}}\right) \quad (9)$$

4.2.2. Outage probability
Outage probability is another critical performance metric that quantifies the reliability of the communication system. It represents the likelihood that the received SINR for a given user falls below a predefined threshold γth, which is necessary for maintaining an acceptable quality of service. The outage probability for user k is defined as (10):

$$P_{out,k} = \mathbb{P}(SINR_k < \gamma_{th}) \quad (10)$$

the outage probability $P_{out,k,1}$ for user k in Cluster 1 can be expressed as (11):

$$P_{out,k,1} = \mathbb{P}\left(\frac{|h_{k,1}w_{k,1}|^2\alpha_k p_1}{\sum_{j=1,j\neq k}^{k}|h_{k,1}w_{k,1}|^2\alpha_k p_1+\sigma^2} < \gamma_{th}\right) \quad (11)$$

in the same way the outage probability $P_{out,k,2}$ for user k in Cluster 2 can be expressed as (12).

$$P_{out,k,2} = \mathbb{P}\left(\frac{|h_{k,2}w_{k,2}|^2\alpha_k p_2}{\sum_{j=1,j\neq k}^{k}|h_{k,2}w_{k,2}|^2\alpha_k p_2+\sigma^2} < \gamma_{th}\right) \quad (12)$$

4.2.3. Spectral efficiency
Spectral efficiency measures the efficiency with which the available bandwidth is utilized to transmit data. It is defined as the data rate per unit bandwidth and is a key indicator of the system's ability to maximize throughput. For a given user k, the spectral efficiency is expressed as (13):

$$\eta_k = log_2(1 + SINR_k) \quad (13)$$

for user k in Cluster 1, the spectral efficiency $\eta_{k,1}$ can be expressed as (14):

$$\eta_{k,1} = log_2(1 + \frac{|h_{k,1}w_{k,1}|^2 \alpha_k p_1}{\sum_{j=1,j\neq k}^{k} |h_{k,1}w_{k,1}|^2 \alpha_k p_1 + \sigma^2}) \quad (14)$$

similiarly for user k in Cluster 2, the spectral efficiency $\eta_{k,2}$ can be expressed as (15):

$$\eta_{k,2} = log_2(1 + \frac{|h_{k,2}w_{k,2}|^2 \alpha_k p_2}{\sum_{j=1,j\neq k}^{k} |h_{k,2}w_{k,2}|^2 \alpha_k p_2 + \sigma^2}) \quad (15)$$

4.2.3. Ergodic capacity

Ergodic capacity represents the long-term average capacity of the communication channel, considering the variations in channel conditions over time. It is a key performance metric that reflects the overall potential of the system to deliver high data rates. The ergodic capacity for user k is defined as (16):

$$\mathbb{C}_k = \mathbb{E}[log_2(1 + SINR_k)] \quad (16)$$

in Cluster 1, the ergodic capacity for user k, $\mathbb{C}_{k,1}$ can be written as (17):

$$\mathbb{C}_{k,1} = \mathbb{E}[log_2(1 + \frac{|h_{k,1}w_{k,1}|^2 \alpha_k p_1}{\sum_{j=1,j\neq k}^{k} |h_{k,1}w_{k,1}|^2 \alpha_k p_1 + \sigma^2})] \quad (17)$$

likewise, in Cluster 2, the ergodic capacity for user k, $\mathbb{C}_{k,2}$ can be written as (18):

$$\mathbb{C}_{k,2} = \mathbb{E}[log_2(1 + \frac{|h_{k,2}w_{k,2}|^2 \alpha_k p_2}{\sum_{j=1,j\neq k}^{k} |h_{k,2}w_{k,2}|^2 \alpha_k p_2 + \sigma^2})] \quad (18)$$

here, $\mathbb{E}$ [·] denotes the expectation operator, which averages the capacity over the different realizations of the channel. Ergodic capacity provides a measure of the average data rate that can be sustained by the system over a long period, considering the stochastic nature of wireless channels. It is an essential metric for evaluating the performance of MIMO-NOMA systems in diverse and dynamic wireless environments.

5. RESULTS AND DISCUSSION

Figure 2 shows BER performance as a function of SINR for a MIMO-NOMA system with four users of different proximity to the BS. The nomenclature used to indicate the users are user 1 (nearest), user 2, user 3, and user 4 (farthest). This plot shows the effect of user proximity on BER for different SINR conditions, revealing the disparity in performance that was effected among users due to the underlay in the power-domain multiplexing system and SIC. From the graph, user 1 provides a BER that is the smallest under all SINR values tested as the user gets the highest power and receives the least level of interference. As seen, from an increment in the SINR, the BER for user 1 impressively increases, this means that the system is very effective in maintaining a very low BERs for users with high received signal strengths.

User 2 and user 3, on the other hand, have intermediate BER's and are slightly poorer compared to user 1. That is because they suffer from increased interference whereas the received power level is poorer. Nevertheless, the system can control the rate of interference effectively for the users at medium distances as their BER curves significantly improve with increasing SINR.

The user at the furthermost position will experience the highest BER as compared to the rest of the users. This occurs because of a decrease in received power and an elevation in interference levels with distance from the BS. For user 4, the BER curve begins with a higher rate to further drop with the growing SINR above the others, and this is what makes low error rate guaranteed for the users far away in the MIMO-NOMA system.

The logarithmic scale of the relationship between BER and SINR is shown by the y-axis. From 0 to 30 dB of SINR, each user shows a significant decrease in BER, which once again emphasizes the need for high SINR for correct operation of the system. In the figure, the power domain multiplexing of MIMO-NOMA is very advantageous, and with interference management and error rate alleviated to a great extent from the users closer to the BS via SIC. In summary, Figure 2 shows the BER performance overview for different users in a MIMO-NOMA system under varying SINR conditions.

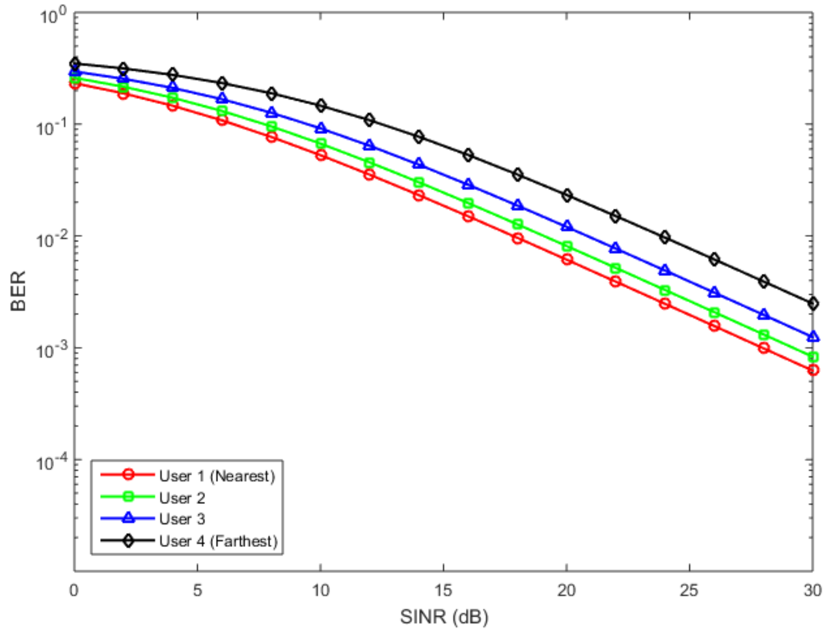

Figure 2. BER performance analysis for MIMO-NOMA system

Figure 3 depicts the outage probability performances versus SINR of a MIMO-NOMA network with beamforming capabilities in a Nakagami-m fading channel. The figure shows the performances of four different users, randomly distributed at different distances from the BS: user 1 (nearest), user 2, user 3, and user 4 (farthest). It clearly shows strong influences of the user's distance on the system performance in terms of communication reliability versus the log scale curve of the outage probability across SINR.

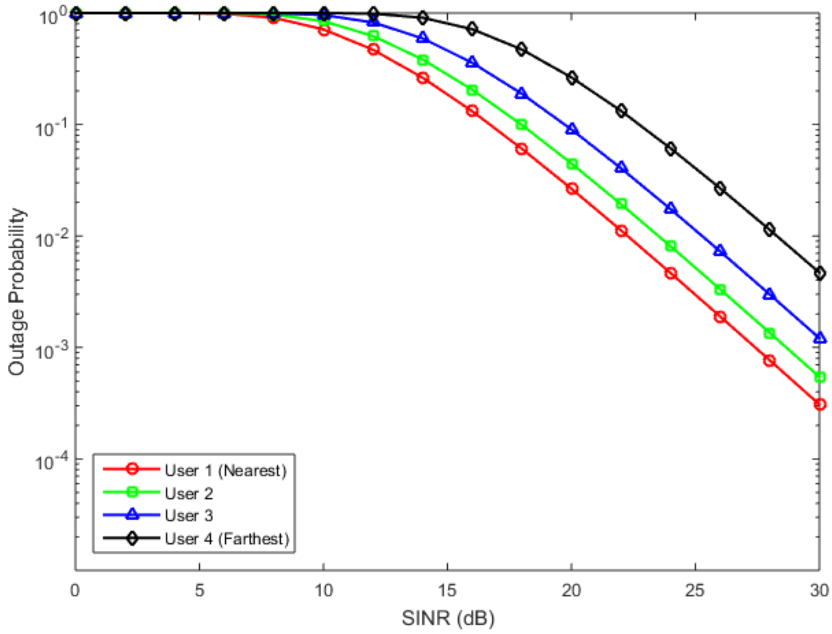

Figure 3. Outage probability analysis for MIMO-NOMA system

User 1, represented by the red curve, has the lowest outage probability for any given SINR value, and this shows that users located at a lower distance to the BS obtain a higher level of reliability with high power levels in the received signal and low interference. The green curve representing user 2 has higher outage probabilities compared to user 1 but still shows good performance as the sinr increases. User 3, represented by the blue curve, has a higher probability of outage, indicating the effect of a lower power of signal and increased interference while moving far from the BS. User 4 with the black curve displays the most problems—really severe ones in maintaining reliable communication for users the farthest from the BS.

It is obvious that the outage probability for all users witnesses a pronounced decrease when SINR increases from 0 to 30 dB. The value of the outage probability for users situated closer to the BS experiences the maximum enhancement. A decrease in this improvement for users situated away occurs at a less pronounced rate, which strongly highlights the fact that interference and signal degradation are still critical problems. The logarithmic scale for the y-axis further emblazons the fact that the decrease in outage probability is of an exponential nature with an increase in SINR, and the gap in performance of users at different proximities becomes extremely obvious. The results thus emphasize the need for strategies to improve SINR and control interference for a reliable communication service, especially at the cell edge where most users fall.

Figure 4 shows the performance of spectral efficiency over the SINR for a MIMO-NOMA system serving four users at different distances from the access point. The users are classified as user 1 (nearest), user 2, user 3, and user 4 (farthest). The distance of the users affects the spectral efficiency under a dynamic SINR environment.

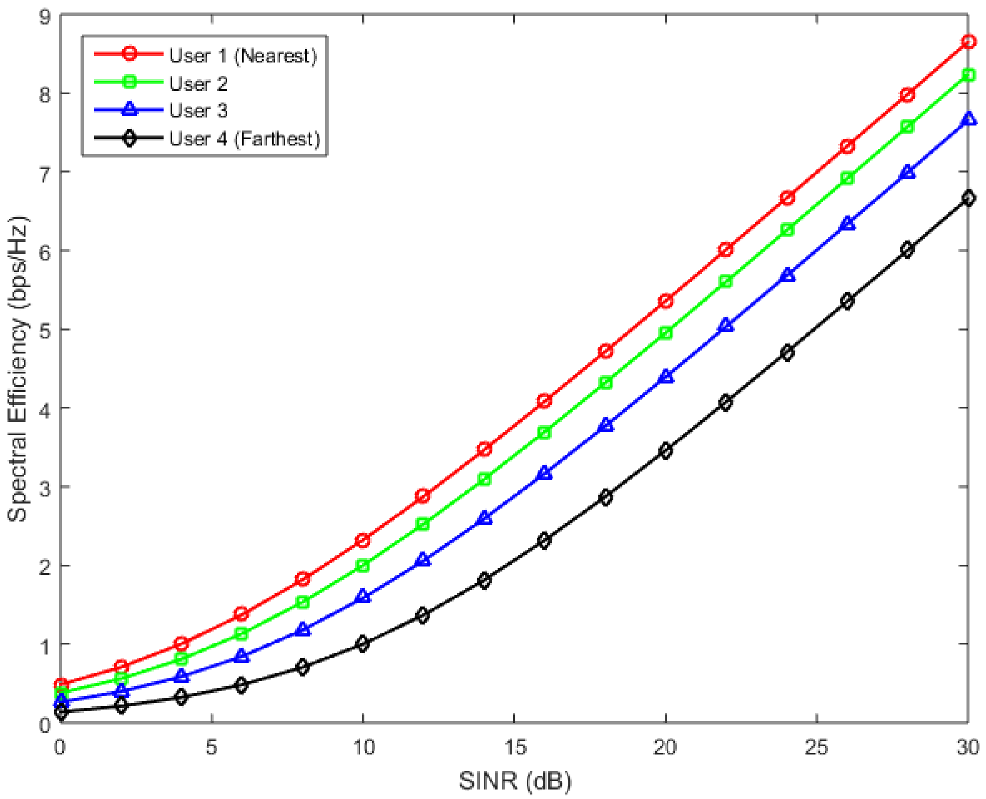

Figure 4. Spectral efficiency analysis for MIMO-NOMA system

User 1 is represented by the red curve and attains the highest spectral efficiency for every SINR value. This indicates that the received signal power is highest for the user closest to the BS, with low interference and thus enjoying a higher spectral efficiency. The green curve, which corresponds to user 2 shows a little drop in the spectral efficiency compared to user 1; however, it is still at a satisfactory level that reinforces the good performance of the system while dealing with moderate interference levels from the users at moderate distances. On the other hand, user 3 shown by the blue curve, has more lost spectral efficiency compared to the first two users, showing how significant the effects of lowering signal strength and increasing interference are when moving further from the BS. Finally, user 4 represented by the black curve is characterized by the lowest spectral efficiency, which shows the level of challenge in obtaining high spectral efficiency for users at the largest distances from the BS.

As SINR increases from 0 to 30 dB, there is a significant improvement in the spectral efficiency for all users, hence the critical necessity of a high SINR toward realization of the optimal system performance. The rate of the increase in spectral efficiency for the users is more severe for users close to the BS and less severe for far-away users, which shows that persistent interference is a challenge responsible for signal degradation. The results indicate the need to develop strategies that will improve SINR and manage the interference for end users, particularly those on the boundaries of the service area, in order to sustain a high spectral efficiency.

Figure 5 shows Ergodic capacity versus SINR for four users in the MIMO-NOMA system. The four users are denoted as user 1 (nearest), user 2, user 3, and user 4 (farthest). This figure gives a better understanding of how user distance from the BS impacts long-term average capacity under different SINR levels. As seen, user 1 attains the maximum ergodic capacity at any SINR, given the fact that he is the nearest to the BS. This is because it experiences higher received power and lower interference than the other user, hence enabling better data rates. Ergodic capacity for user 1 grows very rapidly with SINR, meaning that performance gain under good signal conditions is strong.

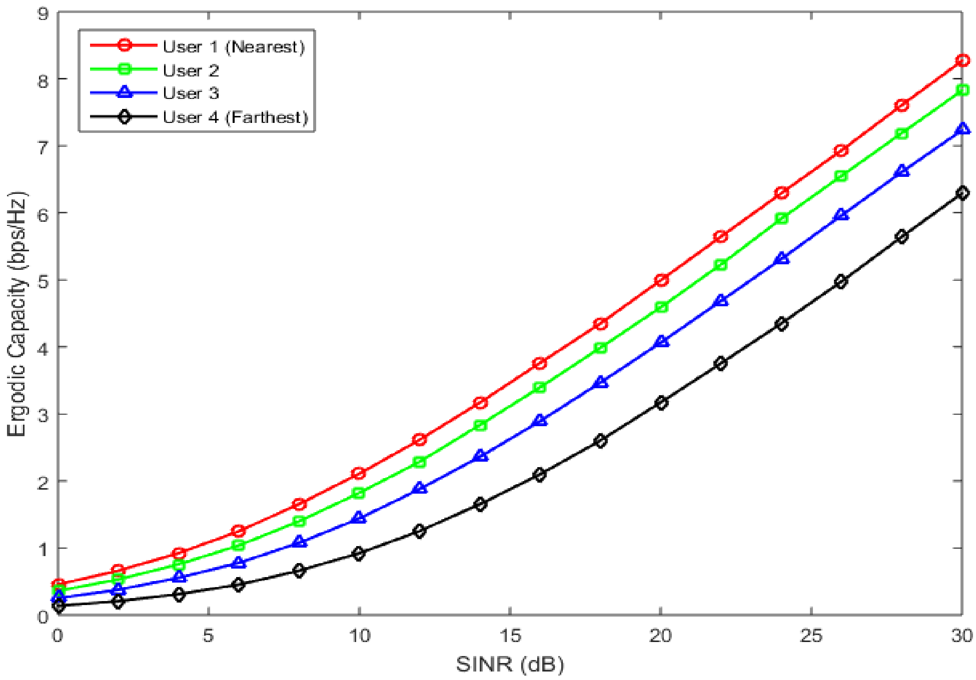

Figure 5. Ergodic capacity analysis for MIMO-NOMA system

User 2 and user 3, being placed in locations at a moderate distance from the BS compared to user 1, offer less ergodic capacities but still show significant increments as SINR improves. That performance shows how MIMO-NOMA can handle interference and optimize capacity for intermediate-distance users. User 4 offers the lowest ergodic capacity, located at the maximum distance from the BS among the four users. Among these factors, the degraded received power and increased interferences are some of the factors that lead to such a poor performance. However, the ergodic capacity for user 4 increases in a very normal way with an increasing SINR, indicating that the system has the ability to improve the capacity even for the most remote users, but at a lesser rate than those users that are closer.

In general, Figure 5 brings to the fore the potential of the MIMO-NOMA system in increasing ergodic capacity among the users at different proximities. The graph vividly emphasizes that the performance is optimized at high SINR and that faraway users suffer when it comes to high data rates. From the above analysis, it is emphasized that advanced techniques might turn out to be necessary for further maximization in capacity for farthest users in the network.

6. CONCLUSION

The comprehensive analysis of the MIMO-NOMA system under Nakagami-m fading reveals that the performance of the system in terms of BER, outage probability, spectral efficiency, and ergodic capacity is considerably improved. The obtained results have explicitly shown that the interference cancellation through SIC techniques could significantly enhance the performance of the system in the power domain multiplexing and effectively cancel out the interference to maximize signal quality. BER analysis confirms that the error rate has significantly decreased with increasing SINR, whereas the results obtained for the outage probability stress the reliability of the system. In addition, the analyses of spectral efficiency and ergodic capacity show the potential of a system in obtaining optimum data rates and long-term average capacity. Future studies on this work could include advanced modulation schemes, adaptive power allocation, and machine learning techniques, which are to pave the path for efficient and reliable next-generation wireless communication networks.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Rubab Ahmmed	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	
Md. Humayun Kabir		✓				✓		✓	✓	✓	✓	✓		
Md. Alomgir Kabir	✓		✓	✓			✓			✓	✓		✓	✓
Kasira-Tut-Tarfi	✓			✓		✓		✓		✓			✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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