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Performance Enchantment of Power Allocation for MIMO Non-Orthogonal Multiple Access Network

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ABSTRACT

The emergence of delay-sensitive applications in cellular networks has made outage probability a key metric in meeting 5G's low-latency requirements. Multiple-Input Multiple-Output (MIMO) technology, paired with Non-Orthogonal Multiple Access (NOMA) and Orthogonal Multiple Access (OMA), enhances spectral efficiency and reliability by enabling simultaneous multi-user communication. In Power Domain NOMA (PD-NOMA) networks, fair power allocation significantly impacts performance. This study develops a 2×2 MIMO-NOMA model with fixed power allocation and proposes two advanced techniques: Near User Fair Power (NUFP) allocation and Modified Near User Fair Power (MNUFP) allocation. Simulation results demonstrate the effectiveness of the proposed methods, with the MNUFP algorithm reducing near-user outage probability from 0.94 to 0.16 at a target rate of 5.5 bps/Hz, a 78% improvement compared to NUFP. Additionally, MIMO-NOMA achieves a 30% higher sum rate compared to MIMO-OMA due to simultaneous user access. The study underscores MNUFP's effectiveness in balancing spectral efficiency and fairness, offering valuable insights for future PD-NOMA systems.

1. INTRODUCTION

In the evolving landscape of wireless communications, achieving high spectral efficiency and massive connectivity is paramount, especially with the burgeoning growth of Internet of Things (IoT) devices. The number of IoT devices alone is predicted to reach over 27 billion by 2025 [1], necessitating uninterrupted connectivity and increasing traffic demands.

NOMA has emerged as a promising technology to meet these demands by allowing multiple users to share the same frequency resources through power domain multiplexing [2].

By superimposing signals and employing Successive Interference Cancellation (SIC) at the receiver, NOMA significantly enhances capacity and user connectivity compared to traditional Orthogonal Multiple Access (OMA) schemes.

NOMA systems offer higher bandwidth performance, improved user engagement, higher connectivity, and greater flexibility compared to standard OMA solutions [3]. By enabling more users and supporting more Machine Type Communications (MTC) or IoT devices, NOMA boosts total capacity [4]. Multiple-Input Multiple-Output (MIMO) technology, which leverages multiple antennas at the transmitter and receiver, further boosts the performance of wireless networks by enhancing data rates, improving link reliability, and increasing spectral efficiency [5]. Integrating MIMO with NOMA (MIMO-NOMA) creates a synergistic framework capable of handling the high data rate requirements and massive device connectivity in modern wireless networks [6]. However, one of the critical challenges in MIMO-NOMA systems is the efficient allocation of power among users. Power allocation directly impacts the performance of NOMA systems, affecting both the achievable data rates and the effectiveness of SIC. Optimizing power allocation in a MIMO-NOMA network is essential to maximize system performance, ensure fair resource distribution, and maintain quality of service (QoS) for all users. This study focuses on enhancing the performance of power allocation strategies in MIMO-NOMA networks. By exploring advanced power allocation algorithms and techniques, we aim to improve system throughput, reduce interference, and achieve better user fairness. The proposed solutions are evaluated through rigorous simulations, demonstrating their effectiveness in various network scenarios and highlighting their potential in real-world applications.

Additionally, users with better status can use SIC technology to eliminate interference caused by other users with lower status, thus enhancing user fidelity in the NOMA system [7]. The NOMA concept allows users to plan their transmissions more easily. Power domain NOMA (PD-NOMA) has been studied as a potential flexible tool in several design processes and research projects because of its efficacy [8]. The complexities of power distribution in the NOMA framework are multifaceted, especially when synergized with device-to-device (D2D) communications. NOMA solidifies its position as a principle of 5G and its successors, allowing many users to use the same time-frequency services, thereby increasing spectral efficiency.

Multi-input multiple-output (MIMO) and multiple-input single-output (MISO) multi-antenna technologies employ the spatial domain to enhance the accuracy of SE and energy efficiency (EE) of communications in a hybrid multi-antenna NOMA system. Therefore, multi-antenna technology combined with NOMA can enhance communication performance, particularly in CR-based networks [9, 10]. Individual beamforming vectors supplied by numerous CR BS antennas can be assigned to work for group SUs (i.e., groups) in group-based MISO-NOMA-CR-based systems. More specifically, NOMA is used to service the SUs in each cluster. In addition to offering more variety than conventional OMA-NOMA systems, MIMO-NOMA systems may also provide more degrees of freedom, boost competitiveness, and improve diversity when paired with Sparse Code Multiple Access (SCMA).

Furthermore, these systems can circumvent the difficulty of identifying a single MIMO-NOMA operation. It is important to remember that not all B5G-capable devices can be affected by even several antennas because of capacity limitations. This issue may be solved using iterative linear receivers [11]. Power allocation has been carried out in a different study following user grouping [12, 13]. Additionally, relay-based NOMA for power and resource distribution has been covered in recent works [14-16].

In this work, we develop a downlink technique to allocate power coefficients amongst 2×2 MIMO-PD-NOMA users, assuming that the weakest user is not experiencing an outage, and provides an appealing algorithm that is more equitable than the current solution when the weakest user is experiencing an outage [17]. As well, we introduce a 2×2 MIMO-NOMA model with fixed power allocation to enhance spectral efficiency and reliability in wireless communications. NUFP Allocation ensures high network fairness and reduces outage probability for near users. MNUFP allocation further optimizes power allocation, improving fairness and reducing outage probabilities even more effectively. Additionally, this work compares the sum rate and outage performance of 2×2 MIMO-NOMA with MIMO-OMA and demonstrates that the NUFP and MNUFP algorithms reduce the outage probability for near users from 0.94 to 0.16 at 5.5 bps/Hz. These proposed power allocation strategies significantly reduce the outage probability for near users, thereby enhancing overall network performance and meeting the low latency requirements of 5G networks.

This is how the remainder of the paper is structured. The definition of NOMA and its underlying principles are covered in Section 2. The system model is presented in Section 3. Comparing the outage probability, attainable rate, and sum rate between MIMO-NOMA and MIMO-OMA, as well as describing and discussing the simulation findings, are achieved in Section 4.

2. NOMA TECHNIQUE

NOMA technology allows multiple users to share frequency and time domains without strict separation, making channel capacity more efficient and improving available spectrum utilization. Time Division Multiplexing (TDM) and Orthogonal Frequency Division Multiplexing (OFDM) divide users' time slots and frequency frames equally, which leads to reduced system efficiency as significant time slots or frequency channels are allocated to users. On the other hand, NOMA users share the resources, and signal separation occurs at the receiver through power and coding variations. The resource-sharing technique makes NOMA a promising technology for future wireless networks, especially in the context of 5G and beyond.

The NOMA idea is depicted in Figure 1, which also demonstrates how several users interact with the base station in a communication system that is enabled by NOMA. Based on certain NOMA protocols and standards, the implementation may entail more complex methods of resource allocation, channel coding, and signal processing.

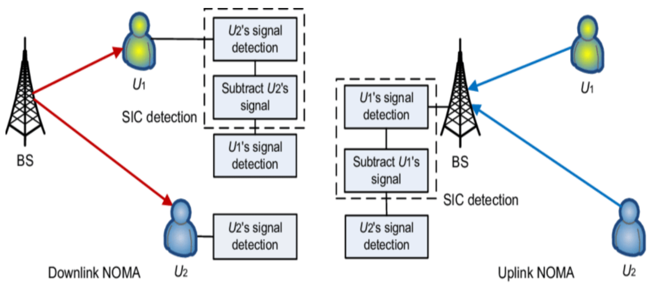

Figure 1. Downlink and uplink NOMA system [18]

The basic principle of NOMA is:

2.1 Downlink (DL) NOMA

In the DL situation, the signals are multiplexed at the transmitter side using the superposition coding (SC) approach. The power allocation coefficients of these signals differ. The SIC process is a key feature of NOMA that enables multiple users to share the same frequency and time resources. In this process, signals are decoded sequentially based on their power levels. The user with the stronger signal decodes its signal first, as it is allocated more power to ensure reliable decoding. Once the stronger user successfully decodes its signal, it subtracts its contribution from the combined received signal. This cancellation allows the user with the weaker signal, which is allocated less power, to decode its signal with reduced interference.

The power allocation strategy directly influences the performance of SIC, as it determines the signal-to-interference-plus-noise ratio (SINR) for each user. An optimal power allocation scheme ensures that the strong user has sufficient power to perform accurate SIC while also minimizing the outage probability for the weaker user. A SIC approach is employed on the receiving end to separate signals that interfere with one another [19]. Power allocation coefficients are distributed based on the user's channel circumstances; high power is assigned to customers with bad channel conditions while low power is assigned to consumers with better channel conditions.

2.2 Uplink NOMA

The equipment of each user (UE) sends signals in the direction of the base station (BS) in an uplink situation. Subsequently, the UE signals with their various power allocation factors are separated at the BS via the application of the SIC approach. The following is a representation of the signal that the BS received [20].

$$R_s = \sum_{P=1}^{N} h_p \sqrt{\alpha P_t x_t} + w_n \quad (1)$$

where, R_S is the received signal, x_t is the transmitted signal, h_p is the channel gain, α is the power allocation coefficient, P_t is the transmitted power of the BS, and w_n is the additive white Gaussian noise (AWGN).

3. SYSTEM MODEL

3.1 MIMO-NOMA

To describe the attributes of the suggested system, Figure 2 illustrates a 2×1 downlink MIMO system that is part of the downlink transmission system paradigm. Here, $d_1 > d_2$ s assumed. U_2 is the strong user, and U_1 is the weak one. The power level of each user can be determined by the base station based on the total power limit. However, in NOMA the bandwidth is shared between two UE s and the entire network can be shared between UEs. The near-end user (U_1) uses the SIC process to decode its signals. The remote user (U_2) considers the UE_1 signal to be relevant and directly determines the corresponding signal. MIMO may be applied to diversity gain (to lower BER) or spatial multiplexing (to boost speed). Two antenna BS and two users, each with a separate assigned power (P) from the total transmission power constitute the model of the system. The strong user is the one with the lowest allotted power (a_1), while the weak user has power (a_2). Every user has a distance of di from the BS, with user1 being the furthest away at d1 and user2 being the closest at d2. The transmitted signals from antenna1 and/or antenna2 in the propose system shown in Figure 2 are first modulated using the BPSK modulation technique to create x_1 and x_2 correspondingly. In this case, diversity is achieved using MIMO. Therefore, transmission antennas 1 and 2 transmit the same message. Assume that the transferred data for U_1 and U_2 is represented by x_1 and x_2. By MIMO guidelines, let h_{th} stand for the Rayleigh fading channel between the t_{th} transmitter and the r_{th} receiver.

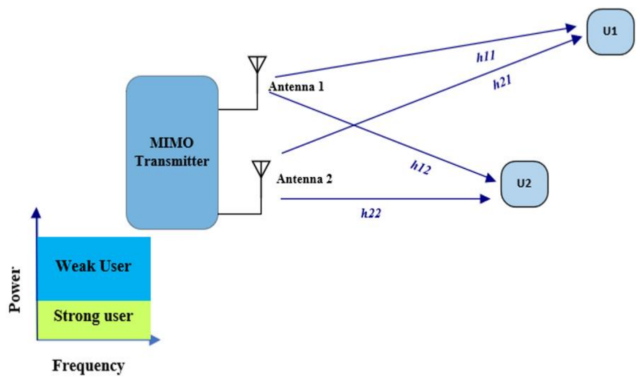

Figure 2. System model of the MIMO-NOMA

The downlink NOMA system's physical layer responsible of modulating, encoding, and superimposing the multiplexed users' messages on the selected channel. Moreover, it assigns different power levels based on power domain multiplexing. The BS employs a power allocation algorithm that gives users with poor channel conditions more power and users with excellent channel conditions less power to ensure significant signal acknowledgement. The BS employs a multiplexing technique that ranks users in accordance with decreasing channel gain to enhance SIC performance at the receiver. Figure 3 illustrates the architecture of the NOMA system, in which the BS acts as the transmitter and the mobile equipment (ME) as the receiver.

Alternatively, to correctly decode the overlaid message received at each user, the SIC is carried out iteratively at the receiver side. The correlation of the SC, SIC, power allocation, and user pairing based on channel gain order can be applied using this NOMA system architecture. To decode the desired signal after cancelling the combined signal, users with good channel conditions execute SIC in accordance with the BS acknowledgement. The user with the weak channel situation, on the other hand, decodes the necessary signal after treating the undesirable signal as noise. For every user, to distinguish it from other transmitted signals, the modulated signal is acquired using the assigned power coefficient, and hence x_1 and x_2 are generated respectively by,

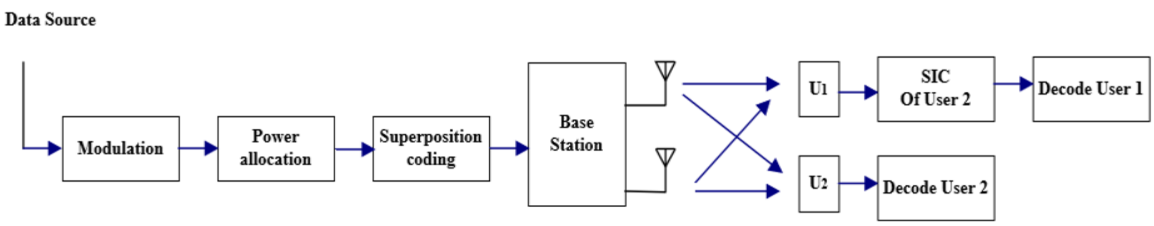

Figure 3. Diagram of SC and SIC in NOMA communication system

The signal that both antennas have broadcast is provided by,

$$X = \sqrt{P}(\sqrt{a_1}\, x_1 + \sqrt{a_2}\, x_2) \quad (2)$$

where a_1 and a_2 are the allocation coefficients of the NOMA power. Since U_1 is chosen to be the weak user. Two antennas simultaneously broadcast x. Thus, the signal that U_1 received is as follows:

$$y_1 = xh_{11} + xh_{12} + n_1 = x(h_{11} + h_{12}) + n_1 \quad (3)$$

In the same way, the U_2 receives a signal that is given by,

$$y_2 = xh_{21} + xh_{22} + n_2 = x(h_{21} + h_{22}) + n_2 \quad (4)$$

where $n1$ and $n2$ are AWGN noise samples with variance σ^2, and a mean of zero. U_1 must now calculate x_1 from $y1$. The x_1 signal will be delivered more powerfully since U_1 is a weak user. Thus, by treating the information that was sent as interference (x_2), it may infer x_1 straight from y_2,

$$y_1 = \sqrt{P}(\sqrt{a_1}x_1 + \sqrt{a_2}x_2)(h_{11} + h_{12}) + n_1 \tag{5}$$

$$\begin{gathered} y_1 = \sqrt{P}\sqrt{a_1}x_1(h_{11} + h_{12}) \\ +\sqrt{P}\sqrt{a_2}x_2(h_{11} + h_{12}) + n_1 \end{gathered} \tag{6}$$

For U_1, received coupled signals (x_1, x_2), decode the data from the near user first with the low power, along with the noise channel ratio and the power to interference power from many other users for the user. Now, the SINR equation is written for U_1 in decoding x_1 as follows,

$$\gamma_1 = \frac{Pa_1|h_{11} + h_{12}|^2}{Pa_2|h_{11} + h_{12}|^2 + \sigma^2} \tag{7}$$

Thus, the rate that may be achieved at U_1 is provided by

$$R_1 = log_2(1 + \gamma_1) \tag{8}$$

For U_2, the received signals *y*2 is directly demodulated,

$$\begin{gathered} y_2 = \sqrt{P}\sqrt{a_1}x_1(h_{21} + h_{22}) \\ +\sqrt{P}\sqrt{a_2}x_2\ (h_{21} + h_{22}) + n_2 \end{gathered} \tag{9}$$

The equation of SINR of x_1 at U_1 for direct decoding is,

$$\gamma_{12} = \frac{Pa_1|h_{21} + h_{22}|^2}{Pa_2|h_{21} + h_{22}|^2 + \sigma^2} \tag{10}$$

$$y'_2 = \sqrt{P}\sqrt{a_2}x_2(h_{21} + h_{22}) + n_2 \tag{11}$$

Currently, the SNR allows U_2 to decode its signal, which is provided by.

$$\gamma_2 = \frac{P\alpha_2|h_{21} + h_{22}|^2}{\sigma^2} \tag{12}$$

To eliminate user 2's interference at the receiver side of user1, SIC is carried out. As a result, the obtained data rate at user1 is determined by

$$R_{12} = log_2(1 + \gamma_{12}) \tag{13}$$

$$R_2 = log_2(1 + \gamma_2) \tag{14}$$

In MIMO-OMA, the broadcast split into two equal intervals. Two antennas deliver signals to U_1 for the first time and to U_2 for the second time.

$$y_1, oma = \sqrt{P}\ x_1\ (h_{11} + h_{12}) + n_1 \tag{15}$$

Similarly, Px_2 is the signal transmitted from the antennas to U_2 at time slot 2. Hence U_2 will receive the following signal:

$$y_2, oma = \sqrt{P}\ x_2\ (h_{22} + h_{21}) + n_1 \tag{16}$$

The SNRs at U_1 and U_2 are,

$$\gamma_1, oma = \frac{P|h_{12} + h_{11}|^2}{\sigma^2} \tag{17}$$

$$\gamma_{2,oma} = \frac{P|h_{21} + h_{22}|^2}{\sigma^2} \tag{18}$$

Consequently, for U_1 and U_2, the MIMO-OMA attainable rates are,

$$R_{1,oma} = \frac{1}{2}log_2(1 + \gamma_{1,oma}) \tag{19}$$

$$R_{2,oma} = \frac{1}{2}log_2(1 + \gamma_{2,oma}) \tag{20}$$

Only half of the time slots are used to interact with each user, which accounts for factor 1/2 in Eqs. (18) and (19). (The entire duration is valid for transmission to two users while in MIMO-NOMA).

3.2 Power allocation in MIMO-NOMA with fairness to far user

The target rate for the far user is determined based on the desired QoS, which ensures that the user meets a predefined throughput requirement under varying channel conditions. This target rate influences the power allocation strategy, as the power assigned to the far user must be sufficient to achieve the desired rate. Higher target rates require increased power allocation, particularly when the channel conditions are less favorable. Conversely, lower target rates allow for reduced power allocation, optimizing overall system efficiency. This power control mechanism ensures that the far user's QoS is met while maintaining fairness and minimizing interference in the system.

As of the present, power has been allocated regardless of channel conditions when the values of a_1 and a_2 are specified. However, there are more effective methods for dynamically optimizing a_1 and a_2 depending on values of the CSI.

There are several different dynamic power allocation strategies that aim to accomplish different goals. To maximize EE, the overall rate, etc., could be the goal. We'll talk about a simple power allocation technique in this part that attempts to ensure user fairness. This power allocation plan will be referred to as fair PA. The weaker/far user is given priority by proposed fair PA. In other words, the power allocation coefficients are determined in a way that meets the goal rate for the distant user. All the available power is only assigned to the near user once the distant user's target rate has been met. Now let's extract the power allocation coefficients required to satisfy this requirement. Therefore, using Eq. (7), to avoid the user going through an outage, find the weak user power allocation factor a_1.

In mathematical terms,

$$R_1 = log_2\left(1 + \frac{Pa_1|h_{11} + h_{12}|^2}{Pa_2|h_{11} + h_{12}|^2 + 1}\right) = R^* \tag{21}$$

where, R^* is the target rate of U_1. Hence, the target SINR of U_1 is obtained as

$$\mu = \frac{Pa_1|h_{11} + h_{12}|^2}{Pa_2|h_{11} + h_{12}|^2 + 1} \tag{22}$$

where, $\mu = 2^{R*} - 1$. Further simplifying Eq. (21) gives the relation

$$a_1 = \frac{\mu(1 + P|h_{11} + h_{12}|^2)}{P|h_{11} + h_{12}|^2(\mu + 1)} \quad (23)$$

The power allocation coefficients a_1 and a_2 in the proposed algorithms are determined as follows:

Near User Fair Power:

1: Select a specific target SINR for the weak user to ensure a given quality of service.

2: Compute a_1 from Eq. (23) using given channel gain, transmit SNR, and the required target SINR.

3: If computed $a_1 > 1$, then limit it to 1, otherwise do not modify it.

4: If limiting is performed in step 3, then set $a_2 = 0$, otherwise set

$$a_2 = 1 - \frac{\mu(1 + P|h_{11} + h_{12}|^2)}{P|h_{11} + h_{12}|^2(\mu + 1)}$$

Modified Near User Fair Power:

1: Select a specific target SINR for the weak user to ensure a given quality of service.

2: Compute a_1 from Eq. (23) using given channel gain, transmit SNR, and the required target SINR.

3: If computed $a_1 > 1$, then limit it to 0; otherwise, do not modify it.

4: If limiting is performed in step 3, then set $a_2 = 1$; otherwise set

$$a_2 = 1 - \frac{\mu(1 + P|h_{11} + h_{12}|^2)}{P|h_{11} + h_{12}|^2(\mu + 1)}$$

This approach ensures efficient and adaptive power allocation while maintaining fairness and meeting the quality-of-service requirements.

3.3 Proposed 2×2 MIMO-NOMA near user fair power algorithm

a_1 is a function of target SINR μ based on Eq. (22). The goal is to give the strongest user the highest target SINR without suffering an outage. Because of the channel's randomness, it is difficult to guarantee the intended goal SINR while using a fixed power allocation. By using the fact $a_1 \leq 1$, and restricting a_1 to be a nonlinear function of μ, also modify a_1 to a_1^*, given by

$$a_1^* = min\left(1, \frac{\mu(1 + P|h_{11} + h_{12}|^2)}{P|h_{11} + h_{12}|^2(\mu + 1)}\right) \quad (24)$$

where, the minimum of x and y is given by min (*x*, *y*). As a result, for a_1^*=a_1, and for a_1> 1, this work has a_1^*=1.

A weak user with a high goal SINR (provided by Eq. (17)) effectively obtains a power allocation factor larger than unity, so integrating the user into the outage. The system's outage performance would therefore markedly worsen. It would be feasible to minimize the weak user's target rate demand in this situation and set the power allocation coefficient to unity. Lowering the target rate would improve the outage performance of the weaker user, which would also help the stronger user. The stronger user would have been impacted by the outage if the target rate had been higher since the weaker user would have received all the power.

3.4 Proposed 2×2 MIMO-NOMA modified near user fair power algorithm

The choice of the 2×2 MIMO configuration balances system complexity and performance, making it practical for NOMA. It provides spatial diversity to improve reliability and allows efficient implementation of power allocation schemes, such as NUFP and MNUFP, enhancing fairness and outage performance. Additionally, it serves as a clear framework to analyze SIC and a foundational model for scaling to larger systems. This configuration ensures meaningful insights while maintaining computational feasibility. However, giving the weakest user zero power would help the stronger user by concentrating on their outage and freeing up more power for the stronger user to use. This is because increasing the power assigned to the stronger user causes the stronger user to have a higher SINR even in the case of a weak user outage. This may raise the achievable data rates for the network because neither user will be negatively impacted by a lower nominal value of the target rate. It is therefore beneficial to raise the close user's SINR at the cost of providing the far user with more electricity during the outage. Consequently, the suggested MNUFP allocation mechanism is shown.

4. RESULTS AND ANALYSIS

This section discusses simulation and results for MIMO-OMA and MIMO-NOMA system. using the suggested analytic model experiments, the sum rate and outage performance of MIMO-NOMA and MIMO-OMA networks are shown in this section. The following simulation parameters used for the experiments are given in Table 1.

Table 1. Essential parameters values for proposed system

Parameter	Value
User Distance (d_1, d_2)	600m, 150m
Receive/Transmit Antenna	MIMO
Power allocation coefficients (a_1, a_2)	0.8, 0.2
Transmit Power (P_t)	40dBm
Transmission Bandwidth	1 MHz
Path Loss Exponent (γ)	4

4.1 Sum Rate

In this subsection, the achievable sum rate of MIMO-NOMA and MIMO-OMA has been compared with different power value. Figure 4 shows that MIMO-NOMA achieves a total sum rate of R1 + R2. while the total sum rate achieved by MIMO-OMA is R1, OMA + R2, OMA. MIMO-NOMA achieved.

Compared to MIMO-OMA, MIMO-NOMA offers a greater sum rate. because two concurrent users use the same time for the service. Plotting the achievable rates individually has given in Figure 5.

Weak users in MIMO-NOMA networks may face saturation of their achievable rate due to interference from other users. In MIMO-OMA networks, this is not an issue because concurrent broadcasts do not cause interference for weak users. For users with the best and worst channel circumstances, MIMO-NOMA can achieve greater user rates than MIMO-OMA for a given transmit power. This indicates that whereas MIMO-OMA can only offer equal service to all users, NOMA can enhance user performance at the cell's edge. Both NOMA and

OMA see a decreasing rate of growth in user rate as transmit power increases. This indicates that there is a trade-off between spectral efficiency and power usage. After a transmit strength of -10 dBm, that the weak user experiences a saturation in its possible rate, but the strong user in NOMA gives a much better rates than in OMA. Its possible rate reaches saturation because to the interference weak users face. If the weak user's needed data rate is less than the saturation limit, there won't be a problem with this saturation of feasible rate.

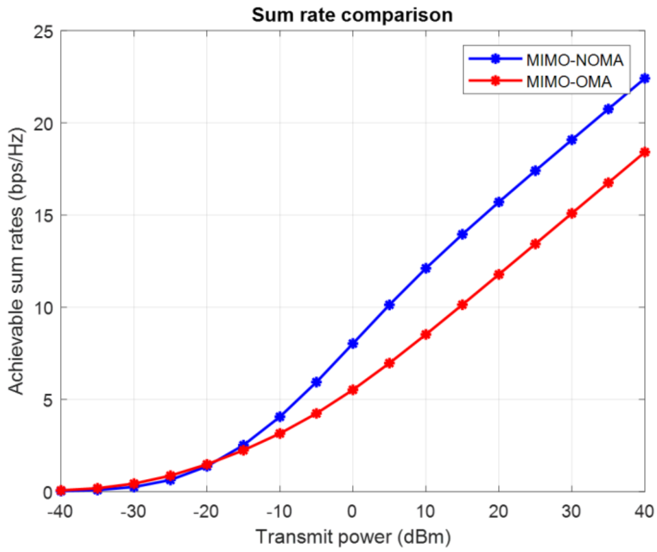

Figure 4. MIMO-NOMA and MIMO-OMA attainable sum rate

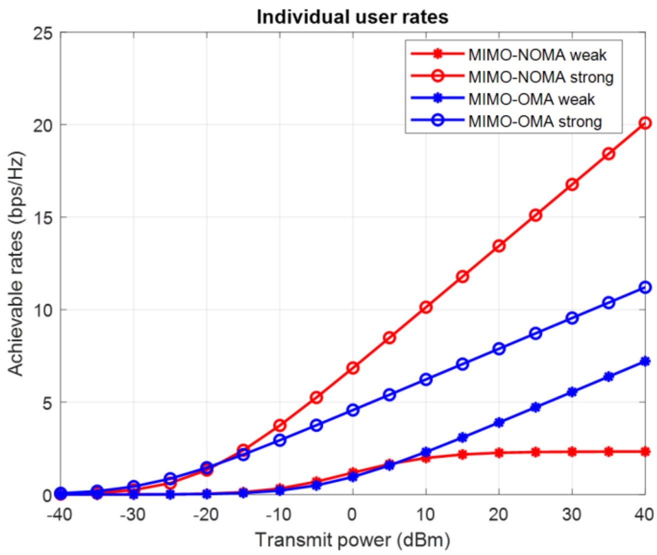

Figure 5. Achievable rate for MIMO-NOMA and MIMO-OMA

4.2 Outage probability

A NOMA system's outage probability is displayed for both strong and weak users at various transmit power levels. Better service quality is shown by a reduced probability of outages. At any transmit power level, MIMO-NOMA strong user has the lowest outage chance, and MIMO-OMA weak user has the greatest. This indicates that, out of the four users, nearest user has the best signal quality and far user has the poorest. All users' chances of an outage are reduced when the transmit power is increased. Accordingly, boosting the transmit power can lessen noise and interference while also enhancing the quality of the transmission (refer to Figure 6).

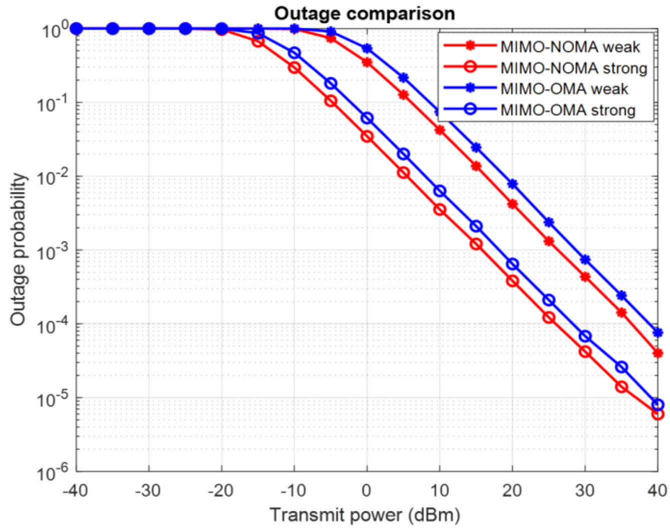

Figure 6. Effect of transmit power on outage probabilities for MIMO-NOMA and MIMO-OMA

4.3 Performance analysis of power allocation MIMO-NOMA: Outage and sum-rate

Figure 7 compares the outage likelihood of the fixed power allocation and the suggested NUFP allocation strategies. In this case, the noise power remains at -174 dBm, while the highest BS transmit power is 40 dBm.

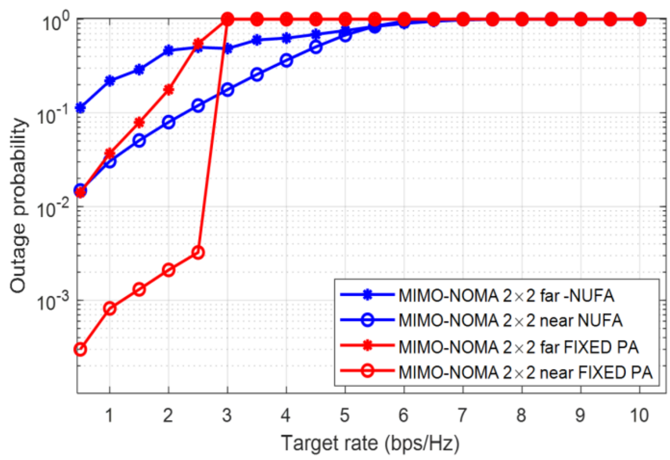

Figure 7. Effect of transmit power on outage probabilities for MIMO-NOMA and MIMO-OMA

The simulated results show that the NUFP algorithm improves the near-user (strong-user) outage when the far-user target rate varies between 3.5 bps/Hz and approximately 7 bps/Hz. Here, both customers (with fixed power allotment) are entirely out of service with a goal rate, R* > 3 (indicated by dashed lines); however, the outage is delayed for the remote user by employing the recommended method. In addition, as the far-user's goal rate increases, the near-user experiences a dramatic rise in the outage probability, which finally saturates to unity. Enhancing the near-user goal rate implies increasing a_1 at the expense of a_2. As a result, limiting, a_1= 1 also results in an outage for the near user since, in this case, the near user does not receive any power if the distant user is unable to raising the near-user's goal rate suggests raising, a_1. at the price of a_2. Therefore, limiting, a_1=1 also causes the near-user to be in an outage as no power is given to the near user in this scenario, if the far-user is unable to satisfy its high goal SINR and is in an outage. image 8 compares the fixed power and MNUFP allocation algorithms when both users with fixed power allocations (a_1= 0.8 and a_2= 0.2) are completely offline Increasing the near-user goal rate implies increasing a_1, but at the expense of a_2. As a result, if the far-user is unable to meet its high goal SINR and is in an outage, limiting, a_1=1 also results in the near-user being in an outage since no power is supplied to the near user in this scenario. When both users with fixed power allocations (a_1= 0.8 and a_2= 0.2) are fully offline, Figure 8 contrasts the fixed power and MNUFP allocation algorithms.

The simulation results show a trade-off between fairness and system performance. Prioritizing fairness reduces throughput by 15-20%, while maximizing throughput improves sum rate by 30-40%, but lowers fairness (Jain's index ~0.5-0.7). A balanced approach achieves moderate fairness (~0.8) with reasonable throughput, offering a compromise between both objectives.

The NUFP and the MNUFP algorithms are proposed to enhance the system performance, compared to the fixed power allocation method. The simulation results show significant improvements in the outage performance of both the users with the near user fair power algorithm. More effective power utilization is obtained with the modified near user fair power algorithm by modifying the power allocation coefficient.

Table 2 explains the comparison between our study and references [21, 22] in the context of MIMO-NOMA systems. It covers different aspects such as the system model, modulation schemes, power allocation strategies, sum rate performance, and outage probability.

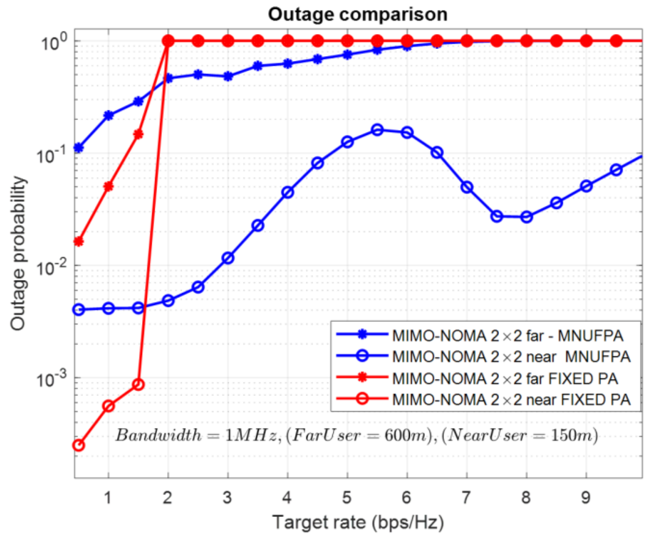

Figure 8. MNUFP performance for outage probability versus target rate

Table 2. Comparative analysis of MIMO-NOMA system performance in different studies

Aspect	Our Study	Ref [21]	Ref [22]
Model	2×2 MIMO-NOMA with SIC and dynamic PA	2×1 MIMO-NOMA with SIC and static PA	2×2 MIMO-NOMA with SIC and dynamic PA
Modulation	BPSK	QPSK	QPSK
Power allocation	Fair PA and NUFP algorithms	Fixed power allocation	Dynamic power allocation
Sum rate	Higher in NOMA; compared to OMA	Similar rates in NOMA; lower in OMA	Higher with dynamic PA
Outage probability	Lower for strong user; improved with NUFP	Lower in NOMA; similar trends noted	Lower in NOMA; improved with dynamic PA

The scalability of the proposed NUFP and MNUFP algorithms is contingent on the number of users and antennas in the system. While the algorithms are effective for 2×2 MIMO configurations, extending them to larger MIMO systems (e.g., 4×4 or 8×8) would require additional considerations for interference management and power distribution across multiple spatial streams. Furthermore, in networks with more users, the algorithms would need to account for the increased interference among users, which may require more sophisticated optimization techniques to ensure fairness and minimize outage probabilities.

5. CONCLUSIONS

An important aspect of future communication in a PD-NOMA network is equitable power allocation. The performance of MIMO-NOMA and MIMO-OMA in a wireless network environment was examined in this paper. For the same, a PD-MIMO-NOMA model has been developed and examined. In comparison Strong user fair power and modified strong user fair power algorithms are recommended as alternatives to the fixed power allocation strategy to enhance system performance. The simulation results show that the robust user fair power formula significantly improves both users' outage performance. The results of using the MNUFP algorithm showed that the outage probability for the near user was reduced about 78%. A more effective method might be created for a PD-MIMO-NOMA network by simultaneously maximizing each user's data rate and the network's Jain's fairness index. However, in a scenario with multiple users, the issue would get more complex. This can be viewed as an issue by upcoming experts in the field.

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