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5G Mobile Communication Performance Improvement with Cooperative-NOMA Optimization

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Abstract: : The 5G mobile communication cellular networks are expanding rapidly. With the quick development of several new services and mobile applications, there is an anticipated consumption of frequency and bandwidth resources in the upcoming cell phone networks. Therefore, networks suffer from low speed and high latency. Corporative Non-Orthogonal Multiple Access (C-NOMA) is an approach method to meet the various needs of improved user fairness, high reliability, high spectral efficiency (SE), extensive connectivity, raising data rates, high flexibility, low transmission latency, massive connectivity, low delay, higher cell-edge throughput, and superior performance. This paper mainly focuses on power-domain (PD-NOMA), which employs successive interference cancellation (SIC) at the receiver and superposition coding (SC) at the transmitter. Also, this paper compares C-NOMA, NOMA, and OMA for different types of environmental fading. This paper shows how NOMA performance can be improved when combined with numerous confirmed wireless communication network strategies, including cooperative C-NOMA system communications, with the help of optimization. The simulation results demonstrated enhancements in cooperative NOMA compared to non-cooperative NOMA and OMA with the help of MATLAB and NYUSIM simulations. The results also demonstrated that the improvement is valid with the increase in bandwidth frequency signal spectrum for the varying near and far user distances.

Keywords: 5G, NOMA, Cooperative NOMA, Fading channel, mmWave, Optimization

1. Introduction

The rapid expansion of mobile cellular applications has driven the anticipated enormous improvement in data traffic for cellular mobile communication in the future. Spectral efficiency is consequently one of the main challenges to enhancing mobile broadband (eMBB) features, including virtual reality and videos. Furthermore, 5G has to accommodate various instances via machine-type communication (MTC) to meet the increasing demand for the Internet of Things (IoT). Massive machine-type communication, which has low data rates, and MTC, which has high reliability and low latency, are the two basic types of MTC. The network must support many connections with limited, brief messages for enormous MTC, and it must be inexpensive and energy-efficient to allow for widespread implementation [1], [2].

Determining the performance of mobile communication systems is crucial for next-generation wireless networks that make use of various access strategies that are very spectrum-efficient. Various systems of orthogonal access technologies have been presented as both the current and prior generations of mobile communications. The two multiple access strategy types are OMA and NOMA, depending on the resource allocation method and facilities assigned to all individual users in the system. The strategy technique, orthogonal frequency division multiple access (OFDMA), is represented by three facilities: (CDMA) Division Multiple Access with Coding Domain, (TDMA) Division Multiple Access with Time Domain, and (FDMA) Division Multiple Access with Frequency Domain, are the most common multiple access OMA techniques [3], [4].

Whether a user has a strong or weak channel state, a specific frequency resource is allocated to them in OFDMA and OMA, which results in low throughput and spectral efficiency for the system. Meanwhile, several mobile users with various channel conditions are concurrently assigned the same frequency resource in NOMA. Consequently, the dominant user utilizes the resources assigned to the less powerful user and SIC processes at the users' receivers can mitigate interference. Thus, there will undoubtedly be a considerable boost in the probability of achieving higher throughput and better spectral efficiency [5].

Cooperative communication NOMA networks, often called

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C-NOMA networks, use the wireless channel's broadcast characteristics by incorporating relays that serve as an alternate link in cases of weak transmission. The cooperation process is performed using relaying nodes. Employing relays in NOMA networks enhanced diversity gain and throughput in network performance once cooperative communication was successfully implemented in 5G. Relaying networks might be source nodes facilitating user interaction or specialized relay nodes [6]. Cooperative communication is one of the main physical layer technologies that aim to maximize spectral efficiency. The idea is to enhance the transmission and reception processes by utilizing the users' standard information and resources [7]. The paper aims to investigate and enhance the 5G performance through the use of power-domain (PD-NOMA), which employs successive interference cancellation (SIC) at the receiver and superposition coding (SC) at the transmitter. The paper also aims to investigate C-NOMA, NOMA, and OMA for different types of environmental fading. On this aspect, the paper proposes a study of C-NOMA system communication for uplink NOMA and downlink NOMA as a new technique system used to enhance the performance of 5G mobile cellular networks to mitigate the three features as eMBB enhances mobile broadband, m-MTC massive machine-type communication, and URLLC ultra-reliable and low-latency communication. As a contribution, the paper shows how NOMA performance can be improved when combined with numerous confirmed wireless communication network strategies, including cooperative C-NOMA system communications, with the help of optimization. The simulation and evaluation results proved that the proposed system provides significantly higher performance in terms of data rate, BER, and outage probability and reduces the power consumption to 52.6% and 54.7% compared to NOMA without cooperative and without NOMA, respectively, which is higher than the related works. The rest of this study is in the following order: Section 2 presents the multiple access and NOMA techniques. In Section 2, detailed related works concerning C-NOMA have been presented and discussed. Section 4 describes the proposed C-NOMA when integrated and optimized with the 5G scheme. Sections 5 and 6 presented the modelling, simulation, and evaluation of the proposed system combination for DL and UL C-NOMA channel systems. Finally, the conclusion is in Section 7.

2. Multiple Access and NOMA Techniques

Two main types can be categorized as multiple access (MA) techniques: OMA and NOMA. Figure 1 shows the milestone developments of multiple access [8]. Conventional OMA technique methods provide radio resources to numerous users; they are orthogonal to other users concerning time, frequency, or code domain. Ideally, OMA's orthogonal resource allocation would not cause any interference between users. In conventional OMA technique methods, the total number of orthogonal resources and their allocation complexity determine the maximum number of supported users [9]. Moreover, the demanding requirements of incoming cellular systems, such as spectrum with higher efficiency, massive connections with a higher range of quality of service (QoS), lower latency, and fairness of users, have not been achieved by OMA.

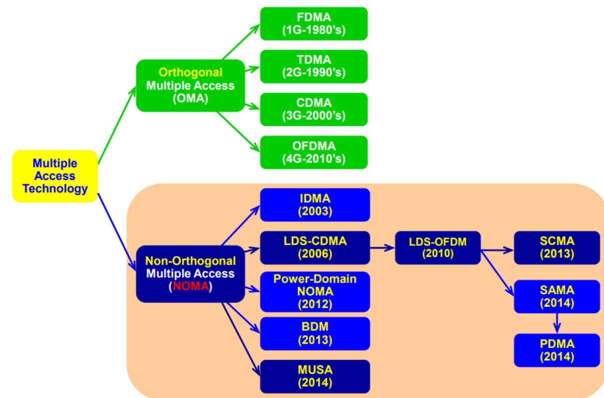

Figure 1. The milestone developments of multiple access [10].

Considering all of these needs, it is not unexpected that promising communication systems and new technologies are considered a problem. Consequently, NOMA is introduced as a possible technology that might be applied to satisfy the new requirements. NOMA is a practical approach in network wireless communication for creating new radio access for (5G) mobile cell networks. NOMA can achieve excellent spectrum efficiency by combining the concept of Superposition Coding SC, which is used on the transmitting side, with the SIC principle, which can be utilized on the receiving side [10].

The NOMA system, an upcoming physical layer communication technique, has attracted much attention as a new method for boosting the vast number of users that can be serviced concurrently by arranging many users carrying on the same spectrum resource allocation but at various power allocation levels. The primary justification for implementing NOMA in 5G is its capacity to accommodate numerous users concurrently while utilizing similar frequency and time resources [11]. The Code domain multiplexing technique and the power domain multiplexing technique are two of NOMA's primary standards. This separation domain often belongs to one of two techniques: power-based or code-based, which results in NOMA processes specific to the power domain or code domain, accordingly [12]. Depending on their channel status information, different users in the power domain NOMA are assigned varying power levels (CSI). Sequential interference cancellation (SIC) at the decoder is achievable by the difference in power levels and channel gains. NOMA utilizes SC to utilize the advantages of the power domain and SIC for multiuser identification. As a result, SIC is required on the destination receiver side. Different codes are assigned to various users within the source code domain, multiplexing NOMA to facilitate multiuser communications [13], [14]. Compared with

traditional OMA, NOMA may provide more significant sum rates, reduced outage probabilities, and improved customer fairness [15].
The NOMA technique utilizes SIC, wherein the first nearby user decrypts another user's signal from a received signal that has been superposed coded before decoding his message from the signal. In particular, during SIC, the nearby user decrypts the information signal from the far user. However, the data of the weak user needs to be decoded by the nearby user. To provide the weak user, the strong user may as well provide him with the information that the far user possesses. The nearby user will give the far user variance in retransmitting data since the far user's channel with the transmitting base station (BS) is weak. In other words, the same message will be sent to the far-away user two times. One message is from the BS, while the other is from a nearby user serving as a relay. As a result, we can anticipate a drop in the far user's outage probability [16], [17]. Furthermore, NOMA can be implemented using (massive-MIMO) relaying, which significantly enhances throughput when compared to traditional (MIMO-OMA) [18], [19].

The two main types of NOMA technique schemes are the power and coded NOMA techniques. Several users share the same time-frequency code resources in the power domain NOMA but are assigned varying power levels based on their channel quality. The power NOMA technique uses SIC at the receiver side to identify different users using the power difference between users. Except for its inclination to use low-density or non-orthogonal sequences with limited coding, the coded NOMA technique is comparable to CDMA or multi-carrier CDMA (MC-CDMA) [7], [18]. NOMA's fundamental idea is that numerous signals of different power allocation levels are connected on the transmitter side to create a superimposed signal (SS). Successive interference cancellation SIC, as seen in Figure 2, is employed on the receiving end to retrieve each user's signal from the superimposed signal SS to guarantee a weak user's QoS. By considering other signals as interference, the far-right user can specifically decrypt the strongest signal. SIC terminates if the decrypt signal is its data. If not, the next strongest signal will be deciphered by the receiver, subtracting the decrypted signal from SS.

In the NOMA technique system, SIC is a crucial tool used at the receiver, enabling the detection and decoding of many users. In transmitter/receiver (uplink/downlink detection), the SIC processor first decodes a prominent interference and subtracts it from the SS to retrieve each user-desired signal. The superposition of many signals with varying power levels is crucial to diversifying each user signal. Moreover, the SIC is performing at a specific UE end. Because in the downlink, each user's equipment (UE) gets the other user's signal (the required interference signal) across its channel. The following formula relation will be

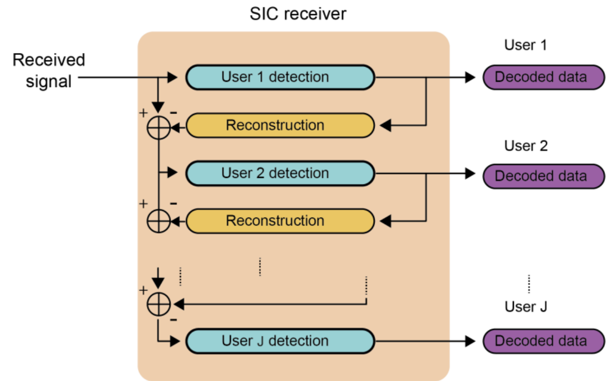

Figure 2. The process steps of the SIC technique [16].

used to determine the possible data rates (R) for each UE paired with NOMA: [20]

$$R_{\text{NOMA}} = B * \beta * \log_2(1 + (\alpha * \text{SINR})) \tag{1}$$

where the portion of the total bandwidth waveform B occupied by the UE is represented by β, and the portion of the power resource allocated is represented by α.
The data rates (R) for OMA in comparison to NOMA are calculated as follows [20]:

$$R_{\text{OMA}} = B * \beta * log_2(1 + \text{SINR}) \tag{2}$$

Several reasons show the domination of NOMA over conventional OMA; these include [21], [22]:

- NOMA achieves superior spectral efficiency.
- NOMA can support massive connectivity;
- The user experiences less latency because they do not have to wait for a scheduled time to transmit their information;
- NOMA can preserve diverse quality of service and user fairness.

To fully utilize the benefits of NOMA, several restrictions and implementation concerns must be resolved, such as [23], [24]:

- Every user with lower channel gains must decode the data of every other user.
- The subsequent decoding of all other users' information will likely be done incorrectly when a user's SIC error happens.
- In order to reap the purported advantages of power-domain multiplexing, a significant differential in channel gain between strong and weak users is necessary.
- Every user must provide the BS with information

about their channel gain.

Cooperative communications attracted more attention in wireless networks because it might provide spatial location variety to reduce fading and overcome the challenges of installing several directional on compact communications terminals. Multiple relay nodes are designated in a communications cooperative system to aid a source in forwarding information to the appropriate recipients [25].

In wireless networks, a cooperative communication system is an efficient way of expanding coverage and offering location diversity. Reducing cell edge users' outage probability and raising their overall quality of service is the primary objective of implementing cooperative NOMA. As cooperative communications might reduce fading and solve the challenge of installing multiple antennas on small wireless connections, such as physical variety, it has been highly recommended for implementation during the deployment of 5G [26], [27].

Cooperative communications, when implemented with NOMA, can enhance and increase the coverage capacity and reliability of the system. The NOMA systems technique, along with earlier information, is utilized by the C-NOMA technique. By using the NOMA technique, users with greater network characteristics enable other users to decode the information messages. As a result, these users serve as relays to increase the dependability of users' reception for users with weaker connections to the BS. The C-NOMA technique in the fifth generation is considered to maximize the potential of NOMA in multiuser environments where one of the users acts as the relay role for another user. The purpose of C-NOMA is to reduce this restriction by enabling weaker power users to transmit stronger power users' signals over wireless communication without any interference. The capacity to improve system performance, particularly efficiency and reliability, two major issues in wireless communication, is another important benefit of utilizing cooperative communications in NOMA [25], [27].

3. Related Works

Two primary types of NOMA solutions have been studied to overcome the complicated separation of all users' data. Power-domain NOMA is one method, and code-domain NOMA is another. NOMA has numerous benefits. It is an appropriate multiple access candidate system for mobile and massive machine-type communication[28].

Researchers in [29] examined the spatial and transmission diversities in C-NOMA to improve the sum rate. Researchers proposed a user pairing technique where near field user pairs serve as relays for user pairs in the far field region. to increase the transmission diversity in the cooperative phase. Researchers incorporated a space-time block code and considered a non-linear energy harvesting model at the near field user pair to alleviate the problem of energy consumption.

A two-phase cooperative communication system is proposed in [30]. The authors used the NOMA technique to allocate radio resources and power for the relays. Their results demonstrated that this approach offers a substantially higher coverage probability and data rate performance compared to non-cooperative communication systems, while also reducing power consumption by as much as 16.7%.

In [22], the authors used three scenarios: OMA technology, NOMA technology by using Genetic Algorithms (GA), and NOMA technology by using Gray Wolf Optimization (GWO). They performed comparisons with and without neighbouring cell interference. Their findings demonstrated that their proposed method—NOMA by employing GWO—is superior to the other two situations in terms of user fairness and sum rate.

The performance of Massive-MIMO and NOMA for both conventional and C-NOMA is explored in [31]. The author explored the efficacy of Downlink (DL) and Uplink (UL) NOMA Power Domain (PD) in a 5G network. The results show that MIMO-NOMA remarkably improve performance in term of BER and power required in transmission in the download transmission. Moreover, the average capacity rate has been increased with uplink transmission.

Two novel approaches to improve the signal efficiency SE of the downlink (DL) NOMA (PD) integrated with a cooperative cognitive radio network (CCRN) in a 5G network were studied in [11]: The approaches made use of single-input and single-output (SISO-MIMO) and massive-MIMO in the same network and a single cell. According to their findings, increasing the number of users and utilizing M-MIMO, along with effective bandwidth shaping techniques, efficient channel coding techniques, and substantial multiple access techniques, are the key strategies for enhancing SE.

The authors in the paper [32] analysed the outage probability and sum rate in the case of the DL dynamically ordered NOMA system. Their study maximized the sum rate by using Karush Kuhn Tucher's technique (KKT). Researchers studied and simulated to confirm the expression obtained for outage probability and sum rate over Rayleigh channel fading. Their results showed that the sum rate was maximized using the KKT technique.

In [33], researchers developed a hybrid NOMA supported DL transmission for the SISO and MIMO scenarios based on SDMA and TDMA. Authers showed that DL hybrid NOMA outperform OMA.

Researchers in [34] proposed and investigated a novel constructive multiple access (CoMA) as an alternative method for SIC at the receiver and attractive solution for user pairing. Authers obtained an optimal precoder to reduce the total transmission power according to a QoS constraint. Researchers investigated a precoder to minimize the CoMA symbol error rate SER subject to power constraint.

An overlapping O-C-NOMA technique is proposed in [35]. Researchers formulated an optimization problem to increase the cell-edge users QoS by controlling the O-C-NOMA between cell-centre and cell-edge users. Researchers observed that O-C-NOMA enables more flexible resource sharing and cooperation between users, outperforming the conventional C-NOMA.

It is clear from the previous studies that OMA suffers from poor data rates and signal quality. Moreover, NOMA can fix this problem by employing suitable power allocation. Thus, NOMA is worth investigating and will be an excellent candidate for achieving the paper's objectives. Using the same band of frequency simultaneously for numerous users in the cell and some form of corporative communication, such as D2D NOMA, can be extremely helpful in achieving massive connections. Moreover, using a power allocation approach in transmissions between the base station (BS) and the mobile station (MS) in the downlink and uplink phases, user fairness, secure connectivity, and spectral efficiency can all be satisfied by NOMA.

4. Proposed Methodology

A C-NOMA transmission technique is proposed to utilize previous information that is accessible in NOMA systems. Users collaborate to enhance and improve the systems through performance and power-domain multiplexing, similar to NOMA, but with user cooperation. If the power allocated to user i is represented by P_i and channel gain for user i is represented by h_i, the received signal y_i can be stated as:

$$y_i = \sqrt{P_i.h_i} \; . \; x_i + n_i \tag{3}$$

where x_i is the transmitted signal by the user i and n_i is represents the Additive White Gaussian Noise (AWGN) at the receiver side for the user i.

The optimization involves power allocation based on channel conditions. If P_{ij} is denoted the power allocation on the subcarrier j for user i, and h_{ij} is the channel gain on the subcarrier j for user i, the received signal for the user y_{ij} for traditional OMA can be expressed as:

$$y_i = \sqrt{P_{ij}.h_{ij}} \; . \; x_{ij} + n_{ij} \tag{4}$$

where x_{ij} is the transmitted signal by user i on the subcarrier j, and n_{ij} is AWGN on the subcarrier j for user i. The power allocation in this system is done across subcarriers to optimize system performance.

User collaboration in C-NOMA is active among users, such as relaying signals or sharing decoding information to improve reliability. While in traditional NOMA and OMA, users do not typically collaborate, each user is treated independently based on their channel conditions. Furthermore, in C-NOMA, users collaborate to mitigate interference, particularly for users with poorer channel conditions. While in traditional NOMA, interference is managed through power-domain multiplexing; users do not actively collaborate to reduce interference. With the above C-NOMA collaboration, the spectral efficiency and reliability aim to improve and provide higher system throughput. The capacity of users in C-NOMA will be enhanced through non-orthogonal resource allocation and user collaboration. Users with superior communication conditions, in particular, need to decrypt the messages of other users due to the usage of SIC techniques at the receivers. As a result, users with strong signals are employed as relays to increase reception reliability for users with weak signal base station connections.

Ultra-wideband (UWB) and Bluetooth are local short-range communication technologies that send messages from users with better channel conditions to others with less favourable conditions. This cooperative NOMA can maximize diversity gain for all users by achieving the desired outage probability and signal diversity sequence. In reality, the system complexity required to coordinate collaboration among users might render it impractical to invite every user in the network to participate in C-NOMA. One promising way to reduce system complications is by adopting user pairing. As illustrated in Figure 3, the proposed cooperative communication uses one or more relays to increase the signal strength between the source and destination. Relays use two separate frames, with direct phase transmission occurring in the first frame and relays using the second frame to forward information to the final destinations. In

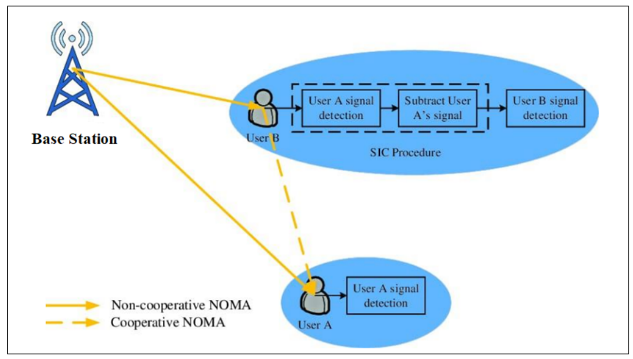

Figure 3. (C-NOMA) and (Non-C-NOMA) Communication.

the proposed cooperative communication systems, amplifier and forwarding (AF) and decode and forwarding (DF) are two forwarding protocols that relay use to send the received information signals to the appropriate destinations. Furthermore, based on the relaying operation, relays during the past ten years can be broadly divided into half-duplex (HD) and full-duplex (FD). In contrast to HD, an FD relay keeps data transmission and reception rates and frequency simultaneously. Therefore, the FD relay achieves a higher spectral efficiency relative to its HD counterpart. Figure 3 illustrates how, with traditional NOMA, fewer power users indicate persistent interference. The SIC cannot cancel interference when the reference user exhibits higher power. Cooperative NOMA can be used to get around this restriction. By enabling lower-power users to relay higher-power users' signals over the air without interference, cooperative NOMA aims to mitigate this restriction. Higher-power users can mix the relayed signal with the base station's received signal, utilising any algorithm [32].

As in traditional NOMA, user A uses the SIC to remove user B's signal from the total received signal before user A is identified. This supposes that user B is the reference (higher power level user) and that user A is an interfering user (lower power level user). According to cooperative NOMA, users that interfere (user A) transmit the signals that the SIC user (B) detects across the airspace. This enables user B, who has a higher received power level, to receive multiple copies of its signal. The signal relayed by the interfering participant, User A, may not be disrupted by interference from lower-power users. Meanwhile, the signal received directly from the source might still experience interference from lower-power users, which cannot be mitigated through SIC. According to the description above, user A's signal is presumed to be lower power. Once recognized, it can be regenerated and cancelled from user B's total signal before being relayed since adding an extra iteration is required. Afterwards, user B's (higher power user) signal can be transmitted across the air. At the data symbol level $b^{\wedge}$, the many copies of user B's signals can be joined using any combining technique.

The cooperative NOMA that is being proposed includes diversity-exploiting techniques to cancel out interfering signals linked to each user. Cooperative NOMA considers that the lower-power users are expected to retransmit the symbols their higher-power users' SIC have identified (usually by decoding and forwarding). Because lower power users transmit an interference-free replication of the identical signals that are also received directly from the base station (assuming that downlink), higher power users exploit these extra signals to exploit diversity. The performance is enhanced by combining these signals. The proposed approach combines the ideas of simultaneous usage of time-frequency resources, in which numerous users share them, with simultaneous decoding and subtraction of interference from received signals (SIC). The C-NOMA with the SIC algorithm's high-level overview process is depicted in Figure 4.

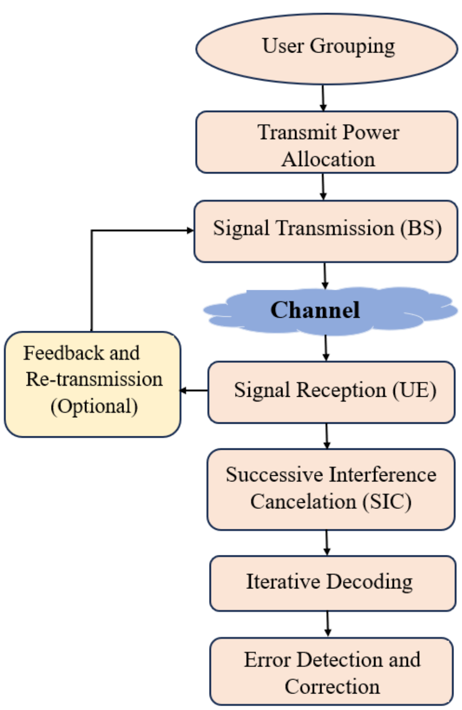

Figure 4. The Process of a High-level Overview of the C-NOMA SIC algorithm.

The users in a group receive superposed signals from the base station. These signals are encoded in a way that enables simultaneous transmission. Each user in the group receives the superposed signal, which contains multiple users' information. Users performed SIC to decode the strongest signal in the received superposition. They first decode the waveform with the greatest level of power (strongest) and subtract that from the received signal. If there are more signals in the superposition, users iterate through the SIC process to decode and subtract interference until all signals are decoded. After interference cancellation, each user performs error detection and correction to recover the original information. Users may send feedback to the base station indicating successful or unsuccessful decoding depending on the system design. The base station can then decide whether to retransmit the information.

Permitting several users to share a single resource can significantly improve the efficiency of the spectrum and increase the number of served users compared to traditional orthogonal multiple access schemes. However, advanced signal processing techniques and careful power allocation are required for optimal performance. Further, by using SIC techniques in NOMA, the strong user has already deciphered the message from the weak user; hence, it makes sense to consider using the DF protocol for weak signals. It is possible to explicitly re-modulate and retransmit the weak signal from a location closer to the intended recipient. A beneficial feature of cooperative NOMA is a notable improvement in weak user reliability. This leads to an improvement in the fairness of NOMA transmission, especially in the cases where the BS illustrates the weak user as being at the cell's border. NOMA is an efficient method of mitigating multipath fading because it can increase diversity gain for the poor NOMA user.

5. System Modeling and Implementation

This work studies wireless transmission for a BS with users at different distances—near user NU and far user FU. As seen in Figure 5, we considered that every endpoint is equipped with a single antenna. In the downlink scenario, the BS generates two quadrature phase shift keying (QPSK) signals for each user. QPSK is selected in this study since all the symbols in this modulation scheme have the same absolute value in both the natural and imagery parts, meaning they have the same amount of transmitted power. This reduces the complexity of designing a multi-level amplifier at the receiver and makes signal processing much more manageable. The signal is multiplied by a factor based on each user's distance from the BS. For near users, this factor is (α_N), and for far users, it is (α_F), where (α_F) > (α_N). This is because it is assumed that to ensure user fairness, the far user must be applied with greater force than the near user. Additionally, the two scaling elements' relationship might be stated as follows:

$$\alpha_F + \alpha_N = 1 \tag{5}$$

At the M^{th} node, the signal to be received can be stated as:

$$\gamma_M = h_M(+\sqrt{\beta_N P_{SN}}) \tag{6}$$

where the total allocated power is denoted as P for the two users, and s_M Represents a QPSK signal, which can take four possible complex values defined as ($s_M = -1, +1, -j1, +j1$) the outcome of transmitting a pair of bits. Furthermore, h_M represents a Rayleigh flat fading channel that is non-selective and has a mean of 0 and a variance of 1, denoted by h_M, $CN(0, 1)$. The channel's power normalization across the BS and the nearby user, $|h_n|^2$, has a much higher magnitude than the channel's normalized power within a distance from the far user and the BS, $|h_f|^2$, that is ($|h_f|^2 < |h_n|^2$). This is because of the losses that occur when signals propagate wirelessly. Moreover, $n, CN(0, \sigma_n^2)$

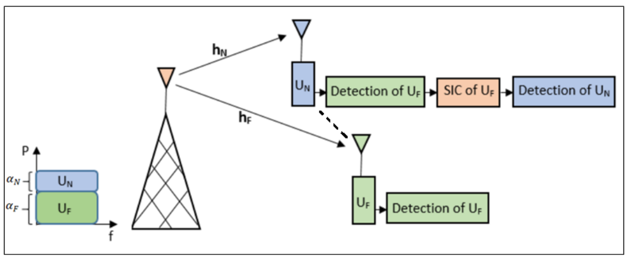

Figure 5. Cooperative NOMA with Two Users DL.

depicts a null mean complex AWGN and a variance of σ_n^2. This is individually added at every node. Additionally, the user's (M) signal-to-interference-plus-noise ratio (SINR), represented by γ_k, can be written as follows:

$$\gamma_M = \frac{\alpha_M P |h_{MSM}|^2}{\alpha_L P |h_{MSL}|^2 + |n_M|^2} \tag{7}$$

where $L \in \{F, N\}$ and$\neq$ M, then: Equation (7) can be described as:

$$\gamma_M = \frac{\delta_M |h_M|^2}{\delta_L |h_M|^2 + 1} \tag{8}$$

where ($\delta_M = \frac{\alpha_p \alpha_M P}{\sigma_n^2}$) and ($\delta_M = \frac{\alpha_L P}{\sigma_n^2}$) show the interested user's (SNR) and interference-to-noise ratio (INR). Thus, for a given M^{th} user, the Shannon capacity of this system can be calculated as follows:

$$C_M = 0.5\log_2(1 + \gamma M), \tag{9}$$

Two-time slots are used for the signal transmission. First, the initial time slot was mentioned as a straightforward transmission slot, and the second as a relaying slot. The BS employs NOMA in the direct transmission slot to send data to the far user (h_F) and the near user (h_N). Before decoding its data, the strong near user builds SIC to decipher that of the far user. The distant user merely carries out direct decoding. After the direct transmission slot, the following data rates might be achievable for the strong near user and weak far user, respectively:

$$R_n = 0.5\log_2\left(1 + \alpha_n \rho |h_n|^2\right) \tag{10}$$

$$R_{f,1} = 0.5\log_2\left(1 + \frac{\alpha_f \rho |h_f|^2}{\alpha_n \rho |h_f|^2 + 1}\right) \tag{11}$$

where:

α_n: near user coefficient power allocation.

α_f: far user coefficient power allocation.

h_n: BS and near-user channel.

h_f: BS and far user channel.

ρ: transmit $SNR = \frac{P}{\sigma^2}$,

where P represents the power transmitted and σ^2 is the variance of the noise. Usually, α_f is greater than α_n , and the sum of α_n and α_f is equal to one. Because there are two-time slots with equal durations, the factor (0.5) is in front of the achieved rates; thus, the achievable rates for the initial time slot alone are R_n, R_f. The second time slot is the relaying slot. Since the strong, nearby user decrypted the weak, distant user's data in the previous time frame, the nearby user already has it. During the relay time window, the nearby user transmits this data to the distant user. After the relaying slot, the far user's attainable rate is:
The second half of the time slot is the relaying slot. Since he decrypted the far user's data during the previous time frame, the close user already had it. During the relaying time slot, the near user transmits this data to the far user. After the relaying slot, the far user's attainable rate is:

$$R_{f,2} = 0.5\log_2(1 + \rho|h_n f|^2) \tag{12}$$

Here, $h_n f$ is the space between the far and the near user, and ($R_(f, 2) > R_(f, 1)$) Thus, the far user receives the entire transmit power without partial power distribution or interference from other transmissions. The far user receives two copies of the same signal information via two distinct channels after the two-time intervals. This allows the far user to use a diversity-combining method. Then, for instance, combine selection to select the copy with a high signal-to-noise ratio. Following selection and combining the far user's rate, the result is as follows:

$$R_f = 0.5\log_2\left(1 + \max\left(\frac{\alpha_f \rho |h_f|^2}{\alpha_n \rho |h_f|^2 + 1}, \rho |h_{nf}|^2\right)\right) \tag{13}$$

The far user rate that could be attained with non-cooperative relaying would be the following:

$$R_{f,\text{noncooperative}} = \log_2\left(1 + \frac{\alpha_f \rho |h_f|^2}{\alpha_n \rho |h_f|^2 + 1}\right) \tag{14}$$

While non-cooperative NOMA communication will consume the entire time slot for transmission, the factor of (0.5) is not present here. Half the time slot will be set aside for the OMA system, such as TDMA, to transmit data from distant users. Consequently, the following would be the far user achievable rate:

$$R_{f,\text{OMA}} = 0.5\log_2\left(1+\rho|h_f|^2\right) \tag{15}$$

The previous model dealt with the model of downlink NOMA, in which the end users receive the NOMA signal from the BS. NOMA was used in the uplink in this part. When users transmit to the BS, they engage in uplink communication, as depicted in Figure 6.

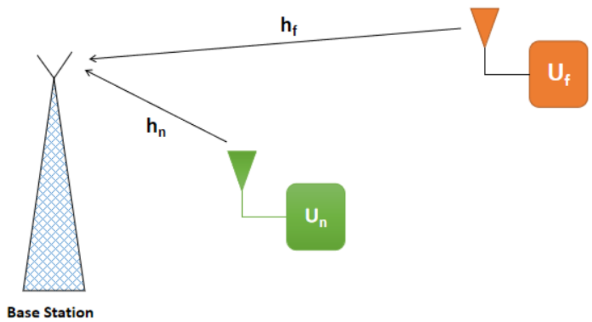

Figure 6. he Model of The Uplink NOMA Channel [36].

In this model, the uplink NOMA channel, U_f presents as the far or weak user, U_n as a near or strong user, d_f and d_n represents the distances from far and near users to the base station, respectively. The corresponding Rayleigh fading coefficients are represented by h_f and h_n where $(d_n < d_f)$ and $|h_f|^2 < |h_n|^2)$.
The power domain multiplexing process is carried out differently for the uplink NOMA channel. The BS employed SC to carry out power multiplexing domain in downlink NOMA. Users transmit power in uplink NOMA, constrained by the capacity of their batteries. As a result, both users can broadcast at their highest power. The variations in the channel gains of the users cause the differential in the power domain at the receiver side, the BS. In the signal model for uplink NOMA channel, the message to be transmitted is denoted by x_f and x_n, for U_f and U_n respectively. If each user utilizes the same amount of power to convey their signals. Far user transmits the signal transmitted by the far user is $U_f = \sqrt{P}x_f$ and the signal transmitted by the nearby user is $U_n = \sqrt{P}x_n$. The signal received equation at the BS is:

$$y = \sqrt{P}x_f h_f + \sqrt{P}x_n h_n + w \tag{16}$$

where $\sqrt{P}x_f h_f$is the term for a far or weak user, and $\sqrt{P}x_n h_n$ is the term for near or strong user.
As anticipated initially, U_n is closer to the BS, therefore U_n has a stronger channel gain amount when compared to U_f, that is $|h_n|^2 > |h_f|^2$. Therefore, the signal that is received, the allocation power of the user U_n will be dominated. This implies that the BS can handle the U_f as interference and decrypt the x_n directly. Then, it can perform successive interference cancellations to retrieve the far user x_f.
From the above description, the development of power domain differentiation is achieved. The uplink NOMA and its downlink equivalent have been diverged. The users would see different channel benefits if they were far enough off from one another. Because of this, the BS can distinguish between signals even when there is a lack of power control or superposition coding. The power control is not caused by deliberate superposition coding as in downlink NOMA but rather by intrinsic variations in the channel gains.
As a significant observation from the above description, user channel gains must be sufficiently distinct for uplink NOMA to be effective. The BS cannot differentiate between the signals of both users in the power allocated if their channel gains are comparable. Then, power control needs to be implemented. In other words, the users need to transmit at varying power levels.
Consequently, in uplink NOMA, the SIC order is flipped. First, the signal of the strong user is deciphered. While the far user's signal is decoded initially in downlink NOMA. Significantly considering the far user U_f information signal as interference, the near-user signal U_n is decoded first to determine the archivable rates of uplink NOMA. The rate at which the close user U_n data can be decoded at the BS; therefore:

$$R_n = \log_2\left(+\frac{P|h_n|^2}{P|h_f|^2+\sigma^2}\right) \tag{17}$$

Then, next to the process of Successive Interference Cancellation (SIC), the far user U_f rate achieved is:

$$R_f = \log_2\left(1+\frac{P|h_f|^2}{\sigma^2}\right) \tag{18}$$

6. System Simulation and Evaluation

This section demonstrates that NOMA fulfils the requirements for 5G better than OMA techniques. Furthermore, the downlink NOMA and uplink NOMA in this section were evaluated and studied. The software used for all simulation results in this paper was MATLAB (V 2022a) and NYUSIM (V 3.1). Table I shows the simulation parameters used to compare NOMA with OMA-OFDM.

Different implementations were compared between the NOMA technique and the OMA technique applied by OFDMA for rate pairing of users one to user two in (bps/Hz), represented in Figure 7

For analysis and discussion, assuming that there is a pair of users in the system network, a symmetric downlink medium is used, and the users are at the same distance from the base station, draw the bounds of the feasible rate zones for both users. The SNRs for users one and two are the same at (20 dB). Figure 7 shows that NOMA outperforms OFDMA in rate pairings, except in corner cases, where rates are equivalent to single-user capacities. Both users receive

TABLE I. Simulation parameters used to compare NOMA with OMA-OFDM.

Parameters	Data
Number of Base Stations	1
Number of Users Equipment	2
Number of Antennas at the BS	64
Power (P), $P_1 = P \cdot \alpha$, $P_2 = P - P_1$	$P = 1$
Transmit Power (splitting factor)	$\alpha = 0 : 0.01 : 1$
Channel Gain: G_1, G_2	$G_1 = G_2$ for symmetric $G_1 > G_2$ for un-symmetric
Bandwidth in Hz	20 MHz
Rate R_1	$\log_2(1 + P_1 \cdot G_1)$
Rate R_2	$\log_2(1 + \frac{P_2 \cdot G_2}{P_1 \cdot G_2 + 1})$
Channel Gain Type	[Rayleigh fading]

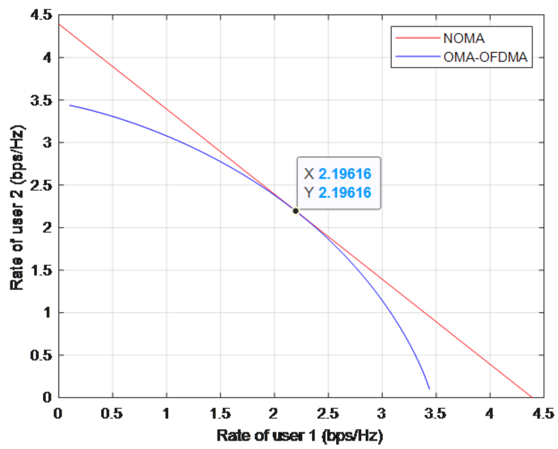

Figure 7. NOMA versus OMA-OFDM for user one to user two rates, SNR user one and SNR user two are equal (20 dB) and symmetric rate pairs.

2.19616 bps/Hz throughputs for both OFDMA; further NOMA at the fairness level is high. However, compared to OMA-OFDMA, NOMA produces significantly greater rate pairings. Sum capacity and specific system throughputs are larger with NOMA when the fairness is lower. When the channel fading is unsymmetric rate pairs for user one and user two, SNR user one (20 dB) and SNR user two (2 dB), the performance will be shown in Figure 8.

It is clear that with un-symmetric rate pairs, compared to OMA OFDMA, NOMA achieves significantly higher rate pairings, particularly for the far user. Pairing two users with more distinctive channel settings to perform NOMA can result in a stronger performance gain.

A. Downlink Cooperative NOMA Channel System

The BS transmitter uses SC for non-orthogonal user multiplexing, which is the primary goal of downlink NOMA. Subsequently, every user's data is subsequently channel-coded, modulated, and combined with signals from other users. The user terminal performs SIC (the order of increasing gain should be followed when decoding SIC in the downlink). Any other user can block the user whose

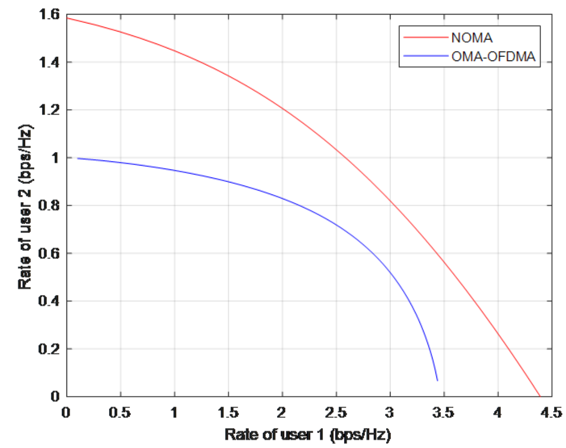

Figure 8. NOMA versus OMA-OFDM for user one to user two rates, SNR user one (20 dB) and SNR user two (2 dB) unsymmetric rate pairs.

channel state is worse than their own. Table II summarizes the main simulation parameters used to compare the DL NOMA and OMA for two weak and strong users and three weak, medium, and strong users. Figure 9 compares NOMA

TABLE II. Simulation parameters used to compare DL NOMA with OMA-OFDM for two and three users in the system.

Parameters	Data
Number of Base Stations	1
Number of User Equipment	2, weak and strong 3, weak, medium, and strong
User Distances	2 Users: [60, 20] m 3 Users: [80, 40, 20] m
Number of Symbols	32
Number of Subcarriers	128
Cyclic Prefix Length	16
Channel Length	16
SNR dB Range	-10:10:80, 90
Number of Blocks	1024
Mean Square Value	1
Signal Power	1
Path Loss Exponent	2
Channel Gain Type	Rayleigh fading

for users weaker near and stronger far and OMA for users weaker near user and stronger far user for BER regarding SNR (dB).

Two users' simulation findings showed that at low SNR, OMA performs slightly better than NOMA. This result is caused by simultaneous transmission interference for OMA users but not for NOMA users, who suffer from it. However, NOMA performs better than OMA at high SNR because it offers higher capacity. The simulation results at BER with (10^{-5}) shows that NOMA for weaker near users has SNR (73 dB) and NOMA for stronger (far) users with SNR (68 dB) as pair users have higher values than OMA weaker near users with SNR (66 dB) and OMA stronger far user with SNR (58 dB). Similarly, for the two users, for

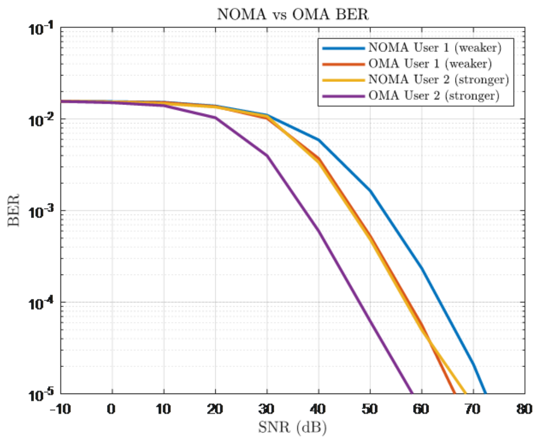

Figure 9. NOMA and OMA comparison for weaker (near) user and stronger (far) user.

the three users, BER versus SNR for NOMA and OMA, OMA outperforms NOMA slightly at low SNR, as shown in Figure 10. Due to simultaneous transmission, NOMA users suffer from interference, but OMA users do not encounter this kind of interruption. On the other hand, NOMA beats OMA at high SNR by providing a higher capacity spectral. The simulation results at BER with (10^{-5}) shows that NOMA for weaker near user has SNR (of 88 dB), NOMA mid user has SNR (of 84 dB), and NOMA stronger far user has SNR (77 dB) as three pair users has higher value than OMA weaker near user with SNR (69 dB), OMA mid user SNR (63 dB), and OMA stronger far user with SNR (59 dB) [37]. The increase in the number of users in DL C-

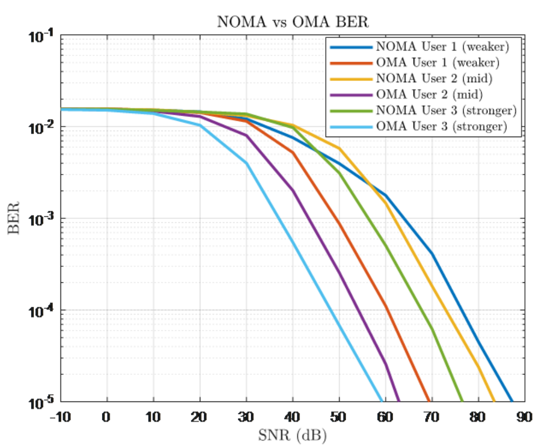

Figure 10. NOMA and OMA comparison for three users: near (weaker) user, middle user, and far (stronger) user.

NOMA has several impacts. With the increase in the number of users, the potential for cooperation increases, leading to enhanced throughput for all users involved. With more users, the spectral efficiency increased since the resources were utilized more efficiently. As the number of users increases, interference among users also increases. However, with proper power allocation, interference can be mitigated effectively. Increasing the number of users increases the complexity of the cooperative NOMA system, especially regarding resource allocation, power control, and signal processing at the BS and UE. With more users, ensuring fairness becomes crucial. Resource allocation algorithms must be designed to maintain fairness among users while maximizing system throughput. C-NOMA can potentially improve energy efficiency by exploiting the gain of multi-user diversity. With more users, the energy efficiency gains may become more pronounced, especially if users have varying channel conditions.

A comparison of outage probability versus SNR (dB) for OMA, C-NOMA, and Non-C-NOMA is graphed in Figure 11. Depending on the fundamentals, the probability of

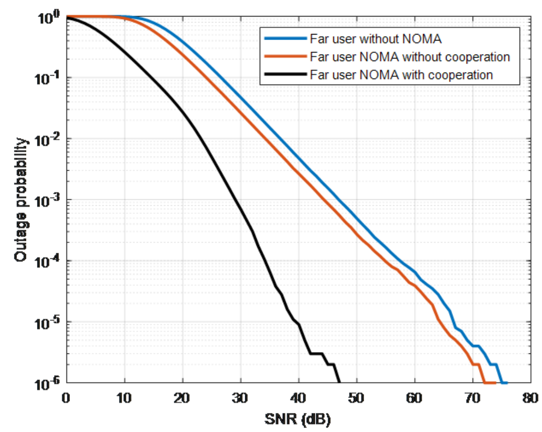

Figure 11. A comparison of (OMA), (C-NOMA), and (Non-C-NOMA) Channels for the probability of outage versus SNR (dB).

outage increases as the threshold SNR increases. It is clear from Figure 11 that the outage probability (at 10^{-6}) in cooperative NOMA has a lower value of SNR (47 dB) than the other two systems, non-cooperative NOMA SNR (73 dB) and OMA with SNR (76 dB). As illustrated in the graph, Cooperative communication is beneficial.

B. Uplink Cooperative NOMA Channel System

No power control has been established in the uplink UL NOMA model system simulation. In order to facilitate power domain multiplexing, the intrinsic variations in the channel gains are utilized. Figures 12 and 13 show that the outage probability related to SNR transmission varied for various channels fading. The relaying channel fading model (as a more realistic model) has a value of (5e-05), and channel fading Rician has a lower value of outage probability (7e-05) in transmit SNR (60 dB).

The simulation results for cases of fading channels showed that the types of fading channels affect outage probability. Tests with uplink NOMA outage probability versus transmit SNR (60 dB) have used signal spectrum bandwidth for near and far users. Different bandwidth frequencies are allocated to the model. Figures (14, 15 and 16) show the numerical

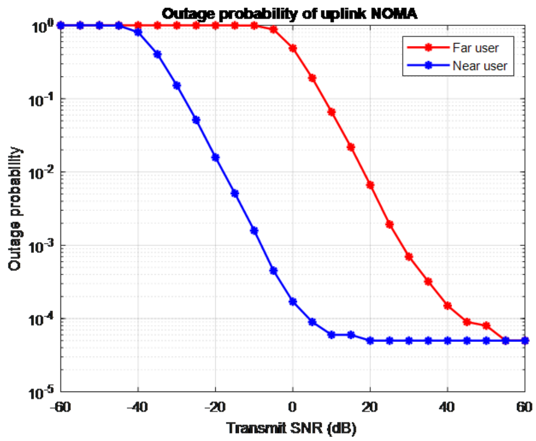

Figure 12. The Probability of Outage Versus Transmit SNR comparison for Far and Near users with Rayleigh channel fading.

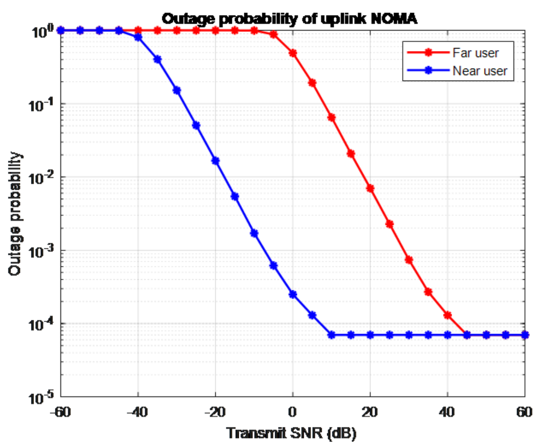

Figure 13. he Probability of Outage Versus Transmit SNR comparison for Far and Near users with Rician channel fading.

simulation for model bandwidth with (10^5,10^6,and 10^7 Hz) respectively.

The analytical results indicate that the outage probability increases when the bandwidth frequency signal spectrum increases. Noise power in the uplink NOMA technique is evaluated in this paper.

As presented in Figures (17, 18, and 19), with an increase in noise power (-164, -174, and -184), the outage probability of uplink NOMA decreases (18e-05, 11e-05, and 6e-05), respectively, with the power noise. The numerical results show increased noise power decreases outage probability when transmitting SNR. With the varying near and far user distances, an improvement in the performance of the model was obtained in the simulation result. From the numerical results in Figures (20 and 21), for the user distance pair (800-100 m), the probability of outage is lesser for either the two users experience, or for the distance pair (800-500 m), the probability of outage

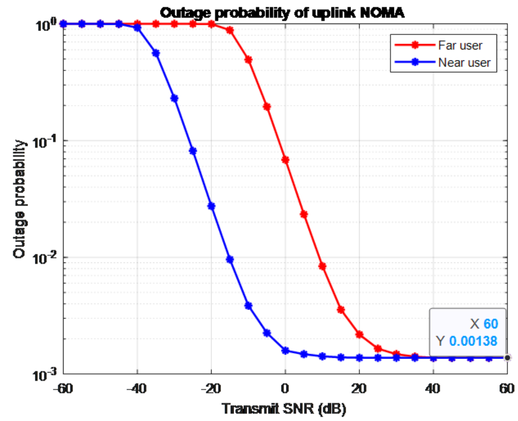

Figure 14. Uplink NOMA Signal Spectrum bandwidth with value (10^5 Hz.) for strong near and weak far users.

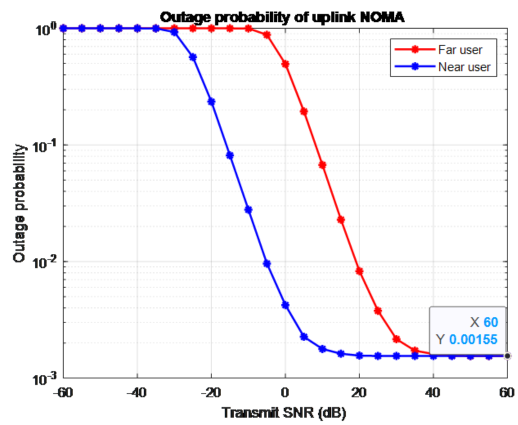

Figure 15. Uplink NOMA Signal Spectrum bandwidth with value (10^6 Hz.) for strong near and weak far users.

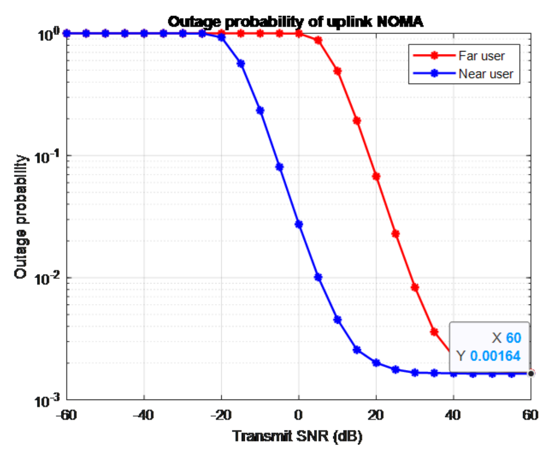

Figure 16. Uplink NOMA Signal Spectrum bandwidth with value ($10^7 Hz.$) for strong near and weak for users

is higher for either the two users experience. This finding validates that when the channel circumstances between the

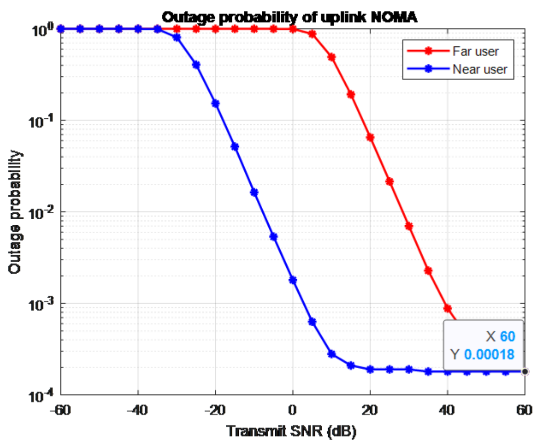

Figure 17. The probability of outage versus transmits SNR (60 dB) for the case noise power value (-164 dB).

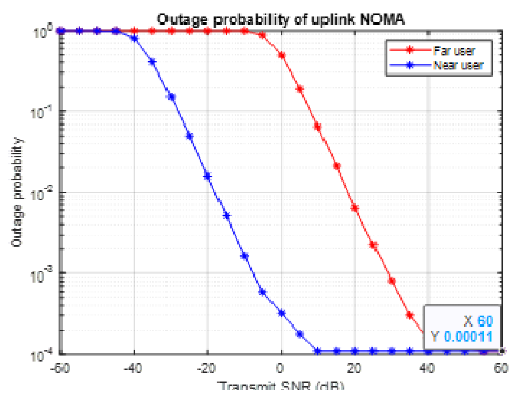

Figure 18. The probability of outage versus (60 dB) transmit SNR for the case noise power value (-174 dB).

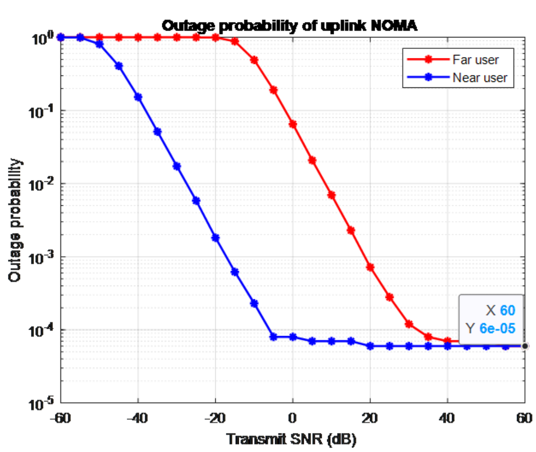

Figure 19. The probability of outage versus (60 dB) transmit SNR for the case noise power value (-184 dB).

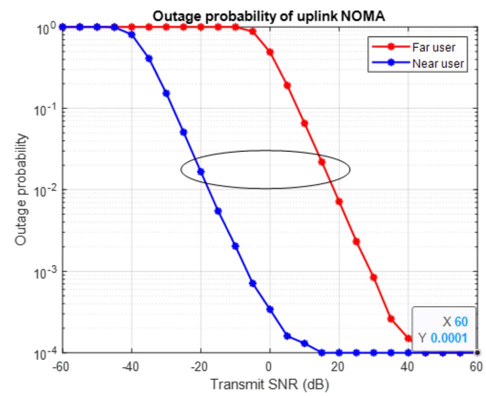

Figure 20. The probability of outage with regard to (60 dB) transmit SNR for user distance pairs (800-100 m) and similarly for transmit SNR (20 and 40 dB).

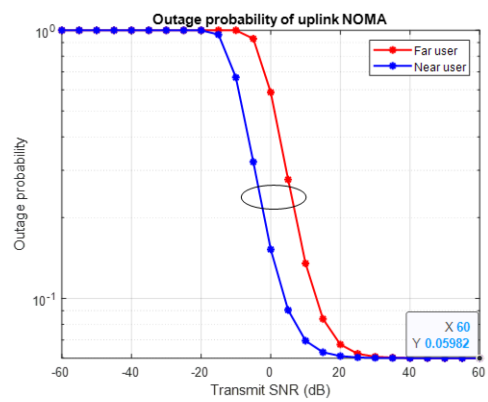

Figure 21. The probability of outage regarding (60 dB) transmit SNR for user distance pair (800-500 m), and similarly for transmit SNR (20 and 40 dB).

users become significantly distinct, the C-NOMA technique performs better than other techniques. The same parameters are used in the UL C-NOMA simulation results, except in the channel fading scenario, where Rayleigh and Rician channel fading are used. Rayleigh fading is commonly used to model wireless channels in urban and suburban environments with many obstructions and scattering objects, resulting in many reflected signals arriving at the receiver with random phases and amplitudes. While Rician fading is suitable for modelling wireless channels in environments with a dominant line-of-sight (LOS) path and scattered paths, this often occurs in rural or suburban areas with fewer obstructions.

7. Conclusions and Future Work

This paper investigates the performance of the technique systems for OMA, C-NOMA, and non-C-NOMA for uplink and downlink channel fading. A comparison was studied, and it was observed that the NOMA technique achieves much higher rate pairs than the OMA-OFDMA technique, especially in the case of unsymmetric rate pairs. For UL-NOMA channel fading, BER regarding SNR dB was studied in cases of two users (near and far) and three users near, middle, and far.

Numerical simulation proved that NOMA outperforms

OMA at high levels of SNR by offering high capacity. C-NOMA, non-C-NOMA, and OMA channels for outage probability versus SNR are studied in this paper. The probability of an outage in cooperative NOMA is lower than in the other two systems, non-cooperative NOMA and OMA.

In contrast, non-cooperative NOMA has a lower outage probability compared with OMA. The results show that the probability of an outage increases with the increase in bandwidth and frequency of the signal spectrum. An improvement in the model's performance obtained in the simulation resulted from varying near and far user distances. This result confirms that NOMA gives superior performance when channelling among users in the communication systems becomes more efficient. One of the limitations of this study is investigating the impact of C-NOMA on latency, which is worth investigating in comparison to other studies. For future work, we can integrate other techniques with C-NOMA, such as massive MIMO or mm-wave for uplink and downlink networks, to enhance the performance and contribute toward meeting the capacity demands expected in future 5G mobile communication networks.

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