IJCDS 1571001387

International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Net. Tech. #, No. #(Mon-20..)

5G Mobile Communication Performance Improvement with Cooperative-NOMA Optimization

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Received ## Mon. 20##, Revised ## Mon. 20##, Accepted ## Mon. 20##, Published ## Mon. 20##

Abstract: The 5G Mobile communication cellular networks are expanding rapidly, and with the quick development of several new services and mobile applications are anticipated consumption of frequency and the bandwidth resources in 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 of cooperative (NOMA) compared to non-cooperative (NOMA) and (OMA) with the help of MATLAB and NYUSIM simulations. The results also demonstrated the improvement is valid with the increase of bandwidth frequency signal spectrum for the varying of near and far user distance.

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 enhance mobile broadband (eMBB) features which include virtual reality and videos eventually. Furthermore, 5G has to accommodate a wide variety of instances via machine-type communication (MTC) in order to meet the increase demand for the Internet of Things (IoT). The feature 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 a huge number of 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 had been presented as both the current and prior generations of mobile communications cellular. The two multiple access strategy types are: (OMA) and (NOMA), depending on the method the resources facilities that are assigned to all individual users in the system communication. The strategy technique, orthogonal frequency division multiple access (OFDMA), represented with three facilities, (CDMA)

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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].

The throughput and spectral efficiency, 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 as a whole. While, in NOMA, several mobile users with various channel conditions are concurrently assigned the same frequency resource. As a result, the strong user uses the resource that was allocated to the weak user, and (SIC) procedures at users' receivers can reduce interference. Consequently, undoubtedly be a significant considerable boost the probability of achievement higher throughput furthermore better spectral efficiency [5].

Cooperative communication NOMA networks, often referred to as cooperative (C-NOMA) networks, make use of the wireless channel's broadcast characteristics by incorporating relays that serve as an alternate link in case of weak transmission. The cooperation process is performed using relaying nodes. Employing relays in NOMA networks improved enhanced diversity gain and throughput in network performance once cooperative communication was successfully implemented in 5G. Relaying networks might be either source nodes that facilitate user interaction or specialized relay nodes [6]. One of the main physical layer technologies that aims to maximize spectral efficiency is cooperative communication. The idea is to enhance the transmission and reception processes by utilizing the users' common information and resources [7].

This paper proposes a study of (C-NOMA) system communication for uplink NOMA and downlink NOMA as a new technique system for enhancement the of the 5G mobile cellular performance to mitigate the three features as (eMBB) enhance mobile broadband, (mMTC) massive Machine-Type Communication and (URLLC) Ultra-Reliable and Low-Latency Communication.

The rest of this study is in the following order. In section 2, the multiple access and (NOMA) technique is presented. In section 3, a detailed related works concerning(C-NOMA) has been presented and discussed. Section 4 explains a description of the proposed (C-NOMA) when integrated and optimized with 5G scheme. Section 5 and 6 presented the modelling, simulation and evaluation of proposed system combination. Finally, the conclusion is in the Section 7.

2. Multiple Access and NOMA Technique

Two main types can be categorized to multiple access (MA) techniques: as (OMA), while the other is (NOMA). Figure 1 shows the milestones developments of multiple access [8]. Conventional (OMA) technique methods provide radio resources to numerous users they are orthogonal to other users with regard to time, frequency, or code domain. OMA's orthogonal resource allocation would not cause any interference between users, ideally. In conventional (OMA) technique methods, the total amount 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 higher range of quality of service (QoS), latency lower, and fairness of users, have not been achieve by (OMA).

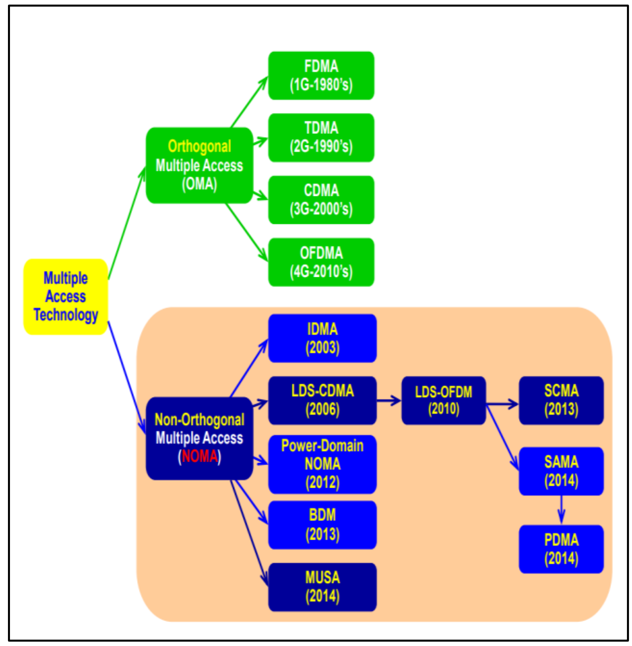

Figure 1: The milestones developments of multiple access [10].

Considering all of these needs, it is not unexpected that promising communication systems and new consider them a problem. Consequently, (NOMA) is introduced as a possible technology that might be applied to satisfy the new requirements. (NOMA) is an effective approach in the field of networks wireless communication for creating new radio access for (5G) mobile cell networks. (NOMA) can achieve great 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 is an upcoming physical layer communication technique, attracted a lot of attentions as a new method for boosting the huge numerous numbers of users that can be serviced concurrently by arranging many users carried on the same spectrum resources allocation but at various power allocation levels. The main justification for implementing NOMA in 5G is its capacity to accommodate numerous users concurrently while utilizing similar frequency and time resources [11]. Code domain multiplexing technique and power domain multiplexing technique are two of (NOMA's) main standards. This domain of separation often belongs to one of two techniques: power-based technique or code-based technique, which result in (NOMA) processes that are 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). At the decoder, sequential interference cancellation (SIC) is rendered achievable by the difference in power levels and channel gains. To utilize the advantage of the power domain and (SIC) for multiuser identification, NOMA utilizes (SC). As a result, at the destination receiver side, (SIC) is required. Different codes are assigned to various individual 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 information signal received 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 his retransmission of data since the far user's channel with the transmitting (BS) is weak. In other words, the same message will be sent to the far user two times. One message is from the base station (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 is significantly enhances throughput when compared to traditional (MIMO-OMA). [18, 19].

The two main types of NOMA technique schemes are power NOMA technique and the coded NOMA technique. In the power domain NOMA, several users share the same time-frequency code resources however are assigned varying power levels based on their channel quality. Power NOMA technique uses (SIC) at the receiver side to identify different users by making use of the power difference between users. With the exception of its inclination to use low-density or non-orthogonal sequences that have limited, coded NOMA technique is comparable to (CDMA) or multi carrier CDMA (MC-CDMA) [7, 18].

The fundamental idea underlying NOMA 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 successively retrieve each user's signal from the superimposed signal (SS) in order to guarantee a weak user's (QoS). By considering other signals as interference, the far user can specifically decrypt the strongest signal. (SIC) terminates if the decrypt signal is its own data. If not, the next strongest signal will be deciphered by the receiver, which will then subtract the decrypt signal into (SS).

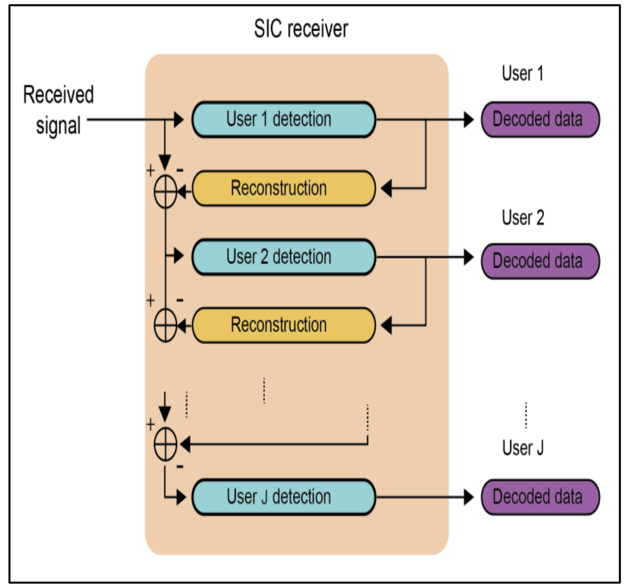

Figure 2: The process steps of (SIC) technique [16].

In (NOMA) technique system, (SIC) is a crucial toll that is used at the receiver enabling detecting and decoding huge number of users. In transmitter/receiver (uplink/downlink detection), the (SIC) processor first decodes a prominent interference and then subtracts it to take out from the (SS) in order to retrieve each user-desired signal. The superposition of many signals with varying power levels is crucial to diversification each user signal and performing (SIC) at a specific UE end because in downlink each User Equipment (UE) gets the other user's signal (which is the required and interference signals) across its channel. The following formula relation it will be used to determine the possible data rates (R) for each user equipment (UE) paired with NOMA: [20]

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

where the portion of the total bandwidth waveform B occupied by the UE represented by β and the portion of the power resource allocated represents by α.

The data rates (R) for OMA in comparison to (NOMA), is calculated as [20];

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

Several reasons showing the domination of NOMA from the conventional orthogonal multiple access (OMA), these include [21, 22];

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

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

a. a. Every user with lower channel gains must decode the data of every other user.
b. The subsequent decoding of all other users' information is likely to be done incorrectly when a user's SIC error happens..
c. In order to reap the purported advantages of power-domain multiplexing, a significant differential in channel gain between strong and weak users is necessary.
d. Every user must provide the BS with the 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 challenges of installing several directionals on compact communications terminals. Multiple relay nodes are designated in communications cooperative system to aid a source in forwarding information to the appropriate recipients [25]. In wireless networks, 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 be implemented with NOMA, can enhance and increase the coverage capacity level and higher reliability of the system. The NOMA systems technique with earlier information is utilized by the cooperative NOMA (C-NOMA) technique. By using the (NOMA) technique, users that has greater network characteristics enable other users to decode the information messages, and as a result, these users serve as relays to increase the dependability of users' reception for users with weaker connections to the base station (BS). C-NOMA scheme in fifth-generation considered to maximize potentials of NOMA in multiuser environments where one of users acted 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 the 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 in order to overcome the complicated received data separation of all users. Power-domain NOMA is one method, and code-domain NOMA is another. Because of these numerous benefits, NOMA may be an appropriate multiple access candidate system for mobile and massive machine type communication (m-MTC), which will be handled and provided by 5G and next-generation networks in the future [28].

In [21], authors used three scenarios, OMA technology, NOMA technology by using Genetic Algorithm (GA), and NOMA technology by using Gray Wolf Optimization GWO. They performed comparisons with and without neighboring cell interference. Their findings demonstrated that, in terms of user fairness and sum rate, their proposed method—NOMA by employing GWO—is superior to the other two situations.

In [29], a novel cooperative NOMA transmission strategy is proposed for a downlink system with three users. Authors studied closed-form expressions to derive the high-level asymptotic behavior of signal-to-noise ratio (SNR) regions as well as the rates of sum for the proposed method. By adjusting the direct-link users' decoding order, the authors' cooperative NOMA strategy can function in the presence of strong inter-user interference (IUI) and significantly exceed current methods rates of sum.

Authers in [8] considered the combination of reconfigurable intelligent surfaces (RISs), (Massive-MIMO), and uplink coded (NOMA) domain. They assumed that each (RIS) would cover a cluster of users and that the base station (BS) could create beams diversity toward the (RISs) while in line-of-sight. Authors investigated how to optimize the (RIS) phase shifts so that users could use them. To obtain information about the coupling between the (RIS) phase shifts and other variables, such as the detection sequence and the utilized filtration systems, they employed sum-rate optimized period shifts to provide a decoupled estimate for each of these variables. Using a semidefinite programming (SDP) reduction of the now-separated challenge, they discovered the final phase shifts, which can be effectively solved using convex optimization techniques. The findings of their paper demonstrate that their method is a successful RIS modification technique.

The paper in [20] proposed the performance of communication system for 2-users in 3 phases, NOMA with cooperation, NOMA without cooperation and OMA techniques. The project analyzed and compared with respect to various parameters over a channel. The authors evaluated the improvements of the communication

Regarding to parameters like outage probability, achievable channel capacity, bit error rate and sum rate. They investigated for an effective communication system the outage probability should be less, the achievable capacity should be more, bit error rate should be less and in case of sum rate it should be more.

The performance of (Massive-MIMO) and Single Carrier with Frequency Domain Equalization (SC-FDE) block transmission technology and (NOMA) for both conventional and (C-NOMA) is explored in [30]. They considered that (NOMA) and (C-NOMA) techniques, connected to (Massive-MIMO) and (SC-FDE) (ZF and MRC were the two receivers used). The MRC is generally a better solution because of its enhanced simplicity, and its performance is quite similar to that of the (ZF). This combination might be thought of as being effective in fulfilling the needs of future 5G developments.

As a fundamental component of 5G, device-to-device (D2D) communication can reuse network resources to enhance the overall communication network's spectrum utilization. When combined with NOMA technology, D2D and MEC communication throughput and user access density can be effectively increased. This has been studied in [32]. The authors also presented a numerical comparison between the NOMA and OMA modes, demonstrating the superiority of the NOMA-based D2D offloading systems over OMA. Their numerical findings demonstrated that NOMA multiple access is a more effective way than OMA to enhance system performance.

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 studied in [11]: There 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 huge multiple access techniques, are the key strategies for enhancing (SE).

In [33], the effectiveness of a (C-D2D) network with (NOMA) is researched. Where each D2D link exhibits separated independent Nakagami-m fading. Closed-form calculations for throughput and probability of outage are offered to assess the system improvement. Furthermore, reliability of obtaining analytical results is demonstrated by numerical data.

4. Cooperative NOMA Optimization

A cooperative NOMA (C-NOMA) transmission technique is proposed to entirely utilize Previous information that is accessible in (NOMA) systems. Users collaborate to enhance and improve the systems as a whole performance and power-domain multiplexing similar to NOMA, but with the added aspect of 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:

$$y_{i=}\sqrt{P_i \cdot h_i} \cdot x_i + n_i \tag{3}$$

where x_i is the transmitted signal by the user i and n_i is represent 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 subcarrier j for user i, the received signal for user y_{ij} for traditional OMA can be expressed as:

$$y_{i=}\sqrt{P_{ij} \cdot h_{ij}} \cdot x_{ij} + n_{ij} \tag{4}$$

where x_{ij} is the transmitted signal by user i on the subcarrier j, and n_{ij} is (AWGN) on 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, but users do not actively collaborate to reduce interference. With the above (C-NOMA) collaboration, the spectral efficiency and reliability aims to improve and to provide higher system throughput. The capacity of user 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 signal employed as relays to increase the reliability of reception for users with weak signal base station connections.

Ultra-wide band (UWB) and Bluetooth are two types of local short-range communication technologies that can be utilized for sending messages from users with better channel conditions to others with less favorable conditions. This cooperative NOMA can maximize diversity gain for all users by achieving the desired probability of outage 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 the system complication through the adoption of 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.

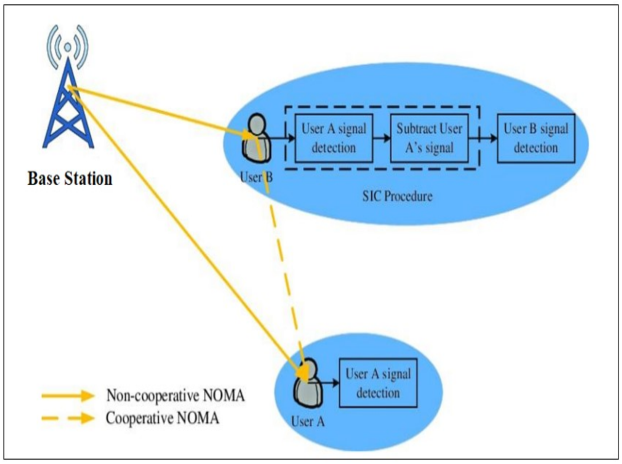

Figure 3: (C-NOMA) and (Non-C-NOMA) Communication.

In the proposed cooperative communication systems, Amplifier and Forwarding (AF) and Decode and Forwarding (DF) are two forwarding protocols that relays use to send the information signals that are received to the appropriate destinations. Furthermore, based on the relaying operation, relays during the past ten years can be broadly divided into two categories: half-duplex (HD) and full-duplex (FD). In contrast to (HD), an (FD) relay keeps both data transmission and reception rates is at the same time and frequency concurrently. Therefore, as relative to its (HD) counterpart, the (FD) relay achieve a higher spectral efficiency. Figure 3 illustrates how, with traditional (NOMA), the fewer power users are indicative of persistent interference. and the SIC is unable to 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 received signal from the base station utilizing any type of algorithm [30].

As in the scenario of traditional NOMA, user (A) uses the (SIC) to remove user B's signal from the total received signal before user A is identified. This is supposing that user B is the reference one (higher power level user) and that user A is an interfering user (lower power level user). According to cooperative NOMA, users that interfere (users A) transmit the signals that the (SIC) user (B) detects across the air space. This enables user (B), who has a higher received power level, to receive multiple copies of its signal. The signal relayed by the other interfering participant (user A), which might be unaffected by lower power user interference, and the signal received directly from the source, where interference caused by lower power users cannot be eliminated via (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 all that is required. Afterwards, user B's (higher power user) signal can be transmitted across the air. At the data symbol level b^, the many copies of user B's signals (higher power) can then 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, as considered that the lower power users are expected to retransmit the symbols that their higher power user's SIC has identified (usually by employing decode and forward). Because of the reason that 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 take advantage of 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 it with simultaneous decoding and subtraction of interference from received signals (SIC). The (C-NOMA) with (SIC) algorithm's high-level overview process is depicted in Figure 4.

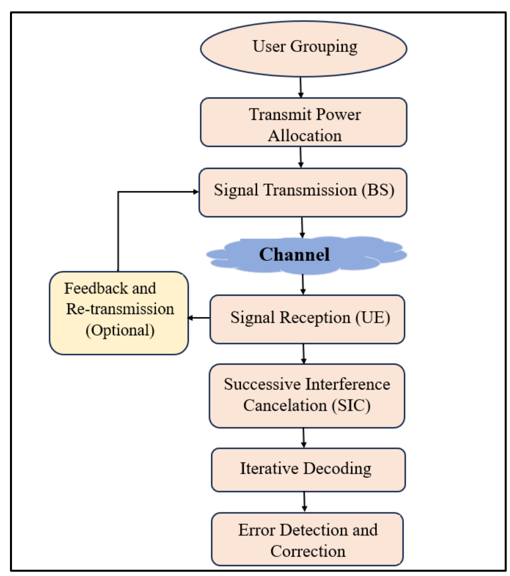

Figure 4: The process of high-level overview of the cooperative NOMA SIC algorithm.

Each user group in the system goes through the same procedure repeatedly. Based on their channel circumstances and quality of service requirements, users are grouped. There are several users sharing the same resources (code, time, frequency, etc.) in (NOMA) as long as they are aware that complex decoding techniques will be used by the receiver to differentiate them. Different power levels are assigned to each member of a group. Usually, the power distribution is determined by each user's channel gains. 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) subtract that from the signal which is received. 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. Depending on the system design, users may send feedback to the base station indicating successful or unsuccessful decoding. The base station can then decide whether to retransmit the information.

By permitting several users to share a single resource, it can significantly improve efficiency of spectral and increase the numerous of served users compared to traditional orthogonal multiple access schemes. However, it requires advanced signal processing techniques and careful power allocation to achieve 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 think about using the DF protocol for weak signals. It is possible to explicitly remodulate and retransmit the weak signal from a location closer to the intended recipient. Beneficial advantages feature of cooperative NOMA is that There is a notable improvement in the weak user's 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 border of the cell. NOMA is an efficient method of mitigating multipath fading because it can achieve an increased diversity gain for the poor NOMA user.

5. SYSTEM MODELLING AND IMPLEMENTATION

This work studies wireless transmission for a base station (BS) with users at different distances—near user NU and far user FU. As seen in Figure 5, we considered that every endpoint had a single antenna. For every user, the BS produces two quadrature phase shift keying (QPSK) signals during the downlink process. Because each symbol in this modulation scheme has the same transmitted power—that is, the same magnitude in the real and imagery parts. As a result, (QPSK) was chosen for this study. This significantly simplifies signal processing and lowers the complexity of the multi-level amplifier design at the receiver. For each user, the signal is multiplied by a factor based on distance from the base station (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 in order 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:

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

where the total allocated power denoted as P, for the two users, 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 distance from the far user and the BS, $\left|h_f\right|^2$, that is ($\left|h_f\right|^2 < |h_n|^2$). This because of the losses that occurs when signals propagate wirelessly.

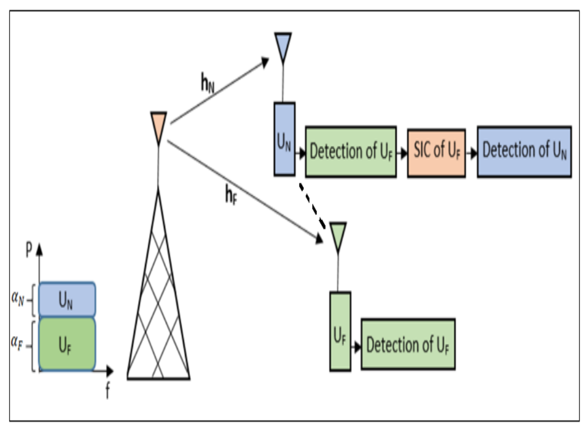

Figure 5. Cooperative NOMA two users downlink (DL).

Moreover, n, CN (0, σ_n^2) 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 γk, 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 ($\delta_M = \frac{\alpha_M P}{\sigma_n^2}$) 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:

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

Two time slots are used for the signal transmission. First, the initial time slot was mentioned to 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 own 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:

$$R_n = 0.5\, log_2(1\alpha_n\rho|h_n|^2) \quad (10)$$

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

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 (near) user decrypted the weak (far) user's data during the previous time frame, the close user already had it. The near user simply sends this data to the far user during the relaying time window. At the conclusion of 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 essentially transmits this data to the far user. At the conclusion of the relaying slot, the far user's attainable rate is:

$$R_{f,2} = 0.5\, log_2(1 + \rho\, |h_{nf}|^2) \quad (12)$$

Here, h_{nf} is the space from the far and the near user, and ($R_{f,2} > R_{f,1}$) thus the far user receives entire transmit power and there is no partial power distribution or interference from other transmissions. The far user then receives two copies of the same signal information via two distinct channels at the conclusion of the two-time intervals. This allows the far user to use a diversity combining method. Then, for instance, utilize selection combining to select the copy that had a high signal-to-noise ratio. Following selection combining, the far user's rate, the result is as the following:

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

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

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

While non-cooperative NOMA communication will consume the entire time slot for transmission, the factor of (0.5) is not present here. Half of 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:

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

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

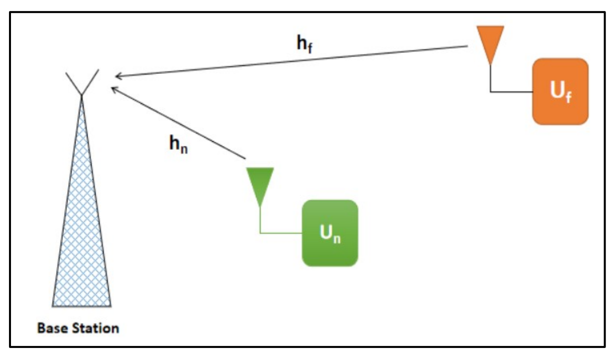

Figure 6: The Model of Uplink NOMA channel [38].

In this model for uplink NOMA channel, U_f presents as the far or weak user, U_n as the 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 represented by h_f and h_n where ($d_n < d_f$) and $|h_f|^2 < |h_n|^2$).

For the uplink NOMA channel, the power domain multiplexing process is carried out differently. 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 are able to 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).

The signal model for uplink NOMA channel, the message to be transmitted 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. The signal that transmitted by far user $(U_f = \sqrt{P}x_f)$ and the signal transmitted by near user $(U_n = \sqrt{P}x_n)$.

The signal received equation at (BS):

$$y = \sqrt{P}x_f h_f + \sqrt{P}x_n h_n + w \qquad (16)$$

where: $\sqrt{P}x_f h_f$ for far or weak user term, and $\sqrt{P}x_n h_n$ for near or strong user term.

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 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 cancellation for retrieve the far user x_f.

From the above description, The development of power domain differentiation. Here's where uplink NOMA and its downlink equivalent diverge. 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 in a lack of power control or superposition coding. To clarify, the power control is not caused by deliberate superposition coding as in downlink NOMA, but rather by intrinsic variations in the channel gains.

Significant observation from the above description, User channel gains need to be sufficiently distinct for uplink NOMA to be effective. The BS cannot differentiate between the both two users signal 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 is therefore:

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

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

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

6. SYSTEM SIMULATION AND EVALUATION

The purpose of this sections is to demonstrate that NOMA fulfills the requirements for 5G better than OMA techniques. Furthermore, the downlink NOMA and uplink NOMA in this section evaluated and studied. The software is used for all simulation results in this paper was MATLAB (V 2022a) and NYUSIM (V 3.1). Different implementation compared between NOMA technique and OMA technique applied by OFDMA for rates pairing of users one to user two in (bps/Hz) represented in Figure 7.

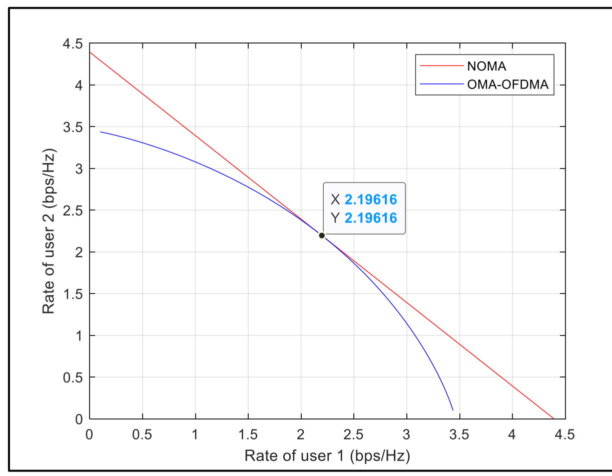

Figure 7: NOMA versus OMA-OFDM for two uses with equal to (20 dB) and symmetric rate pairs.

For analysis and discussion, assuming that there is a pair user in the system network, a symmetric downlink medium used, the users are at the same distance from the base station, and 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, overall, NOMA outperforms OFDMA in rate pairings, except in corner cases, where rates are equivalent to single-user capacities. Both users receive 2.19616 bps/Hz throughputs for both OFDMA further NOMA at the fairness is high. However, compared to OMA-OFDMA, NOMA produces significantly greater rate pairings. Sum capacity and certain system throughputs are larger with NOMA when the fairness is lower.

When the channel fading is un-symmetric rate pairs for user one and user two that SNR user one (20 dB) and SNR user two (2 dB), the performance will be as shown in Figure 8.

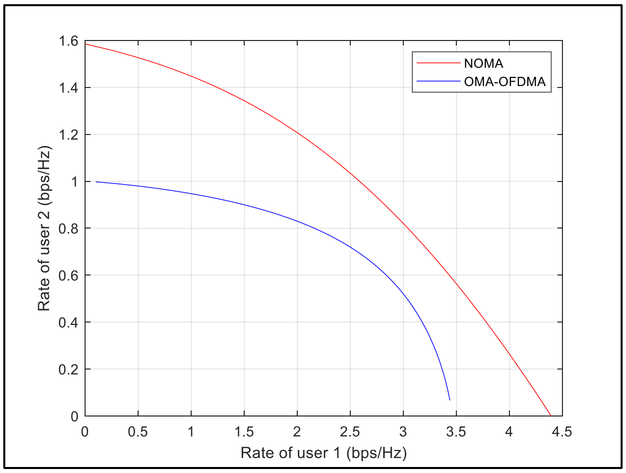

Figure 8: NOMA versus OMA-OFDM with SNR user one (20 dB) and SNR user two (2 dB).

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

6.1 Downlink Cooperative NOMA Channel System

The base station (BS) transmitter uses (SC) for non-orthogonal user multiplexing, which is the main goal of downlink NOMA. Subsequently, every user's data is separately channel coded and modulated, and subsequently 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). The user whose channel state is worse than their own can be blocked by any other user. Figure 9 shows a comparison between NOMA for users weaker (near) and stronger (far) and OMA for users weaker (near) user and stronger (far) user for BER regards to SNR (dB).

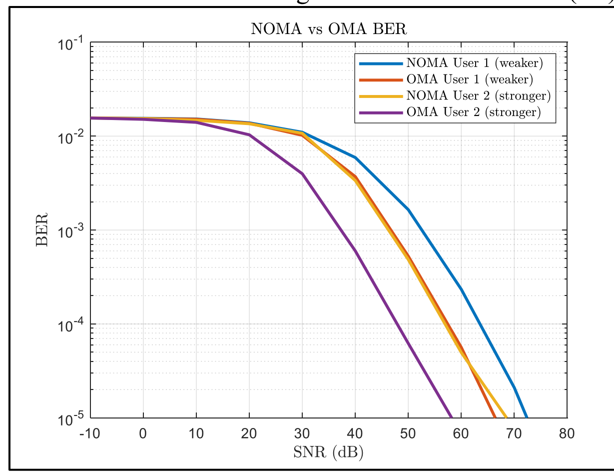

Figure 9: NOMA and OMA comparison for weaker (near) user and stronger (far) user.

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 $(\mathbf{10^{-5}})$ shows that, NOMA for weaker (near) user has SNR (73 dBm) and NOMA stronger (far) user with SNR (68 dBm) as pair users has higher value than OMA weaker (near) user with SNR (66 dBm) and OMA stronger (far) user with SNR (58 dBm). Similarly for the two users, for 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, OMA users, however, 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 $(\mathbf{10^{-5}})$ shows that, NOMA for weaker (near) user has SNR (88 dBm), NOMA mid user has SNR (84 dBm), and NOMA stronger (far) user has SNR (77 dBm) as three pair users has higher value than OMA weaker (near) user with SNR (69 dBm), OMA mid user SNR (63 dBm), and OMA stronger (far) user with SNR (59 dBm) [29].

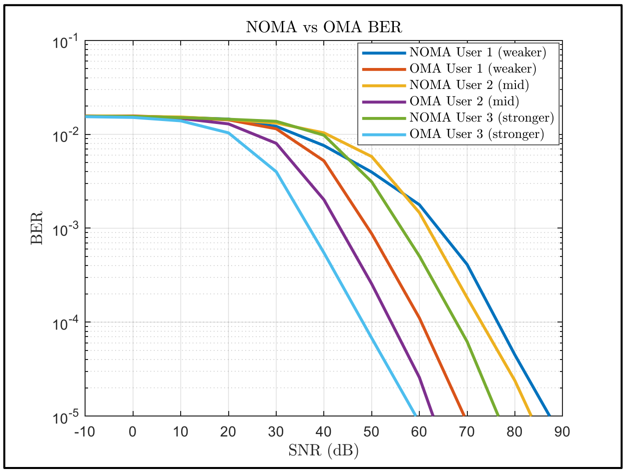

Figure 10: NOMA and OMA comparison for three users near (weaker) user, middle user, and far (stronger) user.

A comparison for outage probability versus SNR (dBm) for (OMA), (C-NOMA), and (Non-C-NOMA), is graphed in Figure 11.

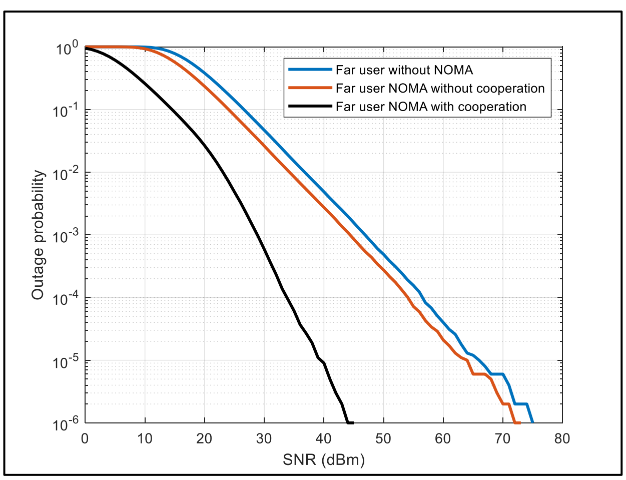

Figure 11: A comparison for (OMA), (C-NOMA), and (Non-C-NOMA), Channels for probability of outage versus SNR (dBm).

Depending on the fundamental that probability of outage increases as the threshold SNR increases. It is clear from Figure 11 that the outage probability (at $\mathbf{10^{-6}}$) in cooperative NOMA has lower value of SNR (44 dBm) from other two systems non-cooperative NOMA SNR (73 dBm) and OMA with SNR (75 dBm). As illustrated in the graph, the Cooperative communication is clearly beneficial.

6.2 Uplink Cooperative NOMA Channel System

In uplink NOMA model system simulation, there is no power control in established. In order to facilitate power domain multiplexing, the intrinsic variations in the channel gains are utilized.

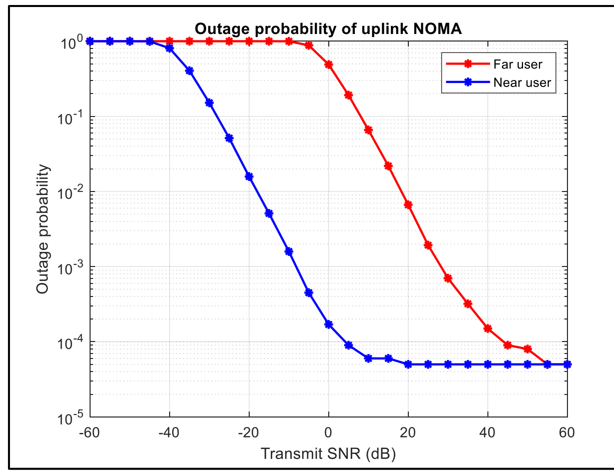

Figure 12: The Probability of outage Versus Transmit SNR comparison for Far and Near users with Rayleigh channel fading.

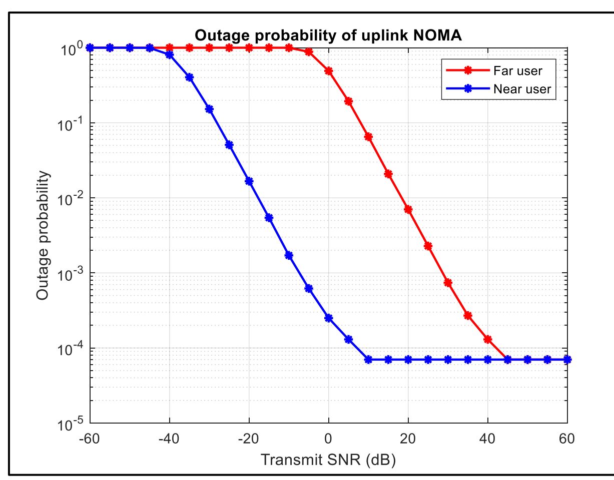

Figure 13: The Probability of outage Versus Transmit SNR comparison for Far and Near users with Rician channel fading.

From figures 12 and 13, the outage probability related to SNR transmission varied for Varity channels fading. The relaying channel fading model (as a more realistic model) has a value of (5e-05), and channel fading Rician has lower value of outage probability (7e-05), in transmit SNR (60 dB).

From the simulation results for cases of fading channels, observed that the types of fading channel effects on outage probability. Test with uplink NOMA outage probability versus transmits SNR (60 dB), have been conducted with signal spectrum bandwidth for near and far users. Different bandwidth frequency is allocated for the model. Figures (14, 15, and 16) shows the numerical simulation for model bandwidth with $(\mathbf{10^5, 10^6, and\ 10^7\ Hz})$ respectively.

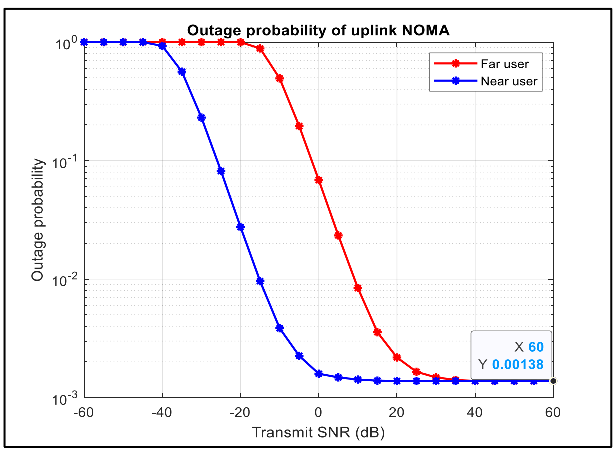

Figure 14: Uplink NOMA Signal Spectrum bandwidth with value ($\mathbf{10^5}$ Hz.) for strong (near) and weak (far) users.

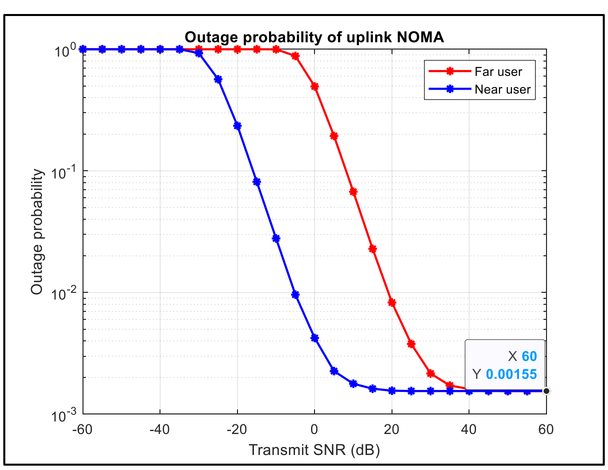

Figure 15: Uplink NOMA Signal Spectrum bandwidth with value ($\mathbf{10^6}$ Hz.) for strong (near) and weak (far) users.

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

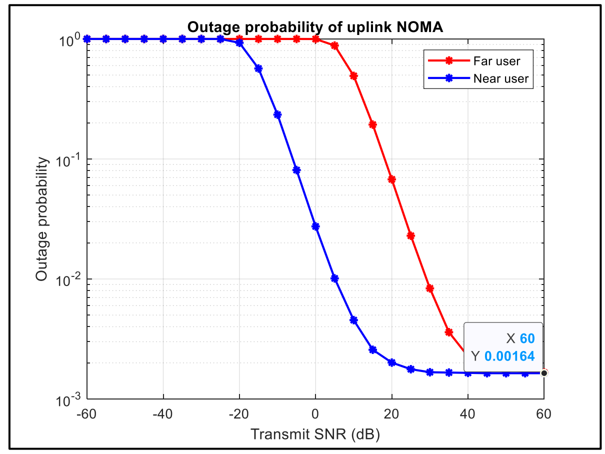

Figure 16: Uplink NOMA Signal Spectrum bandwidth with value ($\mathbf{10^7}$ Hz.) for strong (near) and weak (far) users.

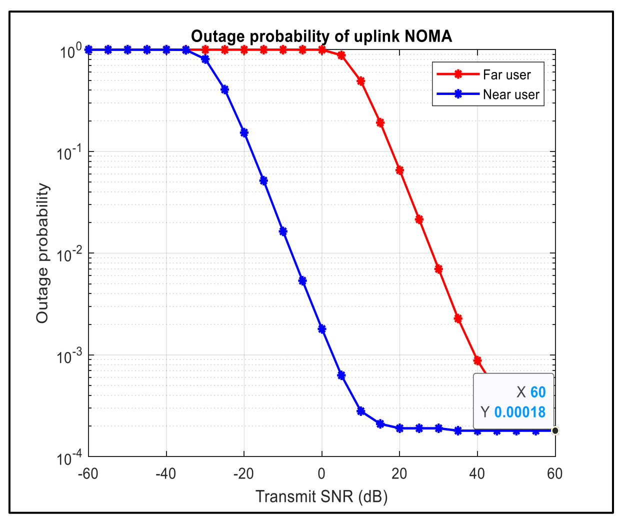

Figure 17: The probability of outage versus transmits SNR (60 dB) for the case noise power value (-164 dB).

As presented in the Figures (17, 18, and 19), with increase of noise power (-164, -174, and -184), the outage probability of uplink NOMA decrease (18e-05, 11e-05, and 6e-05) respectively with the power noise. The numerical result show that with increase noise power, outage probability decrease regards to transmit SNR.

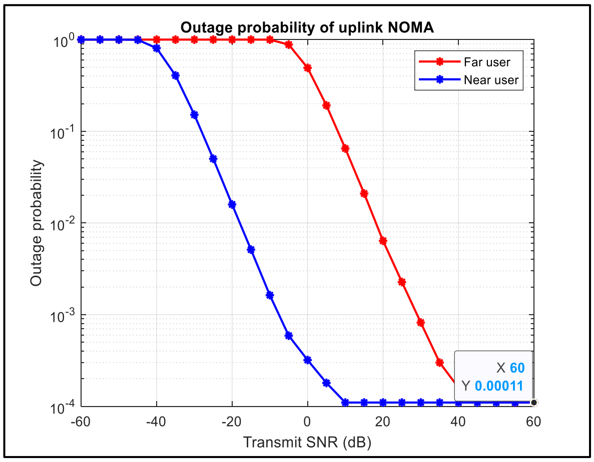

Figure 18: The probability of outage versus (60 dB) transmit SNR for the case noise power value (-174 dB).

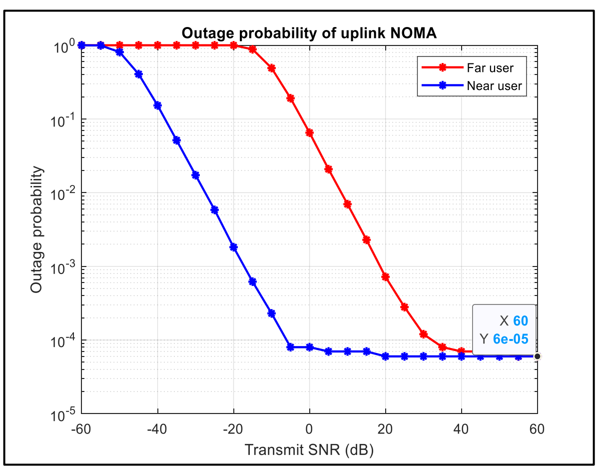

Figure 19: The probability of outage versus (60 dB) transmit SNR for the case noise power value (-184 dB).

With the varying of near and far users distance, an improvement in performance of the model obtained in the simulation result. From numerical results in Figures (20 and 21), for user distance pair (800-100 m), the probability of outage is lesser for either the two users experience, and for distance pair (800-500 m), the probability of outage is higher for either the two users experience. This finding result validates that when the channel circumstances between the users develop significantly distinct, Cooperative NOMA technique performs higher than other techniques.

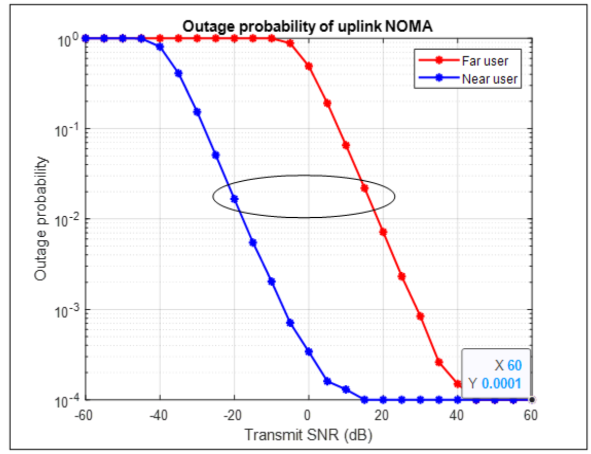

Figure 20: The probability of outage regards to (60 dB) transmit SNR for user distance pair (800-100) m similarly for transmit SNR (20 and 40 dB).

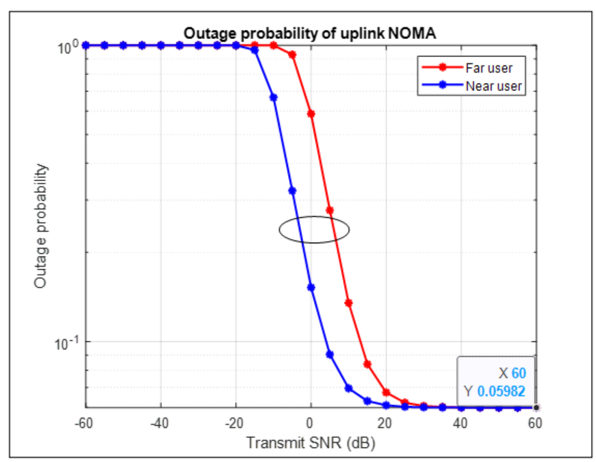

Figure 21: The probability of outage regards to (60 dB) transmit SNR for user distance pair (800-500 m), similarly for transmit SNR (20 and 40 dB).

7. Conclusion

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 studied and observed that (NOMA) technique achieves much higher rate pairs than (OMA-OFDMA) technique especially in the case of un-symmetric rate pairs. For (uplink NOMA) channel fading, (BER) regards to SNR (dB) studied in cases two users (near and far), and three users (near, middle, and far). Numerical simulation proved that at high level of (SNR), (NOMA) outperforms (OMA) by offering high capacity. (C-NOMA), (Non-C-NOMA), and (OMA) channels for outage probability versus SNR studied in this paper. The probability of outage in cooperative (NOMA) has lower value from other two systems non-cooperative (NOMA) and (OMA), while non-cooperative (NOMA) has less outage probability compared with (OMA). The results show that the probability of outage increases with the increase of bandwidth frequency signal spectrum. An improvement in performance of the model obtained in the simulation result with the varying of near and far user distance This result confirms that is, (NOMA) gives superior performance when the conditions of channel among users in the communication systems become more efficient.

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