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NOMA Performance Improvement with Downlink Sectorization

Hurianti Vidyaningtyas [1, 2*], Iskandar [1*], Hendrawan [1], Aloysius A. Pramudita [2]

[1] *School of Electrical Engineering and Informatics, Bandung Institute of Technology, Indonesia.*

[2] *The University Center of Excellence for Intelligent Sensing-IOT, Telkom University, Bandung, Indonesia.*

Abstract

This study tackles the growing challenge of inter-user interference in Non-Orthogonal Multiple Access (NOMA) systems, particularly as user density increases in modern communication networks. The primary objective is to improve system performance by implementing a downlink sectorization strategy, which groups users into distinct sectors to manage interference and optimize resource allocation. A Sequential Power Allocation (SePA) algorithm was introduced to enhance power distribution within sectors, aiming to maximize both user capacity and overall sum rate. The methods employed included detailed simulations comparing the performance of traditional NOMA systems and those incorporating sectorization. The results demonstrate that sectorization can significantly boost the system's sum rate by up to 25% and reduce decoding errors by as much as 51%, particularly when the number of users per sector is kept under 20. However, performance saturation occurs beyond this threshold, where additional users do not contribute to further improvements. The novelty of this research lies in applying spatial sectorization to NOMA, showing that spatial sectorization can minimize intra-sector interference, improve power efficiency, and maintain reliable communication in high-demand environments such as the Internet of Things (IoT). This study provides valuable insights for optimizing NOMA systems, crucial for next-generation wireless networks.

Keywords:

NOMA;

Sectorization;

Maximum User;

Interference Mitigation.

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1- Introduction

Non-Orthogonal Multiple Access (NOMA) technology is considered a key evolution in future radio access technology, especially in increasing the capacity and efficiency of telecommunication networks [1, 2]. Unlike the Orthogonal Multiple Access (OMA) approach that has been widely used from the third generation (3G) to the fourth generation (4G), in NOMA technology, the process at the transmitter side involves the use of Superposition Coding (SC) to combine signals from multiple users at the same frequency but with different power into one complex signal [3]. Successive Interference Cancellation (SIC) techniques are used on the receiver to separate these signals into individual user components. This approach offers a more straightforward detection and decoding process than traditional techniques [4]. This enables significant capacity improvements and a fairer user experience, especially at the network periphery, where channel conditions vary widely among users [5]. In particular, NOMA offers a solution to support many users in modern communication systems, often called "massive users". NOMA allows multiple users to share the same frequency resources simultaneously by utilizing the differences in their channel conditions. This is in contrast to traditional orthogonal compound access schemes such as OFDMA (Orthogonal Frequency-Division Multiple Access) that allocate different frequency resources to each user. This approach significantly increases the utilization of available bandwidth and can potentially support more users in a given spectrum [6]. Research by Saito et al. [7] showed that by grouping users based on their channel conditions, NOMA could significantly improve the spectral efficiency and capacity of the network, making it an ideal solution for networks with a large number of users. In addition, NOMA provides essential

* **CONTACT**: huriantividya@telkomuniversity.ac.id; iskandar@itb.ac.id

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advantages in maximizing spectral efficiency, as described by Dai et al. (2015) [6], Islam et al. (2017) [8], and Nakamura et al. (2015) [9]. Using the Successive Interference Cancellation (SIC) technique, NOMA can handle variations in channel conditions among different users, thus making more efficient use of the available spectrum. Recent research by Vidyaningtyas et al. [10] has also shown that NOMA increases capacity and fairness in resource allocation among users.

With the advent of technologies such as the Internet of Things (IoT), the number of devices requiring communication services has skyrocketed, presenting unique challenges for communication systems. Managing capacity becomes critical, particularly in congested network environments where many devices operate simultaneously. As the user base grows, downlink NOMA systems face inherent limitations in handling many users simultaneously without significant disruption. This increased user density exacerbates the interference problem, further straining the system's ability to maintain high transmission quality and efficiency. The high level of user interference in the NOMA system adversely affects the system performance as the number of users increases. This interference not only reduces the sum rate but also increases the bit error rate (BER), making it a challenge to achieve reliable communication. This interference demands advanced interference management and user clustering techniques to maintain acceptable performance levels. Effective user clustering and interference management strategies are essential to address these issues and ensure optimal performance in NOMA systems [7]. Other studies have explored various strategies to overcome these challenges, including power allocation algorithms, user pairing methods, and advanced signal processing techniques [11, 12]. Although there has been some progress, there is still a need for more effective solutions that can improve the overall performance of the NOMA system, especially in terms of user clustering and interference management.

One proposed method to mitigate interference is dividing all users into smaller groups. Kang & Kim [13] conducted optimal user grouping with two users per group, focusing on user channel gain. This approach not only reduces decoding complexity but also improves system performance by focusing on increasing the sum rate. The study results also show that grouping users with the strongest and weakest signals does not always yield optimal results for maximizing the sum rate in NOMA systems. In Bui et al. [14], interference mitigation is performed using an iterative algorithm for two users with fairness outcomes for each accessing user. The algorithm continues to be iterated until a pair that provides the best fairness is obtained. Zhang et al. [15] discussed the neighbor-based pair search method that was performed, and in Zhu et al. [16], grouping for 2 users was carried out, focusing on optimal user power allocation to optimize the sum rate achievable within its minimum limit. CR-NOMA was developed by Ding et al. [17] and has significant sum rate improvements but is highly complex. User grouping using beamforming was also conducted in Choi [18], but it was still limited to 2 users per beam and focused on the generated beamforming vectors. Pairwise user grouping will yield the best performance in NOMA. However, if the number of users is large, there will be high complexity on the transmitter side in the data transmission process. Therefore, user grouping for more than two users has been developed by several researchers, including studies by Chen et al. [19], Ali et al. [20], You et al. [21], and Prabha Kumaresan et al. [22]. Chen et al. [19] proposed a user grouping and power allocation strategy based on a dynamic programming model with Lagrange multipliers to maximize energy efficiency in downlink NOMA systems, optimizing resource allocation for better throughput. In Ali et al. [20], a dynamic user grouping method and power allocation policy for uplink and downlink NOMA were developed, focusing on channel gain differences to improve system throughput. You et al. [21] applied genetic algorithms for user grouping in hybrid downlink NOMA systems, aiming to optimize spectral efficiency through genetic-based selection and evolution. Artificial Neural Networks (ANNs) were used for efficient user grouping in 5G NOMA systems, offering low-complexity solutions to address channel condition variability [22]. These methods have not considered spatial user grouping. All these studies focus on grouping based on channel gain differences, spectral efficiency, or power allocation without considering the physical position of users spatially.

Research related to clustering and power allocation in NOMA has been widely discussed in the literature. Wang et al. [23], in their survey, reviewed user clustering techniques in NOMA systems, highlighting the importance of spectral efficiency and fairness in the system. Despite providing a comprehensive review, this study does not provide practical implementations or simulations to validate the proposed clustering strategies. Moreover, clustering optimization under imperfect Successive Interference Cancellation (SIC) conditions is also poorly discussed, which is a major challenge in real implementation. Another study by Xiong et al. [24] proposed a user clustering method for cell-free massive MIMO-NOMA systems. This scheme uses Jaccard coefficients to cluster users with significant channel differences, which are then optimized through a successive convex approximation (SCA)-based power allocation algorithm to maximize spectral efficiency. Although this study shows better performance in simulation, it does not address the impact of user mobility and interference between clusters, which are important in large-scale system environments. Mouni et al. [25] introduced a hybrid OMA-NOMA system designed to handle the imperfect SIC problem. This paper proposes an adaptive clustering scheme based on Minimum Signal-to-Interference-plus-Noise Ratio (SINR) Difference (MSD), which aims to improve performance despite the presence of multiple users and imperfect SIC conditions. Although these hybrid systems show advantages in various scenarios, the lack of exploration into multi-cell or large-scale environments limits their applicability in the real world. Furthermore, Hamedoon et al. [26] proposed a user clustering scheme to handle the coexistence of near-field (NF) and far-field (FF) communications in future networks. They developed a coalitional game-based clustering algorithm that can optimize beam assignment and SIC decoding order. Although this solution shows improved performance in simulation, this paper does not fully address the challenges of multi-user mobility and dynamic beamforming techniques, which are critical in real-world deployments.

Based on the existing literature, there are several research gaps that this study addresses. First, there are still few studies that comprehensively discuss how to deal with imperfect SIC in NOMA systems with high user density. Second, most of the existing studies focus more on the static condition of users, while the impact of user mobility on the performance of NOMA systems and clustering techniques has not been explored in depth. Third, previous studies have not provided adequate solutions for inter-cluster and inter-cell interference management in large-scale NOMA systems. Lastly, although many promising results were shown in simulations, real-world implementation, especially in the context of the coexistence of near-field and far-field communications, still requires more exploration. This research aims to address some of these gaps by utilizing sectorization and the SePA algorithm to reduce interference, optimize power allocation, and improve performance in high user density scenarios. In addition, this research will also explore how sectorization can be adapted under dynamic user mobility conditions.

Previous research found that most studies focus on optimally grouping users without considering the interference that occurs within these groups. However, inter-user interference is one of the main issues in NOMA. However, inter-user interference is one of the main issues in NOMA. This can lead to interference between users from different clusters or sectors. To address this problem, this paper proposes the concept of spatial cell sectorization in the downlink NOMA system, with the aim of minimizing interference between users and between sectors. The main contributions of this paper are:

- Using downlink sectorization, identify effective interference mitigation strategies in NOMA systems by considering users' distance, position, and channel gain. This can potentially improve overall system performance.
- This research provides an in-depth analysis of how cell sectorization in the downlink can affect NOMA system performance, including sum rate improvement and Bit Error Rate (BER) reduction.
- This research aims to show and prove that sectorization in NOMA can maximize power usage and reduce decoding errors, which can lead to improved communication reliability in NOMA systems.

This paper consists of 4 sections. The first section is an introduction to the background of the problem and a literature review of previous research. Section II describes the spatial sectorization of the NOMA downlink. Experimental results and discussion are discussed in section III. The last section is the conclusion and proposed future research.

2- Downlink Sectorization on NOMA

Non-orthogonal multiple access (NOMA) is a promising technology for enhancing system capacity and efficiency which is critical to support the growing connectivity demands in modern wireless networks. This synthesis explores the role and performance of NOMA in scenarios with massive users, for example in the context of massive MIMO and Internet of Things (IoT) applications. NOMA can serve more users simultaneously compared to orthogonal multiple access (OMA). However, the achievable sum rate can be lower due to intra-sector interference contamination and imperfect successive interference cancellation (SIC) [27]. While NOMA can outperform OMA in certain contexts, hybrid approaches that combine NOMA with other techniques, such as sectorization, are expected to improve performance. In sectorization, which refers to the division of network cells into sectors to increase capacity and efficiency, is applied to NOMA systems to be able to improve spectrum efficiency in each sector by allowing more users to communicate simultaneously in the same spectrum. This has the potential to increase the sum rate especially in areas with high user density.

The relationship between NOMA and sectorization also includes the ability to manage interference more effectively. Dividing a cell into sectors means dividing the number of users into smaller groups so that the interference experienced by each user only comes from other users in the same sector. This will affect the performance of the SIC at the receiver side in order to optimally return the signal. Integrating NOMA into the sectorization strategy is expected to produce a network that is more flexible, adaptive, and efficient in meeting increasingly complex and diverse communication needs. The following presents the difference in maximum capacity achievement between conventional NOMA and NOMA with sectorization.

Therefore, in this study, we will develop a more optimal method for the use of sectorization in NOMA. To support this research, we have conducted several necessary steps. These steps are presented in Figure 1. The following flowchart illustrates the processes in our methodology for evaluating the performance of a sectorized NOMA system using the Sequential Power Allocation (SePA) algorithm. The process begins with initializing the simulation parameters, such as the number of users, cell radius, power budget, noise density, and other factors critical to network performance. Once the parameters are set, users are randomly distributed within the cell and assigned to different sectors to reflect real-world user distribution scenarios. Next, sectorization is applied to the NOMA system by dividing the network cell into multiple sectors (e.g., 2, 4, or 8 sectors) to spatially group users, which helps in managing inter-user interference more effectively. Thereafter, the Sequential Power Allocation (SePA) algorithm is implemented to sequentially allocate power to users based on their channel gain and distance from the base station, ensuring optimal power distribution and system efficiency. Simulations are then run to observe the network performance under these conditions. After the simulation, various analyses are performed including comparing the performance metric (sum rate) between the sectorized and non-sectorized NOMA systems, calculating the sum rate for each sector and the system as a whole, analyzing the Bit Error Rate (BER) to evaluate decoding errors, and investigating the impact of the number of users per sector on the sum rate performance. Finally, the simulation is terminated, and the results are collected for further analysis, providing valuable insights for optimizing NOMA systems with sectorization and adaptive power allocation techniques.

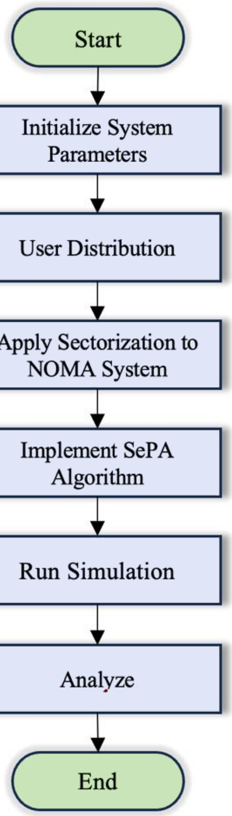


Figure 1. Flowchart of Methodology

2-1- Conventional NOMA for Multiple Users

NOMA is one of the multiple access methods proposed in the upcoming modern communication technology. In this approach, several users simultaneously utilize communication resources with a non-orthogonal concept. This means that users do not share time or frequency exclusively but rather utilize the different signal strength levels each user receives. Users who are in poor channel gain are given a higher power allocation compared to users who are in better channel conditions. Under perfect CSIT conditions, this channel gain depends on the user's distance from the base station; a more significant distance indicates a worse channel gain. Users with stronger signals tend to detect and process signals more easily, whereas users with weaker signals have difficulty detecting but can still process signals using signal recovery techniques, specifically successive interference cancellation (SIC) techniques. This method allows more users to share communication resources without the need for exclusive allocation.

NOMA is most effective when utilized by two users, also known as user pairing, where one user is located at the cell edge, and the other is near the base station. However, in real-world scenarios, the number of users is continuously increasing, necessitating an evaluation of NOMA for multiple users. In this context, power allocation becomes crucial to ensure optimal performance of NOMA. Effective power allocation is essential for managing interference and maximizing the system's throughput. As the number of users increases, it becomes more challenging to allocate power efficiently due to the varying channel conditions and interference levels each user experiences. Therefore, for NOMA with many users, power allocation for all users is divided using the Sequential Power Allocation (SePA) algorithm [10].

Figure 2 shows an illustration of Non-Orthogonal Multiple Access (NOMA) technology and the Successive Interference Cancellation (SIC) process used at the receiver side to handle transmission to multiple users in a wireless communication system with one base station (BS) serving N users. In this scheme, the power allocation is organized at the transmitter, with lower power being assigned to users closer to the transmitter and gradually increasing for more distant users. This demonstrates the use of power-domain-based NOMA, where users at more distant locations are given more power to compensate for the decrease in signal strength due to longer distances and other factors that affect signal propagation.

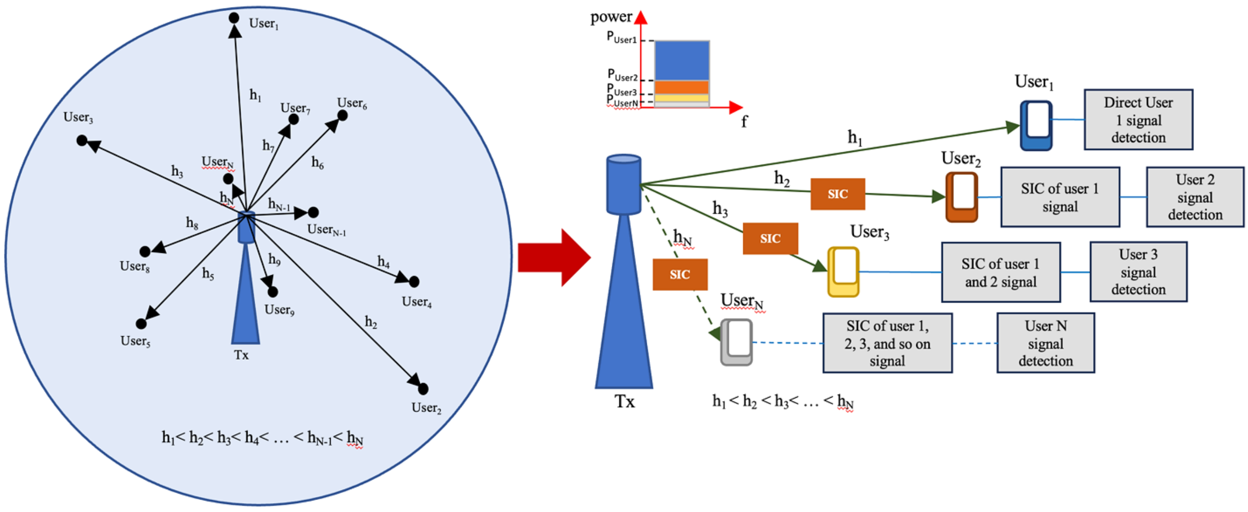


Figure 2. Downlink NOMA using SIC for N users

Each user receives a mixture of signals that overlap at the same frequency and applies the SIC technique to detect its own signal. *User₁*, which receives the largest power allocation, can detect its own signal directly without removing signals from other users. However, starting from $User_2$ to $User_N$, each user must perform SIC to remove signals from more distant users before detecting their signals. As the number of users increases, the complexity of performing SIC increases, allowing more errors in the decoding process due to more incredible difficulty in identifying and removing overlapping signals. As the number of users in the NOMA system increases, less power is allocated to closer users, while the SIC process becomes more complicated and error-prone. This leads to an increased error probability when overlapping signals from multiple users have to be cancelled one by one.

Based on Figure 2, $User_1$ with channel h_1 is the farthest user from the Base Station (BS) and the weakest. $User_2$ with channel h_2 is the second farthest user, and so on, until the *N*-th user with channel h_N, which is closest to the BS. If $S_1, S_2, \ldots, S_N$ is the signal to be sent to the user, then the NOMA send a signal that will enter the channel as a result of superposition coding (SC) at the BS as follows:

$$s_{NOMA} = \sqrt{P_1}\,S_1 + \sqrt{P_2}\,S_2 + \cdots + \sqrt{P_{N-1}}\,S_{N-1} + \sqrt{P_N}\,S_N \tag{1}$$

We can succinctly express s_{NOMA} as follows:

$$s_{NOMA} = \sum_{i=1}^{N} \sqrt{P_i}\,S_i \ ; \qquad for\ \ i = 1, 2, \ldots, N \tag{2}$$

P_i is the power allocation of the *i*-th user based on its channel gain. Power allocation plays an important role in NOMA. All users in NOMA will use the same frequency and time, so strong co-channel interference between users will be significant. Therefore, good resource management will facilitate returning each signal to the receiver [28]. The power allocation in this study is based on the sequential power allocation (SePA) principle [10], which divides the power allocation sequentially. Users who are farthest from the BS are given the most power allocation so that the quality of their received signal is as good as that of users close to the BS. The SePA algorithm is described as follows

$$P_i = \begin{cases} \kappa(1-\kappa)^{i-1} P_t \ , \ i < N \\ P_{i-1}\left(\frac{(1-\kappa)}{\kappa}\right) P_t, \ \ i = N \end{cases} \tag{3}$$

The system transmit power value is symbolized by P_t. In the SePA algorithm, an initial constant is set first, namely Parameter κ, where $\kappa + (1-\kappa) = 1$. The value of κ is optimized to balance the power distribution among users. Higher values of κ result in steeper power reduction between users, while lower values distribute power more evenly. The study by Vidyaningtyas et al. [10] explored different values of κ to find the optimal balance between power efficiency and interference management. The division of power allocation for all users must follow the following conditions [29]

- The total power allocation in one cluster is equal to 1.

$$1 \geq \sum_{i=1}^{N} P_i \tag{4}$$

- The power allocation value for the farthest user ($User_1$) must be greater than the total power allocation of the other users. This applies similarly to subsequent users.

$$P_i \geq P_{i+1} + P_{i+2} + \ldots + P_N \tag{5}$$

When a transmitted signal enters a Rayleigh channel, the amplitude of the signal received by the receiver follows a Rayleigh distribution. This distribution describes the probability of occurrence of various signal amplitudes. The Equation for the Rayleigh distribution is given by:

$$f(x) = \begin{cases} \frac{x}{\sigma^2} e^{-\frac{x^2}{2x^2}} & x \geq 0 \\ 0 & otherwise \end{cases} \tag{6}$$

Each user in a beam area receives the same signal at the receiver, but the channel gain parameters differ based on the user's distance from the base station (BS). The received signal for each user can be expressed as:

$$y_i = h_i S_{NOMA} + \eta_i \tag{7}$$

Where n_i is Additive White Gaussian Noise (AWGN) with zero means and variance = σ^2. h_i represents Rayleigh fading channel. The Rayleigh fading model describes a scenario where the signal experiences localized scattering without a dominant line-of-sight component.

Substitute Equation 1 into Equation 7 and look at the received signal for user$_1$ (the furthest user but the largest power allocation).

$$y_1 = h_1 \left(\underbrace{\sqrt{P_1} S_1}_{targeted\ and\ dominating} + \underbrace{\sqrt{P_2} S_2 + \ldots + \sqrt{P_N} S_N}_{interference} \right) + \eta_1 \tag{8}$$

where $\sqrt{P_1} S_1$ is the desired and dominating target signal belonging to user$_1$. Other received signals will be considered as interference. With the highest power allocation given to user 1, the messages addressed to him will dominate the received signal. Therefore, user1 can directly perform decoding, while other users' messages are considered interference. Hence, the SINR for decoding user 1's signal is

$$SINR_1 = \frac{P_1|h_1|^2}{P_2|h_1|^2 + P_3|h_1|^2 + \ldots + P_N|h_1|^2 + \sigma^2} \tag{9}$$

Next, look at the received signal of user2 (the second farthest user),

$$y_2 = h_2 \left(\underbrace{\sqrt{P_1} S_1}_{not\ targeted\ but\ dominating} + \underbrace{\sqrt{P_2} S_2}_{targeted} + \underbrace{\ldots + \sqrt{P_N} S_N}_{interference} \right) + \eta_2 \tag{10}$$

The signal $\sqrt{P_1} S_1$ owned by user1 is the most dominant signal with the largest power allocation. All users in the cell receive this signal. Therefore, user$_2$ must decode user$_1$'s message first and then perform SIC to remove it from signal y_2. Received signals from other users are considered as interference. Assuming the SIC is perfectly processed, the resulting signal becomes,

$$y_2 = h_2 \left(\underbrace{\sqrt{P_2} S_2} + \underbrace{\ldots + \sqrt{P_N} S_N} \right) + \eta_2 \tag{11}$$

Then the SINR for decoding the user$_2$ signal is as follows,

$$SINR_2 = \frac{P_2|h_2|^2}{P_3|h_2|^2 + \ldots + P_N|h_2|^2 + \sigma^2} \tag{12}$$

User$_3$ needs to decode the user1 and user$_2$ signals and perform SIC to remove them from the y_3 signal. The same process is done up to the *N*-th user, so in general, the SINR for decoding each signal is,

$$SINR_i = \frac{P_i|h_i|^2}{P_{i+1}|h_i|^2 + \ldots + P_N|h_i|^2 + \sigma^2} \tag{13}$$

We can succinctly express $SINR_i$ as follows:

$$SINR_i = \frac{P_i|h_i|^2}{\sum_{j=i+1}^{N} P_j|h_i|^2 + \sigma^2} \tag{14}$$

So, the rate value that each user can achieve is

$$R_i = B\ log_2(1 + SINR_i) \tag{15}$$

The total of all rates achieved by users in 1 cell is named the sum rate, and the Equation can be written as follows,

$$R_{sum} = \sum_{i=1}^{N} R_i \tag{16}$$

2-2- NOMA Sectorization for Multiple Users

The Sectorization technique is studied in this research to develop an effective strategy for NOMA to handle many users in several telecommunication cases, such as massive IoT. The interference as the main problem in NOMA implementation is expected can be reduced by dividing cells into sectors. This technique will influence the received power distribution in the spatial domain. The users that are located inside a certain sector will allocate higher received power than the users that are located outside that sector. Each sector can be viewed as a group of users and contributes to the situation in which interference only occurs within the same sector and is not significant across other sectors in the entire cell. Thus, sectorization is proposed as a method that can facilitate better interference management, improve successive interference cancellation (SIC) performance, and enhance the signal quality received by users in each sector. An illustration of NOMA with sectorization is shown in Figure 2.

Figure 3 illustrates a downlink directional cell with one base station (BS) with k sectors, which, in this illustration, M is 2. Cell sectorization involves dividing a network cell into smaller parts or sectors. There are N users in each sector with the number of users in each sector not always equal and the physical position of the users randomly distributed. The concept of sectorization is used to mitigate interference and focus the signal energy in one direction, like conventional beamforming. This technique allows frequency reuse in each sector, which increases the overall network capacity. Each sector has an antenna or antenna array pointing towards a specific area. Sectorization in this study uses an antenna array with a fixed beam pattern so that the weights of each sector are orthogonal. The antenna array can also combine identical duplicates of signals sent by different sending antennas constructively, in other words, having the same phase as the direction or location of the intended receiver [30]. The received signal is the total sum of the current and phase distribution of the antenna array used. With sectorization, users in other sectors are no longer significant interference and have the potential to reduce overall interference.

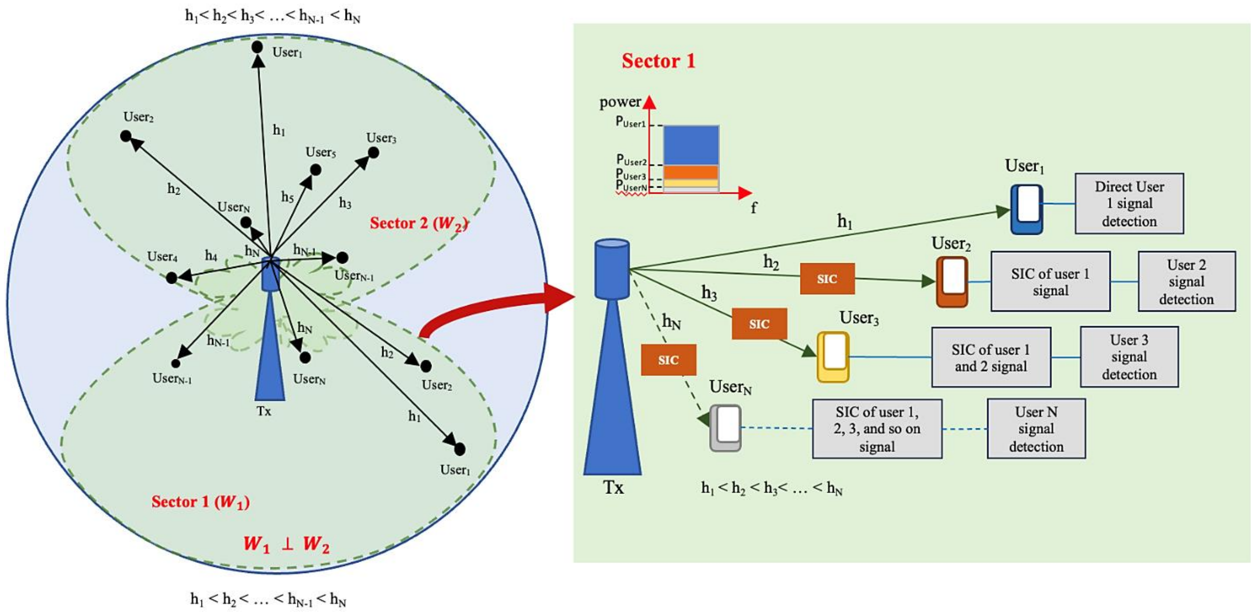


Figure 3. Illustration of downlink NOMA sectorization

The fundamental difference between conventional NOMA and sectorized NOMA is in the process of transmitting and receiving the signal. In conventional NOMA, all users are processed together. In contrast, in sectorized NOMA, signals are processed according to the user in the sector, and other users in different sectors will be ignored because they are minimal interference. Due to sectorization using an antenna array, the receiving power of each user at the receiver (P_{ir}) will be affected by the weight of each sector (w_i), which is written as follows

$$P_{ir} = P_i |h_i w_i|^2 \tag{17}$$

if the transmit signal from the BS is equal to Equation (1), and P_{ir} is the received power actually received by the *i*-th user after the signal passes through the channel, then the receive signal of the *i*-th user in the *k*-th sector at the receiver side is written as follows,

$$y_{i,k} = h_{i,k}\, w_{i,k}\; S_i + \underbrace{\textstyle\sum_{j\neq i} h_{i,k}\, w_{j,k}\; S_j}_{\text{Intra-Sector User Interference}} + \underbrace{\textstyle\sum_{l\neq k}\sum_m h_{i,l}\, w_{m,l}\; S_{m,l}}_{\text{inter-sector interference}} + \eta_i \tag{18}$$

Intra-sector user interference is interference that occurs between users within the same sector of a cell. It is caused by multiple users in the same sector transmitting at overlapping frequencies or time slots, causing interference between their signals. Inter-sector interference occurs when signals from one sector in a cellular or wireless network interfere with signals in adjacent sectors, where *l* is a sector other than the *k*-th sector and *m* is a user in another sector. Where $h_{i,l}$ is the channel gain between the *i*-th user in sector k and the base station in sector l. $w_{m,l}$ is the beamforming component for the *m*-th user in sector *l*. It directs the signal to the user in the neighbouring sector. It directs the signal to users in different sectors. $S_{m,l}$ is the transmitted signal for the mth user in sector *l*.

The decoding process in each sector is the same as in conventional NOMA. User_1 in sector *k* can perform decoding directly. User_2 has to decode user_1's message first and then perform SIC to remove it from signal y_2. *User3* to the *N*-th user performs the same process to get their respective received signals. The SINR for decoding the i-th user's signal in the k-th sector is expressed as:

$$SINR_{i,k} = \frac{P_{ir,k}\left|h_{i,k}w_{i,k}\right|^2}{\sum_{j=i+1}^{N} P_{jr,k}\left|h_{i,k}w_{i,k}\right|^2 + \sum_{l\neq k}\sum_{m} P_{mr,l}\left|h_{i,l}\, w_{m,l}\right|^2 + \sigma_{i,k}{}^2} \tag{19}$$

So that the rate value that can be achieved by each user in the k-th sector is

$$R_{i,k} = B\, log_2\left(1 + SINR_{i,k}\right) \tag{20}$$

The total of all rates achieved by users in 1 sector is named the sum rate, and the Equation can be written as follows,

$$R_{sum,k} = \sum_{i=1}^{N} R_{i,k} \tag{21}$$

3- Simulation Results and Discussion

3-1- Simulation Results

In this section, we evaluate the performance of sectorization against variations in the number of users in the NOMA downlink system. In the simulations, sectorization was implemented as a strategy to improve the performance of Non-Orthogonal Multiple Access (NOMA) systems by dividing the network cell into smaller spatial regions or sectors. This approach was used to isolate users into specific groups, reduce interference, and optimize power allocation. The implementation of sectorization in simulation is described as follows:

- The simulation divided the coverage area of a base station into several sectors, each covering a specific angular range within the circular cell. Each sector was treated as a smaller, independent area where users were grouped together.
- The sectors were defined based on spatial geometry. For example, dividing the cell into two sectors results in each sector covering 180 degrees, four sectors cover 90 degrees each, and eight sectors results in 45 degree sectors.
- Sectorization was static in the simulations, meaning the angular range of each sector remained fixed throughout the simulation. Users were distributed within the sectors based on their physical location within the cell, with no overlap between sectors.

The sectorization is assumed to be a limited area with a radiation pattern that has users in it and other users are considered as interference from different sectors. The number of users in one cell is 20. In NOMA with sectorization, 20 users are divided into several sectors with varying numbers. Users are assumed to be randomly distributed by assuming their position using their distance to the BS. The user distance is also used to calculate the user channel gain on the Rayleigh channel. The distribution of power allocation for each user in conventional NOMA and NOMA with sectorization uses the SePA algorithm [10]. The simulations carried out in this study are:

1. Comparing the sum rate of OMA, NOMA, and NOMA with sectorization to see the effectiveness of sectorization in NOMA,
2. Analyze the SINR at the receiver on NOMA and NOMA with sectorization to see the effect of sectorization in mitigating interference,
3. Comparing the sum rate at different numbers of sectors to see the effect of the number of sectors on the sum rate performance of NOMA,
4. Analyze the comparison of the number of users in various sector variations by dividing the number of users equally and unequally to see the effect of these conditions on the sum rate of users in sectorization,
5. Analyze the number of users varying in one sector based on the increase in the sum rate in that sector. Based on the results of this simulation analysis, the maximum number of users in a sector will be obtained,
6. Analyze the comparison of SIC performance at the receiver side for NOMA and NOMA with sectorization displayed in the form of average BER. This simulation aims to see the effect of sectorization in restoring the quality of the received signal.

Table 1 presents the simulation parameters to provide a comprehensive overview of this study's simulation and evaluation process.

Table 1. Simulation parameters

Parameter	Value
Bandwidth	5 Mhz
Number of users	20
Total power budget	-20 dBm – 60 dBm
Noise density	-174 dBm/Hz
Path loss model	Rayleigh Channel
Cell radius	500 m
Minimum distance between user and BS	50 m
SePA constant (κ)	0.8

First, we evaluated the sum rate values in a NOMA system with and without sectorization, with the number of users in a cell consisting of 20 users varying in location, channel gain, and distance from the Base Station (BS). The simulation without sectorization was conducted by directly allocating power using Equation 3 for all users. In contrast, in the simulation with two sectorizations, the users were divided into two sectors, each comprising 10 users. The power allocation between the two sectors was performed separately. The results of these simulations are shown in Figure 4.

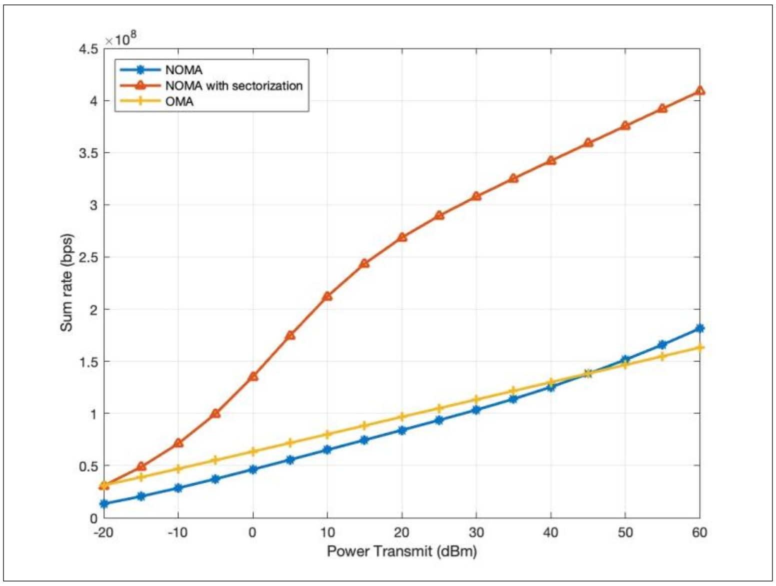


Figure 4. Comparison of Sum Rate between NOMA with 2 Sectorization and without Sectorization

The graph in Figure 4 compares the performance of conventional NOMA without sectorization and NOMA with two sectorizations against OMA, revealing that conventional NOMA with many users is not better than OMA. This is due to increased user interference, which increases the complexity of Successive Interference Cancellation (SIC) at the receiver end [31, 32]. Additionally, NOMA, which relies on power differences in its multiple access process, will need help allocating power for many users. Therefore, an experiment was conducted using sectorization in NOMA, where a cell is divided into two equal sectors. A total of 20 users are evenly divided into the two sectors based on their location. The performance with the sectorization concept shows a significant improvement compared to conventional NOMA. This indicates that with sectorization, the total number of users divided into two spatial sectors can reduce interference among users, making the SIC work at the receiver end easier compared to conventional NOMA.

The increase in transmit power leads to a linear increase in the sum rate for all tested technologies; however, the benefits of NOMA with sectorization become more evident at higher power levels. This indicates that at high power levels, the advantages of optimized interference management and resource allocation strategies in NOMA with sectorization become more dominant.

Second Scenario, analyzing the impact of sectorization on the average SINR of users in each sector. In conventional NOMA, the SINR of 20 users is calculated and then averaged. Meanwhile, 20 users are divided according to the number of sectors analyzed in sectorized NOMA. The SINR value shown is the average SINR value for one sector. Figure 5 illustrates the relationship between the number of sectors and SINR at a transmit power of 20 dB in a NOMA system calculated before the SIC process is performed. SINR, or Signal-to-Interference-plus-Noise Ratio, is a crucial indicator that shows the quality of a signal in relation to interference and noise received. In conventional NOMA, interference comes from other users within the cell, whereas in sectorized NOMA, interference comes from other users within the same sector and from users in other sectors. The graph shows how changes in the number of sectors affect SINR for different configurations, ranging from conventional NOMA to systems divided into six sectors.

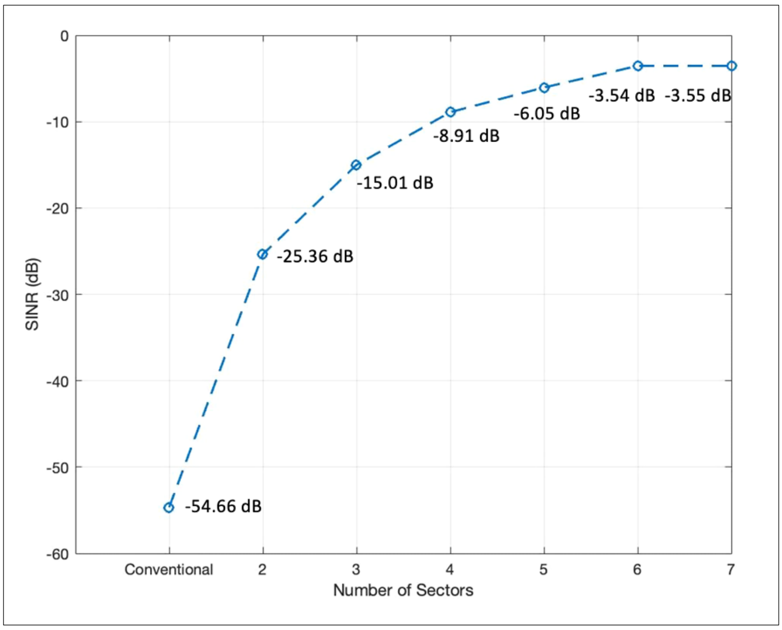


Figure 5. **SINR for Conventional NOMA and Sectorization**

In the conventional NOMA configuration, involving 20 users without sectorization, the SINR was recorded as the lowest. This indicates that power allocation without sectorization leads to significant interference among users because the power allocation strategy in the algorithm (3) with provisions (4) and (5) will provide a significant power allocation value. As the number of users per sector decreases, from 10 users in two sectors to 3 users in six sectors, there is a consistent increase in SINR values. This increase shows that by reducing user density within each sector, the power allocation given is not too significant, and the interference caused by other users within the same sector is reduced. In the case of seven sectors with 3 users in the analyzed sector, the SINR value obtained is the same as that of NOMA with six sectors. This explains that the number of users in the sector greatly affects the average SINR value, where power allocation distribution is based on the number of users in the sector, resulting in similar SINR values for both six and seven sectors configurations with the same number of users. Therefore, sectorization confirms that the reduction in inter-user interference is successfully achieved through better isolation and resource management.

The conclusion from this analysis is that sectorization in NOMA substantially enhances network performance through significant reduction of user interference, resulting from improved power allocation management. Implementing sectorization enhances the system's ability to efficiently utilize the available spectrum, ensuring each user receives a cleaner signal for processing. This strategy is crucial for supporting the needs of modern communication networks facing challenges from increasing user numbers and high service demands, especially in scenarios like massive IoT, where communication efficiency and stability are critically important.

In the third scenario, simulations were conducted to observe the impact of the number of sectors within a cell on the sum rate of users within it. The simulated number of sectors includes two, four, and eight, each with equal angular sizes of 180, 90, and 45 degrees, respectively. A total of 20 users were divided into different configurations in the NOMA system with sectorization: two sectors with 10 users per sector, four sectors with 5 users per sector, and eight sectors with 2 or 3 users per sector.

Figure 6 is a graph that shows a significant increase in the sum rate as the number of sectors increases from 2 to 4 and 8. The recorded delta sum rate illustrates this; from NOMA with two sectors to four sectors, there is an increase of 2.96×10^8 bps, and from 4 sectors to 8 sectors, there is an increase of 5.69×10^8 bps. This demonstrates the effectiveness of reducing user interference within the same sector by dividing them into smaller sectors, thereby enhancing the performance of SIC decoding.

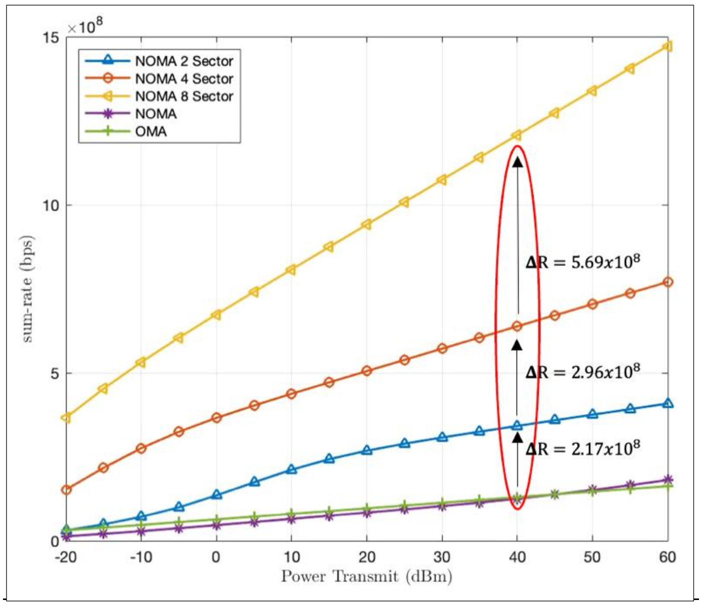


Figure 6. **Performance of NOMA with Different Numbers of Sectors**

The above indicates that a larger number of sectors with fewer users in each sector can minimize interference between users in the same sector while increasing the effectiveness of SIC. SIC is a technique where the strongest signal is decoded first; weaker signals are decoded by reducing interference from previously decoded signals. With an increase in the number of sectors, the probability that signals with adjacent strengths need to be cancelled at one time decreases, which eases the SIC process and reduces the possibility of errors during decoding.

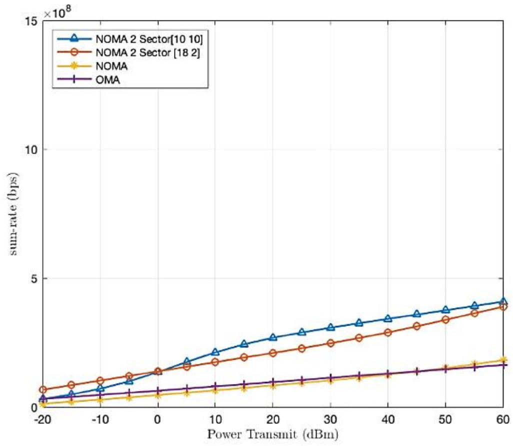
The fourth scenario compares the performance of the NOMA system with sectorization with an equal number of users and a different number of users for each sector. This situation describes a residential area that allows a more even distribution of users. In contrast, the situation with a significant difference in the number of users describes an area with public services, where one area has more users than another. The same number of users for 2, 4, and 8 sectors are [10,10], [5,5,5,5], and [2,2,3,3,2,3,2,3,2,3], respectively. The significant differences in the number of users for the three-sector scenarios are [18,2], [8,2,8,2], and [5,0,0,7,0,6,0,2], respectively. In sector 8, with a different number of users, four sectors have no users.

In all the sector scenarios presented in Figure 7, the blue line representing equal user distribution consistently performs better than the red line representing different user distributions. Increasing the number of sectors from 2 to 4 and 8 remains the same trend, where the equal user distribution still provides higher sum rates at each transmit power level. However, there is a sizable sum rate difference between the same and different number of sectors in sector 8 of 5.3×10^{8} bps at 40 dBm transmit power. This value is larger than the sum rate difference of two and four sectors, which are about 0.52×10^{8} bps and 0.18×10^{8} bps, respectively. This is because the simulation with a significant number of users in 8 sectors has four sectors without users, so the 20 users are only divided into the remaining four sectors. This imbalance in user distribution can lead to increased interference and decreased power allocation efficiency, reducing the system's overall performance [4, 33].

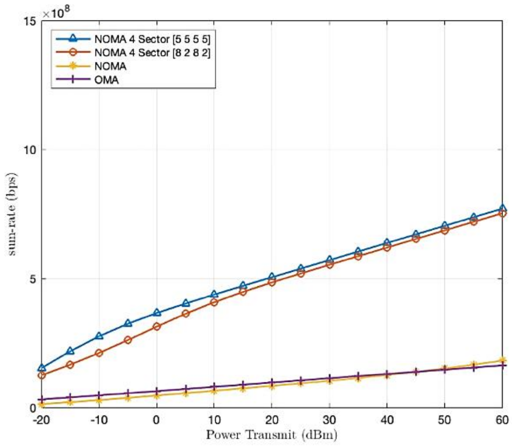
From these simulation results, it can be concluded that an equal number of users in the NOMA system gives more optimal results than a significant number of users in all sectorization configurations. It can be interpreted that the even power distribution and less complexity of interference management in the same number of users help to increase the effectiveness of the SIC technique, maximizing the overall communication throughput. This advantage of equal number of users confirms the importance of balanced resource distribution in improving the performance of NOMA systems.

The fifth simulation scenario aims to demonstrate SIC's maximum ability to separate the signals of all users in 1 sector from the decoding process at the receiver. Simulation scenarios were carried out on sectors 2 and 4, with the number of users in each sector ranging from 10, 15, 20, 25, to 30.

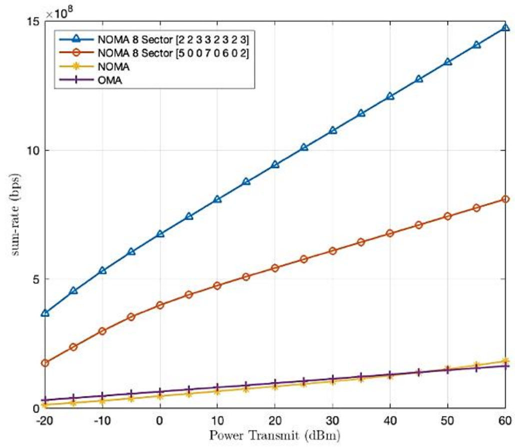
Figure 8 shows the effect of the number of users on the sum rate for the two scenarios of two and four sectors. Both graphs show that the sum rate increases with increasing transmit power (dBm) for all NOMA sectorizations. However, in NOMA sectorization, there is saturation at 40 users for two and 80 users for four sectors. In the 2-sector configuration (a), NOMA with two sectors and a total of 40 users shows an increase in sum rate of about 3.5x108 bps at a transmit power of about 60 dBm, after which the increase becomes insignificant for an increasing number of users. Similarly, in the four-sector configuration (b), NOMA with four sectors and 80 users saturates at a sum rate of about 7.2x108 bps at a transmit power of about 60 dBm. This shows that adding more users does not significantly increase the sum rate after a certain point.



(a) 2 Sectors

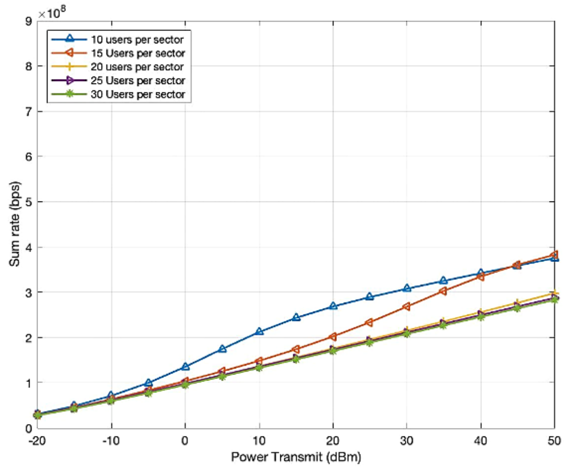


(b) 4 Sectors

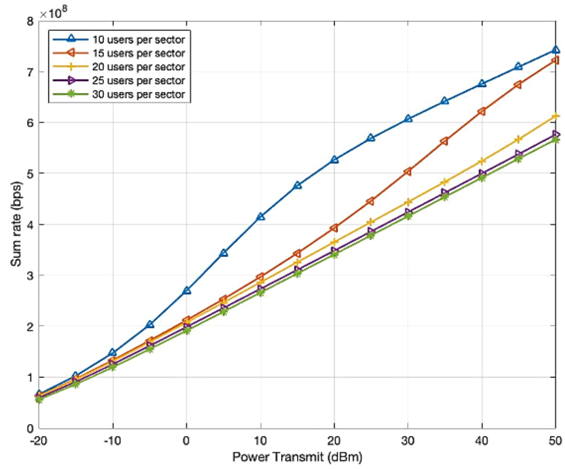


(c) 8 Sectors

Figure 7. Variations in the Number of Users within Each Sectors



(a) 2 Sectors



(b) 4 Sectors

Figure 8. Variations in User Numbers in the Same Sectors (a) 2 Sectors (b) 4 Sectors

The analysis shows that saturation of the number of users occurs at 20 users per sector, both for two sectors (40 users in total) and four sectors (80 users in total). This saturation indicates that after reaching a certain number of users in each sector, additional users no longer increase the sum rate significantly. This implies that the NOMA system reaches its optimal limit in managing interference and utilizing the available spectrum when the number of users in a sector exceeds 20 users per sector. This is due to increased intra-sector interference that cannot be fully addressed by Successive Interference Cancellation (SIC) techniques. However, NOMA is known to be better than OMA in this regard. This saturation emphasizes the importance of planning and managing the number of users in each sector to ensure optimal performance of the NOMA system.

Comparisons between NOMA without sectorization and NOMA with sectorization show that NOMA with sectorization consistently performs better. NOMA with sectorization performs better, as shown by the line representing NOMA with 15 users. Increasing the number of sectors allows for more even user distribution and more effective interference management, ultimately increasing the sum rate. The advantage of NOMA in maximizing communication throughput compared to OMA is especially evident in scenarios with a large number of users. This underscores the importance of balanced resource distribution and effective interference management strategies in the NOMA system [6, 34].

The sum rate value that tends to saturate at the number of users 20 for the 2-sector and 4-sector scenarios is continued with simulations to see the performance of SIC on the Bit Error Rate (BER) parameter achieved against the number of users in 1 sector. The BER performance is shown in Figure 9.

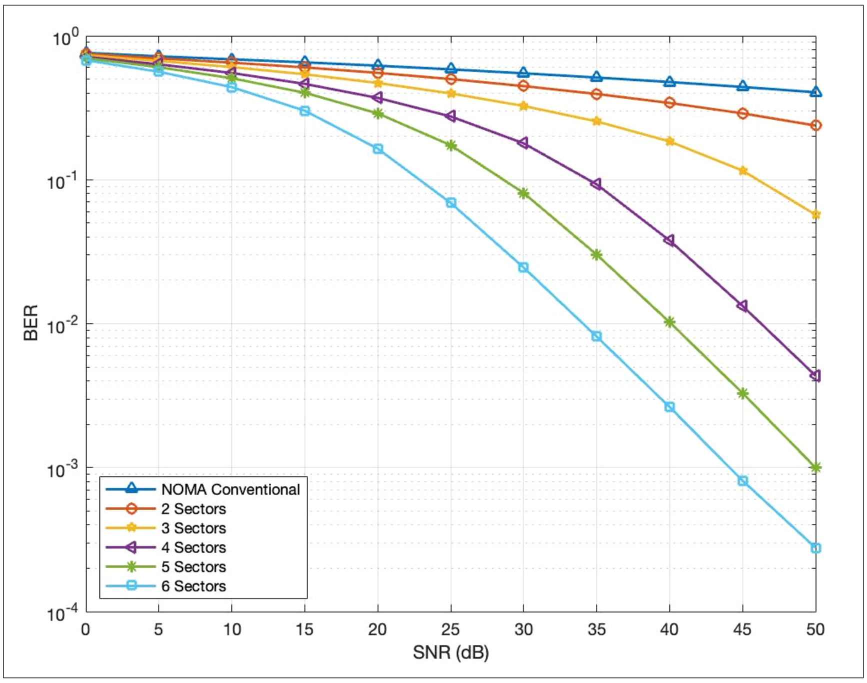


Figure 9. BER for Various Number of Sectors

Figure 9 shows the SIC performance results in terms of Bit Error Rate (BER) for the Non-Orthogonal Multiple Access (NOMA) system in various sectorization configurations at different Signal-to-Noise Ratio (SNR) levels. The graph shows that conventional NOMA, which serves 20 users, has a higher BER compared to sectorization scenarios that reduce the number of users in each sector. At an SNR of 40 dB, the difference between various sector configurations becomes very apparent. Conventional NOMA, with 20 users, records a BER of approximately 0.477, indicating that user interference is very dominant, leading to a relatively high error rate compared to the sectorized system. However, when the system is divided into two sectors with 10 users per sector, there is a BER reduction of 0.136 from conventional NOMA. As the number of sectors increases to three, four, five, and six sectors, each serving 7, 5, 4, and 3 users respectively, a significant reduction in BER is observed, with BER values of 0.184, 0.0377, 0.0102, and 0.0026. This reduction indicates that the fewer users there are in each sector, the more effective the sectorization is in controlling interference and improving communication quality.

This reduction in BER indicates that by decreasing the number of users per sector, the NOMA system can reduce user-to-user interference, a primary factor increasing BER. At the receiver, the SIC process is simplified because the successive cancellations required are fewer, thus reducing the potential for propagation errors. Moreover, reducing the number of users allows for more effective power allocation and better signal management, enhancing signal reception quality and reducing decoding errors. This demonstrates that sectorization is effective in reducing the bit error rate by dividing users into smaller groups.

The simulation results provide substantial insights into the performance improvements achieved by applying sectorization to downlink NOMA systems. First, it was observed that sectorization significantly increases the overall sum rate of the system compared to conventional NOMA. As shown in Figure 3, the sum rate improved by up to 25% when users were divided into two sectors, compared to a non-sectorized system. This improvement can be attributed to the reduction in inter-user interference within each sector, which allows for more efficient power allocation using the SePA algorithm. These findings align with previous studies from Chen et al. [19] on interference management in NOMA systems, but sectorization offers a more practical solution by spatially isolating users.

Another key result is the observed performance saturation at 20 users per sector, as shown in Figure 7. Beyond this point, adding more users does not yield significant gains in sum rate. This suggests that while sectorization can handle a moderate number of users effectively, excessive user density in each sector leads to diminishing returns. This behavior is likely due to the increasing complexity of Successive Interference Cancellation (SIC) as more users are added, which complicates decoding and increases the potential for decoding errors. This observation is consistent with studies by Saito et al. [7], which highlight the challenges of handling large user groups in NOMA.

Furthermore, the Bit Error Rate (BER) analysis presented in Figure 9 confirms that sectorization reduces decoding errors significantly. The BER decreased by up to 51% when users were divided into smaller sectors, demonstrating that the spatial isolation of users improves the effectiveness of SIC. By minimizing intra-sector interference, each user receives a cleaner signal, which results in fewer decoding errors and higher overall system reliability. These findings underscore the importance of managing user density and interference through spatial techniques, as suggested in a previous study by Islam et al. [8].

In conclusion, all these graphs indicate that sectorization in NOMA systems is an effective strategy for optimizing resource utilization and reducing error rates, particularly in dense network conditions. Sectorization in NOMA has been proven to reduce user interference within a cell. This strategy not only helps increase data throughput and reduce BER but also plays a crucial role in supporting the growing network demands for capacity and speed, especially in applications requiring massive connectivity, such as the Internet of Things (IoT) and high-speed mobile communications. However, further research is needed to analyze the complexity of antenna design in forming these sectors. Regarding the optimal capability of SIC to separate received signals, the fewer the number of users within a sector, the lower the average BER for all users in that sector. In summary, a comparison of related studies on reducing intra-cell interference is presented in Table 2.

Table 2. Comparison of related studies

Researcher	Method	Number of Users/ Group	Parameter input			Performance
			Power transmit	Channel gain	User position	
Ding et al. (2016) [17]	CR-NOMA	2	✓	✓		Individual Data Rate, Sum Rate
Kang & Kim (2018) [13]	Suboptimal algorithm	2	✓	✓		Sum Rate
Zhang et al. (2018) [15]	Hill climbing search and simulated annealing	2	✓	✓		Throughput, computational complexity
Bui et al. (20190 [14]	Iterative algorithm	2	✓	✓	✓	Rate Fairness
Zhu et al. (2019) [16]	Mixed integer	2	✓	✓	✓	Sum Rate
You et al. (2020) [21]	Genetic algorithm (user population)	3	✓	✓	✓	Throughput
Hamedoon et al. (2024) [26]	Game-based clustering algorithm	6	✓	✓	✓	Sum Rate
Present Study	**Sectorization downlink**	**20**	✓	✓	✓	**Sum Rate, BER, maximum number of users**

Based on the summary shown in Table 2, previous studies have offered various innovative approaches for user grouping and pairing in NOMA systems using different methods to achieve the desired performance parameters. Most of these studies, such as CR-NOMA, suboptimal algorithm, mixed integer, iterative algorithm, and hill climbing search and simulated annealing, focused on improving the sum rate or user throughput for user pairing with 2 users per group. Further studies on a larger number of users have been conducted by You et al. [21] and Hamedoon et al. [26]; however, the maximum number of users per group is still limited to 3 and 6 users, respectively.

Compared to these approaches, the downlink sectorization used in this study demonstrates a significant advantage in handling a larger number of users while maintaining high performance, such as better sum rate and lower BER. In this study, sectorization can achieve a maximum number of users up to 20 users per group. By isolating users into sectors, interference can be minimized, which in turn enhances the overall system performance. This sectorization strategy not only increases the capacity of the NOMA system but also ensures the efficient utilization of available resources. Overall, the table illustrates that the study conducted by authors with the downlink sectorization method can overcome the limitations of previous methods in terms of user capacity, power allocation efficiency, and interference management, making it a superior solution for NOMA systems in high-density environments.

3-2- Discussion

The simulation results presented in this study provide valuable insights into the potential performance improvements of sectorized Non-Orthogonal Multiple Access (NOMA) systems. In the context of real-world conditions, several assumptions and considerations have been applied to ensure the relevance and feasibility of implementing sectorization in NOMA systems. One of the main aspects considered is the fact that sectorization is already used in existing communication systems today. The use of sectorization allows existing physical infrastructure to remain in use without requiring significant changes, as sectorization typically involves dividing the service area into several sectors managed by different antennas at the base station. Thus, the implementation of sectorization in NOMA systems can be carried out more easily, as it only requires adjustments to the logical infrastructure, particularly on the transmitter and receiver sides. These improvements or changes include more dynamic power allocation management, the development of more efficient interference cancellation (SIC) algorithms, and the adaptation of algorithms capable of optimizing performance in high user density environments. Therefore, while the physical infrastructure does not require extensive modifications, the logical infrastructure must be enhanced to address the challenges posed by network dynamics and complex traffic patterns in real-world scenarios.

However, the proposed sectorization and Sequential Power Allocation (SePA) algorithm may face various challenges in practical deployments due to varying network topologies and user mobility. In real-world scenarios, network topologies are often irregular, with uneven user distribution influenced by geographical and environmental factors, such as dense buildings in urban areas or open fields in rural areas. This leads to different signal propagation conditions in each region. For instance, in dense urban environments, the presence of tall buildings and other obstacles can cause signal blockages and increased multipath fading effects, resulting in uneven user distribution and high interference conditions. In such cases, the effectiveness of sectorization may decrease, as users within a sector can experience highly variable signal conditions. Therefore, the SePA algorithm may require further adjustments to account for heterogeneous channel conditions and implement more dynamic power allocation techniques that can respond to changes in user positioning and interference levels in real-time.

User mobility is another crucial factor that affects the performance of the proposed approach. As users move between sectors or across the network, the SePA algorithm must continuously adjust power allocation to maintain optimal performance. High-mobility users, such as those in vehicles, may experience rapid changes in channel quality, making it difficult to maintain efficient power allocation. In such cases, real-time updates of Channel State Information (CSI) are required, and any delay or inaccuracy in obtaining this information can degrade system performance. To address these challenges, the sectorization and SePA algorithm can be enhanced with predictive mechanisms or machine learning approaches that can anticipate user mobility patterns and proactively adjust power allocation. Moreover, to handle varying user densities and traffic demands across different sectors in large-scale networks, more adaptive or dynamic sectorization techniques are needed. These techniques can optimize the number of users per sector based on real-time traffic and mobility patterns, thus enhancing the scalability and flexibility of the SePA algorithm in real-world deployments, particularly in high-demand environments such as the Internet of Things (IoT) or 5G networks.

To overcome the limitations observed at higher user densities in NOMA systems, particularly related to interference and power allocation, several methods have been proposed. These methods aim to address the performance saturation seen as user numbers per sector increase. One such strategy is user grouping and dynamic sectorization, which involves dynamic user grouping and sectorization based on real-time traffic loads and user mobility. This method could optimize the number of users in each sector. Instead of having a fixed number of users per sector, the system would adjust sector sizes dynamically to manage user density more effectively. By adjusting the number of users per sector in real time, this approach can prevent performance saturation, allowing for more efficient power allocation and reduced interference by redistributing users based on their real-time signal conditions and channel requirements.

Another promising approach is the use of machine learning for user grouping. Machine learning (ML) techniques can be utilized to predict user mobility patterns, traffic loads, and channel conditions. ML algorithms can optimize power allocation, user grouping, and interference management by learning from historical data and adjusting resources in real-time. Machine learning enables the system to predict and proactively address congestion and interference in high-density networks. This dynamic resource management can significantly reduce the limitations caused by high user density, ensuring more efficient power distribution and improved SIC performance.

Lastly, improving the power allocation algorithm to be more dynamic in response to variations in the number of users and their channel gains can further enhance performance in NOMA systems. This includes techniques for power allocation distribution or detection methods tailored to user needs based on their distance and channel gain conditions. The power allocation algorithm can distribute power according to the conditions of each sector based on the number of users, their distance, and channel gains, even when several users are in the same position.

In summary, while the proposed sectorization and SePA algorithm show significant promise in controlled simulations, their performance in practical deployments will depend on their ability to adapt to complex and dynamic network conditions, including user mobility, heterogeneous topologies, and fluctuating traffic patterns. Future research should focus on refining these techniques to ensure robust and efficient performance across a range of practical deployment scenarios.

4- Conclusion

This study has demonstrated that sectorization, combined with the Sequential Power Allocation (SePA) algorithm, significantly enhances the performance of downlink Non-Orthogonal Multiple Access (NOMA) systems. By spatially isolating users into specific sectors, inter-user interference is minimized, leading to substantial improvements in system sum rate and a notable reduction in decoding errors. The simulation results showed a sum rate improvement of up to 25%, alongside a 51% reduction in Bit Error Rate (BER) when compared to traditional NOMA systems without sectorization. The findings also revealed a performance saturation point at 20 users per sector, beyond which the addition of more users does not yield further gains. This highlights the importance of controlling user density within each sector to ensure optimal system performance.

The implications of these results are particularly relevant for modern wireless networks, including those supporting the Internet of Things (IoT) and other high-density user environments. Sectorization offers a scalable and effective solution to manage interference, thereby enabling NOMA systems to accommodate a larger number of users without compromising communication quality. The study also underscores the critical role of power allocation strategies in maximizing system efficiency, with the SePA algorithm proving to be an effective method for distributing power among users in sectorized NOMA systems.

Future research should focus on exploring more dynamic and adaptive sectorization techniques that respond to real-time user distributions and traffic demands. Additionally, the integration of machine learning algorithms to optimize user clustering, power allocation, and interference management could further enhance the performance of NOMA systems. Further experimental validation in real-world network scenarios will also be essential to confirm the practical applicability of the proposed solutions.

5- Declarations

5-1- Author Contributions

Conceptualization, H.V. and I.; methodology, H.V., H., and A.A.P; software, H.V. and A.A.P.; validation, I., A.A.P., and H.V.; formal analysis, I. and A.A.P.; investigation, H.; resources, I.; data curation, A.A.P.; writing—original draft preparation, H.V.; writing—review and editing, I. and H.; visualization, H.V. and A.A.P.; supervision, I., H., and A.A.P.; project administration, H.; funding acquisition, H.V. All authors have read and agreed to the published version of the manuscript.

5-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

5-3- Funding

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5-4- Institutional Review Board Statement

Not applicable.

5-5- Informed Consent Statement

Not applicable.

5-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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