Enhancing Bit Rate using Hybrid Access Method based on NOMA and CDMA for 5G Networks

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Abstract: - Non-orthogonal multiple Access (NOMA) is a transformative wireless communication technique that has gained significant attention for its ability to enhance spectral efficiency and capacity in modern communication systems. Unlike traditional orthogonal multiple access methods, which allocate separate frequency, time, or code resources to users, NOMA controls power domain multiplexing to enable multiple users to share the same time and frequency resources simultaneously. This work provides comprehensive details about NOMA and proposes a hybrid access method that benefits from NOMA and the Code Division Multiple Access (CDMA) to enhance the bit rate in the downlink from Base Station to mobile nodes. Simulation results prove that the proposed technique enhances the bit rate for users even the far ones from the base station.

Key-Words: - 5G, CDMA, NOMA, SIC.

Received: June 23, 2022. Revised: August 21, 2023. Accepted: September 19, 2023. Published: October 23, 2023.

1 Introduction

NOMA is an advanced multiple-access technique that is used in wireless communication systems, especially in 5G networks. It is designed to improve spectral efficiency, increase capacity, and enhance user fairness by allowing multiple users to share communication channels at the same time and using the same frequency.

In traditional multiple access schemes such as Frequency Division Multiple Access (FDMA), adopted in 1G, Time Division Multiple Access (TDMA), used in 2G, and CDMA, adopted in 3G, users are allocated separate frequency, time, or code resources to avoid interference between them. However, those technologies suffer from limitations in terms of capacity and efficiency.

NOMA takes a different approach by allowing users' signals to overlap in the power domain. This means that multiple users can transmit their data using the same time and frequency resources, with their signals superimposed on each other. The key idea behind NOMA is to allocate different power levels and modulation schemes to different users and enable their signals to coexist and be separated at the receiver.

In NOMA, users with better channel conditions are assigned lower power levels, while users with poor channel conditions receive higher power levels. The imbalance of power allows the receiver to distinguish and separate users' signals using advanced signal processing techniques. Interference cancellation algorithms, such as Successive Interference Cancellation (SIC), are employed to decode the signals of different users one by one and improve the overall system performance.

Although NOMA has witnessed high performance in comparison to its counterpart of Orthogonal Frequency Division Multiple Access (OFDMA) and former techniques such as TDMA and FDMA, it has some limitations and challenges.

This work highlights the NOMA technology, its limitations, challenges, and benefits. In addition to proposing a hybrid access technique that benefits from both CDMA and NOMA to produce a higher bit rate for the same transmitted power when mobile nodes receive a signal from the base station (downlink) for 5G networks. Matlab is used to simulate the code. Simulation results show that the proposed algorithm outperforms NOMA in terms of bit rate.

The remaining of this article is organized as follows: part 2 presents general information about NOMA, part 3 presents the benefits of NOMA, part 4 presents NOMA transmission system, part 5 presents NOMA in MIMO, part 6 presents the spectrum allocation in NOMA, part 7 presents Successive Interference Cancellation (SIC), part 8 presents issues and challenges of NOMA, part 9 presents Code Division Multiple Access (CDMA), part 10 presents general hybrid systems that can be formed by NOMA and CDMA, part 11 presents the proposed solution and simulation results, and finally, part 12 the conclusion.

2 What is NOMA

1G networks uses FDMA, [1], as the access technique, it enables users to share the communication channel by sending their signals at the same time but using different frequency. 2G networks use TDMA, [2], as the access technique, it enables users to share the communication channel by using the same frequency but each user is allocated a different time slot, and because the timing is very fast, it sounds like users are sending and receiving at the same time. 3G adopted a different technology, CDMA, [2], where users are sending and receiving simultaneously, and using the same frequency, but each user is allocated a different code for its data to be distinguished and extracted. 4G adopted the OFDMA, [1], a scheme to achieve higher data rate and spectrum efficiency. Figure 1 presents the differences between the FDMA, TDMA, and CDMA.

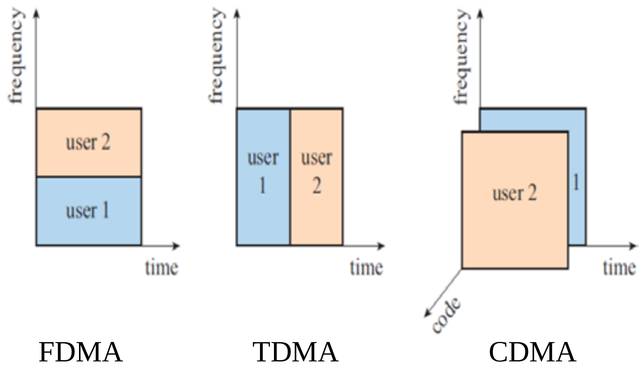

Fig. 1: The difference between FDMA, TDMA, and CDMA

NOMA, [3], uses a different approach than the methods mentioned above.

Multiple users share the same time and frequency resources for simultaneous transmission and reception. The sharing of resources in NOMA is achieved through power domain multiplexing, where users' signals are allocated different power levels to allow overlapping transmissions.

Users in NOMA are allocated different power levels based on their channel conditions, quality of service requirements, or other criteria. Weaker users are assigned higher power levels, while stronger users receive lower power levels. This power allocation determines how the users' signals are superimposed and shared in the power domain.

The signals of different users are superimposed using different power levels. Users' signals are multiplied by their respective power allocation coefficients and then added together, resulting in the superimposed signal that is transmitted over the shared resources.

The superimposed signal, which contains the signals of multiple users, is transmitted at the same time and frequency. The overlapping nature of the transmissions is possible due to the varying power levels assigned to each user, which allows their signals to be separated at the receiver.

On the receiver side, sophisticated signal processing techniques are employed to separate and decode the individual user's signal. The receiver performs interference cancellation and detection algorithms to differentiate and extract the signals of different users from the received superimposed signal.

Once the individual user signal is separated, it is decoded using appropriate decoding algorithms based on the modulation and coding schemes employed by each user. The decoded signals contain the users' intended information.

The network layer (layer 3) in a wireless communication system is responsible for routing and forwarding data packets between nodes and handling the logical addressing of devices within the network. The network layer operates independently of the bit rate and modulation techniques that are used at the physical layer, such as NOMA, [4].

3 Benefits of NOMA

NOMA offers several benefits in wireless communication systems, [5].

It significantly improves spectral efficiency by allowing multiple users to share the same time and frequency resources simultaneously. Unlike traditional orthogonal multiple access schemes, which allocate non-overlapping resources to users, NOMA enables overlapping of users' signals in the power domain. This efficient utilization of resources leads to higher data rates and capacity within the available bandwidth.

NOMA increases the capacity of the system by allowing multiple users to access the same resources simultaneously. It enables more users to be served within a given time and frequency allocation. This is particularly valuable in scenarios with a high density of users or when the spectrum availability is limited.

It offers enhanced user fairness by dynamically allocating power levels based on users' channel conditions. Weaker users are allocated higher power levels, allowing them to achieve better performance and coverage. This ensures that all users have access to the resources according to their requirements, which results in a more equitable distribution of system resources.

It provides flexibility in managing and allocating resources. It can adapt to varying channel conditions and quality of service demands by adjusting power allocations and modulation schemes for different users. This adaptability allows NOMA to cater to the diverse needs of different users, applications, and services.

NOMA can be seamlessly integrated with existing multiple access technologies, such as OFDMA used in 4G systems. It can be deployed as a complementary technique for further enhancement of the performance and efficiency of the system.

It can reduce latency in wireless communications by enabling simultaneous transmission and reception, such as real-time voice and video communication, and IoT devices.

It can simplify the network design by reducing the need for complex resource allocation and scheduling algorithms. It depends on streamlining rather than time in the allocation of resources to users.

NOMA is adaptable and can be implemented in different wireless communication technologies, including 4G, 5G networks, and future wireless standards. And so, it can support diverse services with different QoS requirements, enabling the coexistence of low-latency services with high throughput in the same network.

NOMA is useful in Multi-User Multiple Input Multiple Output (MU-MIMO) applications, where multiple users share the same time and frequency resources.

It is considered a key enabling technology for future wireless communication systems, such as 5G and beyond. It addresses the increasing demand for high data rates, massive connectivity, and diverse applications. NOMA provides a foundation for accommodating the exponential growth of connected devices and emerging communication requirements.

4 NOMA Transmission System

NOMA transmission system, [6], involves several algorithms to efficiently allocate resources, assign power levels, and perform superposition coding (Figure 2), while specific algorithms can vary based on system design and optimization objectives. By and large, the general algorithmic flow for the NOMA transmission system is as follows:

User Selection algorithm that measures the channel conditions for all users ranks the users based on channel quality or other criteria, and selects the users to be multiplexed, considering factors such as available resources and QoS requirements.

Resource Allocation algorithm that divides the available time-frequency resources into resource blocks, allocates resource blocks to the selected users, ensures efficient utilization of the available spectrum, and considers factors such as channel conditions, user requirements, and system optimization objectives during resource allocation.

Power Allocation algorithm that assigns different power levels to the signals of the multiplexed users, considers the channel conditions, QoS requirements, and fairness criteria, and optimizes power allocation to maximize system performance, such as maximizing the sum-rate or satisfying target Signal to Interference and Noise Ratio (SINR) requirements.

Signal Encoding algorithm that encodes the data of each user using suitable encoding techniques (such as error correction coding) for reliable transmission. While the Modulation algorithm maps the encoded data into a suitable modulation scheme, such as Quadrature Amplitude Modulation

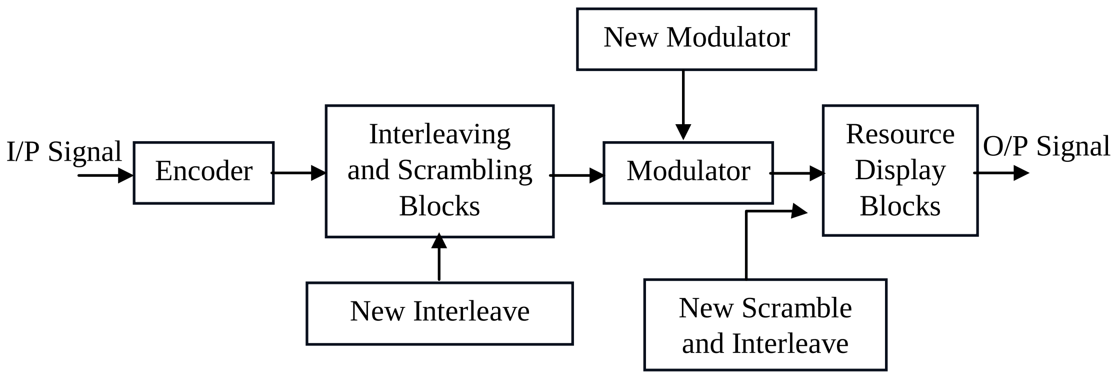

Fig. 2: Transmission system in NOMA

(QAM), [7], to generate the modulated symbols. Superposition Coding algorithm that combines the modulated symbols of the multiplexed users using superposition coding, and linearly superimposes the signals to create a composite signal that carries the information of all multiplexed users simultaneously.

The precoding algorithm is an optional algorithm that applies precoding techniques, such as beamforming or spatial multiplexing, to optimize transmission performance when multiple antennas are available, enhance signal quality, mitigate interference, and improve spatial separation of the users' signals.

Transmitting the Composite Signal algorithm that transmits the composite signal over the wireless channel using the assigned power levels and modulation scheme, and utilizes advanced techniques such as beamforming or multi-antenna transmission to improve signal propagation and coverage.

Specific algorithms are employed in the NOMA transmission system that can vary based on the network requirements, deployment situation, and system optimization goals. Various optimization algorithms, such as convex optimization, game theory, or machine learning techniques, may be utilized to enhance the performance and efficiency of the NOMA transmission system.

5 NOMA in MIMO

Multiple-Input Multiple-Output (MIMO), [8], is a technology that utilizes multiple antennas at both the transmitter and receiver to improve the capacity and reliability of wireless communication systems. It takes advantage of the spatial diversity and multiplexing gain which are provided by multiple antennas.

Both technologies together can further enhance the performance of wireless networks. NOMA can be applied to a MIMO system in different approaches such as:

Spatial NOMA, where in a MIMO system, different users can be assigned different spatial resource blocks by using beamforming techniques. NOMA can be applied by allowing users in the same spatial resource block to share the same time-frequency resources, this allows for increased spectral efficiency and capacity.

Power-domain NOMA, where in a MIMO system, users with better channel conditions can be assigned higher power levels in comparison to users with weaker channel conditions. By applying power-domain NOMA, multiple users can share the same time-frequency resources using different power levels, this enables better utilization of the available resources and improves the overall system capacity.

Hybrid NOMA-MIMO, [9], where a hybrid approach can be used by combining the concepts of NOMA and MIMO. This involves using both power-domain and spatial-domain NOMA techniques in a MIMO system. By utilizing multiple antennas and allocating different power levels to users, both gains of spatial and power domain multiplexing can be achieved simultaneously.

6 Spectrum Allocation and Power Management

Spectrum allocation in NOMA, [10], plays a crucial role in determining how resources such as time, frequency, and power are allocated among multiple users. Unlike traditional orthogonal multiple access schemes where each user is allocated separate orthogonal resources, NOMA allows multiple users to share the same time-frequency resources non-orthogonally.

In NOMA, users are distinguished based on their channel conditions, and they are assigned different power levels and data streams to enable simultaneous transmission and reception. The spectrum allocation in NOMA involves different key aspects.

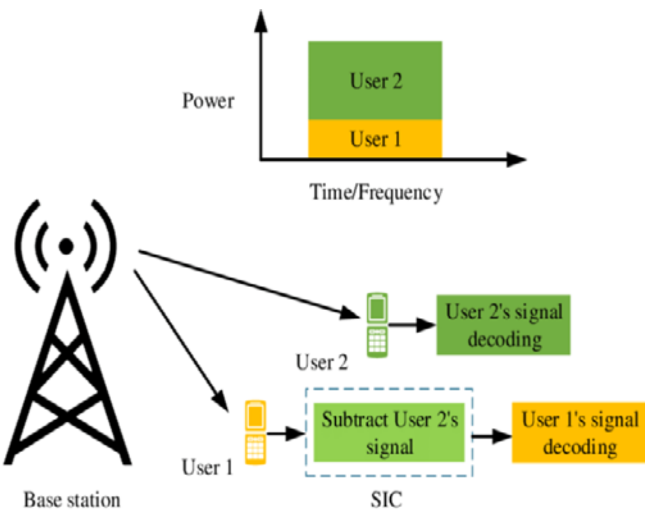

Fig. 3: Downlink NOMA, single cell, one BS and two users, [11]

Users in NOMA are allocated different power levels based on their channel conditions. Users with better channel conditions are assigned higher power levels, while users with weaker channel conditions are allocated lower power levels. This power allocation ensures that users with poorer channel conditions can still decode their signals by treating other users' signals as interference (Figure 3).

Users are typically allocated the same time-frequency resource blocks, which can be subcarriers in the frequency domain or subframes in the time domain. Each user's data is superposed and transmitted in the same resource block, which allows for simultaneous transmission and reception. The allocation of resource blocks can be based on scheduling algorithms that consider the channel conditions, user priorities, and QoS requirements.

NOMA often employs user grouping techniques to further enhance system performance. Users with similar channel conditions are grouped and assigned to the same resource blocks. This grouping facilitates the power-domain multiplexing gain and helps to improve the overall spectral efficiency of the system.

Accurate channel estimation is vital in NOMA to determine the user's specific power levels and mitigate inter-user interference. Robust channel estimation techniques are used to estimate the Channel State Information (CSI) of each user, which is then utilized for power allocation and interference cancellation.

The specific approach of spectrum allocation in NOMA can vary depending on the system design, deployment situation, and performance objectives. Advanced algorithms and optimization techniques are employed to maximize the system capacity, throughput, and fairness while considering the QoS requirements of different users.

7 Successive Interference Cancellation (SIC)

SIC, [12], is a signal processing technique used in wireless communication systems to separate multiple signals transmitted simultaneously over the same frequency band.

When multiple users transmit their signals over the same frequency using different power levels, those signals are superimposed and transmitted to the receiver. To decode each user's data, the receiver needs to separate the signals from each other and cancel the interference caused by stronger signals.

The algorithm of SIC is as follows:

1. The receiver detects the signal with the strongest power level and decodes its data using an advanced signal processing algorithm.
2. The decoded data is subtracted from the received signal, which removes the interference caused by the strongest signal.
3. The remaining signal, which includes the signals from the other users, is then processed to detect the signal from the user with the next strongest power level. The detected signal is decoded, and its data is subtracted from the received signal, which again removes the interference caused by the second strongest signal.
4. This process continues until all the signals have been detected and decoded.

SIC algorithm in a wireless communication system can be represented mathematically as follows:

Assuming n users are transmitting their signals over the same frequency band in a NOMA system. The received signal at the receiver can be expressed using (1):

$$Pr = \sum_{i=1}^{n} \sqrt{P\_k} * h\_k * x\_k + N \quad (1)$$

where Pr is the received signal, P_k is the power allocated to user n, h_k is the channel gain of user n, x_k is the signal transmitted by user k, and N is the additive noise.

To decode the signal from user 1 with the strongest power level, the receiver estimates its signal using maximum likelihood detection, as shown in (2).

$$R\_1 = Max\ (|Pr - \sqrt{}P\_1 * h\_1 * x\_1|\hat{}2) \quad (2)$$

where R_1 is the estimated signal of user 1.

The estimated signal R_1 is then subtracted from the received signal Pr, which results in the interference cancellation, see (3)

$$Pr\_1 = Pr - \sqrt{}P\_1 * h\_1 * R\_1 \quad (3)$$

The receiver then estimates the signal from user 2, which can be represented using (4).

$$R\_2 = Max\ (|Pr\_1 - \sqrt{}P\_2 * h\_2 * x\_2|\hat{}2) \quad (4)$$

The estimated signal R_2 is subtracted from Pr_1 to obtain Pr_2 using (5)

$$Pr\_2 = Pr\_1 - \sqrt{}P\_2 * h\_2 * R\_2 \quad (5)$$

This process continues until all the signals from all users have been detected and decoded.

By canceling out the interference caused by stronger signals, SIC enables the receiver to detect weaker signals accurately, which improves the overall performance of the wireless communication system.

8 Issues and Challenges

Although NOMA provides several advantages, there are some challenges and issues that need to be addressed for its successful implementation, [13], [14].

NOMA depends on the concept that users consider other signals as interference. Managing this interference is crucial to maintaining reliable communication. Interference cancellation techniques, such as SIC, are used to mitigate the interference effects. However, the effectiveness of interference cancellation depends on accurate channel estimation, receiver complexity, and the number of users who are sharing the same resource. Accurate Channel State Information (CSI), [15], is essential for successful NOMA operation. Channel estimation becomes challenging in NOMA due to the presence of co-channel interference and the need to estimate the channels of multiple users in the same resource block. Estimating channels accurately becomes more difficult in cases with fast fading, mobility, and varying channel conditions.

NOMA depends on appropriate user pairing and grouping to maximize system performance. Selecting the optimal user pairs and groups is based on channel conditions, which is a complex task. Incorrect pairing or grouping decisions can lead to degraded performance and unfair resource allocation.

NOMA introduces additional complexity in terms of interference cancellation, power allocation, and receiver design in comparison to traditional orthogonal multiple access schemes. The increased complexity can impact system implementation, receiver hardware, and computational requirements. Moreover, the signaling overhead associated with channel estimation, power control, and user grouping can reduce the available resources and increase the system overhead.

Ensuring fairness among users and providing satisfactory QoS for all users are challenging in NOMA. Users with better channel conditions receive more power allocations, potentially causing performance imbalance and reduced fairness. Managing QoS requirements while maximizing system capacity requires careful resource allocation strategies and scheduling algorithms.

Implementing NOMA in existing wireless communication systems can be challenging due to compatibility issues. NOMA often requires modifications to the physical layer and higher-layer protocols, which may not be compatible with legacy devices or infrastructure. Ensuring backward compatibility or gradual migration to NOMA-based systems can be a significant challenge.

Addressing these issues in NOMA requires advanced algorithm design, optimization techniques, and system-level considerations.

9 Code Division Multiple Access

CDMA, [2], is a multiple-access technique used in wireless communication systems (3G). It allows multiple users to share the same frequency band simultaneously by assigning unique codes to each user.

CDMA assigns a unique spreading code to each user, which is used to spread the user's signal over a wide frequency band. The spreading codes are designed to have good correlation properties, ensuring that different users' signals can be separated at the receiver. The spreading codes are typically pseudorandom binary sequences.

Multiple users can transmit their signals simultaneously within the same frequency band. The unique spreading codes assigned to each user allow their signals to coexist and be distinguished at the receiver based on the correlation properties of the codes.

CDMA systems often employ power control mechanisms to regulate the transmitted power of each user. Power control is essential to mitigate interference and maintain a desired Signal-to-signal-to-interference ratio (SIR) at the receiver. Power control algorithms adjust the transmitted power levels based on the channel conditions and system requirements.

It exhibits a soft capacity limit that the system capacity gradually decreases when more users are added. CDMA can accommodate more users by reducing the data rate or allocating less power to each user. The flexibility of CDMA allows for more dynamic resource allocation and adaptation to varying traffic demands.

CDMA systems can exploit the inherent interference rejection capability that is provided by the spreading codes. Correlation at the receiver side can separate and recover the desired user's signal while rejecting interference from other users. However, the performance of interference rejection depends on the code properties, Signal-to-Noise Ratio (SNR), and interference levels.

CDMA has robust behavior against multipath fading and interference. The spreading of signals over a wide bandwidth helps combat fading effects by spreading the signal energy across multiple frequencies. This allows for improved signal reception even in challenging radio propagation environments.

While CDMA offers several advantages, there are some challenges and issues associated with its implementation.

The near-far problem occurs when users in close proximity to the Base Station (BS) transmit at high power levels, causing interference to users farther away. This phenomenon can degrade the system performance and impact the capacity of CDMA systems. Power control algorithms are employed to mitigate the near-far problem by adjusting the transmitted power levels of users based on their channel conditions. However, achieving efficient power control across all users in dynamic environments can be challenging.

CDMA systems are susceptible to interference from other CDMA users operating in the same frequency band. This includes both co-channel interference from other users and adjacent-channel interference. The presence of interference can degrade the signal quality and increase the Bit Error Rate (BER) for CDMA users. Advanced receiving techniques, such as Multiuser Detection (MUD) algorithms, [15], are used to mitigate interference and improve system performance. However, the complexity and computational requirements of MUD algorithms can be significant.

Although CDMA has a soft capacity limit, the achievable capacity is still influenced by factors such as the available bandwidth, signal quality, and interference levels. As the number of active users increases, the capacity of CDMA systems gradually decreases due to the limited spreading gain and increased interference. Efficient resource allocation and interference management techniques are required to maximize the system's capacity while maintaining satisfactory performance.

CDMA systems [16] involve complex receiver design, particularly for MUD and interference cancellation.

CDMA systems require accurate timing and synchronization between the transmitter and receiver to maintain orthogonality and maximize system performance. Timing and synchronization errors can cause interference among users and degrade the system's overall performance. Achieving precise synchronization can be challenging, especially in wireless environments with multipath propagation, fading, and mobility.

CDMA operates in a wide frequency band due to its spreading technique, but it still requires a specific band allocation for deployment. This can lead to limited flexibility in spectrum allocation and potential conflicts with other communication systems or services.

10 Hybrid System - NOMA and CDMA

Creating a hybrid system between NOMA and CDMA involves combining these two multiple access techniques to leverage their advantages. NOMA allows multiple users to share the same frequency and time resources, while CDMA assigns a unique code to each user to distinguish its signal. a hybrid NOMA-CDMA system may include the following:

10.1 System Architecture and Design

This model defines the overall architecture of a hybrid system, including the number of users, base stations, and available frequency bands. It decides how NOMA and CDMA will be integrated, for example, NOMA could be used for certain users and CDMA for others.

10.2 User Grouping

This model divides users into different groups based on their channel conditions and QoS requirements.

10.3 Transmission Process

This model encodes the signals using superposition coding, where the base station sends multiple signals simultaneously to all users. Then, signals are decoded at the receiver using SIC or other advanced detection techniques.

On the other hand, CDMA assigns unique spreading codes to each user to separate their signals. While the receiver uses correlation-based decoding to recover the original data.

10.4 Interference Management:

Both NOMA and CDMA involve managing interference and designing interference mitigation techniques to ensure efficient signal recovery for all users.

NOMA users can be considered using advanced interference cancellation techniques, while CDMA users can be considered interference rejection techniques.

The only hybrid system that uses NOMA and CDMA is proposed by, [17], which differentiates inter-cluster users based on spreading codes, while intra-cluster users are differentiated based on different power levels.

11 Proposed Solution and Simulation Results

Integrating CDMA into NOMA can be challenging, as these multiple access schemes are fundamentally different. CDMA depends on orthogonal spreading codes to separate users, while NOMA depends on power domain separation and SIC. However, it's possible to adapt CDMA principles to a NOMA framework in certain scenarios. Next, a simplified mathematical framework is provided to illustrate the integration of CDMA into a NOMA system:

In a typical CDMA system, each user is assigned a unique orthogonal spreading code (Ci). In this integration scenario, power and modulating data symbols are allocated based on codes (Ci). Consider a user NOMA system as an example.

Different power levels are allocated to the users based on their channel conditions and QoS requirements, whereas P1 and P2 are the allocated powers to user 1 and user 2, respectively.

Considering the Quadrature Phase Shift Keying (QPSK) as modulation schemes to map users' data symbols onto complex symbols (s1 and s2) for user 1 and user 2, respectively.

Creating the superimposed signal for transmission, which is the sum of the individual user signals weighted by their allocated power, (6)

$$x = \sqrt{(P1)}*s1+\sqrt{(P2)}*s2 \quad (6)$$

The transmitted signal (x) is affected by channel conditions as it propagates to the receiver until it is received as shown in (7).

$$y = h1*x + h2*x + n \quad (7)$$

Where h1 and h2 represent the channel gains for user 1 and user 2, and n is the additive white Gaussian noise.

On the receiver side, SIC is applied to decode the signals as described previously in section 7. Considering user 1 has a stronger signal than user 2, then the user 1 signal will be decoded first.

$$y1=h1*\sqrt{(P1)}*s1+h1*\sqrt{(P2)}*s2 + n \quad (8)$$

Then, subtract the signal of user 1 from the received one to decode the signal of user 2 as shown in equation 9.

$$y2 = (y1=h1*\sqrt{P1}*s1 + h1*\sqrt{P2}*s2 + n) - h1*\sqrt{P1}*s1 \quad (9)$$

Finally, proper demodulation and decoding are used to extract the original data symbols of users from (y1 and y2).

In the next scenario, each user is assigned k-codes (k=2 as an example) using the CDMA principle, and so, the user can receive k-times several bits using the same power level in NOMA, knowing that detection and extraction of the user's data in CDMA is done by pure mathematical calculation (correlation), that does not need heavy processing or energy consumption, and so, does not reflect negatively on the draining power from the battery of mobile node.

Then, the BS sends two messages to users 1 (far from BS) and user 2 (near to BS), the power allocation factors α1 and α2 are allocated to user 1 and user 2 respectively, given that (α1 + α2 = 1). Simulation results using Matlab represent the bit rate for both users when NOMA is adopted as shown in Figure 4.

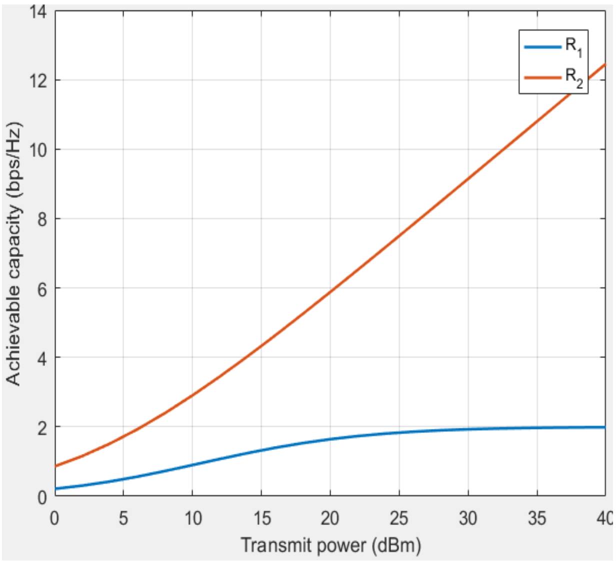

Fig. 4: Capacity in NOMA vs transmitted power

After applying CDMA to NOMA as a hybrid system with the same conditions applied before, and two codes are assigned to each user, simulation results show that the data rate is increased when two CDMA codes are allocated to each user for the same transmitted power, as shown in Figure 5.

The previous results show that CDMA can enhance the bit rate of users, especially those far from BS based on the number of allocated CDMA codes.

In communication systems such as 5G, the numerical stability is not associated with the calculation of the received bit rate, it is generally, related to the stability and accuracy of numerical methods and algorithms used in computational simulations and mathematical calculations. And so, in the context of the calculation of the received bit rate, stability is more related to signal processing and system performance rather than numerical stability.

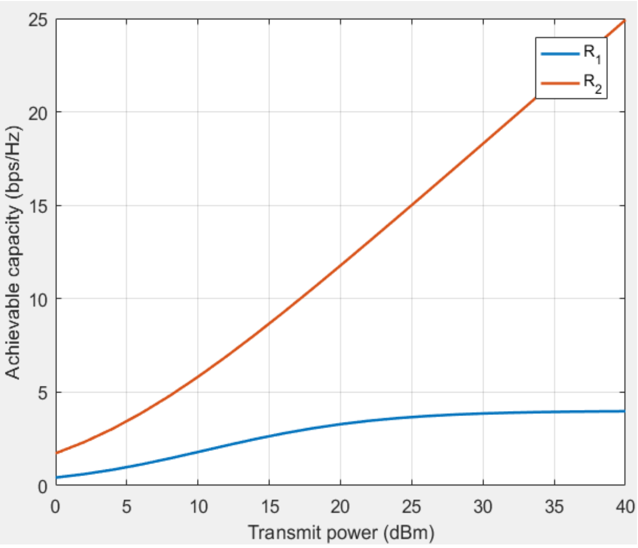

Fig. 5: Capacity in Hybrid NOMA-CDMA vs transmitted power

However, to calculate the received bit rate in a communication system, factors such as the modulation scheme, channel conditions, SNR, bandwidth, and noise. The received bit rate can be calculated using Shannon's equation:

$$C = B*\log_2(1+SNR) \quad (10)$$

Where B is the channel bandwidth

12 Conclusion

This work presents comprehensive and detailed information about CDMA, NOMA, and related information to NOMA such as SIC, its relation to MIMO, etc. It is clear that NOMA has very high advantages over other access methods such as CDMA and OFDMA, but still faces issues and challenges. Nevertheless, it provides high capacity, low latency, high throughput, and improves efficiency. This work illustrates all related topics about NOMA in addition to proposing a hybrid access method; that merges between CDMA and NOMA to increase the bit rate in case of a downlink from base station to mobile node. Simulation results show that the proposed technique enhances the bit rate of users even when the user is far away from the base station.

In the future, work will focus on minimizing the consumed energy in processing the received signal and so increasing the lifetime of mobile battery.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

Yahia Jazyah as a single author, carried out all the stages of the research including the letirature review, implementation of the algorithm in Matlab, simulation and optimization, testing and collecting the results, and writing the manuscript.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflict of interest to declare.