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Performance Enhancement of 5G Networks: Remodeling Power Domain Scheme Through NOMA-MIMO Technologies Integration

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***Abstract*—** *The integration of multiple-input multiple-output (MIMO) and non-orthogonal multiple access (NOMA) technologies addresses critical challenges such as massive connectivity, low latency, and high dependability in 5G cellular systems and beyond. However, resolving these issues required additional research, particularly in the case of 5G networks employing MIMO. This involved enhancing and reevaluating parameters like bit error rate, downlink spectrum efficiency, average capacity rate, and uplink transmission outage probability to optimize performance. The devised model utilized Quadrature Phase Shift Keying modulation on selected frequency channels, accommodating users with diverse power location coefficients, signal-to-noise ratios, transmit powers, and bandwidths. Evaluating the proposed model's effectiveness involved testing and comparing results to previous research. Download transmission results demonstrated that MIMO-NOMA significantly improved the bit error rate performance and transmitting power for the best-evaluated user. For uplink transmission, the average capacity rate was used to assess performance, indicating an increase in the average capacity rate for the best user and a decrease in outage probability. Closed-form formulas for bit error rate, spectrum efficiency, average capacity rate, and outage probability for both downlink and uplink NOMA, with and without MIMO, were derived. In essence, adopting MIMO-NOMA led to a remarkable improvement in the performance of all users, even those facing challenges such as interference or fading channels.*

Keywords*— *Multiple-input multiple-output (MIMO), Non-orthogonal multiple access (NOMA); spectrum efficiency (SE); Bit Error Rate (BER); Outage Probability (OP).

I. BACKGROUND

In recent decades, wireless communication has undergone a significant technological transformation. The evolution from basic voice communication to highly interactive communication has necessitated high data rates and uninterrupted connectivity. Additionally, there is a surging demand for mobile devices. To address future requirements, researchers are actively developing fifth-generation (5G) and beyond-fifth-generation (B5G) wireless communication networks. Non-orthogonal multiple access (NOMA) emerges as a promising scheme for these networks, capable of meeting the escalating needs of a vast user base, connectivity demands, cost-effectiveness, limited bandwidth, and extensive coverage requirements. However, the implementation of NOMA in wireless communication networks comes with both challenges and advantages.

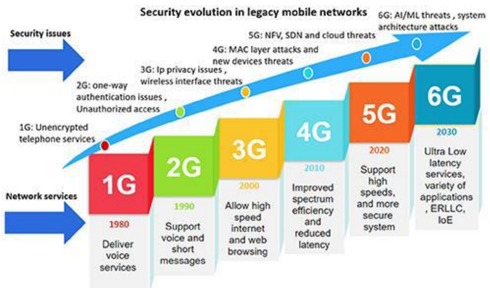

Fig.1.1: Evolution from 1G to 6G (B5G)

In order to address the limitations of 5G and beyond fifth-generation technologies and establish innovative technological pathways for spectrum efficiency and energy efficiency at minimal costs, exploring multiple-access systems becomes imperative to partially mitigate these challenges. The conventional orthogonal multiple access (OMA) schemes employed in 1G through 4G cellular networks, allocating different frequencies, resource blocks, time slots, or codes to individual users, prove insufficient to handle the anticipated high demands for network traffic and user density in the future. The fundamental advantage of orthogonality lies in assigning various resources to users, ensuring zero interference while accessing network resources (Kalra and Chauhan, 2014) [1].

In NOMA, numerous users within the same cell simultaneously share a single frequency channel, offering advantages such as improved cell-edge throughput, enhanced spectrum efficiency, loose channel feedback, and reduced transmission delay. NOMA outperforms conventional OMA by servicing multiple customers simultaneously using the same frequency resource and employing successive interference cancellation to reduce interference and achieve superior spectral efficiency. It facilitates large-scale connectivity, accommodating a vast number of users. The simultaneous transmission nature of NOMA enforces a set time period for information delivery, reducing latency. NOMA's flexible power control between strong and weak users ensures user fairness and accommodates different quality of service (QoS) requirements (Ahmad, 2016) [2], ultimately leading to a superior user experience and enhanced cell-edge throughput.

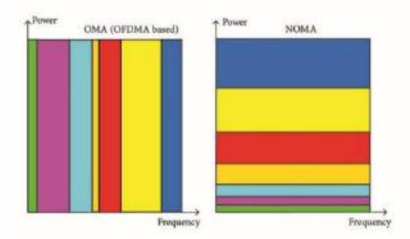

Fig.1.2: Comparison of OMA and NOMA

NOMA has garnered considerable attention as a multiple access method for long-term evolution (LTE) systems. Various NOMA applications are under scrutiny within the third-generation collaboration project (3GPP). In LTE Release 12, NOMA was incorporated for inter-cell-interference (ICI) mitigation as an extension of the network-assisted interference cancellation and suppression (NAICS) (3GPP, 2014).

The goals of achieving user connections, system capacity, and service latency can all be realized through NOMA. Recent advancements in standardization, a unified transceiver design framework, and intriguing use cases in future cellular networks form the basis of the improved NOMA transmission approach. Notably, ongoing 3GPP research, initiated in LTE Release-13, predominantly focuses on downlink transmission. Release-15 shifts the focus to uplink transmissions, emphasizing newly defined grant-free transmission processes with high reliability, low latency, and extensive connectivity in NOMA schemes (Chen et al., 2018) [3].

Despite the numerous benefits of NOMA-assisted wireless communication, several challenges must be addressed to establish an effective communication environment (Vaezi et al., 2019b) [4]. Receiver complexity poses a concern, as each user, even with the worst channel conditions, is required to decode the information of every other user, potentially leading to a more sophisticated and energy-intensive receiver. Serving the maximum number of users encounters hurdles due to increased error risks while decoding information from all users, limiting the serviceable user count. Achieving the intended functionality of the power domain concept in NOMA necessitates sufficient channel gain differences among users. (Vaezi et al., 2019b) [4].

Dai et al. (2018a) [5] provide a comprehensive review of

NOMA fundamentals, contrasting it with OMA and comparing power domain-NOMA (PD-NOMA) and code domain-NOMA (CD-NOMA) in terms of spectrum efficiency, complexity, and performance. Islam et al. (2018) [6] delve into various aspects of downlink PD-NOMA, including different user pairing methods, power allocation, and practical considerations. Lu et al. (2017) [7] conduct an extensive examination of NOMA fundamentals, recent developments, and future research trends, with a focus on comparing NOMA and OMA from an information theory perspective. Vaezi et al. (2019a) [8] cover the flexible integration of NOMA with MIMO, mmWave, CC, CR, security, and energy harvesting.

NOMA (Non-Orthogonal Multiple Access) is poised to shape the future of network technology, finding applications in 5G and beyond. It outperforms OMA, particularly in serving more clients by employing multiplexing in power and code domains. SC and CIC techniques in the receiver facilitate power-domain multiplexing in the transmitter. NOMA aims to enhance spectrum efficiency while ensuring fairness for all users. The grant-free NOMA uplink holds promise for reducing latency, communication overhead, and terminal power consumption in low-traffic or free applications. NOMA, along with tiny cells, contributes to increasing 5G capacity, making it a key player in future network evolution [10].

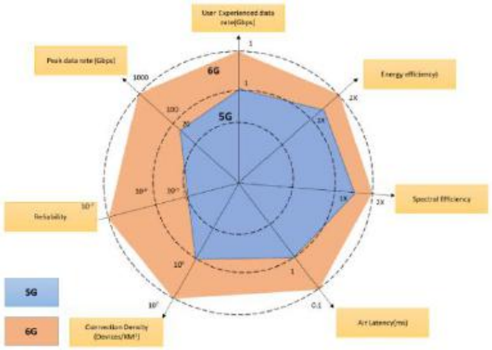

Fig.1.3: Performance requirements between 5G and 6G [24]

In the context of power regulation and allocation mechanisms, the deployment of small cells proves instrumental in managing network traffic load, thereby enhancing Quality of Service (QoS) [11]. Furthermore, the introduction of the "New Radio" (NR) principle in new radio access technologies contributes solutions to address 5G-related challenges. 5G incorporates additional enhancements such as new operational frequency bands, Multiple Input Multiple Output (MIMO), Millimeter Wave (mmWave), and Non-Orthogonal Multiple Access (NOMA). NOMA is particularly favored over Orthogonal Multiple Access (OMA) due to its capability to handle a comparatively higher number of subscribers [11]. The categorization of NOMA under multiple access schemes is presented below:

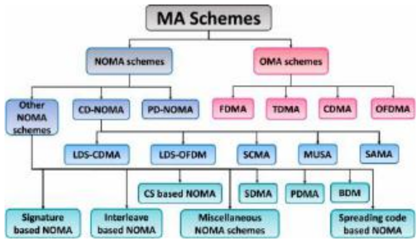

Fig.1.4: NOMA Classification Schemes

NOMA B5G (Beyond 5G)/6G Systems Applications

The impact of technology on human lifestyle is profound, with wireless technologies transforming various aspects such as businesses, infrastructure, and living conditions. The constant search for innovative solutions and avenues for progress has driven the evolution of wireless communication from 1G to 5G, and the journey continues with efforts towards 5G and Beyond 5G (B5G) connectivity by dedicated researchers.

Over a brief span of five years, from 2016 to 2021, mobile data traffic has surged sevenfold, highlighting the rapid pace of development (Benisha et al., 2019) [12]. However, the exacerbation of congestion on a daily basis underscores the inadequacy of available spectrum to meet these escalating demands. The existing network generations—1G, 2G, 3G, and 4G—fall short in ensuring seamless connectivity, leading to the exploration of innovative approaches such as Non-Orthogonal Multiple Access (NOMA).

In recent decades, numerous NOMA schemes have emerged, addressing various applications and use cases. The implementation of NOMA holds promise for enhancing Energy Efficiency (EE) and spectral efficiency in upcoming 5G and B5G wireless communication networks.

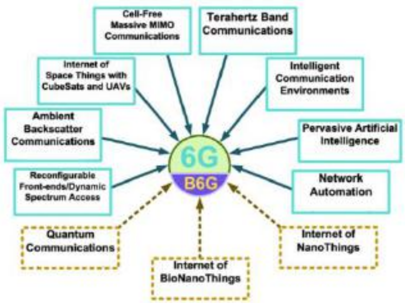

Fig.1.5: Enabling Technologies for 6G and beyond wireless communications systems [25]

The exponential growth of users has led to an increased demand for data rates and connectivity. Addressing these needs can be achieved through cutting-edge technical trends, such as NOMA-assisted Base Stations (BS) [13]. As fifth-generation (5G) mobile communication technology is currently widely accessible, attention is shifting towards the next generation, B5G. The new B5G applications are expected to have additional demands and a larger network capacity compared to current 5G networks. Therefore, the future wireless networks, particularly in the form of sixth-generation (6G) applications, are anticipated to play a key role in various aspects of our lifestyle, economic sectors, and social structures [13]. The wireless networks will serve as the communication channel between people and intelligent machines, emphasizing the need for enhancement and collaboration between the scientific community and industry [13]. By 2030, wireless networks are expected to accommodate increased needs, supporting demanding applications like virtual, augmented, and mixed reality, as well as remote control of delicate operations.

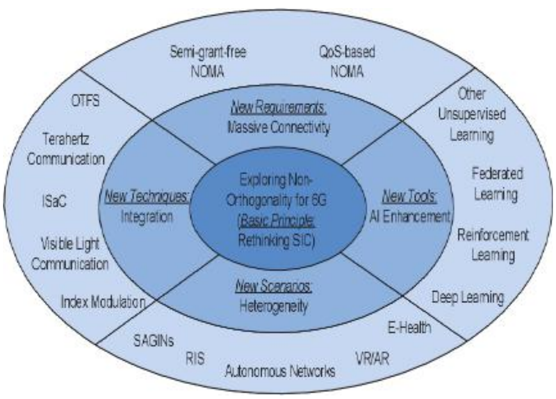

Fig.1.6: Application of NOMA in B5G Networks [26]

Until the year 2030, a plethora of new application possibilities will continue to surface, categorized into three groups: intelligent production, intelligent life, and intelligent society. [14] These categories serve to organize various scenarios, with post-2030 use cases being exemplary instances as identified by Sodhro et al. (2020) and Khan et al. (2020).

- ***Smart Production***

By integrating emerging technologies into business and agriculture, the digital economy has the potential to expand significantly. B5G will leverage information technology to achieve intelligent manufacturing.

- ***Smart Life***

In 2030, the network connecting twin physical locations, coupled with online synesthesia and intelligent interaction, is anticipated to revolutionize our way of life.

- ***Smart Society***

By 2030, the widespread coverage network is expected to substantially extend public service coverage, effectively eliminating regional digital divides. The implementation of a 6G network is poised to enhance overall social governance, establishing the foundation for a more stable society. The applications of B5G are detailed in the table below.

Table 1.1: Beyond 5G/6G Applications [15]

	5G	Use Cases	6G	Use Cases
Data Rate	$1-10\ Gb/s$	Telemedicine	$100\ Gb/s - 1\ Tb/s$	3D holographic AR/VR Robotics Arm
Coverage Extension	0.1 km	The limited scale of IoT network	3D coverage scenarios (10000 m (Sky, 200NM (sea)	Terrestrial, aerial, space and sea domain, massive-scale IoT network
Power Consumption	10 years battery life	IoT devices	50 times improvements compared to 5G, nearly (1 Tb/J)	Wearable user devices Zero energy devices
End-to-End Latency	1–5 ms	Vehicular Networks Military Services	< 1 ms	Healthcare Networks AR/VR Unmanned Ariel Vehicle (UAV) Robotics Arm
Reliable Communication	99.9%	Vehicular Networks Telemedicine	~ 99.9999%	Healthcare Networks AR/VR Unmanned Ariel Vehicle (UAV) Robotics Arm
Massive Connectivity and Sensing	1 $milliondevice/km^2$	IoT devices	10 $milliondevice/km^2$	Wearable user devices AR/VR IoE
Frequency Extension and Improved Spectrum	$3-300\ GHz$	mmWave for fixed access	Up to 1 THz	mmWave Sub-6 GHzExploration of THz bands (above 300 GHz) high-definition imaging and frequencyNon-RF (e.g., optical, VLC) spectroscopy localization
Mobility and speed supportive	500 km/hr	Vehicular Networks	1000 km/hr	Terrestrial, space, sea, aerial, and airline

NOMA-MIMO Technologies

To expedite the development of future intelligent wireless systems, it is imperative to design an energy-efficient Massive multiple-input-multiple-output (MIMO)-non-orthogonal multiple access (NOMA)-aided Internet of Things (IoT) network. Such a network should be capable of accommodating a large number of distributed users and IoT devices, ensuring seamless data transfer and connectivity. The distinctive features of Massive MIMO make it a suitable technology for implementing an energy-efficient IoT network in beyond 5G (B5G) communications, given its utilization of a substantial number of antennas. However, the challenge lies in providing swift data transfer and maintaining hyper-connectivity between IoT devices in B5G communications, posing an energy challenge.

Numerous studies have demonstrated that Non-Orthogonal Multiple Access (NOMA) outperforms Orthogonal Multiple Access (OMA) in terms of performance. NOMA excels in meeting high-demand requirements, including extremely low latency, high spectral efficiency, increased network capacity, and elevated connectivity demand. Additionally, MIMO is acknowledged as a highly adaptable technology capable of enhancing capacity by increasing the potential data rate. In comparison to the combination of MIMO and OMA, MIMO and NOMA (MIMO-NOMA) are anticipated to achieve a higher capacity than MIMO and OMA (MIMO - OMA) [27].

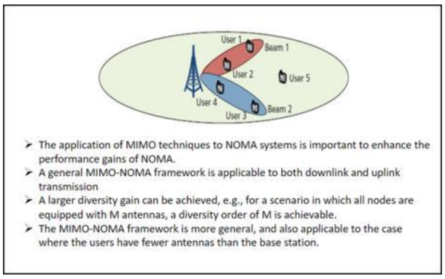

Fig.1.7: NOMA in Massive MIMO System [30]

The requirements for next-generation technology encompass high data rates, substantial spectrum efficiency, successive interference cancellation (SIC), and ultra-reliable low latency (URLL). In the domain of next-generation technologies, the non-orthogonal multiple access (NOMA) scheme is favored over the orthogonal multiple access (OMA) scheme. NOMA presents advantages such as multi-user scaling (multiplexing), optimal spectral efficiency (SE), notable user-pairing improvement, and the capability for multiple users to share a single resource block. To identify the optimal power allocation algorithm for multiple-input multiple-output-NOMA (MIMO-NOMA) technology, researchers conducted comparative analyses of various power allocation algorithms [28].

A multiple input multiple output (MIMO) structure can enhance the overall capacity of modern communication networks without requiring excessive power or bandwidth. To meet the demands for higher user data rates and improved spectrum efficiency, the non-orthogonal multiple access (NOMA) configuration is a fitting candidate for integration with the MIMO structure. The dynamic uniform channel gain difference (DUCGD) user pairing technique plays a significant role in maximizing the capacity of all paired and served users [29]. In summary, the depiction of NOMA in B5G Systems using the MIMO Technique is presented in the figure below.

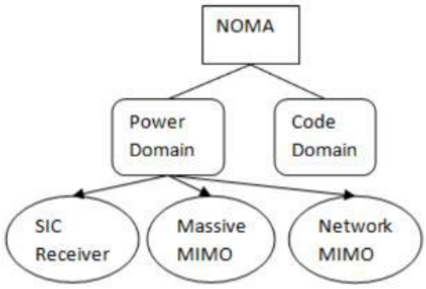

Fig.1.8: NOMA in B5G Systems using MIMO Technique [31]

NOMA technology has been predominantly categorized by researchers into two types: the power domain and the code domain. In the power domain, additional subcategories include the SIC Receiver and Massive MIMO. In Massive MIMO, multiple antennas are employed at both the source and destination points of wireless communication [31].

Artificial Intelligence application to NOMA implementation

Cellular devices and emerging wireless applications are experiencing explosive growth within wireless systems. To support extensive connectivity and high data speeds in constrained environments, research into advanced multiple access technologies, including next-generation multiple access (NGMA), is essential [16]. Non-orthogonal multiple access (NOMA), identified as a potential multiple access method, is considered a crucial component of NGMA. Particularly, the integration of NOMA and multiple-antenna technology has garnered significant interest, revealing substantial connectivity potential [17] [18].

Despite the potential of NGMA, the intricate multi-domain multiplexing makes interference suppression and system optimization more challenging. The communication design of next-generation NOMA systems often leads to a highly complex nonconvex mixed-integer nonlinear programming (MINLP) problem, with the globally optimal solution being extremely difficult to obtain. Recent advances in AI offer opportunities to overcome these challenges, providing automated communication designs to combat the overwhelming complexities [19] – [22]. This has led to investigations into promising and advanced machine learning (ML) methods to empower NGMA through AI. The integration of AI/ML in the planning process of mobile networks is illustrated below.

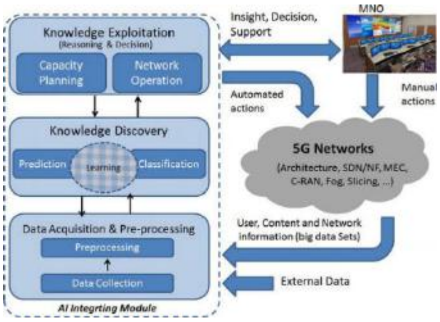

Fig.1.9: Integrating AI/ML in the planning process of mobile networks [32]

AI has the capability to train deep neural networks (DNNs) to approximate optimal solutions for challenging problems, leveraging the exceptional ability of deep models to fit arbitrary functions. The optimal solutions, considered as a non-convex function mapping the system state to optimization variables, can be learned automatically by AI, eliminating the need for expert knowledge and hand-engineered parameter initialization required by traditional optimization methods [23].

Supervised learning, focused on approximating pre-labeled solutions, and unsupervised learning, directly minimizing unsupervised variables, are two main approaches. Common machine learning models in wireless communications include the multi-layer perceptron (MLP) and convolutional neural network (CNN). Reinforcement learning is typically employed for long-term optimization problems modeled using the Markov decision process (MDP). Each base station (BS) is treated as an autonomous agent interacting with its environment to continually enhance decisions through trial and error. It observes the system state at each time slot to determine the optimization variables (actions) and maximize the accumulated discount reward.

The emerging AutoML paradigm [23], which includes hyper-parameter optimization (HO), neural architecture search (NAS), and meta-learning, can be combined to automate the configuration of learning models, significantly reducing human interventions and improving performance. NAS can automatically optimize hyperparameters and neural architecture, while meta-learning aims to create a general initial model quickly adapting to previously unseen communication scenarios. These AutoML techniques can serve as add-on modules to assist NGMA communications based on the requirements of different application scenarios. The figure below illustrates the applications of AI (deep learning) in various layers of B5G Systems.

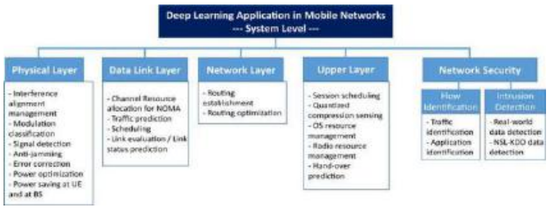

Fig.1.10: Applications of AI (deep learning) in different layers of B5G Systems [33]

To extend the scope of current multiple-antenna NOMA schemes, a novel AI-powered cluster-free NOMA framework has been suggested by researchers. This framework facilitates highly flexible Successive Interference Cancellation (SIC) operations. Nevertheless, the exploration of AI-enabled Next-Generation Multiple Access (NGMA) is still in its initial phases.

Model-based constrained ML for NGMA

NGMA communication design frequently involves non-convex, coupled, and mixed-integer constraints. Learning algorithms often address constraint violations by converting them into loss functions or employing projection operations to discover feasible solutions, even though their capacity to strictly enforce these constraints is limited. Recently, the introduction of the Lagrangian dual method and the interior point method for model-based machine learning has demonstrated the potential of guiding machine learning with constrained optimization theory. This has sparked researchers' interest in exploring model-based constrained machine learning for NGMA communication design.

ML empowered dynamic multi-objective optimization for NGMA

As next-generation wireless systems exhibit time-variant and heterogeneous characteristics, communication design will encounter various competing optimizations, such as system rate objectives, energy consumption, traffic latency, outage probability, and more. Moreover, the dynamic nature of wireless environments can cause these competing objectives and constraints to evolve over time, challenging the prediction of the changing Pareto optimal front. To facilitate dynamic multi-objective optimization, it is essential to explore efficient multitask machine learning methods.

Accelerating AutoML for NGMA

Although machine learning can forecast favorable solutions efficiently through low-complexity forward propagation, the training phase, typically carried out via back-propagation, often demands substantial datasets and imposes notable computational demands. When incorporating AutoML techniques like meta-learning and NAS, the training process can become even more time-consuming and computationally intensive. The challenge lies in addressing the critical research problem of constructing high-performance lightweight models and enhancing AutoML to mitigate training costs for Next-Generation Multiple Access (NGMA).

Problem Statement

In the context of the hybrid technology environment, the integration of MIMO and NOMA technologies is essential to tackle numerous challenges in 5G and B5G cellular systems, addressing issues related to massive connectivity, low latency, and high dependability. The performance of users is particularly affected by interference and fading in the channels, which can hinder connections. However, an increase in the number of antennas and bandwidth in a 5G network, without concurrent improvements in fading characteristics, may lead to performance degradation. This can manifest as a higher bit error rate (BER) and lower spectrum efficiency (SE) for the downlink, as well as a reduced average capacity rate and increased outage probability (OP) for the uplink.

Purpose of the Study

The existing research is focused on achieving improvements in these parameters, and the study will address these objectives.

• Developing an integrated network architecture that combines multiple-input multiple-output (MIMO) and non-orthogonal multiple access (NOMA) technologies in a hybrid configuration.

• Creating a network model focused on achieving massive connectivity, low latency, and high dependability by implementing MIMO-NOMA to address challenges related to near/far user scenarios.

• Enhancing the performance of a B5G network by addressing bit error rate, spectrum efficiency (downlink), average capacity rate, and outage probability (uplink) through the utilization of MIMO technology.

• Analyzing the performance of downlink NOMA in terms of bit error rate and spectral efficiency for different distances, power location coefficients, transmitted power, and bandwidths.

• Analyzing the performance of uplink NOMA in terms of average capacity rate and outage probability for various distances, signal-to-noise ratio, and bandwidth.

II. BACKGROUND LITERATURE

Wireless Communication

Wireless communication has rapidly progressed in the last decade, driven by the widespread use of smart mobile devices and engaging multimedia applications [34,35]. A promising approach to achieve enhanced performance has been proposed: non-orthogonal multiple access (NOMA), aiming to preserve spectral efficiency and ensure widespread accessibility [36,37]. NOMA employs successive interference cancellation (SIC) in receivers with noise, allowing the reception of signals while adjusting the power levels of overlay user signals at the transmitter. This approach limits bandwidth usage for undesired channels and optimizes user rates for desirable channels [38-41].

Non-orthogonal multiple access (NOMA)

Because NOMA involves sequential interference cancellation, SIC is implemented at the power user level, enabling the detection and exclusion of users with stronger channel conditions. Emphasis is placed on extracting data from users with superior channel conditions and weaker interfering users [42]. In the NOMA downlink (DL) system, where power fields are multiplexed, multiple users share the same time, coding, and frequency resources. Each user receives an overlay signal from the base station (BS), encompassing signals for all users [43]. By eliminating the need for users to wait for an orthogonal resource block, NOMA supports extensive connections while significantly reducing transmission delay [44].

In the context of the next-generation communication system, NOMA with SIC stands out as a promising multiple-access strategy [45]. NOMA, as a wireless technology, can meet the demands of the current wireless environment [46]. The assessment of various access technologies is an evolving area [47], and as new features continue to emerge, the primary research focus is on determining spectrum efficiency [48,49].

In uplink (UL) NOMA, multiple users simultaneously transmit signals to their respective BS [50,51]. Consequently, intra-cluster interference impacts a user's received signal, influenced by the channel data of other users [52]. Minimizing interference is crucial, and the BS decodes communications via SIC. Successful application of the SIC approach requires separate message signals with sufficient strength variance to reach the BS receiver. This is typically managed by using various scales at the transmitter in the DL. However, in the UL, the channel gains already provide adequate signal separation, making such adjustments unnecessary. The UL standard emphasizes power control, which is not recommended for UL NOMA broadcasts, as it could compromise channel distinctness to balance the received signal levels of users [53–57].

Multiple-input multiple-output (MIMO)

The capacity of a radio communication channel can be significantly enhanced by deploying multiple antennas in both the transmitter and receiver. In other words, multiple-input multiple-output (MIMO) technology allows the management of numerous independent channels within the same bandwidth, provided the propagation environment is sufficiently rich, but this holds true only with specific antennas [58,59]. While the use of MIMO techniques introduces a new dimension for improving efficiency, recent research has shown considerable interest in the integration of MIMO and NOMA [59,60].

The bit error rate (BER) of the downlink (DL) NOMA network, created in a closed form for BPSK modulation in both perfect and deficient successive interference cancellation (SIC) states, was explored using additive white Gaussian noise (AWGN) and Rayleigh fading channels. Notably, this exploration did not incorporate BER-influencing variables such as distance and power location coefficients [61]. To maximize the power allocated to each NOMA, three power assignment algorithms are proposed in [62,63].

Bandwidth, Average Capacity Rate, Outage Probability, Bit Error Rate & Spectrum Efficiency

Researchers investigated the impact of varying bandwidth and the number of antennas in a 5G network on the uplink's average capacity rate and outage probability (OP), as well as the downlink's bit error rate (BER) and spectrum efficiency (SE), revealing the influence of Rayleigh fading on the network. Analytical processes yielded integral expressions for BER, SE, capacity rate, and OP, and modeling was employed to explore all conceivable system configurations. The study proposed and examined different bandwidths (BWs) for the NOMA system across a Rayleigh fading channel. System enhancements were observed when NOMA and MIMO were integrated to support users. The research focused on the NOMA approach, a fundamental element of 5G technology, with the central idea being the redesign of NOMA-MIMO in the power domain to enhance data rate, capacity, and throughput. This was achieved by proposing a novel NOMA-MIMO power domain architecture.

Proposed Research Literature

As per the author in [65], NOMA systems employ multiple beams forming with a single carrier to accommodate multiple users, utilizing a two-stage beamforming solution with modular beamforming vectors. The design addresses the challenge of shaping transmission packets overall, aiming to identify the power and packet-shaping vectors of users.

MIMO-NOMA Performance

The potential of NOMA can be realized even when users have comparable initial channel conditions, as demonstrated by the author in [66], who devised effective precoding and detection processes to create a significant difference in users' effective channel gains. The performance of MIMO-NOMA was explored when multiple users were combined into a single group, revealing that MIMO-NOMA outperforms MIMO-OMA in terms of total channel capacity and overall practical capacity [67]. The research in [63] addressed the ergodic capacity maximization problem for selective Rayleigh fading MIMO-NOMA systems, utilizing statistical channel state information at the transmitter. The results indicated that MIMO-NOMA techniques exhibit significantly better performance than traditional OMA schemes.

An experimental evaluation in [68] assessed the performance of NOMA downlink integrated with MIMO in real-world scenarios, exploring the integration of NOMA downlink with MIMO as a concept for user connection in the uplink. The author considered various defined power allocation approaches in [69] and demonstrated that NOMA with the proposed user pair strategy performs better than NOMA with the previously discussed signal realignment method. [70] examined multiple NOMA downlink and uplink user power field-based communication systems with various fading conditions for all users adhering to one of several feasible distributions. Analytical formulations of the outage probability (OP) for NOMA downlink and uplink systems were developed, particularly when signal-to-noise ratios (SNRs) are high.

Analytical expressions of OP were further explored in [71], focusing on an unmanned aerial vehicle-assisted NOMA network with uplink and downlink transmissions. The author investigated a unique uplink/downlink NOMA system with a uniform relay and set decoding to enhance fairness and application using statistical channel state information [72].

Correlation Similarity for NOMA Effectiveness

In [73], a strategy for identifying correlation similarity is proposed. The author examined the effectiveness of various NOMA schemes over the tapping delay line channel, considering both regular and high-speed user equipment (UE) mobility, and explored correlation-level modeling in [73-75]. Different NOMA techniques and UE rapid speed operate in distinctive manners.

The potential of NOMA for 5G cellular networks was originally discovered by Saito et al. [76], who also demonstrated that NOMA outperforms OMA in terms of capacity and user fairness. Since then, researchers worldwide have started investigating the application of the NOMA principle to the next generation. Early NOMA research focused on single-input single-output (SISO), where user fairness and power allocation were primary concerns. NOMA's power distribution strategy considers user fairness and sum rate while maximizing the sum rate. This approach ensures that the powerful user does not dominate completely if the goal is to maximize the sum. The dynamic power allocation scheme presented in [77] guarantees that individual rates for both strong and weak users in NOMA are higher than their counterparts in OMA. [78] considers max-min data rate and min-max outage probability, respectively, focusing on user fairness.

Combining MIMO and NOMA

The rapid evolution of wireless communication in recent years has been fueled by the widespread adoption of smart mobile devices and multimedia applications. A promising multiple-access strategy for the next-generation communication system is non-orthogonal multiple access (NOMA) with successive interference cancellation (SIC). Despite ongoing evaluations of various access technologies, research groups are still working to determine the most efficient use of spectrum as new features continue to emerge.

Combining NOMA with multi-input multi-output (MIMO) technology can further enhance performance. In MIMO-NOMA, users are grouped into clusters, and NOMA is exclusively employed within those clusters. Although finding the optimal user pairing necessitates an exhaustive search, [79] employs random pairing to reduce computational costs. Furthermore, [80] suggests a greedy user pairing method, leveraging channel correlation and gain differences to achieve performance close to the ideal scenario. Users within the same cluster share a common precoding vector in MIMO-NOMA, dividing the MIMO channel into multiple parallel single-input single-output (SISO) channels. Consequently, NOMA maintains superiority over orthogonal multiple access (OMA) [81]. [80] explores a comprehensive MIMO-NOMA framework utilizing zero-forcing precoding and signal alignment-based detection to eliminate inter-cluster interference. The paper assumes perfect instantaneous channel state information (CSI) for MIMO settings, acknowledging that this assumption may not be feasible to achieve in practice. Sun et al. investigate optimum and low-complexity suboptimal power distribution strategies to enhance power efficiency. Additionally, [82] analyzes the ergodic capacity of a two-user MIMO-NOMA system, considering total transmit power and the minimum rate constraint of the weaker user. [83] proposes a NOMA strategy for a large MIMO system while considering limitations on feedback channels.

The aforementioned research has primarily focused on single-cell systems, with multi-cell networks introducing the challenge of inter-cell interference (ICI). Researchers are beginning to explore the performance of NOMA in multi-cell networks, suggesting synchronized beamforming strategies in [84] to address ICI in a two-cell MIMO-NOMA network. NOMA also shows promise for communications using visible light [86] and millimeter-wave (mmWave) [85].

III. RESEARCH METHODOLOGY

Research methodology followed a series of steps, including formulating research questions, developing a research design with the selection of a research method, analyzing data through diverse methods, drawing conclusions based on the results, and communicating findings. The primary objective is to integrate multiple-input multiple-output (MIMO) and non-orthogonal multiple access (NOMA) technologies to address challenges faced by B5G cellular systems, including massive connectivity, low latency, and high dependability. However, a literature gap exists concerning the impact of MIMO on parameters like bit error rate (BER), downlink spectrum efficiency (SE), average capacity rate, and uplink outage probability (OP) for B5G. Current research focuses on achieving improvements in these parameters. The research aims to design an integrated network architecture based on MIMO and NOMA, enhancing BER, downlink SE, average capacity rate, and uplink OP in B5G networks. The study will also analyze downlink NOMA performance for various conditions and uplink NOMA performance under different scenarios.

The role of the researcher involves evaluating the performance of DL and UL NOMA PD in a 5G network with and without 64 x 64 MIMO technologies. The study analyzes BER and SE performance of DL NOMA under various parameters and examines average capacity rate and OP performance of UL NOMA in different conditions. The introduction of 64 x 64 MIMO technology enhances DL NOMA performance, addressing near-far user issues and improving overall user performance. The researcher contributes by leveraging MIMO technology, significantly improving the performance of all users.

In the methodology section, NOMA systems using multiple beams and a two-stage beam forming solution are described. Researchers have developed effective precoding and detecting techniques to create a significant gap in effective channel gains, enabling optimal NOMA performance. Studies on MIMO-NOMA reveal superior performance compared to MIMO-OMA in terms of total channel capacity and practical capacity. Ergodic capacity maximization for selective Rayleigh fading MIMO-NOMA systems is explored using statistical channel state information. Experiments evaluate NOMA DL integrated with MIMO and analyze UL NOMA with various power allocation techniques. Additionally, unmanned aerial vehicle-assisted NOMA networks and a novel UL/DL NOMA system are examined. Another method for finding correlation similarity is proposed, exploring NOMA plots under diverse UE speeds and correlation-level modeling.

In this research, the researcher came up with two scenarios.

- Downlink (DL) Scenario
- Uplink (UL) Scenario

- ***Data Collection - Downlink (DL) Scenario***

Shown below is the Downlink (DL) Design.

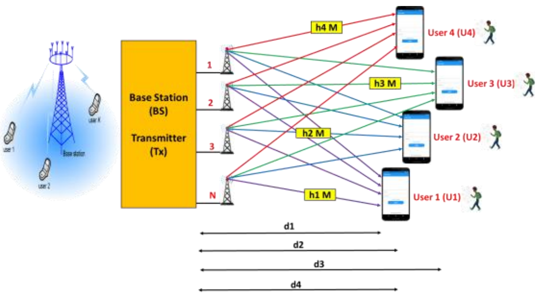

Fig.3.1: Wireless Network - 4 Users (64 × 64 MIMO-DL-NOMA) Power Domain

The table below shows various parameters of the conceptualized design. hT1

Table 3.1: Design Parameters

S/No	Design Parameters	Notation
1	Bandwidth	80 MHz, 200 M
2	Users (4 Users)	U1, U2, U3, U4
3	Distance of Users from the Base Station (BS)	d1, d2, d3, d4
4	Rayleigh Fading Coefficients	hT1, hT2, hT3, h

The distances from the base station vary, with users positioned at different proximities to the base station. The formulas employed for these calculations are presented below, along with references indicating their sources or utilization:

Table 3.2: Design Formulas (DL)

S/No	Description	Formula	Referenc
1	* Total Rayleigh fading channel (each user)	$h_{Ti} = \sum_{i=1}^{M} h_{Ti}$	[87]
2	* Base Stations Encoded Overlay Signal	$x = \sqrt{P}(\sqrt{\alpha_1}x_1 + \sqrt{\alpha_2}x_2 + \sqrt{\alpha_3}x_3 + \sqrt{\alpha_4}x_4)$	[88 - 89]
3	* U Rate R1	$R_1 = \log_2\left(1 + \frac{\alpha_1 P\lvert h_{T1}\rvert^2}{\alpha_2 P\lvert h_{T1}\rvert^2 + \alpha_3 P\lvert h_{T1}\rvert^2 + \alpha_4 P\lvert h_{T1}\rvert^2 + \sigma^2}\right)$	[88]
4	* U Rate R2	$R_2 = \log_2\left(1 + \frac{\alpha_2 P\lvert h_{T2}\rvert^2}{\alpha_3 P\lvert h_{T2}\rvert^2 + \alpha_4 P\lvert h_{T2}\rvert^2 + \sigma^2}\right)$	[88]
5	* U Rate R3	$R_3 = \log_2\left(1 + \frac{\alpha_3 P\lvert h_{T3}\rvert^2}{\alpha_4 P\lvert h_{T3}\rvert^2 + \sigma^2}\right)$	[88]
6	* U Rate R4	$R_4 = \log_2\left(1 + \frac{\alpha_4 P\lvert h_{T4}\rvert^2}{\sigma^2}\right)$	[88]
7	* Spectrum Efficiency	$SE = \frac{Th}{BW}$	[88]

*Where;

i = 1, 2, 3, 4

M (No of Channels) = 64

Power Coefficients = α1, α2, α3, α4 where α1 > α2 > α3 > α4

QPSK Formed Messages = x1, x2, x3, x4

R = U Rate

P = Maximum Power

SIC = Successive Interference Cancellation

SE = Spectrum Efficiency

Th = Throughput

BW = Bandwidth

Conceptualized wireless network consists of a 64 x 64 MIMO system and four DL NOMA users, namely U1, U2, U3, and U4, each with different bandwidths of 80 and 200 MHz. Various distances of the users from the base station are represented by d1, d2, d3, and d4, where d1 > d2 > d3 > d4, indicating the preferred order. Depending on the distance, U1 is considered the weak/far user, while U4 is regarded as the strong/near user from the base station. The selective Rayleigh fading coefficients are identified as hT1, hT2, hT3, and hT4 correspond to |hT1|2 < |hT2|2 < |hT3|2 < |hT4|2.

- ***Data Collection - Uplink (UL) Scenario***

The power domain multiplexing approach in uplink NOMA differs notably from downlink NOMA. In downlink NOMA, the base station (BS) employs superposition coding to achieve power domain multiplexing. In contrast, for uplink NOMA, users are only limited by their battery capacity, enabling both users to transmit at full strength. As a result, fluctuations in the users' channel gains lead to variations in the power domain observed by the BS receiver.

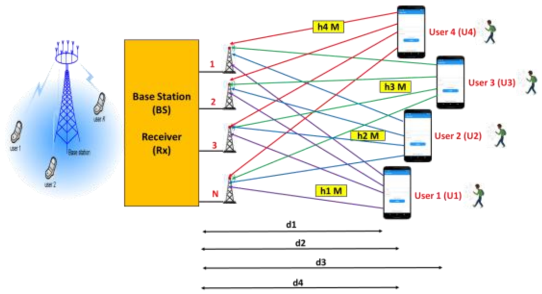

Fig.3.2: Wireless Network - 4 Users (64 × 64 MIMO-UL-NOMA) Power Domain

Assuming a 64x64 MIMO system and a bandwidth of 80 MHz in a wireless network, let x1, x2, x3 and x4 denote the messages that will be transmitted by four UL NOMA users - U1, U2, U3, and U4 - respectively, with both users' signals having the same strength. The various distances of the users from the base station (BS) are represented by d1 > d2 > d3 > d4, with d1 > d2 > d3 > d4 being the preferred order. Depending on the distance, U1 is the weak/far user from the BS, while U4 is the strong/near user. The selective Rayleigh fading coefficients are identified as hT1, hT2, hT3, and hT4 where |hT1|2 < |hT2|2 < |hT3|2 < |hT4|2, indicating the relationship between the coefficients and the users. The formulas used for the calculations are shown below along with their references from where these were taken or used:

Table 3.3: Design Formulas (UL)

S/No	Description	Formula	Referenc
1	* Total Rayleigh fading channel (each user)	$h_{jT} = \sum_{i=1}^{N} h_{iT}$	[87]
2	* Signal Received at the Base Station	$y = \sqrt{P_1}h_{1T} + \sqrt{P_2}h_{2T} + \sqrt{P_3}h_{3T} + \sqrt{P_4}h_{4T} + w$	[88] [89 [90]
3	* Maximum rate User 4	$R_{U4} = \log_2\left(1 + \frac{P\|h_{4T}\|^2}{P\|h_{3T}\|^2 + P\|h_{2T}\|^2 + P\|h_{1T}\|^2 + \sigma^2}\right)$	[91] [92
4	* Maximum rate User 3	$R_{U3} = \log_2\left(1 + \frac{P\|h_{3T}\|^2}{P\|h_{2T}\|^2 + P\|h_{1T}\|^2 + \sigma^2}\right)$	[91] [92
5	* Maximum rate User 2	$R_{U2} = \log_2\left(1 + \frac{P\|h_{2T}\|^2}{P\|h_{1T}\|^2 + \sigma^2}\right)$	[91] [92
6	* Maximum rate User 1	$R_{U1} = \log_2\left(1 + \frac{P\|h_{1T}\|^2}{\sigma^2}\right)$	[91] [92
7	* Capacity U4 (specific target rate)	$C_4 = \sum_{i=1}^{N}\log_2\left(1 + \frac{P\|h_4\|}{P\|h_3\| + P\|h_2\| + P\|h_1\| + N_4}\right)$	[91] [92
8	* Capacity U3 (specific target rate)	$C_3 = \sum_{i=1}^{N}\log_2\left(1 + \frac{P\|h_3\|}{P\|h_2\| + P\|h_1\| + N_3}\right)$	[91] [92
9	* Capacity U2 (specific target rate)	$C_2 = \sum_{i=1}^{N}\log_2\left(1 + \frac{P\|h_2\|}{P\|h_1\| + N_2}\right)$	[91] [92
10	* Capacity U1 (specific target rate)	$C_1 = \sum_{i=1}^{N}\log_2\left(1 + \frac{P\|h_1\|}{N_1}\right)$	[91] [92
11	* Outage Probability Condition U1	[illegible]	[91] [92
12	* Outage Probability U1	[illegible]	[91] [92
13	* Outage Probability Condition U2	$P_r(C_2(k) < r_2) \|\| P_r(C_3(k) < r_3) \|\| P_r(C_4(k) < r_4)) < r$	[91] [92
14	* Outage Probability U2	[illegible]	[91] [92
15	* Outage Probability Condition U3	$P_r(C_3(k) < r_3) \|\| P_r(C_4(k) < r_4)) < r$	[91] [92
16	* Outage Probability U3	$P_r(U3) = (\sum_{k=1}^{N} P_r(C_3(k) < r_3) \|\| P_r(C_4(k) < r_4))/N$	[91] [92
17	* Outage Probability Condition U3	$P_r(C_4(k) < r_4)) < r_4$	[91] [92
18	* Outage Probability U3	$P_r(U4) = (\sum_{k=1}^{N} P_r(C_4(k) < r_4))/N$	[91] [92

*Where;

j = 1, 2, 3, 4

N (No of Channels) = 64

y = Received Signal

w = Noise Power

RU4 = Maximum rate at which BS can decode the data of a nearby user (User 4)

RU3 = Maximum rate at which BS can decode the data of a nearby user (User 3)

RU2 = Maximum rate at which BS can decode the data of a nearby user (User 2)

RU1 = Maximum rate at which BS can decode the data of a nearby user (User 1)

OP = Outage Probability

r = User with different target rates (r1 =1, r2 =2, r3 =3, r4 =4)

C = Capacity of users with different target rates.

C1 = Capacity of user 1 with specific target rate.

C2 = Capacity of user 2 with specific target rate.

C3 = Capacity of user 3 with specific target rate.

C4 = Capacity of user 4 with specific target rate.

Pr = Outage Probability

N = Number of Transferred Samples

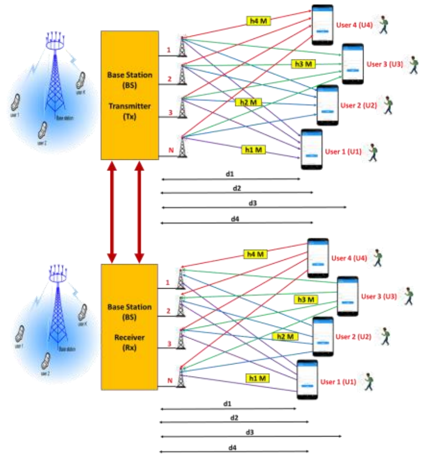

Fig.3.3: Wireless Network - 4 Users (64 × 64 MIMO-DL-UL-NOMA) Power Domain

Simulation Parameters

Using the MATLAB software program, the simulation parameters for the DL and UL NOMA power domains in 5G networks were incorporated, with and without MIMO. Tables 1 and 2 display the simulation parameters that were appropriately taken into account in the simulation model.

Table 3.4: Simulator Parameters for Downlink (DL) Scenario

S/No	Parameters	Values		
Downlink Scenario				
1	Number of Users		4	
2	Transmit Power		0 to 40 dBm	
3	Bandwidth	BW1		80 MHz
		BW2		200 MHz
4	Distances	User 1		900 m
		User 2		700 m
		User 3		400 m
		User 4		200 m
5	Power Coefficients	User 1		0.843
		User 2		0.219
		User 3		0.062
		User 4		0.022
6	Path Loss Exponent		4	
7	MIMO		64 X 64	
8	Modulation		QPSK	

Table 3.5: Simulator Parameters for Uplink (UL) Scenario

S/No	Parameters	Values		
Uplink Scenario				
1	Number of Users		4	
2	Transmit Power		-30 to 30 dBm	
3	Bandwidth	BW1		80 MHz
		BW2		200 MHz
4	Distances	User 1		900 m
		User 2		700 m
		User 3		400 m
		User 4		200 m
5	Path Loss Exponent		4	
6	MIMO		64 X 64	

The researcher employed MATLAB for the analysis in this study.

IV. RESULTS AND DISCUSSION

- ***Downlink Results & Discussion***

According to the Downlink (DL) NOMA system results, adopting 64 X 64 MIMO came up with the following results:

- Enhanced Bit Error Rate (BER) Performance.
- Enhanced Spectral Efficiency (SE) performance.
- The near-far user problem solved.

For varied power location coefficients, transmitted power, and distance parameters when compared without MIMO DL NOMA performance, the performance of all user's approaches that of the other users. Performance of the DL NOMA Bit Error Rate (BER) versus transmitted power at 80 MHz BW is shown below in Fig 4.1.

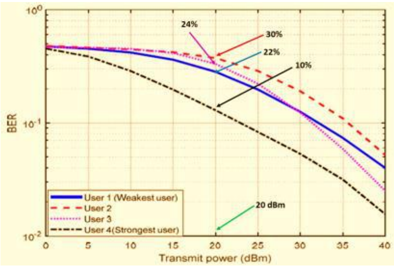

Fig.4.1: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 80 MHz Bandwidth

The results show that;

- As transmitted power rises, BER performance declines.
- As U4 is the closest, its BER performance is the best for all users.
- BER rates for U1, U2, U3, and U4 are determined to be 22%, 30%, 24%, and 10%, respectively, at a transmitter power of 20 dBm.
- BER performance declines as transmitted power increases.

Figure 4.2 below compares the DL NOMA BER performance against transmitted power at 200 MHz BW.

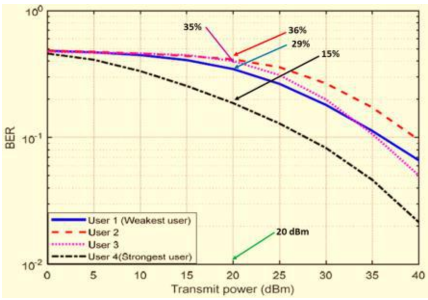

Fig.4.2: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 200 MHz Bandwidth

The results found that U4 being the closest user, its BER performance is the best when compared to all other users. BER rates for U1, U2, U3, and U4 are determined to be 29%, 38%, 35%, and 15%, respectively, at a transmit power of 20 dBm. Best user U4 from the 64 x 64 MIMO DL NOMA improves BER performance from 10-1.48 to 10-4.93 at 200 MHz BW at a transmitter strength of 40 dBm and then from 10-1.68 to 10-5.1 at 80 MHz. In contrast, with a transmitter power of 40 dBm, the Spectrum Efficiency (SE) performance for the best user U4 is enhanced by 8 x 10-2.9 bps/Hz for 80 MHz BW and by 10-1.9 bps/Hz for 200 MHz BW.

UL NOMA systems' results with 64 x 64 MIMO were improved the Outage probability (OP) for 80 MHz BW at Signal to Noise Ratio (SNR) of 1 dB was lowered by 14 x 10-2.9 and the average capacity rate performance increased by 11 bps/Hz. Figure 4.3 below displays the DL NOMA BER performance as a function of transmitted power at 80 MHz BW and 64 x 64 MIMO. The BER rates for U1, U2, U3, and U4 are determined to be 18 x 10-3.8, 17 x 10-3.8, 7 x 10-3.8, and 4 x 10-3.9 at 20 dBm of transmitted power, respectively.

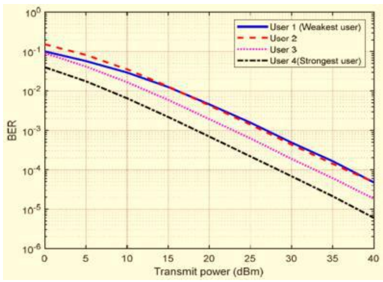

Fig.4.3: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 80 MHz Bandwidth with 64 x 64 for DL NOMA

A transmitted power of 20 dBm, the DL NOMA BER performance at 200 MHz BW and 64 x 64 MIMO is shown in Figure 4.4 below. The BER rates for U1, U2, U3, and U4 are determined to be 45 x 10-3.7, 42 x 10-3.8, 18 x 10-3.6, and 6 x 10-3.8, respectively. The MIMO system improves BER efficiency.

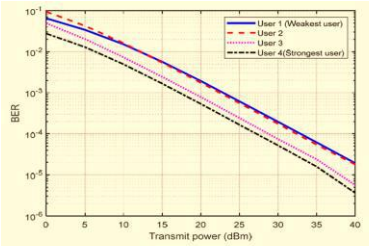

Fig.4.4: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 200 MHz Bandwidth with 64 x 64 for DL NOMA

Figure 4.5 plots the DL NOMA Spectral Efficiency (SE) performance against transmitted power at 80 MHz BW. The results reveal that SE performance improves with increasing transmitted power. The U4 BER performance is therefore the best for all users because it is closest one. Up until the transmitted power reaches 5 dBm, all users' SE performance is clearly distinct from one another.

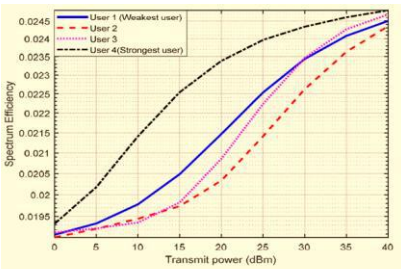

Fig.4.5: Spectral Efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) at 80 MHz Bandwidth for DL NOMA

Figure 4.6 shows the relationship between DL NOMA SE performance and transmitted power at 200 MHz BW. The results show that SE performance improves as transmitted power increases. The finest is U4 SE performance considering that U4 is the closest user as compared to all other users. With an improvement rate of 10-2.2 in the BER, the results are better than those of the best U2 users.

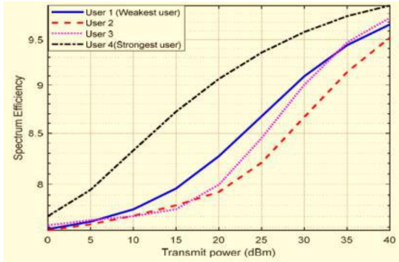

Fig.4.6: Spectral Efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) at 200 MHz Bandwidth for DL NOMA

Figure 4.7 displays the DL NOMA SE's performance in terms of transmitted power at 80 MHz BW and 64 x 64 MIMO. The SE is fairly close for all users at 5 dBm of broadcast power.

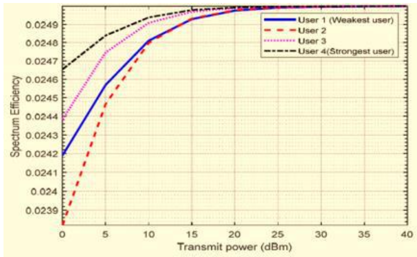

Fig.4.7: Spectral Efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for DL NOMA

Figure 4.8 shows the performance of the DL NOMA SE vs transmission. power at 64 x 64 MIMO and 200 MHz BW. At 15 dBm of transmitter strength, the SE for all users is reasonably near. The SE performed is better; thanks to MIMO.

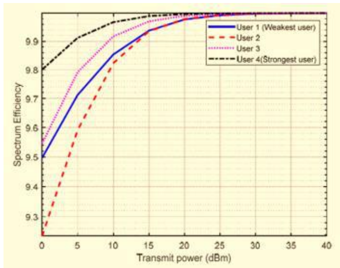

Fig.4.8: Spectral Efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for DL NOMA

- ***Uplink Results & Discussion***

Figure 4.9 shows the UL NOMA average capacity rate vs. SNR at 80 MHz BW. Because U4 is the closest, the result demonstrates that the average capacity rate for U4 is best for all users. The average capacity rate for U1, U2, U3, and U4 is found to be 1.6873, 2.8718, 6.4960 and 12.7814 respectively.

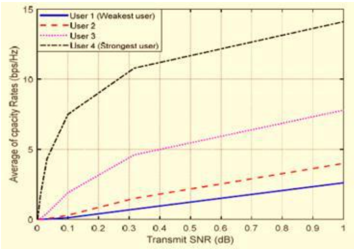

Fig.4.9: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) and 80 MHz Bandwidth for UL NOMA

Figure 4.10 shows the UL average capacity rate at 200 MHz BW. Average capacity rates for U1, U2, U3, and U4 are found to be 2.5923, 3.89479, 7.7821, and 14.0972, respectively at SNR of 1 dB. The findings show that the average capacity rate performance increases along with an increase in SNR. The performance of the capacity average rate was enhanced by 64 x 64 MIMO by 11 bps/Hz and decreased the OP by 11 x 10-2.9 for 200 MHz BW at 0.18 dB SNR for user U4, and reduced the OP by 14 x 10-2.8 for 80 MHz BW at SNR of 1 dB. In general, an increase in BW decreases OP and SE while increasing BER and the capacity average rate. MIMO greatly increases each user's throughput.

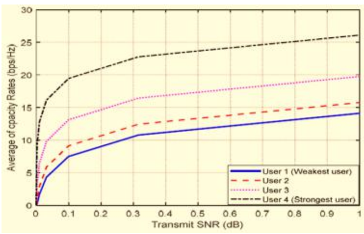

Fig.4.10: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) and 200 MHz Bandwidth for UL NOMA

Figure 4.11 shows the average capacity rate performance for UL NOMA versus SNR at 80 MHz BW and 64 x 64 MIMO. The outcome for the four users were found to be four users is 12.8732, 14.3921, 18.4489, and 24.7714 respectively.

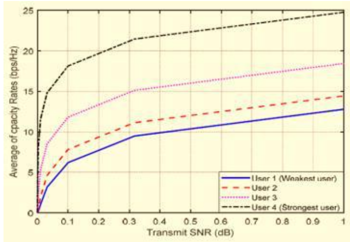

Fig.4.11: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for UL NOMA

Figure 4.12 depicts average capacity rate performance in relation to SNR for 64 x 64 MIMO and 200 MHz BW UL NOMA. The findings indicate that when SNR rises, average capacity rate performance gets better. According to data gathered for four users at the SNR of 1 dB, the values were found to be 14.0921, 15.7563, 19.7586, and 26.1820 respectively. U4's average capacity rate performance is the best. Furthermore, BW and average capacity rate are positively correlated i.e. rising BW translating into rising average capacity rate. When system is improved utilizing MIMO technique, the average capacity rate rises sharply.

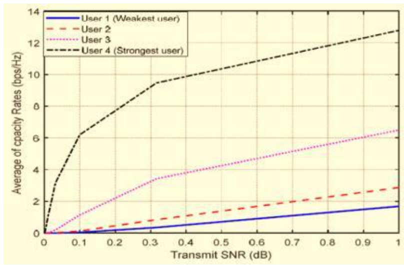

Fig.4.12: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for UL NOMA

Figure 4.13 shows 80 MHz BW plot displaying the association between the UL NOMA of OP and SNR. The values for U1, U2, U3, and U4 are 98.8 x 10-1.9, 97.7 x 10-1.8, 43.3 x 10-1.9, and 14 x 10-3, respectively, when SNR is 0.169 dB.

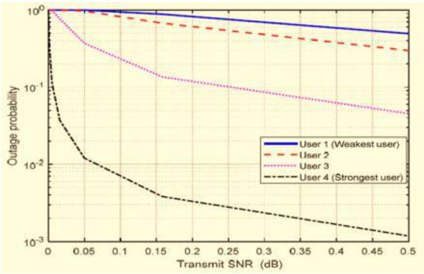

Fig.4.13: OP vs SNR (4 Users, Varied Distances & Power Coefficients) and 80 MHz Bandwidth for UL NOMA

The UL NOMA of OP versus the SNR is shown in Figure 4.14 at 200 MHz BW. The values for U1, U2, U3, and U4 are 0.9746, 0.9744, 0.2809, and 0.0173, respectively, at an SNR of 0.169 dB. The results demonstrate that the OP performance degrades as the SNR increases. Results obtained are better than those of the top U2 users and have increase in average capacity rate.

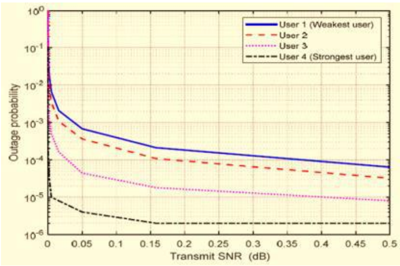

Fig.4.14: OP vs SNR (4 Users, Varied Distances & Power Coefficients) and 200 MHz Bandwidth for UL NOMA

The UL NOMA of OP vs. SNR is shown in Figure 4.15 at 80 MHz BW with 64 x 64 MIMO. The results for U1, U2, U3, and U4 are 0.0061, 0.0026, 0.0002, and 0.0001 at an SNR of 0.169 dB.

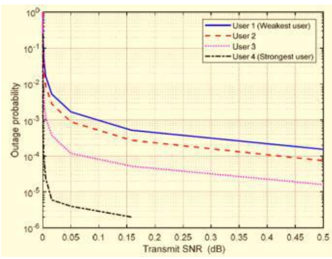

Fig.4.15: OP vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for UL NOMA

The UL NOMA of OP vs. 64 x 64 MIMO at 200 MHz BW is shown in Figure 4.16. The values for U1, U2, U3, and U4 are 20 x 10-3.8, 10-3.9, 10-3.7, and 10-4.8 at an SNR of 0.169 dB. According to the results, the performance of the OP degrades as the SNR rises. A rise in BW causes a decrease in OP, and the two variables are inversely related. When the system is optimized using the MIMO approach, the OP drops significantly. The outcomes are better since there was an improvement rate of 10-1.8 in OP.

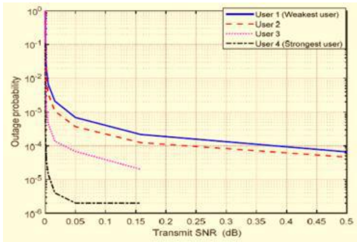

Fig.4.16: OP vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for UL NOMA

V. CONCLUSIONS AND FUTURE WORK

The study underscores the potential advantages of combining MIMO and NOMA technologies within B5G cellular systems, offering valuable insights into optimal configurations for improving performance across diverse parameters. Drawing conclusions from the investigation into the integration of multiple-input multiple-output (MIMO) and non-orthogonal multiple access (NOMA) technologies in B5G cellular systems, the findings are presented.

• Integrating MIMO and NOMA technologies offers a solution to various challenges encountered by B5G cellular systems, encompassing issues such as massive connectivity, low latency, and high dependability.

• The collaborative deployment of MIMO with NOMA leads to notable improvements in key parameters, including bit error rate (BER), spectrum efficiency (SE), average capacity rate, and outage probability (OP).

• The amalgamation of MIMO and NOMA effectively addresses the near-far user's predicament in downlink NOMA. This enhancement is manifested through improved BER and SE performance, aligning the performance of all users more closely.

• Implementation of 64 x 64 MIMO technology in downlink NOMA results in significant enhancements in BER for the best user. Simultaneously, in uplink NOMA, it improves average capacity rate performance and diminishes outage probability for the best user.

• An augmentation in bandwidth correlates with an increase in BER and average capacity rate, accompanied by a reduction in spectrum efficiency and outage probability.

The study exhibited the efficacy of Downlink (DL) and Uplink (UL) NOMA Power Domain (PD) in a 5G network, considering both scenarios with and without 64 x 64 MIMO technology. The following procedures were executed, accompanied by corresponding observations:

• Investigation and assessment of the Bit Error Rate (BER) and Spectral Efficiency (SE) performance of Downlink (DL) NOMA for varying distances and power location coefficients.

• Examination of the Average Capacity Rate and Outage Probability (OP) performance of Uplink (UL) NOMA under different conditions, including varied distances, Signal-to-Noise Ratio (SNR), and Bandwidth (BW).

• Results from the DL NOMA system indicated that the introduction of 64 x 64 Multiple-Input Multiple-Output (MIMO) technology not only enhanced BER and SE performance but also effectively addressed the near-far user's challenge, aligning the performance of each user closely with others.

• Comparative analysis between DL NOMA with and without MIMO revealed that, under factors such as different transmitted power, distance, and power location coefficients, the 64 x 64 MIMO DL NOMA, at 80 MHz BW and 200 MHz BW (with a transmitter power of 40 dBm), improved BER performance for the best user U4 from 10^-1.7 to 10^-5.2.

• In contrast, with a transmitter power of 40 dBm, the SE performance for the best user U4 witnessed an improvement of 0.8% bps/Hz for 80 MHz BW and 1.01% bps/Hz for 200 MHz BW. The results from UL NOMA systems, employing 64 x 64 MIMO, demonstrated notable enhancements.

• For the best user U4, the average capacity rate performance improved by 12 bps/Hz, the OP decreased by 0.0120 for 200 MHz BW at an SNR of 0.17 dB, and the OP decreased by 0.0150 for 80 MHz BW at an SNR of 1 dB.

• An increase in BW led to a reduction in SE and OP while increasing BER and average capacity rate.

• MIMO technology significantly improved the performance of each user.

Future Research

This research seeks to make a valuable contribution to the existing literature by introducing an integrated network architecture based on hybrid technologies, incorporating Multiple-Input Multiple-Output (MIMO) and Non-Orthogonal Multiple Access (NOMA). The objective is to address challenges related to massive connectivity, low latency, and high dependability while effectively resolving issues associated with near/far users. It is important to note that this study did not delve into the collaborative potential of MIMO cooperative NOMA and cognitive radio. Future research endeavors can explore this unexplored avenue to unlock further enhancements in network performance.

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