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

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Abstract — *In 5G mobile systems, Non-Orthogonal Light Acquisition (NOMA) and Multiple End-to-End (MIMO) technologies must overcome numerous obstacles, including space limitations, connectivity restrictions, and the requirement for increased reliability. It is vital to concentrate on enhancing and reconsidering criteria of BER, SE, average power rate and potential for a link transmission error in order to boost performance in 5G networks using MIMO. Phase modulation was accomplished in a few frequency channels by the suggested model, which took into account input power, bandwidth, transmission power, and signal-to-noise ratio. Following an evaluation of the model's efficacy, the results showed superior performance over earlier research. The transmission findings demonstrate that MIMO-NOMA enhances the critical user's bit error rate and transmission power. The average active rate was used to determine link transmission outcomes. Furthermore, in both uplink and downlink scenarios, with and without MIMO, NOMA's BER, SE, average power rate & failure probability was assessed. Study discovered that MIMO-NOMA installation significantly improved performance for all users.*

Keywords*— *MIMO, NOMA, 5G Networks, BER.

I. INTRODUCTION

- **Background**

Wireless transmission has undergone a significant technological revolution during the previous several decades. Future wireless communication networks must be cost-effective, able to support a high user density, demand connectivity, and provide extensive coverage. The transition across several generations has altered people's lifestyles. Cellular networks have undergone a revolution in recent years, moving from first generation (1G) to fifth generation (5G) and beyond (5G) networks. Data rates for voice communication on 1G are measured in kilobits per second (Kbps), whereas data rates for highly interactive multimedia applications on 5G and beyond fifth generation can reach gigabits per second (Gbps).

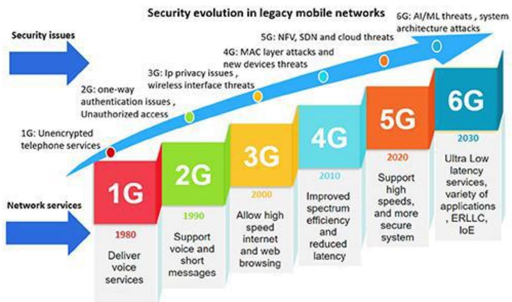

Fig 1: Evolution

In order to surpass the limitations of 5G, we must discover innovative technological approaches that lower costs while increasing spectrum efficiency and energy efficiency. Multiple access systems play a crucial role in addressing these issues in certain ways. When users use network resources, orthogonality assigning frequencies, time slots, or codes to each user to ensures that there is no interference. (Kalra and Chauhan, 2014) [1].

Inherent benefits of NOMA technology include, but are not limited to, high cell-edge throughput, better spectrum utilization, and reduced dependence on accurate channel state information feedback, and low end-to-end latency. This is because it is able to support several users simultaneously within the same frequency resource and with the use of successive interference suppression. The need for large-scale interconnection is provided, this is encountered as it can accommodate a large number of clients at a given time but at the same time, a specific time for information exchange of information transmission is strictly provided to lower the possibility of delays in exchange of information. Due to the reason that NOMA is able to adjust the power level of powerful users over that of powerless users, uniformity of methods and different levels of correctness are achieved and maintained. (Ahmad, 2016) [2].

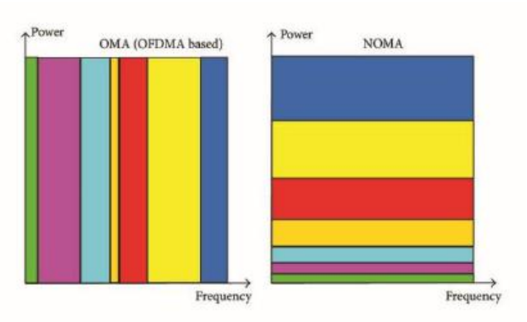

Fig 2: OMA Vs NOMA

NOMA has drawn lot of interest as a multiple access technique for LTE systems. Multiple uses of NOMA are now being investigated by the third-generation collaboration project (3GPP). In order to reduce inter-cell interference (ICI), network-assisted interference cancellation and suppression (NAICS) was expanded to include NOMA in LTE Release 12 (3GPP, 2014) (Chen et al., 2018) [3]. Another vital but difficult duty in NOMA is interference management. Using effective resource allocation systems, networks can be optimized in terms of user coverage and throughput (Vaezi et al., 2019b) [4].

NOMA was thoroughly examined by Lu et al. (2017) [5 - 8], who covered its foundational ideas, contemporary advancements, and prospective research prospects. They thoroughly evaluated the spectrum efficiency, system performance, and receiver complexity of several NOMA designs and made an information theory comparison between NOMA and OMA. In order to address those difficulties, they also highlighted difficult open problems, put up solutions, and recommended potential future research topics.

Two methods that increase 5G capacity are NOMA and tiny cells [10]. The employment of NOMA in conjunction with a useful resource can increase spectral efficiency.

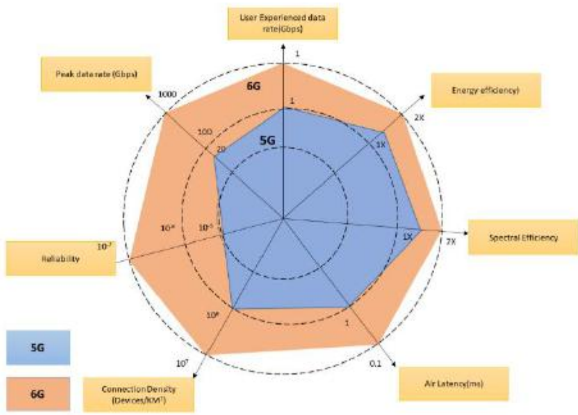

Fig 3: 5G & 6G Performance [24]

New operational frequency bands, MIMO, mmWave (Millimeter Wave), and NOMA are some of the additional improvements included in 5G [11].

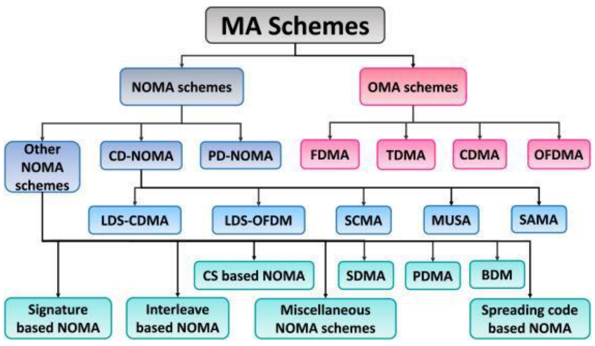

Fig 4: MA Schemes

- **NOMA B5G (Beyond 5G) and 6G Systems: Applications**

Human lifestyle has altered as a result of technology. People are continuously looking for innovative answers to a wide range of issues and seeking new routes for advancement. Wireless communication has progressed from 1G to 5G as a result of people's aspirations. This evolution hasn't halted yet, though. To build 5G and B5G (Beyond 5G) connectivity, researchers are working very hard.

The rising demand for additional devices and greater data rates are the main drivers of ongoing advancement in wireless technology (Benisha et al., 2019) [12]. However, because there is not enough spectrum to meet these requests, congestion is getting worse every day. The current generation of networks—1G, 2G, 3G, and 4G—cannot guarantee continuous connectivity.

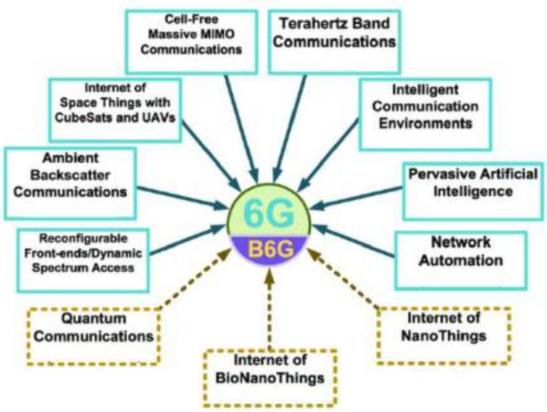

Fig 5: Enabling Technologies [25]

Need for data rates & connection has increased due to the users' exponential growth. Utilizing cutting-edge technical trends like NOMA-assisted BS, these needs can be satisfied. Numerous obstacles must be overcome for NOMA's resource use to be efficient.

Fifth-generation (5G) mobile communication technology is now used by millions of people and is now extensively available in many countries. Therefore, it is now important for business and academia to focus on the next generation. The upcoming B5G apps will have more demand than the current 5G networks and a larger network capacity. As a result, more network capacity will be needed for new 6G applications. One of the key elements of our future way of life, economic sectors, and social structures will be next-generation wireless networks. In order to achieve a unified goal, the scientific community and industry should enhance these networks (Goyal et al., 2019) [13].

Due to the requirements of modern apps, the future generation of wireless networks should accomplish a number of goals to support these applications' QoS. By 2030, we can assume that the wireless networks will need to accommodate the next evolution's increased needs.

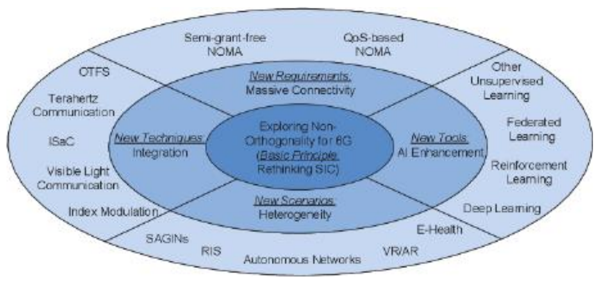

Fig 6: NOMA Applications - B5G [26]z

It is anticipated that there will be many new application opportunities in the future up to 2030 and these can be grouped into three broad areas as follows [14].

- Smart Production

  B5G will use information technology to accomplish intelligent manufacturing. Drones, for instance, are used in agriculture. Virtual reality and robotics will increase production effectiveness. Digital twins and other cutting-edge technologies will significantly increase the impact of intelligent manufacturing in B5G.

- Smart Life

Network of twin bodily areas in 2030, online synesthesia and intelligent interaction are expected to change how we live.

- Smart Society

Due to the ubiquitous availability of the coverage network, public service coverage will noticeably increase by the year 2030. By guaranteeing that all regions have equal access to digital services, this expansion seeks to close the regional digital divide.

Fig. shows the new 6G network scenarios.

Tab 1: Beyond 5G/6G [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**

Creating an energy efficient network incorporating non-orthogonal multiple access (NOMA) with massive MIMO, that assists in serving a large population of distant users and Internet of Things (IoT) devices, is necessary for speeding up the evolution of intelligent wireless systems of the future. This network must eliminate the complexity of networking and the transportation of information. However, such an energy related concern emerges in B5G communications with the aim of ensuring constant connection and provision of fast data transport among IoT gadgets.

MIMO, on the other hand, tends to increase the maximum da te rates which may be achieved and is thus considered to be a very flexible technique by which capacity can be increased. MIMO and NOMA where MIMO is interfaced with NOMA can deliver better capacity when compared to combination of MEMO - OMA [27].

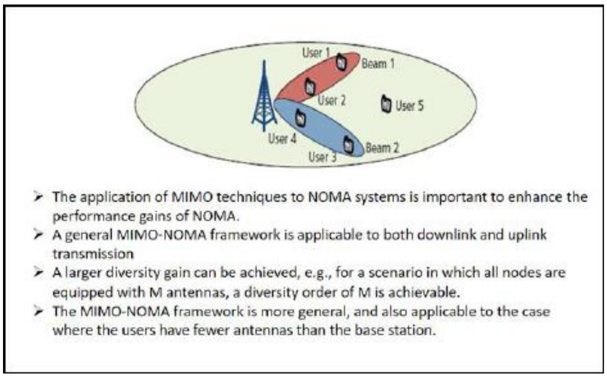

Fig 7: NOMA in Massive MIMO [30]

Researchers compared allocation methods for determining which was best for NOMA (MIMO-NOMA) technology [28]. Utilization of several antennas has been integrated into B5G naturally. Instead of being assigned to orthogonal time-frequency resources, users can be spatially multiplexed when there is an antenna array. Massive MIMO is a non-orthogonal multiple access method that results in interference leaking across beams if a spatial beam is directed at each user. MIMO technologies, such as spatial division multiple access, have been used for many years (SDMA). There is evidence, both theoretically and experimentally, that the broad adoption of Massive MIMO in B5G represents a paradigm change in terms of spectrum efficiency.

Modern communication networks can boost capacity without using excessive power or bandwidth by employing MIMO configuration. A viable solution to address the increasing needs appears to be combination of MIMO structure with non-orthogonal multiple access (NOMA) configuration [29]. Fig. below illustrates how the MIMO approach is used in B5G systems to represent NOMA.

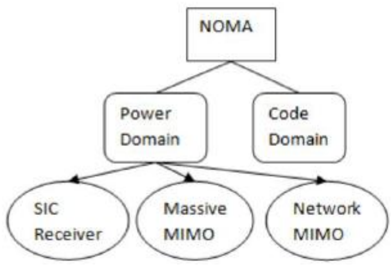

Fig 8: MIMO Techniques: NOMA in B5G - [31]

- **AI applications for NOMA implementation**

Mobile gadgets and new wireless applications are proliferating quickly in wireless systems. Next-generation wireless networks are heavily researching enhanced multiple access technologies. NOMA, one of these technologies, has come up as a promising technique and is considered as a crucial component of next-generation multiple access (NGMA) [16]. Significant interest in and evidence of considerable promise for attaining extensive connection have been generated by the combination of NOMA with multiple-antenna technology [17] [18].

Beamformer-based NOMA and cluster-based NOMA are two primary types of multiple-antenna NOMA algorithms now in use. The beamforming and successive interference cancellation (SIC) designs of these techniques are what set them apart the most. In BB-NOMA, SIC is used to reduce any remaining spatial interference after each user receives a beamforming vector. When consumers have low channel correlations, SIC usage also becomes troublesome. Contrarily, CB-NOMA groups users into clusters, often with the same number of clusters as radio frequency (RF) chains. Contrary to BB-NOMA, CB-NOMA lowers expenses by performing SIC sequentially within each cluster while providing each cluster with the same beamforming vector. According to CB-NOMA, users can be classified into a number of ideal clusters, each of which include users who are highly correlated with one another while being less correlated with one another. Due to channel unpredictability, this ideal presumption might not always be true.

Despite the potential advantages of next-generation multiple access (NGMA), interference suppression and system optimization are made difficult by the complexity of multi-domain multiplexing.

- To transform non-convex issues into solvable convex problems, they rely on complex mathematical transformations and specialized knowledge.
- The initialization parameters for these approaches must be carefully configured for various contexts using labor-intensive hand-engineered designs because they have a significant impact on how well they operate.
- They frequently necessitate numerous cycles to reach convergence, leading to unmanageable computing complexity, particularly in circumstances involving overload or multi-cell networks.

These difficulties make it difficult to use conventional convex optimization techniques effectively in next-generation NOMA systems.

Fortunately, recent developments in artificial intelligence (AI) have made it possible for automated communication designs to address the complexity, opening up new avenues for overcoming the problems listed above [19] to [22]. This has inspired encouraging research into using cutting-edge ML techniques to improve NGMA through AI - ML is still in infancy, even if prior research has established a solid foundation for communication designs using multiple-antenna NOMA. The illustration below shows how AI/ML is applied during planning stage:

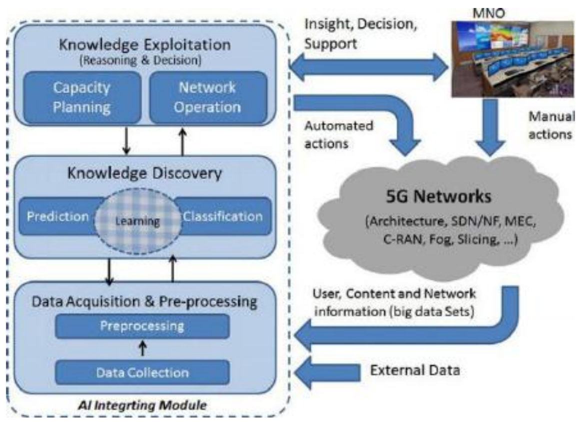

Fig 9: Integration of AI - ML [32]

AI can train deep neural networks (DNNs), which can then use their exceptional function-fitting capabilities to roughly answer complicated problems. AI allows for the automatic learning of high-quality communication designs from data without the need for specialist knowledge or human initialization of parameters, which is occasionally required by traditional optimization techniques.

Automation of the parameters and learning process is essential for next-generation wireless systems, which feature great time-variability and cover a variety of applications. The learning model's neural network design ought to be flexible and capable of self-configuring for different situations. The new AutoML paradigm [23] should be integrated to improve machine learning-based communication design, minimizing the need for human interaction and increasing performance, in order to accomplish automatic construction of learning models [23]. NAS makes it possible for learning models to automatically optimize hyper parameters and neural architectures. In order to support next-generation mobile and wireless communication systems and meet the needs of various application situations, these ML approaches can be added as new modules.

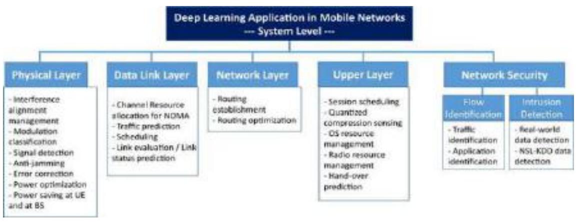

Fig 10: Deep Learning Applications [33]

Research into Next-Generation Mobile and Wireless Communications (NGMA) with AI support is still in its infancy. Here are a few unresolved research questions in this area:

- Machine Learning for NGMA.
- Dynamic Multi Objective Optimization in NGMA Using ML:
  It can be difficult to forecast how the Pareto optimal front will vary as wireless surroundings change over time. This is because the optimal objectives and constraints may also change. It is necessary to look at effective multitask machine learning techniques in order to enable dynamic multi-objective optimization in NGMA.
- NGMA Automated Machine Learning (AutoML) Acceleration:
  While back-propagation-based machine learning can effectively predict desirable solutions, the training process frequently necessitates a large number of data samples and places a heavy computing burden on the system. The training procedure becomes significantly more time-consuming and computationally costly when AutoML techniques like meta-learning and neural architecture search (NAS) are used.

In conclusion, major research paths to solve outstanding difficulties and promote AI-enabled NGMA communication design include the development of model-based constrained machine learning, dynamic multi-objective optimization approaches, and effective AutoML techniques.

Problem Statement

MIMO and NOMA integration technologies in a hybrid technology environment should solve many problems in 5G and B5G mobile systems, which have high connectivity problems, limited space and reliability. User performance is degraded due to channel interference and fading, and eventually the connection is broken due to these interferences. MIMO and NOMA technologies can be combined to develop a hybrid solution that can address many of the challenges facing 5G and beyond. By increasing the number of antennas and bandwidth without improving the weak conditions, it is possible to reduce the performance in the 5G network. As a result, it is possible to increase the BER, decrease the spectral efficiency (SE), decrease average power rate, and increase uncertainty (OP) for the upstream and downstream connections.

Research Objectives

- Designing of an integrated hybrid technologies based network architecture.
- Designing a network for large connectivity, having low latency with high dependability by proposing a network model with enhanced performance with MIMO-NOMA implementation solving near/far user's problems.
- Improving BER, SE for DL, average capacity rate & outage probability (UL) in B5G network utilizing MIMO.
- Evaluation of DL NOMA's BER and SE performance.
- Examining uplink NOMA's bandwidths, SNR and distances.

Research Questions

- Can a network architecture be designed based on hybrid technologies with MIMO and non-orthogonal multi-input?
- Can network design with high connectivity, low latency, and high reliability can be provided by providing a network model with better performance using MIMO-NOMA to solve internal/external user problems?
- How to improve BER, SE (DL), Average Capacity and Loss Probability (UL) in B5G networks using MIMO?
- Can we analyze the correlation of BER reduction and SE performance?
- How can the average power rate and possible NOMA function be examined for varying signal-to-noise ratios, platforms, and distances?

Significance of Research

B5G networks, this architecture tries to offer high reliability, low latency, and huge connection. The suggested network model improves performance and tackles concerns with near/far users by utilizing MIMO-NOMA. Overall goal is to integrate MIMO and NOMA technologies to effectively improve the performance and dependability of B5G networks.

Literature Review

Wireless Communication

Non-orthogonal multiple access (NOMA) [34,35], a promising strategy, has been suggested to fulfill the required aims of retaining spectral efficiency and permitting mass accessibility [36,37]. Signal reception in the presence of noise is made possible by NOMA, which uses receiver-based sequential interference cancellation (SIC) techniques to control the power levels [38-41].

- **NOMA**

NOMA is able to support extremely large connections while significantly reducing transmission delay [42 - 44]. Need of the current wireless environment can be satisfied by NOMA [45, 46], a wireless technology. The evaluation of various access technologies is still developing [47]. Since all features are constantly being produced, the primary leading research group is attempting to determine the efficiency of the spectrum [48,49].

Channel characteristics of other users statically define the interference [50-52]. The BS uses successive interference cancellation (SIC) algorithms to decode the communications in order to reduce this interference. The receiver BS must receive distinct message signals with adequate intensity variance in order for the SIC method to function well. Utilizing various power levels at the transmitter is normally how downlink (DL) signal separation is managed. Such power level changes are not necessary in UL NOMA, though, as the UL channel gains already adequately separate signals. In actuality, the transmit power is optimized by the UL's power control system based on the channel conditions. It is not advised to employ UL NOMA in broadcast scenarios including power regulation since it could make channels less distinct and lead to uneven received signal levels among users. [53–57].

- **MIMO**

MIMO can manage many independent channels in the same bandwidth yet has separate antennas [58–61]. In [62, 63], three power distribution methods are presented to enhance the power allocated to each NOMA. Nevertheless, only a small amount of transmitted symbols is offered to each user, which could produce false results. To guarantee optimum performance, the ergodic rate obtained is monitored and examined for performance of the pre-detection and encoder systems that make it easier to decode the DL and UL signals in the dual receive channels.

- **Bandwidth, Average Capacity Rate, Outage Probability, BER & SE**

The researchers demonstrated the vulnerability of the network to Rayleigh fading. This study used modeling techniques to examine different system designs. Specifically, the researchers proposed and investigated multiple bandwidths (BWs) in the context of a non-orthogonal multiple access (NOMA) system based on an alternating channel. When supporting system users, combination of NOMA and MIMO shows significant improvements [93].

II. RESEARCH LITERATURE

- **MIMO-NOMA Performance**

The successful precoding and detecting techniques developed by the author in [65-66] allow for the realization of NOMA's potential despite similar beginning channel conditions among users. As a result, there are noticeable variances in effective channel gains amongst users. Investigating how MIMO-NOMA performed with several users clustered together. According to the results in [67], MIMO-NOMA performs better than MIMO-OMA. Additionally, [63] used statistical channel state data from transmitter to investigate the maximization problem of ergodic capacity in selective Rayleigh fading MIMO-NOMA systems. According to the research, MIMO-NOMA approaches perform noticeably better than the conventional OMA scheme.

In order to evaluate the effectiveness of NOMA downlink integrated with MIMO in practical settings, an experimental investigation was carried out in [68]. Initially, the combination of NOMA downlink and MIMO was thought of as an idea for user connectivity in the uplink (UL). The study looked at and took into account a number of power allocation strategies as described in [69]. In addition, the author studied a variety of NOMA uplink (UL) and downlink (DL) communication systems [70-72]. For NOMA DL and UL systems, analytical formulations for the outage probability (OP) were created, especially in conditions with high signal-to-noise ratios (SNRs) [95].

- **Correlation Similarity for NOMA Effectiveness**

Experts from across world have begun examining how to apply the NOMA principle to different generation. Majority of initial studies on NOMA relied on single integrated version (SISO), with primary concerns being power distribution and user accuracy [73, 76, 77, 78].

- **Combining MIMO and NOMA**

Since a thorough search is required, finding the ideal user pairing is not easy. Random pairing is used in [79] to reduce the computational cost. Additionally, a greedy user pairing method is suggested in [80 - 83] to provide performance that is close to ideal, based on the channel correlation and gain difference.

The research was restricted to a single-cell system. Inter-cell interference (ICI) is a significant barrier in multi-cell networks, where researchers have just begun to look into the performance of NOMA in these networks. In a two-cell MIMO-NOMA network, there are two ways to deal with the ICI. In [84], synchronized beamforming strategies are suggested [85-86].

III. RESEARCH METHODOLOGY

The goal of this project is to develop an integrated network architecture using MIMO and NOMA. This design will leverage MIMO-NOMA to address distant and exterior issues, as well as a network model that prioritizes high connection, minimal area, and high dependability. user. MIMO enhances the B5G network's BER, downlink SE, average rate capabilities, and UL operation. The performance of 64 x 64 MIMO, DL and uplink UL, NOMA PD technologies in a 5G network was evaluated. They evaluated the performance of BER and SE in DL NOMA with various factors, including distance, local power coefficient, transmission power, and bandwidth. Average power and OP performance in UL NOMA were investigated at various distances, SNRs, and bandwidths. The results revealed that using 64x64 MIMO technology improves BER and SE performance in DL NOMA, hence decreasing the near-user problem. Furthermore, as compared to DL NOMA without MIMO, all users perform similarly at various transmission locations, distances, and power coefficients.

- **Methodology**

NOMA systems serve a large number of users by generating many beams from a single carrier. This approach incorporates a two-stage beam forming solution that makes use of modular beam forming vectors. In addition, a simpler transmission packet shaping problem is constructed to determine the power and packet-shaping vectors of each user. Certain authors have developed successful precoding and detection approaches that result in a large difference between users' effective channel gains.

Researchers tested the effectiveness of combining NOMA in the downlink (DL) with multiple-input multiple-output (MIMO) in conditions that were realistic, offering helpful insights into the theory. Additionally, NOMA in the uplink (UL) was examined while taking into account different power allocation strategies.

A NOMA network with UL and DL broadcasts that was aided by an unmanned aerial vehicle (UAV) was also the subject of research. In order to increase fairness and application, analytical formulations for the OP were generated, and a novel UL/DL NOMA system that combines statistical channel state information was proposed.

Another approach examined effectiveness of several NOMA techniques over delay line channel, taking into account both slow and fast UE speeds as well as correlation-level modeling, with the goal of detecting correlation similarities. The results showed that NOMA approaches behaved differently when UE was operating at regular and rapid speeds.

- Methods

- ***DL Scenario***

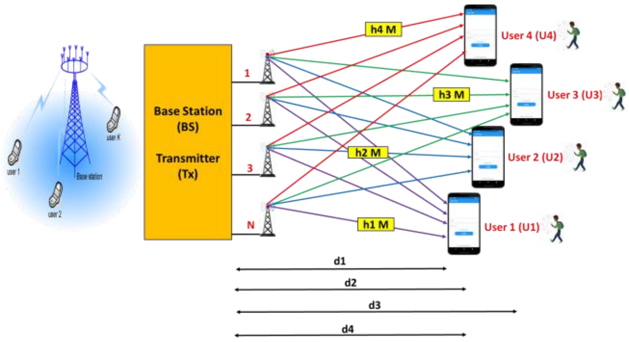

Fig 11: Users 64 x 64 MIMO-DL-NOMA PD

Table 2: Design Parameters

S/No	Design Parameters	Notation
1	Bandwidth	80 MHz, 200 MHz
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	$h_{T1}, h_{T2}, h_{T3}, h_{T4}$

Users' distances, from base station are different, depending on how close or how far they are from it.

Table 3: Design Formulas (DL)

S/No	Description	Formula	Reference
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	$R_1 = \log_2\left(1 + \frac{\alpha_1 P\|h_{T1}\|^2}{\alpha_2 P\|h_{T1}\|^2 + \alpha_3 P\|h_{T1}\|^2 + \alpha_4 P\|h_{T1}\|^2 + \sigma^2}\right)$	[88]
4	* U Rate R2	$R_2 = \log_2\left(1 + \frac{\alpha_2 P\|h_{T2}\|^2}{\alpha_3 P\|h_{T2}\|^2 + \alpha_4 P\|h_{T2}\|^2 + \sigma^2}\right)$	[88]
5	* U Rate R3	$R_3 = \log_2\left(1 + \frac{\alpha_3 P\|h_{T3}\|^2}{\alpha_4 P\|h_{T3}\|^2 + \sigma^2}\right)$	[88]
6	* U Rate R4	$R_4 = \log_2\left(1 + \frac{\alpha_4 P\|h_{T4}\|^2}{\sigma^2}\right)$	[88]
7	* Spectrum Efficiency	$SE = \frac{Th}{BW}$	[88]

*Where;

$i = 1, 2, 3, 4$

M (No of Channels) = 64

Power Coefficients = $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ where $\alpha_1 > \alpha_2 > \alpha_3 > \alpha_4$

QPSK Formed Messages = x_1, x_2, x_3, x_4

R = U Rate

P = Maximum Power

SIC = Successive Interference Cancellation

SE = Spectrum Efficiency

Th = Throughput

BW = Bandwidth

64 x 64 MIMO system and four DL NOMA users i.e. U1, U2, U3, and U4—each with a different bandwidth of 80 and 200 MHz make up conceptualized wireless network. D1, D2, D3, and D4 represent different user distances from the base station; the preferred order is indicated by d1 > d2 > d3 > d4. U1 is viewed as the weak/far user from the base station, whereas U4 is viewed as the strong/near user. Selective Rayleigh fading coefficients identified as h_{T1}, h_{T2}, h_{T3}, and h_{T4} correspond to $|h_{T1}|^2 < |h_{T2}|^2 < |h_{T3}|^2 < |h_{T4}|^2$.

- ***UL Scenario***

PD multiplexing strategy used by NOMA uplink is very different from that of NOMA downlink. The base station (BS) in downlink NOMA uses superposition coding accomplishing power domain multiplexing. However, as users' transmission power constrained by battery capacity in uplink, they are able to transmit at maximum power levels.

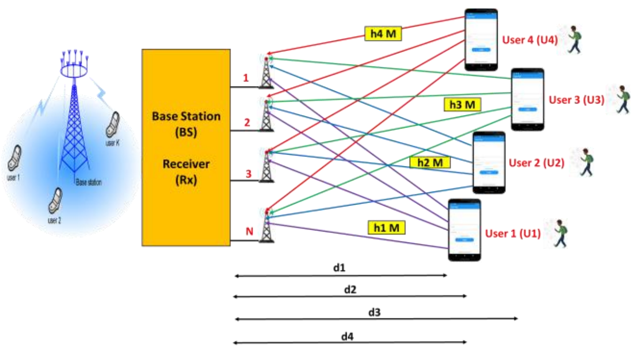

Fig 12: Users 64 x 64 MIMO-UL-NOMA PD

x1, x2, x3, and x4 represent messages delivered by four UL NOMA users (U1, U2, U3, and U4), respectively, in a wireless network with a 64x64 MIMO system and an 80 MHz bandwidth. Users' distances from the base station (BS) are shown as follows: D1 > D2 > D3 > D4; the desired sequence is indicated by D1 > D2 > D3 > D4. Based on their distance, U1 is the far/weak user compared to the BS, while U4 is the near/strong user. Selective Rayleigh fading coefficients are represented by the notations hT1, hT2, hT3, and hT4, where the relationship between fading coefficients and the positions of the users is shown by the following: |hT1|² < |hT2|² < |hT3|² < |hT4|².

Table 4: Design Formulas (UL)

S/No	Description	Formula	Reference
1	* Total Rayleigh fading channel (each user)	$h_{jT} = \sum_{j=1}^{N} h_{jT}$	[87]
2	* Signal Received at the Base Station	$y = \sqrt{P_{U1}}h_{1T} + \sqrt{P_{U2}}h_{2T} + \sqrt{P_{U3}}h_{3T} + \sqrt{P_{U4}}h_{4T} + w$	[88] [89] [90]
3	* Maximum rate User 4	$R_{U4} = \log_2\left(1 + \frac{P\lvert h_{4T}\rvert^2}{P\lvert h_{1T}\rvert^2 + P\lvert h_{2T}\rvert^2 + P\lvert h_{3T}\rvert^2 + \sigma^2}\right)$	[91] [92]
4	* Maximum rate User 3	$R_{U3} = \log_2\left(1 + \frac{P\lvert h_{3T}\rvert^2}{P\lvert h_{1T}\rvert^2 + P\lvert h_{2T}\rvert^2 + \sigma^2}\right)$	[91] [92]
5	* Maximum rate User 2	$R_{U2} = \log_2\left(1 + \frac{P\lvert h_{2T}\rvert^2}{P\lvert h_{1T}\rvert^2 + \sigma^2}\right)$	[91] [92]
6	* Maximum rate User 1	$R_{U1} = \log_2\left(1 + \frac{P\lvert h_{1T}\rvert^2}{\sigma^2}\right)$	[91] [92]
7	* Capacity U4 (specific target rate)	$C_4 = \sum_{i=1}^{N} \log_2\left(1 + \frac{P\lvert h_4\rvert}{P\lvert h_1\rvert + P\lvert h_2\rvert + P\lvert h_3\rvert + N_4}\right)$	[91] [92]
8	* Capacity U3 (specific target rate)	$C_3 = \sum_{i=1}^{N} \log_2\left(1 + \frac{P\lvert h_3\rvert}{P\lvert h_1\rvert + P\lvert h_2\rvert + N_3}\right)$	[91] [92]
9	* Capacity U2 (specific target rate)	$C_2 = \sum_{i=1}^{N} \log_2\left(1 + \frac{P\lvert h_2\rvert}{P\lvert h_1\rvert + N_2}\right)$	[91] [92]
10	* Capacity U1 (specific target rate)	$C_1 = \sum_{i=1}^{N} \log_2\left(1 + \frac{P\lvert h_1\rvert}{N_1}\right)$	[91] [92]
11	* Outage Probability Condition U1	$P_r(C_1(k) < r_1) \| P_r(C_2(k) < r_2) \| P_r(C_3(k) \langle r_3 \| P_r(C_4(k) < r_4)) < r$	[91] [92]
12	* Outage Probability U1	$P_r(U1) = (\sum_{k=1}^{N} P_r(C_1(k) < r_1) \| P_r(C_2(k) < r_2) \| P_r(C_3(k) \langle r_3 \| P_r(C_4(k) < r_4))/N$	[91] [92]
13	* Outage Probability Condition U2	$P_r(C_2(k) < r_2) \| P_r(C_3(k) \langle r_3 \| P_r(C_4(k) < r_4)) < r$	[91] [92]
14	* Outage Probability U2	$Pr(U2) = (\sum_{k=1}^{N} P_r(C_2(k) < r_2) \| P_r(C_3(k) \langle r_3 \| P_r(C_4(k) < r_4))/N$	[91] [92]
15	* Outage Probability Condition U3	$P_r(C_3(k) \langle r_3 \| P_r(C_4(k) < r_4)) < r$	[91] [92]
16	* Outage Probability U3	$Pr(U3) = (\sum_{k=1}^{N} P_r(C_3(k) \langle r_3 \| P_r(C_4(k) < r_4))/N$	[91] [92]
17	* Outage Probability Condition U3	$P_r(C_4(k) < r_4) < r_4$	[91] [92]
18	* Outage Probability U3	$Pr(U4) = (\sum_{k=1}^{N} P_r(C_4(k) < r_4))/N$	[91] [92]

*Where;

$j = 1, 2, 3, 4$

N (No of Channels) = 64

y = Received Signal

w = Noise Power

$R_{U4}, R_{U3}, R_{U2}, R_{U1}$ = Maximum rate when BS can decode data of nearby user (i.e. users 4, 3, 2 and 1 respectively).

OP = Outage Probability

r = User with different target rates (r_1 =1, r_2 =2, r_3 =3, r_4 =4)

C = Capacity of users with different target rates.

C_1 = Capacity of user 1 with specific target rate.

C_2 = Capacity of user 2 with specific target rate.

C_3 = Capacity of user 3 with specific target rate.

C_4 = Capacity of user 4 with specific target rate.

P_f = Outage Probability

N = Number of Transferred Samples

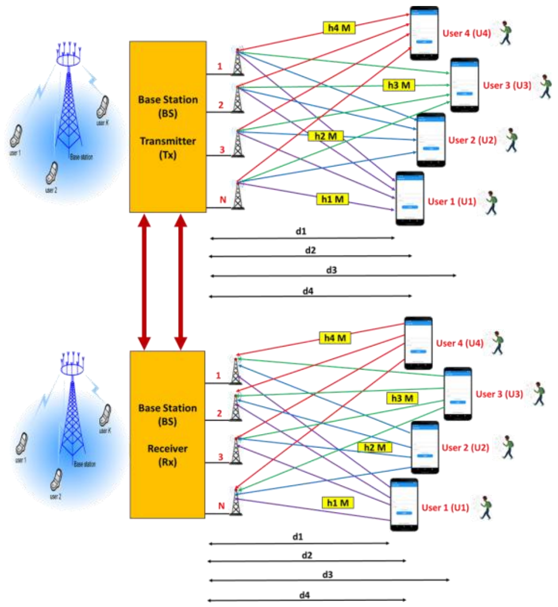

Fig 13: 4 Users 64 x 64 MIMO-DL-UL-NOMA PD

Simulation Parameters

Simulation variables were integrated using MATLAB.

Table 5: Parameters DL

S/No	Parameters	Values		
Downlink Scenario				
1	No of Users		4	
2	Transmit Power		0 to 40 dBm	
3	B/W	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 6: Parameters for Uplink (UL)

S/No	Parameters	Values		
Uplink Scenario				
1	No of Users		4	
2	Transmit Power		-30 to 30 dBm	
3	B/W	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	

IV. RESULTS ANALYSIS

- **Downlink**

- Improved bit error performance (BER).
- Better performance based on spectral efficiency (SE).
- Fixed close user issue

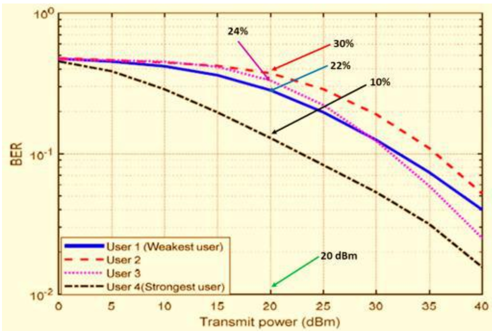

Fig 14: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 80 MHz Bandwidth

As seen;

• The performance of BER decreases with increased transmission power.

• U4 offers the finest BER performance for all customers because it is the closest.

•At 20 dBm transmitter power, BER rates (U1, U2, U3, & U4) are 22.0%, 30.0%, 24.0%, & 10.0%.

Fig below compares performance against transmitted power.

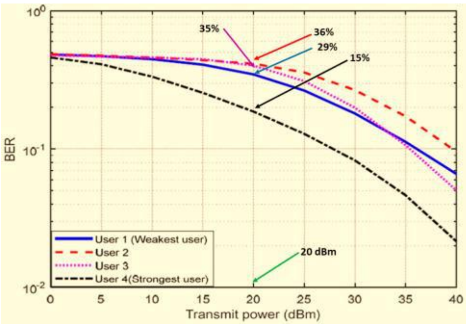

Fig 15: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 200 MHz Bandwidth

The results found that;

- Because of its close proximity to the base station, U4 performs best among all users in terms BER.
- BER rates for U1, U2, U3, and U4 are 29%, 38%, 35%, and 15%, respectively, for a transmission power of 20 dBm.
- With a transmission power of 40 dBm, U4, the top-performing user in the 64x64 MIMO downlink (DL) NOMA system, enhanced its BER performance from 10^-1.48 to 10^-4.93 at a 200 MHz BW and from 10^-1.68 to 10^-5.1 at an 80 MHz BW.
- Furthermore, U4's SE rose by 8 x 10^-2.9 bps/Hz for 80 MHz BW and by 10^-1.9 bps/Hz for 200 MHz BW at a transmission power of 40 dBm.
- The OP for 80 MHz BW at SNR of 1 dB dropped by 14 x 10^-2.9 in UL NOMA systems employing 64x64 MIMO, while the average capacity rate increased to 11 bps/Hz.

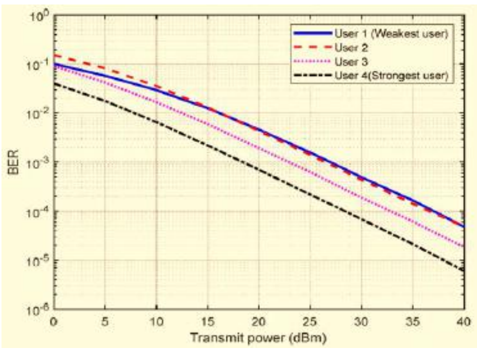

Fig 16: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 80 MHz Bandwidth with 64 x 64 for DL NOMA

As can be seen, MIMO system improves BER efficiency.

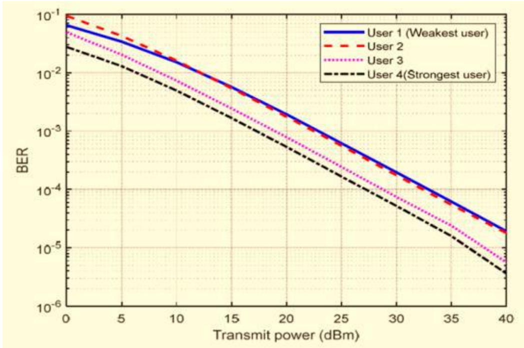

Fig 17: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 200 MHz Bandwidth with 64 x 64 for DL NOMA

Ideal performance (SE) of transmission power and NOMA with an 80 MHz bandwidth is displayed in Figure. The outcomes demonstrate enhanced transmission power and SE performance. User U4 attains the best bit error rate (BER) in comparison to other users because they are the closest user. There is a 5 dBm transmission power difference in each user's SE performance.

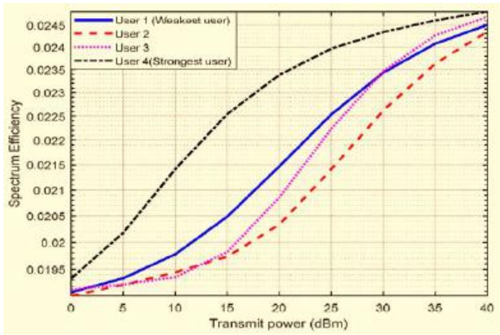

Fig 18: Spectral efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 80 MHz Bandwidth with 64 x 64 for DL NOMA

The SE will perform better and increase the transmission power. Notably, given its close proximity to other users, user U4's SE performance is the most amazing. Additionally, the outcomes show a BER improvement rate of $10^{-2.2}$, outperforming the top user U2.

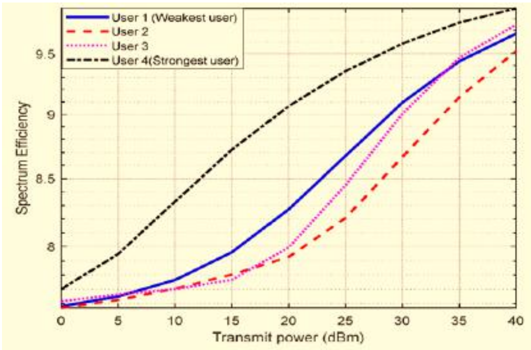

Fig 19: Spectral efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 200 MHz Bandwidth for DL NOMA

In Fig, SE is close for all users @ 5 dBm.

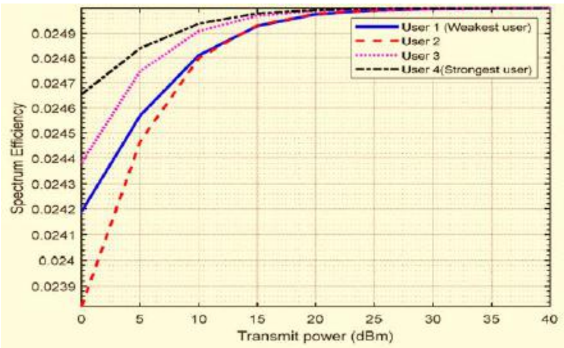

Fig 20: Spectral efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for DL NOMA

SE has improved as a result of MIMO.

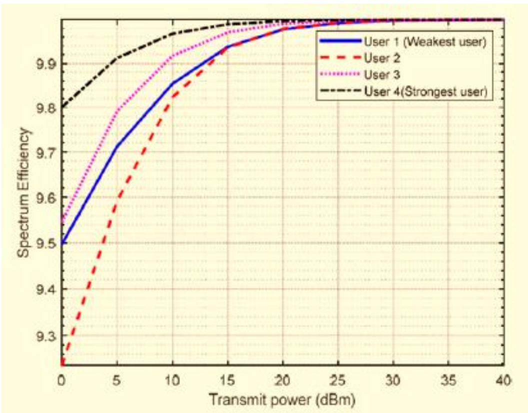

Fig 21: Spectral efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for DL NOMA

- **UL Results & Discussion**

Average capacity rate vs signal-to-noise ratio (SNR) for an 80 MHz bandwidth is shown in Fig 4.9. As a result of being the nearest user, U4 achieves the highest average capacity rate of all users. Specifically, 1.6873, 2.8718, 6.4960, and 12.7814.

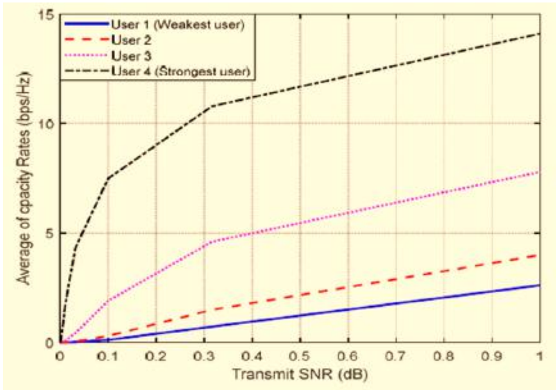

Fig 22: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) and 80 MHz Bandwidth for UL NOMA

Figure show improvement in the average power rating occurs with increasing SNR values. Improvement in average performance rate of 11 bps/Hz when 64x64 MIMO setup is used. As a result of this enhancement, user U4's outage probability (OP) at 200 MHz bandwidth and 0.18 dB SNR was reduced by a factor of 11 x 10-2.9. In a similar vein, the OP was reduced by a factor of 14 × 10-2.8 at an 80 MHz bandwidth and 1 dB SNR. Both average capacity rate and BER increase at the same time. Using MIMO significantly increases throughput for each user.

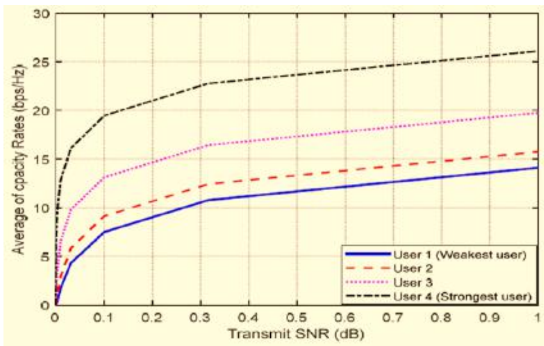

Fig 23: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) and 200 MHz Bandwidth for UL NOMA

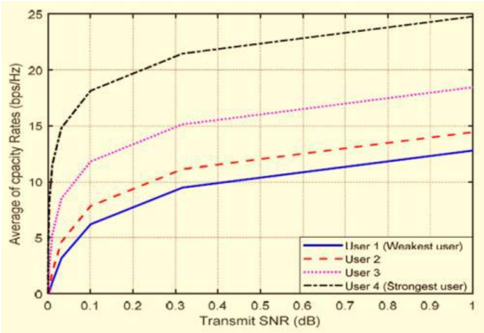

Fig 24: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for UL NOMA

Average capacity rate performance improves with increasing SNR. Data collected at 1 dB SNR for four users revealed the following values: 14.0921, 15.7563, 19.7586, and 26.1820, in that order. U4 performs best at average capacity rate.

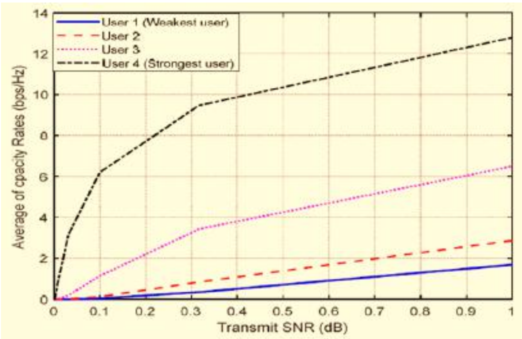

Fig 25: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for UL NOMA

The relationship between OP and SNR for uplink UL NOMA is depicted in Figure, which shows the 80 MHz bandwidth plot. The OP values at SNR of 0.169 dB are shown for U1, U2, U3, and U4.

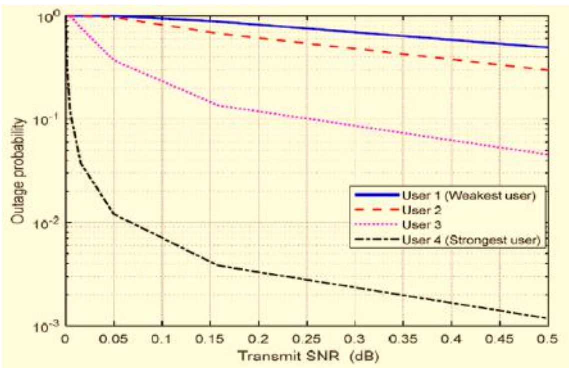

Fig 26: OP vs SNR (4 Users, Varied Distances & Power Coefficients) and 80 MHz Bandwidth for UL NOMA

Results show that the OP performance decreases with increasing SNR.

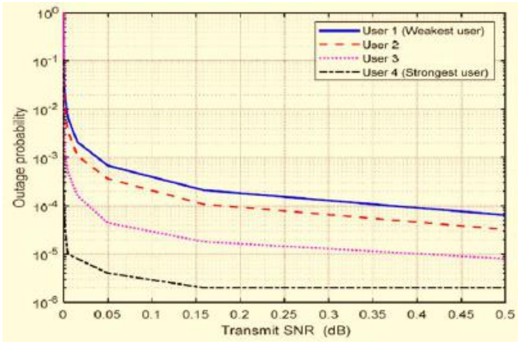

Fig 27: OP vs SNR (4 Users, Varied Distances & Power Coefficients) and 200 MHz Bandwidth for UL NOMA

With 64 x 64 MIMO, UL NOMA of OP vs. SNR is 80 MHz BW. At SNR of 0.169 dB, the findings for U1, U2, U3, and U4 are 0.0061, 0.0026, 0.0002 & 0.0001.

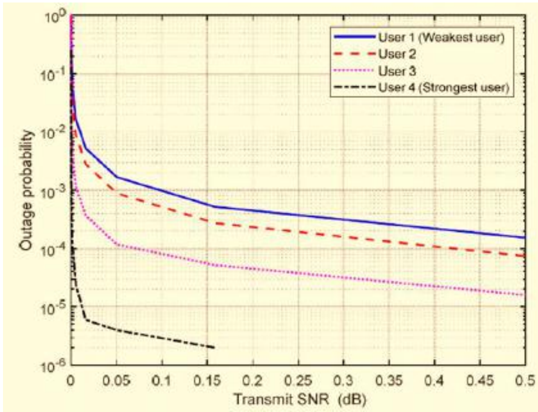

Fig 28: OP vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for UL NOMA

Findings demonstrate negative relationship between two variables, with OP performance declining as SNR rises. OP lowers with increasing bandwidth, and system optimized with MIMO approach, OP drops. OP performed better.

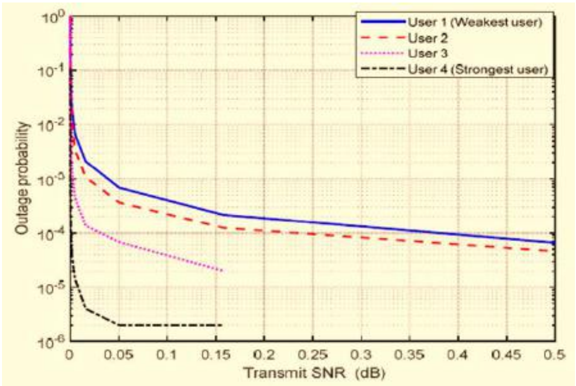

Fig 29: OP vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for UL NOMA

V. CONCLUSIONS

- Checking and analyzing BER and SE for different distances of DL NOMA, power input coefficients.
- Power rate and performance of OP UL NOMA were investigated for various distances, SNR & BW.
- Results of the DL NOMA system showed that the use of 64x64 MIMO improves the BER and SE performance and solves the near-user problem, where each user's performance approaching the work of other users.
- Power transmission, distance, and power distribution are only a few of the metrics that differed between MIMO DL NOMA and non-MIMO. For best-performing user, U4, MIMO DL NOMA 64x64 system showed the best bit error rate (BER), improving from 10^-1.7 to 10^-5.2.
- User U4's performance increased by 0.8% bps/Hz for an 80 MHz bandwidth and by 1.01% bps/Hz for a 200 MHz bandwidth at 40 dBm transmission power in terms of spectral efficiency (SE).
- The results indicated an increase in average power rate for uplink (UL) NOMA systems using 64x64 MIMO, with the best user U4 reaching an increase of 12 bps/Hz. In addition, for 200 MHz bandwidth at 0.17 dB SNR and 80 MHz bandwidth at 1 dB SNR, the outage probability (OP) was decreased by 0.0120 and 0.0150, respectively.
- While BER and average power rate increased, SE and OP decreased as the bandwidth was raised.
- MIMO improves SE performance per-user considerably.

The suggested model includes two bandwidths (80 and 200 MHz), 4 users with various power location coefficients, QPSK modulation, selected frequency Rayleigh fading channels, SNR, and transmit power. The performance of proposed model is assessed using MATLAB software. Results demonstrate MIMO-NOMA enhances the best user's BER performance in comparison to transmitted power in the DL domain.

The strength of the UL was assessed at 80 and 200 MHz BW, average power rating, and OP vs. SNR. For the ideal user (U4) at SNR 1 dB 11 bps / Hz, the MIMO-NOMA model findings indicated a decrease in OP and an increase in average energy rate.

It was found that the suggested network model—which makes use of MIMO-NOMA—was more effective at resolving problems that both indoor and outdoor users encountered. According to the study, MIMO enhanced B5G networks' bit error rate, average power rate, sub-spectrum efficiency, and redundancy. It also assessed the spectral efficiency and bit error rate in the NOMA downlink at various bandwidths, transmission powers, and transfer coefficients. The average power performance and failure risk at various distances, signal-to-noise ratios, and bandwidths were also examined in the study.

MIMO and NOMA technologies are combined to overcome many obstacles in 5G and B5G mobile networks, such as large connectivity issues, less long and more reliable. Channel fading and interference can affect users' performance and may cause their connections to drop. Current literature focuses on how the use of MIMO in B5G can improve and re-evaluate key parameters to increase network performance, such as BER, SE) in DL, average energy density and probability of death (OP) in UL.

VI. FUTURE RESEARCH

The potential synergies between MIMO cooperative NOMA and cognitive radio were not explored in this work. To improve network performance, this topic can be researched upon in future.

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