A Comparative Performance Analysis among Hybrid NOMA Schemes for 5th Generation (5G) and beyond Wireless Communications

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Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing degree at BRAC University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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Abstract

A full-scale implementation of 5G and beyond wireless communication systems require more effective radio access techniques. To address this issue non-orthogonal multiple access (NOMA) technique is considered as a most promising technology in recent times. NOMA is superior in terms of spectral efficiency and user density than the existing orthogonal multiple access (OMA) technique utilizing the limited resources, though NOMA allows controllable interferences by non-orthogonal resource allocation. Successive Interference Cancellation (SIC) can efficiently mitigate the impact of interference when implemented massively, but it raises computational complexity significantly, hence, reduces energy efficiency. In order to alleviate the drawbacks of NOMA, hybrid NOMA schemes have been proposed in recent research works. This thesis work focuses on comparative performance analysis among hybrid NOMA schemes such as MIMO-NOMA, NOMA-GSSK and STBC-CNOMA. The purpose of the work is also to recommend the best suited hybrid scheme for next generation wireless networks. Numerical analysis and simulation results validate the superiority of the NOMA-GSSK scheme in terms of bit error probability and spectral efficiency than other two promising schemes. The findings also suggest that STBC-CNOMA certainly outweighs other two schemes considering system complexity and energy efficiency.

Keywords: NOMA, MIMO-NOMA, NOMA-GSSK, STBC-CNOMA, BEP, Energy Efficiency, Spectral Efficiency, SIC.

Dedication

This thesis research is dedicated to our beloved parents, who have raised us to be the individuals we are today, who have sacrificed their necessity and always been there for us anytime we need them, and who, with their love and goodness, always encourage us.

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List of Acronyms

MIMO	Multiple Input Multiple Output
NOMA	Non-Orthogonal Multiple Access
OMA	Orthogonal Multiple Access
GSSK	Generalized Space Shift Keying
STBC	Space-Time Block Coding
SIC	Successive Interference Cancellation
C-NOMA	Cooperative Non-Orthogonal Multiple Access
SM	Spatial Modulation
BEP	Bit Error Probability
BER	Bit Error Rate
FDMA	Frequency Division Multiple Access
TDMA	Time Division Multiple Access
CDMA	Code Division Multiple Access
OFDM	Orthogonal Frequency Division Multiplexing
FTPA	Fractional Transmit Power Allocation
AWGN	Additive White Gaussian Noise
BS	Base Station

Chapter 1

A Brief Introduction

1.1 Introduction

It is a known reality that a new standard towards wireless communication networks arises to cope with the tremendous growth of digital objects and devices in every 10 years. The desire for higher data rates and less complex smooth networking has led researchers to the new strategies for 5G wireless networks in the fifth century. Until recently, the default methodology to achieve a respectable standard of performance has often been orthogonal multiple access (OMA) techniques [1],[2]Hence, research works are being performed widely overseas in order to fix a common standard for 5G wireless networks to take a step forward towards developing the mobile's future and much further than 2020 broadband networks. The secret to an effective cellular system design is to maximize the amount of times each channel can be reused in a given geographic region. Non-orthogonal multiple access (NOMA) has been recognized in the emerging 5th generation (5G) wireless networks as a promising consideration of multiple access technique to accommodate large number of users in a small area and increase spectral efficiency significantly utilizing limited resources compare to OMA technique [3].

In order to ensure maximum benefit in user performance, NOMA technique relies on multiplexing different users by allocating different power levels to each of them according to their channel conditions in transmitting signal. Then, superposition coding is used in transmitter side to compose the signals and Successive Interference Cancellation (SIC) is implemented in receiver side to detect the desired signal along with bearable increment in system’s complexity. In some recent NOMA research projects, Power Domain (PD) Multiplexing appends a new dimension in NOMA techniques which is worthy for fulfilling the demands of 5G cellular networks [4]. In PD-NOMA power is allocated by the measurement of channel conditions and users positions. Large amount of power is allocated for long distance users with poor channel condition, on the other hand less amount of power is allocated for short distance users with better channel conditions. Such allocation of power makes it simple for the receiver to distinguish signals.

Despite of certain advantages NOMA has some drawbacks. In handling these issues, especially to increase spectral efficiency and to reduce the complexity of the radio system drastically, many researchers proposed different techniques like millimeter waves (mmWave), SSK (space shift keying), MIMO (multiple Input multiple output), STBC (space time block coding), GSSK (generalized space shift keying), and C-NOMA (cooperative NOMA) etc. in making hybrid NOMA schemes for performance improvement of conventional NOMA technique.

NOMA-SSK has been suggested to address the issue of cell-edge users, in which the cell-edge user is multiplexed in the spatial domain to maximize the system's spectral effectiveness by using NOMA and space shift keying (SSK) techniques. A disadvantage of the traditional SSK method is that it can only deliver improvements in diversity. To address this problem, GSSK is proposed. GSSK is nothing but an updated feature of SSK [5]. GSSK methods only determine the cell edge users, the users with lower channel gain. GSSK has its own modulation techniques named as spatial modulation (SM) techniques and antennas are selected in this technique by GSSK mapper. Since selecting all users to perform NOMA is often difficult, it is advisable to incorporate user pairing to reduce the complexity of the system. So at that point, cooperative NOMA is introduced [6]. Following the method of C-NOMA, it is possible to easily group the users as well as reducing the receiver complexity by using less Successive Interference Cancellation (SIC). The recent interest in multiple-antenna data links, also commonly used in various multiple-output (MIMO) systems, was motivated by major capacity improvements and bit error rates (BERs) [7]. The performance of wireless communication networks can be improved by implementing MIMO technique in two separate ways named diversity method and spatial multiplexing. STBC appears as another effective Alamouti coding based technique in some recent works [8], [9]. Space time coding is effective transmission diversity techniques, which are particularly promising for space-time block codes (STBC) due to their low computational complexity.

In this thesis work, we have carried out a comprehensive comparative analysis among hybrid NOMA schemes (MIMO-NOMA, NOMA-GSSK & STBC-CNOMA). The purpose of the investigation is to demonstrate the intuitive insights in order to recommend the suitable hybrid NOMA scheme for meeting up the demand of 5G and beyond wireless communications.

1.2 Motivation & Objectives of the Work:

The volume of network traffic has grown tremendously in recent years due to the large number of users connecting to the network. In addition, the Internet of Things (IoT) boom is anticipated to significantly boost network traffic. Next-generation wireless technology such as 5G are needed to meet this increasing traffic demand to offer benefits such as increased spectral performance, vast connectivity, energy efficient communication systems and quicker response time [1]. Wireless networks of the fifth generation (5G) would accommodate a vast range of links with diverse throughput and latency requirements. The need for significant 5G network coverage and beyond is largely motivated by the explosion of IoT applications, which over the next few years are expected to grow consistently. Several new innovations and standards have been built over the last few years to satisfy the complex demands of 5G and beyond wireless networks. Non-orthogonal multiple access (NOMA) [3], [10], [11] is among them and can be effective to meet the demand of 5G and beyond wireless communications more efficiently than traditional orthogonal multiple access (OMA) systems.

Non-orthogonal multiple access (NOMA) has been generally accepted as a successful way to expand the number of users, strengthen spectral efficiency and promote wireless network user diversity by enabling more than one customers to take a single wireless advantage. Cell-edge consumers face substantially low spectral density in non-orthogonal multiple access (NOMA) system, since only any portion of the overall transmission capacity is assigned. For the paired consumers, this results in poor spectral quality. Usually in NOMA system, multiple user's signals get aggregated through superposition coding in the transmitter side and get decoded utilizing Successive Interference Cancellation (SIC) in the receiver side to detect the desired signal. The exact distribution of transmitting powers for all users along with highly increased complexity due to large number of SIC occurrence for increasing number of users are considered major challenges in conventional NOMA systems.

To overcome the mentioned challenges of NOMA systems, extensive research works are going on in the academia in recent times. Some very high quality research works proposed different contemporary techniques to be integrated with NOMA to enhance the performance of NOMA system. The selection of detailed power allocation and suitable modulation schemes based on very low BER performance is a crucial contribution in [17]. NOMA-GSSK modulation technique can be used to improve the spectral efficiency by exploiting the spatial domain. NOMA-GSSK to resolve this issue in order to maximize spectral performance by leveraging the spatial domain [12]. On the other side, for the fifth generation (5G) and beyond 5G wireless communications, the combination of non-orthogonal multiple access (NOMA) and cooperative communications can also be a very good option. Better spectral efficiency, lower energy consumption, and increased justice can also be generated. If the number of consumers increases, the receiver complexity in the traditional cooperative NOMA increases [18]. In contrast to the two imperfections like timing and channel state information (CSI), the effect of the imperfect SIC on the outage efficiency of STBC-CNOMA is more important [13]. Therefore in contrast with other cooperative NOMA protocols, STBC-CNOMA could be an ideal option for achieving high reliability for the same SIC imperfection status, taking into account the reduced number of SICs in STBC-CNOMA [13].

The research work carried out in [14] regarding performance improvement of NOMA technique highly inspired us to perform further investigation on seeking suitable hybrid scheme to enhance the performance notably and verify its performance with contemporary hybrid NOMA schemes.

In this thesis work, spectral and energy efficiency, bit error rate (BER) and computational complexity have been rigorously analyzed and compared among multiple hybrid NOMA schemes such as MIMO-NOMA, NOMA-GSSK & STBC-CNOMA to identify the well suited hybrid scheme for 5G and beyond wireless communications. To compute bit error probability (BEP) of NOMA-GSSK scheme we attempted differently than [12] in order to implement the simplest equation to calculate the BEP to avoid mathematical complexity of antenna constellation points. The intention of this work is also to analyze the performance of these techniques MIMO-NOMA, NOMA-GSSK and STBC-CNOMA with respect to user’s satisfaction to reduce SIC, BER, on the other hand to increase spectral and energy efficiency significantly. Moreover, in analyzing energy efficiency of the hybrid NOMA scheme we highlighted the significance of considering circuit power consumption to make the results more realistic.

Chapter 2

Literature Review

2.1 Cellular Technology

Due to the rapid changes from 1G to 4G in mobile technology, mobile communications has become more common in recent years. As the number of cellular phone users are increasing enormously day by day, thus we need to develop new and modern technologies and to optimize cellular standard over time in order to meet the increased users ever rising demands. To support massive users within our limited resources, smart and contemporary technologies are necessary. Cellular networks support a large number of users within a small frequency range over a large geographic region. The following figure shows the Cellular Network architecture.

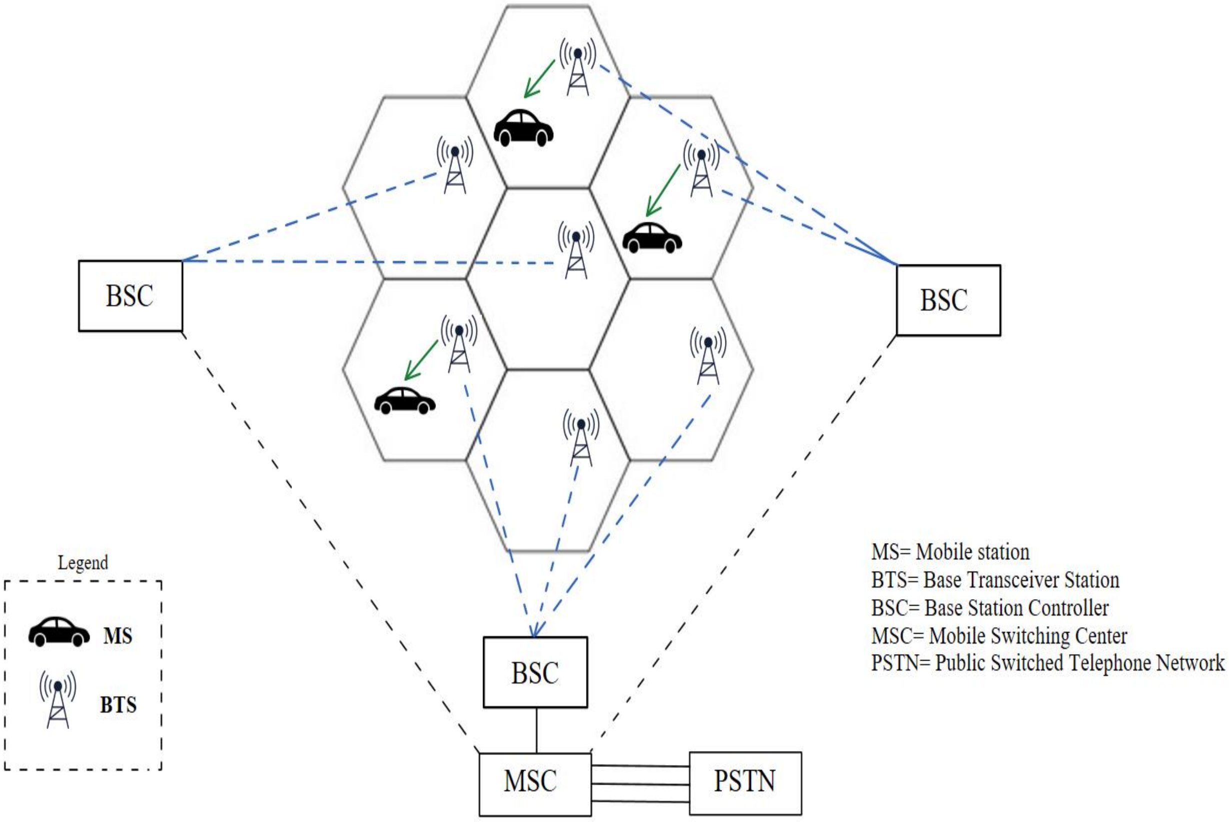

Figure 2.1.1 *Cellular Network Architecture*

Frequency Reuse:

It's the concept introduce with the cellular network to defined frequency spectrum more than once in the same radio system in order to maximize the overall capability of the system without changing the allotted bandwidth [19]. Frequency reuse systems need adequate separation between signals using the same frequencies in order to control reciprocal interaction between them at an appropriate level. Frequency reuse can be accomplished for satellites by using propagation orthogonal polarization states and by using satellite antenna (spot) beams that represent independent, non-overlapping regional areas.

Some arrangements of frequency as follows:

- Base station of specified collective channels in each cell
- A cluster is made up by a group of cells
- Existence of proper number of replicated cells inside the next cluster. Independent channel groups from neighboring cells are often allocated to adjacent cells.

Overview of Generations:

Figure shows the improvement over the years in cellular technology.

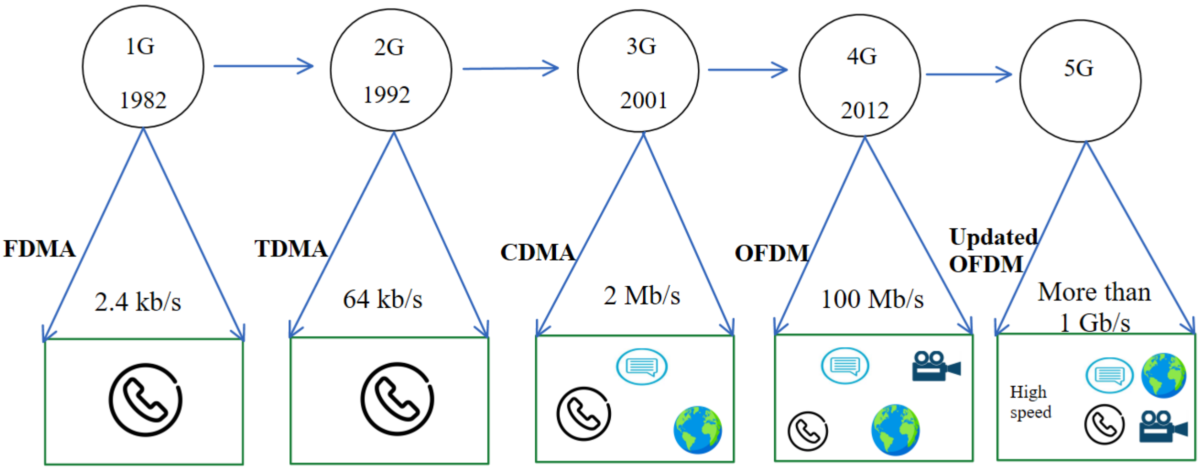

Figure 2.1.2 *Evaluation of Generations*

0G: In the very early age of wireless system, communication was only possible through voice. Typically these cell phones are installed in cars or trucks. These devices were basically half duplex devices and there were also included the technology called MTS (Mobile Telephone System), PTT (push to Talk) as well as IMTS (Improved MTS).

1G: After years the First Generation (1G) was launched in 1895s, where analog cell phones were based on analog communication [19]. In 1G technology, modulation frequency was about 450 MHz which was much higher than the earlier used frequency and Frequency Division Multiple Access (FDMA) is used in this generation. The technologies that was used in 1G was NMT (Nordic Mobile Telephone) and AMPS (Advanced Mobile Phone System) [19]. However in 1G, There were some disadvantages like poor quality, large phone size, frequent call drops, limited capacity and poor hand-off reliability.

2G: So for sorting out this issues here came the Second Generation (2G) in early 1900s [19]. 2G mobile apps were sustainable businesses in 1996. Different multiple techniques were combined in this generation. Early generation was only based on FDMA but 2G also introduced Time Division Multiple Access (TDMA) [19]. It could deliver data at the rate up to 9.6 kbps. More services was included by 2G such as voice, SMS (Short Messaging Service) and MMS (Multimedia Messaging Service) etc.

3G: Mobile communication systems of the third generation (3 G) were introduced around 2000 to provide faster voice, SMS, MMS, video calling and internet services, etc [2]. 3G was basically introduced by the International Telecommunication Union (ITU) called IMT-2000. Packet switching is often used in 3G for voice and data communication, except for the air interface. Digital connectivity, high-speed web and high QoS are some of the primary benefits of 3G due to its equipment creation to address the issue of noise interference, which was a big problem with its predecessor, for enhanced speech efficiency over the air interface. 3.5 G

(HSDPA) are two main variants of 3 G technology that increase the data speed of downlink data transmission ranging from 8 Mbps to 10 Mbps downlink and 3.75 G (HSUPA) which enhance the speed of uplink up to 5.8 Mbps with a reduction in the delay between uplink and downlink [3]. In 3G cellular technology, there are some issues, such as increasing power consumption decreases a device's battery life by making it less efficient.

4G: 4G is the latest generation of broadband networks that potentially replaced 3G networks in the last decade. 4G wireless technology was introduced in 2010, with some substantial changes over its equivalents, such as ITU-IMT adding a capacity of up to 40 MHz and setting its maximum speed requirement of 100 Mbps from one cell to another during handoff. Utilizing multi-antenna MIMO, OFDM upgrades are introduced in 4G [4].

5G: Projects and publications used the term 5G in some articles to define the next advance stage of cellular mobile standards further than the current 4G standards, which are expected to be completed between 2011 and 2013. A new phase of mobile networking technology will be opened up by 5G network technology. The various types of advance 5G technologies and features will be discussed in the following sections.

2.2 Current Era of 4G Cellular Technology

4G seems to be the most innovative telecommunications technology to be replaced by 3G networks. Critical features of 4G technology include accessing information with a flawless link at a certain time, even with a broad range of services that achieve optimal volumes of information, images, data, video, etc. [19]. Dozens IP (Internet Protocol) implementations incorporate the future 4G network infrastructures as a standard protocol to ensure that any user get to choose for each application and environment. Anticipated challenges in this 4G mobile technology that are considered to be solved such as 4G network technology like mobile broadband and less mobility of 1 Gbps for local wireless access would be able to download at a rate of 100 Mbps as well as 4G peak upload speed across 20 MHz wide channels of 128 Mbit/s downlink and 56 Mbit/s uplink [19]. In the implementation of 4G Wireless Networks, security measures must be implemented to promote the most reliable possible data transmission technique. Another major challenge of 4G has to maintain quality of services. Wireless networks ensure that widespread options for uploading music, video and image files without delay are available to all users. Two major wireless standards will be adopted by the 3GPP Organization: LTE and IEEE802.16m [19]. The former is given approval for the further phase while the second is under review and will become part of 4G mobile technology. Mobile WIMAX and LTE-advance technologies are two of the most extreme 4G standard rivals. Mobile WiMAX, for Worldwide Microwave Access Interoperability is a sophisticated mobile broadband wireless network of the next generation based on IEEE 802.16e-2005[38]. Mobile WIMAX is just an extension of the IEEE802.16e. WiMAX can accept data rates with a range of nearly 30 miles, up to 75 Mbps. Mobile WiMAX has proven to be a critical part of the modern and digitized world of today. The need to download and transport data on high-speed mobile devices has driven to the development of new techniques to meet the different demands of mobile computing. It is also a wireless broadband access system. It will have great protection as well as high data transferability, avoid latency, and have the ability to change the bandwidth, restricted to IP addresses. As compared to previous generations of wireless systems, LTE is made up of many new efficient technologies like OFDM (Orthogonal Frequency Division Multiplexing) and MIMO (Multiple Input Multiple Output). LTE utilizes OFDM technology during packet transmission to achieve high data bandwidth by allocating resources such as frequency and time among users orthogonally. In addition to pre-coding and transmission diversity, MIMO operations consist of spatial multiplexing. MIMO technique increases communication systems performance significantly by transmitting and receiving signals through deploying multiple antennas.

2.3 OFDM in 4G Cellular Technology

Using a superior access system, offering higher data speeds in the order of several hundreds of Mbps or even Gbps, for both stationary and mobile users, combine with an all-IP scenario, extended to the core network, 4G can best be thought of combining an advanced radio interface system. Multi carrier approaches are linked to most of the modulation/demodulation and multiplexing/multiple access schemes due to the high data rate requirements of 4G networks and are proposed by all research initiatives. As far as 4G standard issues are concerned, orthogonal frequency division multiplexing (OFDM) based modulation appears to be the most exciting trend [20]. OFDM, since it uses a digital block that can map and allocate different subcarriers orthogonally for each user, allows multiple access networks. OFDM output not only shows better performance based on browsing speed but also by maintaining the ability to manage multipath fading channels almost perfectly. In order to be introduced in 4G networks the efficient use of OFDM in different standards used so far, such as digital audio broadcasting (DAB), terrestrial digital video broadcasting (DVB-T), terrestrial integrated services digital broadcasting (ISDB-T), IEEE802.11a, HIPERLAN/2, IEEE802.11g, IEEE802.11h and IEEE802e provides all the theoretical context provided by the various standardization bodies [20]. There are also various uses of OFDM in LTE and WIMAX, for instance frame structure, subcarriers resource mapping, frequency diversity, multiuser diversity and interference diversity. The advantage of OFDM in digital broadcasting and communications, especially in multipath propagation, interference and fading environment makes the technology a promising 4G alternative.

2.4 Drawbacks of Orthogonal Multiple Access (OMA) Technique

Wireless networking system have experienced a revolution in terms of their multiple access methods over the last few decades. Sophisticated methods of multiple access (MA) have also been viewed as one of the most basic enablers, which have developed dramatic in successive generations [40]. Particularly, multiple access frequency division (FDMA), time division multiple access (TDMA), code division multiple access (CDMA) and orthogonal frequency division multiple access (OFDMA) have been used as the corresponding primary multiple access technologies for 1G, 2G, 3G and 4G wireless communication systems, respectively. The multiple access (MA) methods can usually be split into two groups, orthogonal MA (OMA) and NOMA schemes. OMA techniques consists of Frequency Division Multiple Access, Time Division Multiple Access and Code Division Multiple Access. They enable information to be transmitted the spectrum. But with the growth of users, OMA has become a default approach to wireless communication.

There are some major drawbacks in OMA technique:

- Because of resource splitting, OMA systems also could not deal with the huge networking requirements including its IoT-based upcoming 5G networks, as the number of users that could be served is restricted by the amount of orthogonal programs offered.
- Channel-induced impairments almost always destroy their orthogonality by using orthogonal time, frequency, or code domain.
- The radical spectral efficiency and large networking requirements of 5G remain a challenge for OMA to address.

To serve more subscribers than the number of available orthogonal time-domain, frequency-domain, or code-domain resources, the revolutionary idea of non-orthogonal multiple access (NOMA) has been proposed. We will discuss about it in detail in the following pages.

2.5 **Emerging 5G Cellular Technology**

ICT (Information and communication technologies) is been considered to be essential additive system for social and economic growth, therefore, new advantages and accommodation have been developed which have not been encountered before. Until coverage is significantly expanded, 5G will coexist with current 4G networks, but it will eventually evolve into a standalone network that operates independently. Instant cloud platforms, touch internet, eV2X (enhanced vehicle-to-everything), the Internet of Things (IoT) and contact with automation and drones cannot be supported by the existing 4G/LTE networks, thus maintaining the quality of experience for smartphone users. Like the particles surrounding 4G continues to settle, new focus is shifting steadily forward into potential 5G development. Upcoming 5G networks can still be built in many guidelines by incorporating new content, such as 360-degree scanner and recording, news notation of services, such as smarter mobility and authentication service connection, in this instance, limitless data transmission, a significant quantity of active connections and different style of mobile devices particularly sensors, powered by renewable energy sources [21]. 5G is the next generation of mobile networks, and it's an enormous move forward from what we have now. The jump to 4G networks from 3G was pretty huge. Yet 4g to 5g is several times bigger and hard to comprehend. Innovative improvements in each wireless technology and core networks are expected to deliver 5G services efficiently. 5G will brought a huge change in our daily life. Some major changes are described below:

Exploitation Mobile Data Traffic:

In 2020, the volume of mobile data flow will be 8.3 times greater than in 2015[21]. The response for mobile data flow has increasingly boosted as mobile multimedia content Social media sites and broadcasting are becoming more and more prominent.

Rapid Rise in Linked Devices:

Another way of network evolution is necessary for the increase of active connections. In response to the amount of network traffic, the number of mobile devices has risen significantly by adding innovative product styles, including smart watches, cameras, cars, automation and drones. Globally, the demand for mobile devices and other Internet-connected IoT module is projected to rise from USD7.9 billion in 2015 to USD11.6 billion in 2020 [21].

Big Data Analytics:

Big data analytics is expected to generate new possibilities in different reserves therefore, the importance of data can be derived by information collection, flowing, predictive review, inference, etc. The properties of big data analysis, particularly in the field of information technology and machine learning add a new dimension in the field of ICT.

Cloud Computing:

Mobile cloud computing has become one of the most important technologies for accessing power transfer mobile networks via simpler smart devices. In addition, most telecommunications networks are anticipated to be merged for the mobile computing cloud infrastructure in the 5G era.

The ITU-R categorizes 5G networks in 3 types, including eMBBB services, DRMTC and URLLC [22]. NGMN recommends 14 types of facilities and 24 instances in use and 3GPPP proposes 97 use cases for 5G mobile services [22]. Low latency and mobility are the most noticeable one in some URLL C operation conditions. 3GPP SMARTER has progressed a number of use cases covering various categories of service. The new possibilities for the operation can be divided into five groups, as seen in the diagram below [23]:

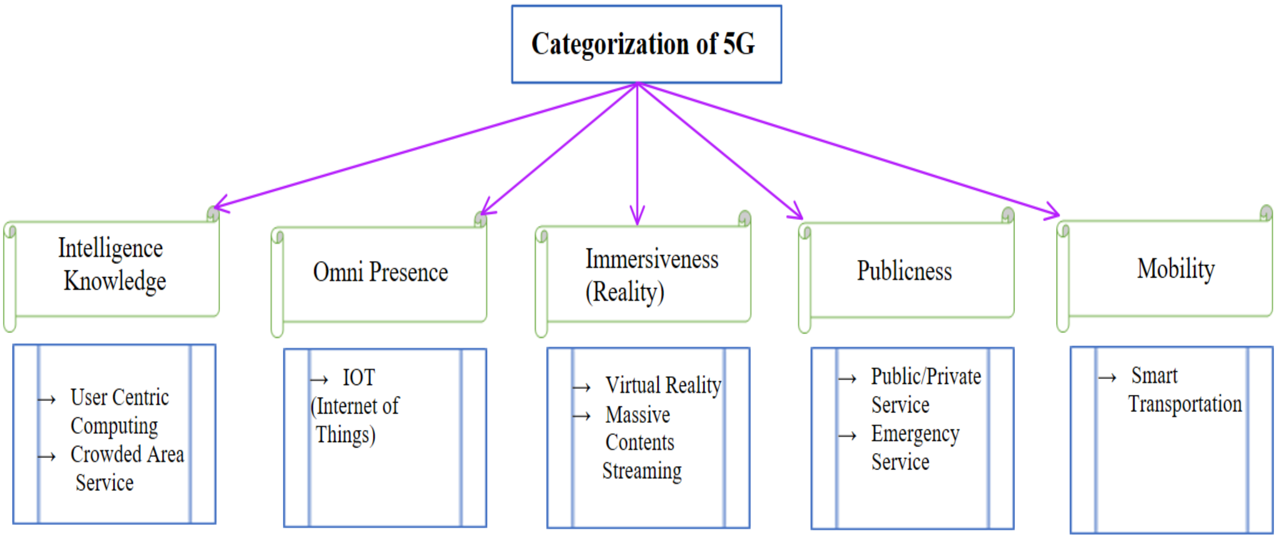

Figure 2.5.1 *Categorization of 5G*

Intelligence:

After identifying, trying to interpret and implying contextual data based on big data collected from different detectors, the consumer receives information. Because of the growing amount of devices and traffic on data, future networking system are projected being more crowded. In order to provide a prompt reaction in the event of a disaster, mobile computing can play a key role to accurately interpret big information from sensor data and it can assist to alert people who are at risk in order to reduce the loss. Crowded areas may be a cause of large quantities of traffic, such as stadiums or concerts. In order to promote intelligent 5G infrastructure, in particular crowded region networks, dense small cell networks cannot be excluded. The existing low-volume content is replaced by UHD and 3D multimedia content, and a higher transmission rate is enabled by 5G networking. Local caching systems are important for the 5T service aim of providing data from local servers.

Internet of things:

Along with compared to 4G, 5G incorporates large number of heterogeneous devices with different characteristics. Smart private platforms include smart phones, savvy glasses, different devices for telemedicine, and motion recognition systems. It is estimated that the value of the demand for these devices will rise to 162.9 million units in 2020[21]. By making use of Big Data technology in order to filter traffic flow information, IoT is supportive in developing efficient infrastructure in cities. The international mobile subscriber identity (IMSI) would soon be depleted by the huge rise in network-connected devices [21].

Enveloping:

VR and AR are the main elements of potential experiences. The use of VR/AR for long periods leads to tiredness and eye strain. To solve the image quality problem, anticipated 5G networks 4-K or 8-K resolutions would have to be managed. By supplying the customer with the capacity to utilize the sensory experiences, teleconference programs need to be more practical. Facilitating VR/AR and teleconferencing facilities in real-time, 5G needs transmission and mobile communications with low latency technology with an incredibly fast rate of data. 5G technology should be able to stream Ultra High Definition (UHD) 4-K and 8-K video [22]. 5G is intended to support expanding multimedia facilities. 4G has a transfer rate of 1-Gbps, but it is also unable to offer holographic telecommunications services. The most desirable aspect of the 5G technology is hologram generation and distribution.

Collectiveness:

Networks should be reconstructed with base stations for mobile devices and key cellular networks as soon as possible in crisis situations. In those cases, infrastructure less networks can only be set up on smart phones. 5G focuses on providing advanced security mechanisms. The 5G technology will enable key operational networks to conclude extremely increased performance and widespread coverage. If a collision in a remote area happens and emergency measures are needed, first aid robots can be used to provide medical care. Ultra-reliable wireless transmission with its tolerable delay of 1 ms, for certain kinds of emergency care is the expectation in 5G wireless networks.

Mobility:

Smart transport refers to a transport system that allows greater protection, greater productivity and quality to be enhanced. These are some of the key allowing technologies for such intelligent transportation networks where 5G combined with AI. Connected cars and RSUs under a dedicated heavily secured, excellent quality, and cloud services transportation network can provide prevention of collisions and pathways optimization infrastructure. The intelligence of autonomous-driving cars is to acknowledge, determine and monitor accordingly. The definition of platooning of vehicles applies to vehicles that move together by following a lead vehicle. 5G technology is important for the provision of real-time connectivity in future cars, and it will open up the potentially broad smart transportation market for wireless operators by burning low latency into the 5G network architecture. Localization is also one of the essential criteria for the acquisition of correct vehicle information for autonomous-driving vehicles.

The specifications of 5G networks for wireless technology to be offered for each service are listed below [22].

Massive connection: Identify all devices worldwide and provide per square kilometer, one million terminals with services.

High reliability: Providing the provision of facilities in an extraordinary scenario as well as guarantee a single packet transmission

Low latency: Reduces the data transmission time.

High mobility: Effective in moving devices.

High energy efficiency: 5G devices are ultra-energy efficient

High cost effectiveness: 5G devices reduces the implementation cost especially in sensors.

Ultra high speed: Providing up to 1 Gbps of data rate encountered by users.

There are several technologies in 5G which technologies make 5G a powerful component for future generation [22]

1. Heterogeneous Network:

- **Small cell:** As the need for higher rates of data grows, reducing the size of the cell is one of the options available to operators. With low operated femto cells commonly used in existing construction and business installations, small cells may have various flavors. For broader Outdoor coverage or filling in holes in coverage of macro cells, higher powered pico cells are used [23].
- **Device to Device Communication:** There are not any additional expenses for linking devices with explicitly neighboring devices in 4G cellular communications. The amount of devices that were engaged can theoretically be very high in situations for instance, machine to machine (M2M) communications. To allow the connections, Device to Device (D2D) communications would quite definitely involve the base station [23].

2. Cellular Specified Software Network:

   Cellular Specified Software Network has gained significant attention in the communication industry in recent years, alongside the advancement of software-defined radio in wireless communications.

3. Massive MIMO and 3 Dimensional MIMO:

   Usage of a large antenna system components, many Orders that surpass the volume today in use, is another technology that is being considered. Massive MIMO will supposedly increase the power by many orders and increase the radiation intensity efficiency at the same time. [24]. It also allows for high resolution beamforming. Significant amounts of channel state data will be needed for beamforming. For FDD systems, massive MIMO can be impractical, but because of channel reciprocity, it can be used in TDD systems. A scarcity of channel types is noticed for IMO systems for Massive MIMO. 3D MIMO that allows for 3D beamforming is another important technique currently considered. Within a cell, this additional control allows more sectored [24]. 3GPP has begun to work on 3D channel modeling.

4. Machine to Machine Communication:

   Many Autonomous connectivity among systems includes new business fields. The capacity for these new applications to cause the size of telecommunications industry to shift gradually. Unique to M2M communications, there are many challenges, not least the functioning efficiently and sometimes limiting control, requirements for size and complexity.

5. Other Technologies:

- **Millimeter-wave:** The usable bandwidth below 6 GHz is small and the re-farming of the analog TV spectrum would not satisfy demand. Millimeter wave frequencies are the most promising, and attempts to make this a reality are already underway. The attributes of higher frequencies and calculation initiatives and channel modeling are not well studied and that will be required.
- **Shared Spectrum:** Cognitive radio has also been encouraged as a response to the situation of frequency spectrum shortages. Authorized Spectrum Access is the alternative approach suggested that could theoretically solve this problem. Based on certain conditions, the LSA (Licensed spectrum access) is intended to enable approved users to access the licensed spectrum.

Although there is nothing at current strong agreement between academics and industry on the concept of 5G Ethernet networks. Therefore, future cellular 5G networks are going to be a mix of various technology facilitating and the greatest problem tends to be to work together with all of them.

2.6 Prospects of Non Orthogonal Multiple Access (NOMA) Technique

The rapid growth of the mobile Internet and the Internet of Things (IoT) is leading to make specifications for wireless communication systems of the 5th generation (5G). NOMA is one of the optimistic innovations that will lead to revolutionary improvements in radio access architecture and also solve the aforementioned challenges of 5G and beyond wireless networks. The basic concept is to promote the allocation of non-orthogonal resources among users with the controllable cost of raising the complexity of the receiver needed to distinguish non-orthogonal signals [25]. NOMA's primary objective is to explore multiplexing of the power domain to serve multiple users at the same time, frequency, or code domain. The signals of multiple users are multiplexed with different received power at the BS over the same subcarrier. Based on the disparity between their channel conditions, the modernity of NOMA is to efficiently distribute the different transmission power to multiple users. NOMA is basically divided into two groups: Power-domain multiplexing NOMA (PDM-NOMA) and Code-domain multiplexing NOMA (CDM-NOMA) [25]. In PD-NOMA, resource allocation flexibility to boost NOMA performance. By implementing redundancy through coding/spreading, the CDM-NOMA facilitates user separation at the receiver. Most of the existing NOMA survey papers concentrate only on the power-domain NOMA system [11] and some code-domain NOMA schemes are briefly added [25]. In this thesis work, our major focus was on PD-NOMA based hybrid NOMA models.

There are some expectation from NOMA which may fulfil the demand for 5G [11] is huge networking and the 5G IoT functionality can be effectively promoted by using NOMA. Along with the idea of NOMA will receive considerable attention from the study of visible light communications (VLC). In VLC frameworks, the application of NOMA will support more users. Hence, the NOMA principle will be able to apply to large-scale cognitive radio inflation decreasing Networks, in order to improve secondary network connectivity.

An integrated NOMA will be Part of the wireless networks of future generations. In order to achieve the key performance requirements of 5G and beyond radio networks, NOMA is considered as a most promising technology to provide high system throughput, low latency, and massive connectivity.

2.7 Benefits of NOMA over OMA Technique

Among all multiple access techniques, as a participant, NOMA has been recognized as having critical features to address OMA challenges and to satisfy the expectation of potential mobile communication systems[1], [10]. The major advantages of NOMA over OMA can be noted as follows:

Massive connectivity:

- Non-orthogonal resource allocation in NOMA indicates that the amount of reasonable subscribers is not limited strictly to the number of orthogonal resources available. In rank-deficient situations, NOMA is therefore able to dramatically increase the number of simultaneous links, so it has the ability to support huge number of increasing subscribers by utilizing the limited resources.

Spectral efficiency and throughput:

- In OMA, as in OFDMA, even if the channel condition is good or poor, the same frequency capability is assigned to each user; thus the overall device suffers from low spectrum efficiency and throughput. On the opposite, the same frequency assets in NOMA, with good and poor channel conditions, is distributed to different mobile users at the same time. Therefore, as depicted in Figure, the probability of enhanced spectral performance and high throughput would be dramatically increased.

Compatibility:

- NOMA is popular through existing and future multimedia applications as well, as the existing architecture does not need major modifications. NOMA has been included in the standards in the third generation long-term evolution advanced collaboration project (3GPPLTERelease13). In LTE, a downlink variant of NOMA, Multiuser Transmission Superposition (MUST), has been used.

Low latency in transmission and cost of signaling:

- A user must first submit a scheduling request to the base station for a traditional OMA based on access grant requests at base stations. Then the BS activates the user's uplink transmission upon receiving this message by interacting with a clear-to-send signal on the downlink channel. Thus a high transmission latency and high overhead signaling would be placed, which in the case of massive 5G-style networking becomes undesirable [26]. On the contrary, NOMA, which is capable of substantially reducing both transmission latency and overhead signaling, will benefit from grant-free uplink transmission. The SIC method can impose additional latency on some NOMA schemes using SIC receivers.

OMA's inadequate performance makes it relevant and unacceptable for future generations of wireless communication systems to include the functionality required to be met. As a consequence, researchers suggest NOMA as a credible candidate to be considered as an alternative and promising multiple access technique for the next generations wireless communication systems.

Chapter 3

Performance Enhancement of NOMA

3.1 Limitations of Emerging NOMA Technique

For next-generation cellular networking, non-orthogonal multiple access (NOMA) is identified as a successful multiple access strategy. Recently, NOMA has been disclosed as an impressive multiple access technique for 5G and beyond 5G wireless networks. The fundamental belief of NOMA lies in several users' overlapping use from the same radio spectrum by allocating resources non-orthogonally.

Until NOMA is getting to be the section of 5G in the near future, there are also several other challenges that must be tackled. The transmitter pays the power to the users depending on their own CSI in a downlink situation. For example, for the achievement of robust efficiency, an appropriate System for CSI responses, an effective channel approximation scheme with proper source signal architecture, is therefore necessary. Just in the desired state of perfect sourcing of CSI data on the transmitter side NOMA is verified. The PAPR (peak-to-average-power ratio) will happen the power amplifier (PA) of the transmitter to operate through a non-linear operating area in multicarrier communications. The influence of PAPR is crucial to determine what approaches need to use to achieve the best NOMA performance [27]. For the purpose of exploiting the full privileges of NOMA, multiple shortcomings and deployment challenges need to be resolved [3], for example,

1. Each consumer wants to decipher all other users' information with worse channel benefits (that are in the same cluster) while decoding its own data [28], resulting in increased complexity of the receiver and energy consumption relative to OMA. The BS

must realize the idealize channel state information (CSI) to orchestrate the SIC compiling arrange, which increments the CSI criticism overhead.

2. If a mistake occurs with a user's SIC, it is possible that the resulting encoding of all other user information will be carried out inappropriately. To reduce the impact of error propagation, this means keeping the number of users in each cluster relatively low. A greater computational complexity and delay on the receiver side is added by the SIC method especially for multi-carrier and multi-user systems. In order to execute SIC, the strong users must realize the power distribution of the weaker users, which also raises the overhead signaling of the system. More inter cell interferences can be implemented into the whole device by assigning more resources to the vulnerable consumers, who are usually in the cell-edge [28], [29].
3. A substantial channel gain differential between the strong and weak users is required to achieve the stated advantages of power-domain multiplexing. Intuitively, this limits the usable number of user pairs, which in turn decreases NOMA's sum-rate advantage.
4. Channel gains (which are in the same cluster) while decoding its own data, resulting in increased complexity of the receiver and energy consumption relative to OMA.Each consumer needs to send back to the BS their channel gain results, and NOMA is naturally susceptible to the ambiguity of this gain calculation [27].

3.2 Performance Improvement of NOMA Technique

Saito et al. first discovered the ability of NOMA for 5G cellular networks [1] and revealed that in terms of capacity and user-fairness, NOMA outperforms OMA. Since then, scholars around the globe have begun to explore how to turn the NOMA definition into the radio connectivity strategy of the next century. Many early studies on NOMA concentrated on single-input single-output (SISO), in which the key issues are power distribution and consumer fairness. In

NOMA, power distribution is not purely directed at optimizing the sum rate, but takes into account the sum rate and consumer fairness as a whole. This is because if the aim is to increase the sum rate, NOMA would delegate all power to the efficient consumer, and therefore gives little gain over OMA. A hierarchical power distribution scheme is proposed in [30], which means that the individual rates for both strong and weak NOMA users are higher than those for NOMA users. In OMA, the corresponding ones, [31] considers the max-min data rate and min-max chance of outage, respectively, in terms of device fairness. Since the problems formulated are non-convex, polynomial algorithms of low complexity that yield the optimal solution are built in both cases. By integrating it with the multi-input multioutput (MIMO) technology, the efficiency of NOMA can be further improved. Users are paired into clusters in MIMO-NOMA, and NOMA is implemented only between users in the same cluster. To obtain the optimal user pairing is non-trivial, since an exhaustive search is necessary. Despite all the related studies, because of the high computational complexity of performing SIC in the receiver side, NOMA is still not commercialized in recent decades. However, the exponential increase in the computing capacity of microprocessors has been given the standardization and commercialization of NOMA technologies an incentive in recent years. LTE Release-14 in 2017 recently specified downlink nonorthogonal transmissions, featuring multi-user sharing technology (MUST) [32]. Through applying the principle of signal synchronization, a novel MIMO-NOMA system for downlink and uplink transmission is introduced in [33]. Closed-form analytical results are generated by using stochastic geometry to promote the performance assessment of the suggested system for randomly deployed users to alleviate the computational pressure. In order to determine the likelihood of device outage and average attainable cost, in [34] establishes theoretical mechanisms for NOMA downlink and uplink multi-cell wireless systems. Two separate NOMA group pairing schemes are in the downlink NOMA system. Considered on the basis of which theoretical conclusions are extracted on outage and achievable data rates. The updated back-off power management framework is introduced in [34] the uplink NOMA and the likelihood of outage and the average achievable rate per UE are extracted. As wireless devices become highly heavily distributed, inter-cell interference has become a dominant power limiting factor, but most of the recent NOMA studies have not discussed it. The various uplink and downlink requirements and for each individual user give clear insight into the selection of suitable users in two-user NOMA clusters, and their numerical findings illustrate the importance of the derived conditions for the selection of users in uplink/downlink NOMA clusters and provide a comparison of the selection of random users [35].

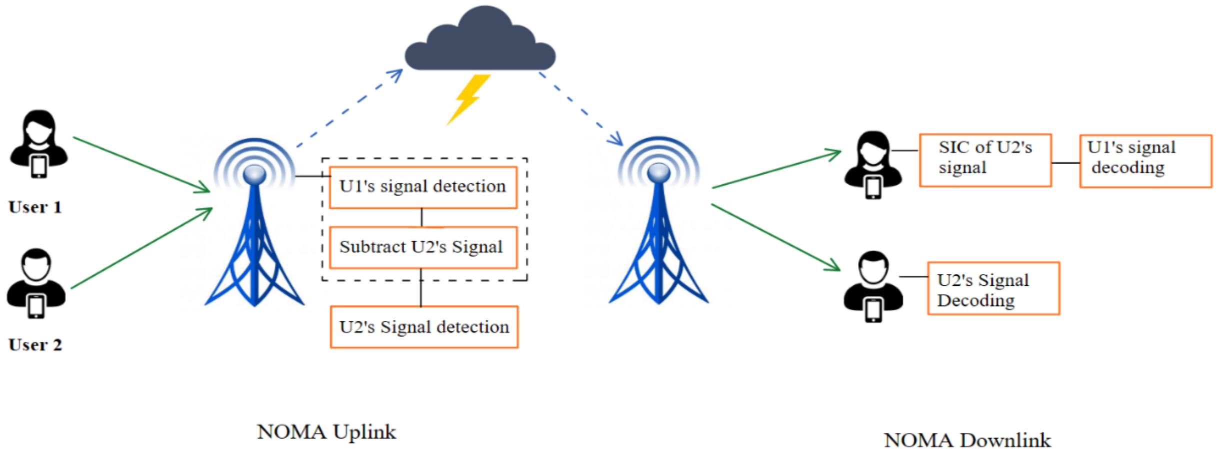

Figure 3.2.1 *An example of NOMA uplink and downlink system*

Several new systems have been built over the past decade to meet the complex criteria of 5G and beyond wireless networks integrating promising technologies such as Multiple-input multiple-output (MIMO) and large MIMO, millimeter wave, cognitive and cooperative communications, physical layer surveillance, visible light communications, energy storage, mobile edge computing. NOMA can be flexibly integrated with many other current and evolving technologies to minimize the limitations of this potential technology in order to fulfill the demand of 5G and beyond wireless communications with greater efficiency. To further maximize the number of users and improve device efficiency in multiple ways, NOMA can be paired with some auspicious technologies describe in [36].

3.3 Generalized Space Shift Keying (GSSK) Technique:

SM (Spatial Modulation) has emerged as being a very successful strategy to further explore the ability of low-complexity transceiver MIMO technique [37]. It enables details of data to be transmitted in two forms: via a diagram of the spatial constellation and via a diagram of the signal constellation. Recently, SM has described itself as an effective principle of propagation that belongs to the family of fractional-RF MIMO wireless systems. Although using a small quantity of RF chains, SM-MIMO at the transmitter takes advantage of the complete antenna system. Since SM only activates one transmitting antenna at a time, it decreases by avoiding the use of numerous RF chains, the hardware in the transmitter. SM does not need specialized identification systems at the receiver because of the lack of inter-channel interference (ICI). The simplest method of SM, called space shift keys (SSK) modulation was proposed in [38] where signals are transmitted using only the transmitter antenna indices. SSK is also seen to have lower complexity and better error efficiency with a modest number of transmit antenna compared to other traditional MIMO approaches such as space time coding in [39] and space-time layered vertical bell laboratories in [40]. In traditional SSK, however the diversity capacity of MIMO systems is not fully explored where only diversity gain is obtained via the multiple receive antennas but no diversity transmission is achieved. The detector complexity for SSK is minimized relative to SM because the information in SSK is only represented by the presence or absence of energy from the triggered antenna for transmission. In order to concurrently relay a data symbol, generalized spatial modulation (GSM) enables more than one transmission antenna at a time. In the triggered mixture of transmitting the transmitted symbol and the antennas, the transmitted information is transmitted from the constellation of the signal. A block with bits of information is mapped in GSM towards a symbol of the constellation and a spatial symbol. The spatial representation is a blend of transmission antennas that are controlled in each case. By base-two logarithms, GSM enhances the cumulative spectral effectiveness [41]. As is the case with our GSSK system, the demonstration of SM in [42] did not thoroughly discuss the concept as the only way to use the antenna indices of relaying information. Although SM has been shown to decrease the complexity of the receiver relative to V-BLAST, this is beyond a semi detection of SM law. However, under traditional channel assumptions, the optimal detector for SM is extracted from [43]. Consequently, compared to SM, the quantity of transmit antennas needed to accomplish a definite spectral efficiency is dropped significantly by more often than half in GSM and the generalized space shift key modulation (GSSK) has suggested to overcome the issues.

A perfect candidate for possible wireless applications is generalized space shift keying (GSSK). In wireless communications, GSSK implicitly inhibits fading to provide better efficiency. Over typical multiple antenna APM systems, findings indicate efficiency improvements (1.5+3dB) [43]. GSSK's transmitted symbols are only a way of defining the triggered antenna. All of the above-mentioned SM advantages gained when reducing the overhead transceiver are thus accomplished. The constellation of GSSK is extensively analyzed, where the fundamental concept that enables GSSK to transcend APM schemes (such as V-BLAST and MRC) in [44]. In precise, by increasing the dimension of the constellation, whose points are well spaced apart, GSSK takes full advantage of the mechanism of fading.

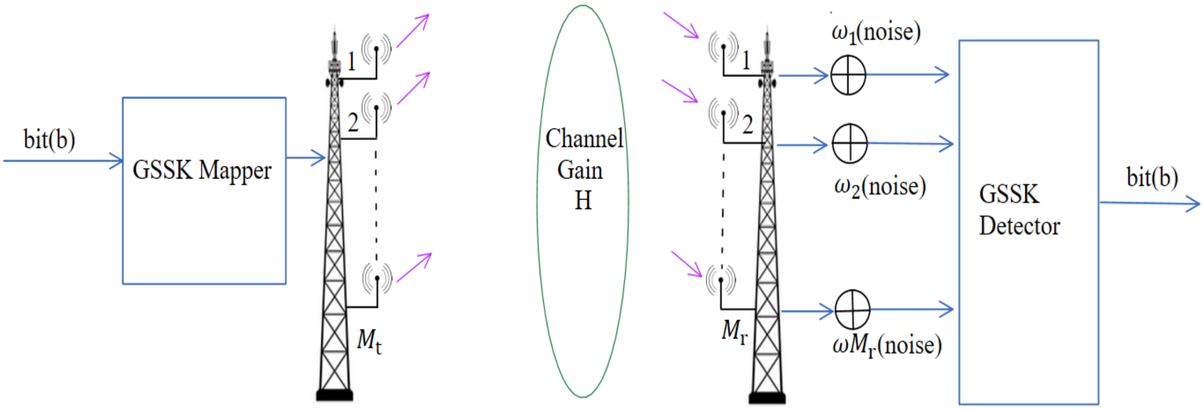

***Figure 3.3.1** GSSK Model Framework*

A MIMO wireless communication with M_t transmit and M_r receive antennas consists of the general device model. The figure (GSSK model framework) demonstrates, the GSSK mapper enters a unique series of independent bits b = $[b_1\ b_2 \dots b_k]$, where m-bit categories are assigned in a constellation vector x = $[x_1\ x_2 \dots x_{M_t}]^T$, with a unity power ($E_X[X^H X]$=1) restriction. The signal is transmitted through a wireless $M_r \times M_t$ channel H and encounters a M_r -Dim white Gaussian (AWGN) noise, ω= $[\omega_1, \omega_2 \dots \omega_{M_t}]^T$. In GSSK, the underlying principle only requires antenna equities to relay information. For that reason, mixture of antenna equities will be included in users. The GSSK tracker calculates the antenna equities which are included during transmission on the receiver side and remaps the symbol to its constituent bits $\hat{b}$. By using M_t active antennas, potential constellation points for GSSK would be the combination of M_t and M_r, $M = \binom{M_t}{n_a}$. Where, M is the size of constellation need to be in terms of multiples of 2, thus the chosen value will be the nearest combination of desired value of M. A random M collections of antenna configurations can be picked. The GSSK mapper law is clear until antenna combination is formulated. Furthermore, m-bit categories = $\log_2(M)$ bits were gathered and plotted to a vector $X_j \triangleq [\frac{1}{\sqrt{n_a}} \dots \dots 0..0\ \frac{1}{\sqrt{n_a}} \dots .0..\frac{1}{\sqrt{n_a}} \dots ..0]^T$, where the antenna mixture for the defined pattern of m bit is defined by j ∈ χ. The X_j symbols do not contain data, but they can be programmed to maximize the transmission. Enabled antennas are defined by the vectorX_j, during which all other antennas appear inactive. The signal obtained is y = $\sqrt{\rho}Hx + w,$ where ρ is the average SNR, H is the gain of channel and w is the AWGN noise which have neutral and identically allocated with variance (0,1). The signal after channel gain is y=$\sqrt{\acute{\rho}}\, h_{j,eff}$ +w ; where $\acute{\rho} = \frac{\rho}{N_t}$, $h_{j,eff}$ is the effective column of H. The identification rule is a problem of maximization over all H efficient columns (there are M of them). Generally, for GSSK modulation, these efficient columns serve as random constellation points.

3.3.1 Hybrid NOMA-GSSK Scheme:

The established services need to be improvised and some modern approaches changed to ensure accelerated performance, customer fairness, low latency and tremendous usability due to the rising need for wireless networking. NOMA is the suitable multiple access technique of the fifth generation (5G) and beyond and is considered as an inspiring strategy to low latency pledge, huge entry to high throughputs and fairness of devices [45], [46]. In the downlink power domain, NOMA superposition coding has been applied upon the transmitter side and signal isolation at the receiving end is completely dependent on SIC [11], [47], [48]. NOMA is a spectrally efficient method in which any user will use the entire spectrum. Accurate power ratios are assigned to each customer depending on the distance from the base station [31]. Signal separation and decoding is completed through multiple user detection (MUD) method [49]. Multiplexed consumer signals are assigned by the base station (BS) to various power levels, superimposed with each other and transmitted. Cell center customers conduct successive interference cancellation (SIC) [50] to restore their signals. Users of Cell-edge do not however, conduct SIC, due to poor channel conditions, experience a drop in spectral quality. Spatial modulation (SM) NOMA has recently been explored in [51], [52], to improve spectral efficiency. Cell-edge consumers face substantially low spectral density in non-orthogonal multiple access (NOMA), since only any portion of the overall transmit power is assigned. For users who are partnered in NOMA, this contributes to low spectral efficiency. To address this issue, the NOMA and Generalized Space Shift Key (GSSK) integration, called NOMA-GSSK, is used to boost spectral efficiency by exploiting the spatial domain [53]. Generalized Space Shift Keying (GSSK) modulation has recently been developed as a low-complexity principle for MIMO wireless systems and proposes a trade-off among complexity and spectral effectiveness. Via multiple active antennas at the transmitter, GSSK offers greater spectral efficiency. In this report, by combining NOMA and generalized space shift keying (GSSK), called NOMA-GSSK, we analyze a new transmission approach to further improve consumer spectral efficiency, energy efficiency and resolve the complexity issue at the receiver side by lowering the number of SIC occurrence. GSSK is a slight modification of SSK that allows multiple active antennas to transmit signals. Comparing between MIMO-NOMA, NOMA-SSK and NOMA-GSSK in [53], the hybrid NOMA-GSSK system achieves better spectral and energy efficiency with lower bit error rate (BER), since consumers are multiplexed by the use of a range of transmit antennas in the power domain along with spatial domains, while in MIMO-NOMA all antennas are being used to distribute the NOMA message.. In hybrid NOMA-GSSK scheme, only cell-edge users transmit their signals implementing GSSK technique and the users who are closer to the BTS will use conventional NOMA technique in transmission.

3.3.2 System Model:

In this work, we consider a downlink NOMA system of 6 users, where the first 3 users are located closer to the base station (BTS) having low transmit power because of strong channel conditions and apply conventional NOMA system and rest of 3 users are cell edge users having high transmit power due to poor channel conditions exploit the spatial domain. A downlink NOMA system of 6 users is portrayed in Figure 1. a hybrid signal, including a single receiving antenna.UE1, UE2, UE3 and simultaneous/frequency/code users, all with different levels of control. To delegate power to the 3 NOMA consumers, fractional transmit power allocation (FTPA) is applied. To distribute power to the 3 NOMA consumers, fractional transmit power allocation (FTPA) is used. Each conventional NOMA user's message signals are encoded first and then modulated through BPSK modulation strategy. Upon modulation, various power rates (power factors) are allocated, this is entirely based on the distances between users and the base station (BS). Noma-GSSK can delegate users with a long distance from base station (BS) with bad channel condition relative to close users with a better channel condition. In multi-user applications, power allocation becomes important [54]. The rising number of NOMA users leads to device volatility and gradual degradation of performance. Signal transmitted after superposition coding is,

$X_{MIMO-Noma}=x_1+x_2+x_3$

where $x_i=\sqrt{p_i}\,S_i$;   (i =1,2,3,4,5,6) ; (1)

here, p_i=Power assigned with UE's

S_i = Signals of UE's.

Message of 3-users (UE_1, UE_2, UE_3) after power multiplexing are,

$x_1=\sqrt{p_1}\,S_1$; $x_2=\sqrt{p_2}\,S_2$; $x_3=\sqrt{p_3}\,S_3$

Table 1: *Distance and power factor for implementation*

Users	Distance from BS	Power factor, α
1	10m	0.002
2	30m	0.02
3	50m	0.05
4	80m	0.15
5	120m	0.32
6	140m	0.45

Power allocation for each user is,

$$P_1=\frac{p_1}{p_1+p_2+p_3+p_4+p_5+p_6} \quad (2)$$

where, $p_1 = \frac{Distance\ of\ Users}{Radius\ of\ BS}$

We assume the radius of base station 150m. In table 1, we calculate the power factor for six users.

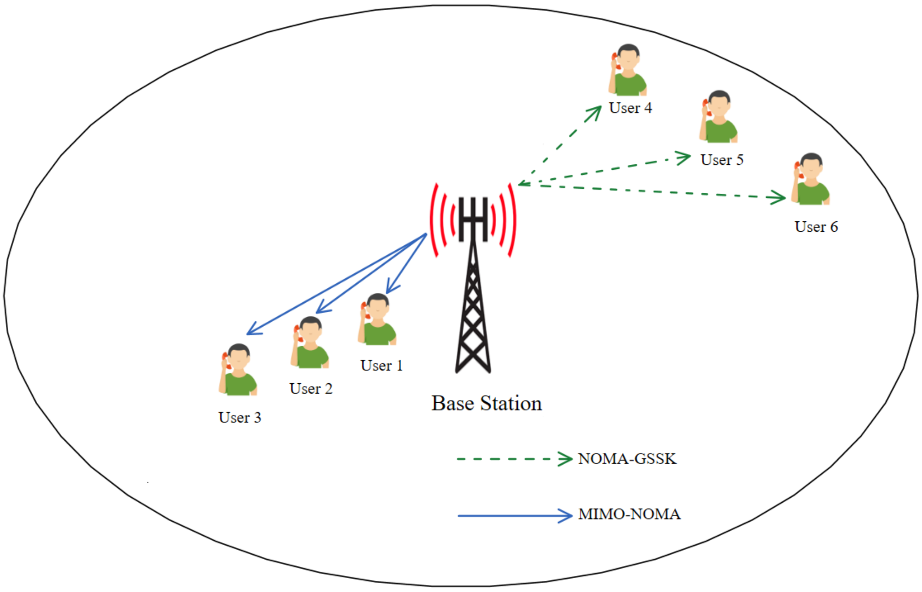

__Figure 3.3.2.1__ An overview of the six-user case system model for NOMA-GSSK

Transmitting signals for $(UE_{4\,,}UE_{5,}\ UE_6)$NOMA-GSSK through GSSK mapper is,

$$x_i = \sum_{i=1}^{N} \sqrt{\alpha_i \mathrm{P} S_i} \qquad ;\ \text{where (i=4,5,6)} \tag{3}$$

Where P represents the total transmit power, S_i denotes i_{th} users' symbol α_i performs as power allocation factor for i_{th} user, so that $\alpha_1 < \alpha_2 < \cdot\cdot\cdot < \alpha_i < \cdot\cdot\cdot < \alpha_N$ and $\sum_{i=1}^{N} \alpha_i = 1$.

$x_4 = \sqrt{\alpha_4 \mathrm{P} S_4}$; $x_5 = \sqrt{\alpha_5 \mathrm{P} S_5}$; $x_3 = \sqrt{\alpha_6 P S_6}$; Therefore, the transmitted signal for cell edge users is,

$$X_{Noma-Gssk} = x_4 + x_5 + x_6 \tag{4}$$

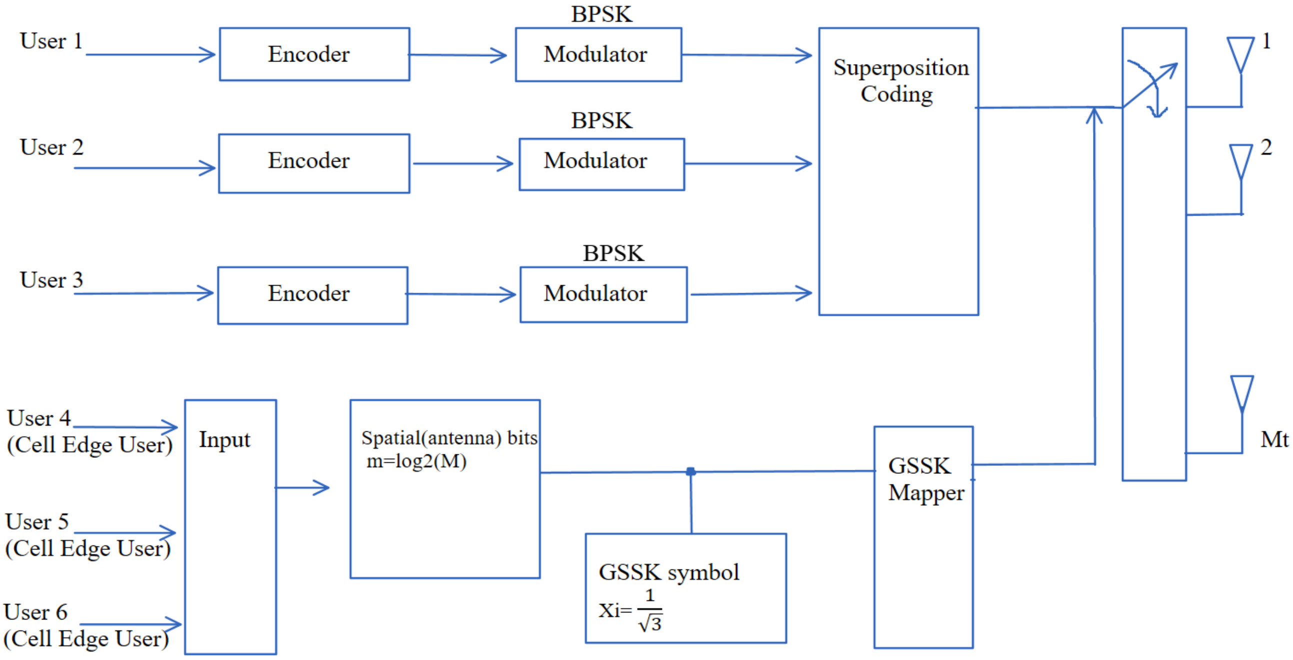

Figure 3.3.2.2 *Transmitting system for NOMA-GSSK.*

Using particular antennas from the full range of transmitting antennas, six users are transmitted, M_t. As demonstrated in Fig.2, three relevant antennas from the full range of six transmitting antennas are transmitted to users, M_t . Cell-edge users' data symbols, are conveyed using the chosen unique antenna package depending on the antenna index information. Moreover, focusing on the GSSK mapping rule, cell-edge consumer symbols are conveyed by antenna allocation. The transmitted signal X_j is expressed as an example of n_a = 3 active transmitting antennas.

$$X_j \triangleq \left[\frac{1}{\sqrt{n_a}} \ldots \ldots 0..0\ \frac{1}{\sqrt{n_a}} \ldots .0..\frac{1}{\sqrt{n_a}} \ldots ..0\right]^T \tag{5}$$

The source produces a random series of independent bits in GSSK modulation [55], grouped into sets of m= $\log_2(M)$ where constellation size, $M = M_tC_{n_a}$.We assume total 6 antennas among them 3 antennas are active, so we get $M = (6C_3) = 20$. We took the nearest value as size of M will be power of two($2^4 = 16$). In the GSSK case, only a constant $\frac{1}{\sqrt{n_a}}$ signal is transmitted by each active transmit antenna since it transmits only antenna index information dependent on the transmit antenna set. Total transmitting signal can be written as,

$$X = X_{MIMO-Noma} + X_{Noma-Gssk} \tag{6}$$

Table 2. *GSSK Mapper Rule corresponding to six transmit Antennas*

Transmitting bits b =$[b_1\ b_2\ b_3\ b_4]$	Antenna combination j	$X_j = [x_1\ x_2\ x_3\ x_4\ x_5\ x_6]^T$
[0 0 0 0]	(1,2,3)	$[\frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ 0\ 0\ 0]^T$
[0 0 0 1]	(1,2,4)	$[\frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ 0\ \frac{x}{\sqrt{3}}\ 0\ 0]^T$
[0 0 1 0]	(1,2,5)	$[\frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ 0\ 0\ \frac{x}{\sqrt{3}}\ 0]^T$
[0 0 1 1]	(1,2,6)	$[\frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ 0\ 0\ 0\ \frac{x}{\sqrt{3}}]^T$
[0 1 0 0]	(1,3,4)	$[\frac{x}{\sqrt{3}}\ 0\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ 0\ 0]^T$
[0 1 0 1]	(1,3,5)	$[\frac{x}{\sqrt{3}}\ 0\ \frac{x}{\sqrt{3}}\ 0\ \frac{x}{\sqrt{3}}\ 0]^T$
[0 1 1 0]	(1,3,6)	$[\frac{x}{\sqrt{3}}\ 0\ \frac{x}{\sqrt{3}}\ 0\ 0\ \frac{x}{\sqrt{3}}]^T$
[0 1 1 1]	(1,4,5)	$[\frac{x}{\sqrt{3}}\ 0\ 0\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ 0]^T$
[1 0 0 0]	(1,4,6)	$[\frac{x}{\sqrt{3}}\ 0\ 0\ \frac{x}{\sqrt{3}}\ 0\ \frac{x}{\sqrt{3}}]^T$
[1 0 01]	(1,5,6)	$[\frac{x}{\sqrt{3}}\ 0\ 0\ 0\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}]^T$
[1 0 1 0]	(2,3,4)	$[0\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ 0\ 0]^T$
[1 0 1 1]	(2,3,5)	$[0\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ 0\ \frac{x}{\sqrt{3}}\ 0]^T$
[1 1 0 0]	(2,4,6)	$[0\ \frac{x}{\sqrt{3}}\ 0\ \frac{x}{\sqrt{3}}\ 0\ \frac{x}{\sqrt{3}}]^T$
[1 1 0 1]	(2,5,6)	$[0\ \frac{x}{\sqrt{3}}\ 0\ 0\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}]^T$
[1 1 1 0]	(3,4,5)	$[0\ 0\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}\ 0]^T$
[1 1 1 1]	(3,5,6)	$[0\ 0\ \frac{x}{\sqrt{3}}\ 0\ \frac{x}{\sqrt{3}}\ \frac{x}{\sqrt{3}}]^T$

The i_{th} user's received signal can be represented as,

$$y_i = h_{ij}x_i + w_i \text{ ; where (i =1 to 6)} \tag{7}$$

The total received signal for six users is,

$$Y = y_1 + y_2 + y_3 + y_4 + y_5 + y_6 \tag{8}$$

$$Y = \sum h_{ij}x_i + w_i \tag{9}$$

where h_{ij} means the channel gain of the i_{th} user using the j_{th} antenna set, and w_i act as additive white Gaussian noise (AWGN).

Bit Error Probability:

BER Since the cell-edge user information is modulated using the antenna set, it should be remembered that they are only concerned with the identification of the transmit antenna set. ML detector error efficiency can be extracted as,

$$BEP = \frac{M_t/2}{M_t - 1}\frac{1}{M_t}\sum_{i_1=1}^{M_t}\sum_{i_1 \neq i_2}^{M_t} Q\,(A) \tag{9}$$

$$A = \sqrt{\frac{\bar{\gamma}}{n_a}\left|\sum_{l=1}^{n_a}\left[h_j(l) - h_k(l)\right]\right|^2} \tag{10}$$

where $Q(A)$ denotes the Pairwise Error Probability (PEP) of the transmit–antennas with i_1, i_2 = 1, 2.…M_t, $Q(\cdot) = 1/\sqrt{2\pi}\int_A^{\infty} \exp(-u^2/2)\,du$, $\bar{\gamma}$ denotes the average SNR and $h_x(l)$ is the x-th constellation point. NOMA-GSSK has a higher range, so instead of one active transmission antenna, GSSK may provide a multitude of active transmission antenna sets.

Spectral Efficiency analysis:

The NOMA-GSSK capacity can be computed as the amount of the usage capacity of the N NOMA and the cell-edge user capacity through the spatial domain. Noma-GSSK average capacity is given by,

$$R_{Noma-Gssk} = \log_2(\ \rho \log_2(\log_2 N)) + R_K \tag{11}$$

Where ρ is the average SNR, N speak for the number of users (N = 3) who use conventional NOMA technique and R_K represents the sum rate of cell edge users (K = 3). So, the Sum rate of cell edge users is,

$$R_K = (1 - BER)[\log_2 M_t C_{n_a}] \tag{12}$$

In equation (12) $M_t C_{n_a}$ is the bionomial coefficient of $(M_t n_a)$ and BER is the bit error performance.

Complexity Analysis (Number of SIC Occurrence):

Throughout the case of NOMA-GSSK, the number of transmitting antennas is smaller for the same number of accommodated users (N+K) than in the case of MIMO-NOMA. It will, however, achieve less complexity than other systems.

$$\mathrm{SIC}_{\mathrm{NOMA-GSSK}} = \frac{\mathrm{N(2+(N-1))}}{2}\,(4\mathrm{M_r M_t M}+2\mathrm{M_r M^{M_t}})\mathrm{N} + (\mathrm{K n_a M_r} \log_2(\mathrm{M_t\, C_{n_a}})) \tag{13}$$

Energy Efficiency Analysis:

Energy efficiency is commonly exemplifying as,

$$\eta = \frac{R}{P_T} \tag{14}$$

Here the capacity denotes R, and P_T means the total power.

$$P_T = P_t + P_c \tag{15}$$

Where P_t is the transmit power and P_c represents the circuit power.

In the spatial domain, using the antenna index set, the cell-edge consumer is multiplexed and the information is transmitted. Because the NOMA-GSSK cell edge user does not use power allocation, compared to MIMO-NOMA, NOMA-GSSK has remarkably high energy efficiency. The energy efficiency of MIMO-NOMA, and NOMA-GSSK are therefore provided by,

$$\eta_{MIMO-NOMA} = \frac{R_{MIMO-NOMA}}{\sum_{i=1}^{N+k} \alpha_i P} \tag{16}$$

$$\eta_{NOMA-GSSK} = \frac{R_{Noma-GSSK}}{\sum_{i=1}^{N} \alpha_i P} \tag{17}$$

In equation. (16) and (17) explicitly demonstrate that, relative to traditional systems, NOMA-GSSK has increased energy efficiency.

The following are the key improvements to our NOMA-GSSK scheme:

- To the best of our knowledge, this is the first comprehensive research on hybrid NOMA-GSSK scheme in order to identify its effectiveness over other promising hybrid NOMA schemes (MIMO-NOMA & STBC-CNOMA). Furthermore, we state a computational structure, diagram of the composite NOMA-GSSK model along with GSSK mapper law for 6 users.
- For calculating the Bit Error Probability (BEP), we use the simplest equation [53] where number of bit error of constellation points is not necessary to be considered.
- We combined the transmit power along with the circuit power to calculate the total power consumption in order to make realistic result for energy efficiency.

- We have depicted energy efficiency curve differently than [54], the aim is to compute the spectral efficiency corresponding to the maximum energy efficiency and also to highlight the green point.

3.4 MIMO-NOMA Scheme

Massive multiple input multiple output (MIMO) systems running in sub-6 GHz frequency bands heavily rely on major spatial multiplexing gains and advantageous features of propagation made by very large antenna arrays to support several consumer nodes in the same time-frequency resource factor at the same time [61]. Sub-6 GHz massive MIMO has also been shown to provide incredible improvements in spectral/energy efficiency [62], [63], [64] and commercial carriers such as Sprint have already been introduced in the United States [65]. Despite these advantages, an overloaded situation in which the number of user nodes exceeds the number of RF chains at the BS may not be able to accommodate large MIMO with OMA. The huge networking requirement of the next-generation wireless standards will therefore not be able to accommodate sub-6 GHz massive MIMO with OMA.

Using systemic application in [56]-[58] which reveals that the incorporation of MIMO with OMA outperforms the performance of traditional OMA technique, truly motivates researchers in carrying out cutting edge research to validate the significant performance improvements of conventional NOMA integrating MIMO technique. For instance, MIMO-NOMA with random beamforming was suggested in [58], where certain transmit beams are randomly generated by a base station with multiple antennas, and users falling through these beams are served in an advantageous manner. It is anticipated that in 5G networks where low-cost and low-power fixed-cell base stations will be used, small cells will be ultra-densely distributed [59]. Consequently, with the rapidly increasing capacities of mobile phones and tablets, it is very possible that such a low-cost small-cell base station has the same number of antennas as consumer handsets, or even fewer. Another example of a 5G implementation of the proposed scheme is cloud radio access networks (C-RANs), in which subscribers are provided by a limited number of low cost remote radio heads (RRHs) to reduce the overhead of the wireless connectivity [60].

3.4.1 System Model of MIMO-NOMA:

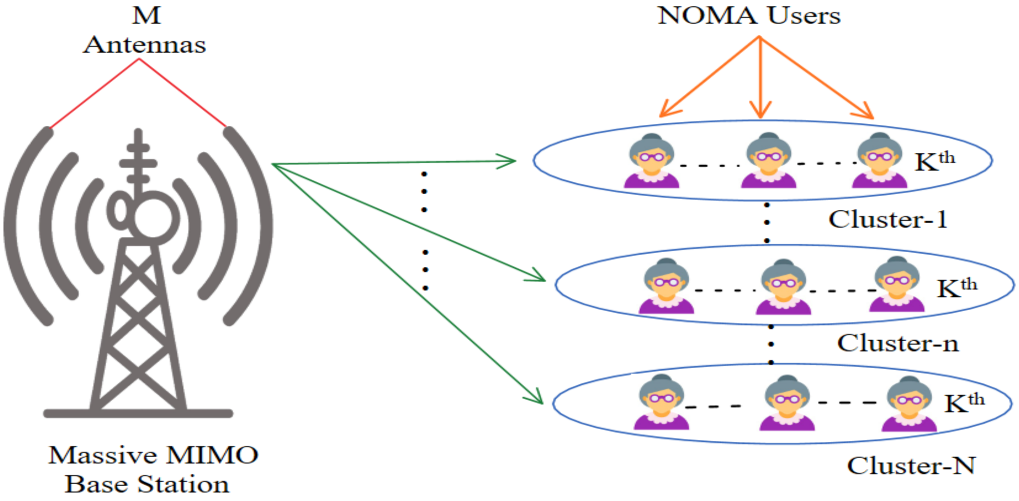

Figure 3.4.1.1 *Model of Massive MIMO-NOMA within N cluster [55].*

Consider a unique TDD multi-user communication device, where, as seen in Fig. , a base station (BS) with M antennas simultaneously provides services to large number of single-antenna mobile users. Note as in future 5G mobile communication networks the number of BS antennas M is proposed to be very high relative to modern systems $M \geq 64$ in [66]. In all other terms, a large-scale antenna array is designed for the BS. The NOMA approach is implemented by integrating consumer clustering and spatial beamforming to take advantage of multiple-antenna advantages to facilitate massive access and increase spectral performance. A spatial beam is shared by the consumers in the same cluster to reduce inter-cluster interaction, and SIC is performed in a cluster to minimize intra-cluster interference.

User Clustering:

It is important to perform user clustering in order to strike a balance between device efficiency and computational complexity in large MIMO-NOMA systems. In general, mobile devices are clustered into a cluster in the same geographic direction, but with different propagation lengths, and users share a transmission beam in a cluster. The same spatial path for users in a cluster is useful for enhancing channel benefit and countering inter-cluster interference, comparable to directional scheduling used over broadcast channels [67]. In addition, the distinctive transmission distances between the BS and users make it easy for smartphone users to use the SIC. We conclude that mobile users are partitioned into N clusters without loss in general, and each cluster comprises K mobile users. Note that the inter-cluster interference and the complexity of the beamforming architecture are calculated by the number of clusters N, while the number of users K in the cluster is influenced by the intra-cluster interference and the complexity of the SIC.

MIMO-NOMA Channel Estimation:

Designing a non-orthogonal channel estimation system for massive MIMO to address this challenge [72]. The users in the N^{th} cluster send a common pilot series $\emptyset_N \in \mathbb{C}^{1\times\tau}$ with τ symbols over the uplink channels at the beginning of each time slot. The length of the pilot series τ must not be less than the number of clusters N, which is typically fulfilled in functional schemes, to ensure pairwise orthogonality. In [73] and [74], compared with traditional orthogonal channel estimation methods, the proposed non-orthogonal channel estimation can shorten the length of the training sequence by N times. Fractional allocation of transmission power is used to distribute power to N users of the NOMA[12]. The signal being transmitted is

$$X = \sum_{i=1}^{N} \sqrt{a_i P_{xi}} \tag{18}$$

Where P represents the total transmit power, x_i denotes i_{th} users' symbol α_i performs as power allocation factor for i_{th} user, so that $\alpha_1 < \alpha_2 < \cdot\cdot\cdot < \alpha_i < \cdot\cdot\cdot < \alpha_N$ and $\sum_{i=1}^{N} \alpha_i = 1$.

We use BPSK modulation scheme to calculate Bit error probability as in [17], [54].

Spectral Efficiency of MIMO-NOMA:

Massive MIMO-NOMA has a great potential to support massive connectivity requirements of the next-generation wireless networks.

For N+K user's capacity for MIMO-Noma is given by,

$$R_{MIMO-Noma} = \log_2(\ \rho \log_2(\log_2(N+K))) \tag{19}$$

Remark 1:

The spectral efficiency of each user is calculated by its own CSI resolution. However the CSI accuracies among the users in a cluster are coupled according to the characteristics of the proposed non-orthogonal channel estimation [75]. It is also likely to maximize the precision of the CSI in a cluster, but not necessarily in the whole system.

Remark 2:

The spectral efficiency of each user is influenced by the power allocation of its related clusters, but not the power allocation of the other clusters. This is since the inter-cluster interference is determined explicitly by the total power of other clusters, namely

$$\sum_{i=1,i\neq N}^{N} \sum_{i=1}^{K} \alpha_{N,K} P_{j,i} = \alpha_{N,K} \sum_{i=1,i\neq N}^{M} P_j$$

Where the total transmission power of the jth cluster is P_j. Thus, for a given cumulative transmission capacity of each cluster, each cluster will independently perform power allocation. Massive MIMO can drastically increase the spectral efficiency of wireless networks via aggressive spatial multiplexing. It is known that, with the prevalent linear processing at the BS, the best spectral efficiency is obtained in under loaded systems.

Complexity Analysis of MIMO-NOMA

The complexity of SIC can be separated into two parts: decoding and subtraction. Indeed, since SIC is not done by the last user of NOMA, the subtraction stage of UE_j is N+K-1. After subtraction, however, NOMA users can decipher their own signals. For all users, complexity can be obtained as,

$$\mathrm{SIC}_{\mathrm{MIMO-NOMA}} = \frac{(\mathrm{N+K})(2+(\mathrm{N+K}-1))}{2}(4\mathrm{M_r M_t M}+2\mathrm{M_r M^{M_t}}) \tag{20}$$

Energy Efficiency of MIMO-NOMA

From NOMA-GSSK section, we can calculate energy efficiency for *N+K* user's of MIMO-NOMA as

$$\eta_{MIMO-Noma} = \frac{R_{MIMO-Noma}}{\sum_{i=1}^{N+K} \alpha_i P} \tag{21}$$

The different work, we focus to calculate EE is circuit power consumption which leads to define the expected battery lifetime. It considers battery type, peak power usage, wireless communication protocol, low latency, throughput, sleep-states, and transmitting data specifications to ensure stable long-term operation of smart device.

3.5 Cooperative NOMA

The cooperative transmission scheme for NOMA (CNOMA) is proposed to take full advantage of previous knowledge available in NOMA technology. In this scheme, the main advantage is that the strong user always decodes the messages of weak signals by recruiting SIC. The strong users will therefore operate as switches to support the weak users with a replica of their messages with the aid of extra time slots. As a result, it will increase the diversity gain [76].

There are two phases in Cooperative Noma (CNOMA) scheme. The first one is Direct Transmission Phase and other one is Cooperation Phase. For a downlink NOMA system, we can consider there will be K users in the system where $\mathbb{K}$ = {1,2,3,4…..,K} has been the list of all devices. Without losing any kind of generality of this system, we can say that 1st user is the strongest and the K^{th} user is the weakest in terms of receiving signal from the BS. From the inside process of direct transmission, all users were sending a NOMA-based superimposed signal by the BS where the strong users will decode the message considering the weak signal as noise. However, this phase followed NOMA downlink scenario. On the other hand in the Cooperation Phase, K-1 time slots are used where the first strong user enables SIC to always interpret its own signal. Then, it will decode the other users messages and subtract them one after another. Though, 1st user has the decoded messages of the K-1 users, therefore, in the first time slot the 1st user will act as BS to the other users and it will send the superimposed signal containing the K-1 users messages and this process will continue. SIC on every superimposed signal and combining the multiples translated signal of the messages will perform by using Maximum Ratio Combining (MRC) [13]. A case of 3 user's Cooperation phase is depicted in the following figure. In this process, CNOMA improves the outage performance of weak users.

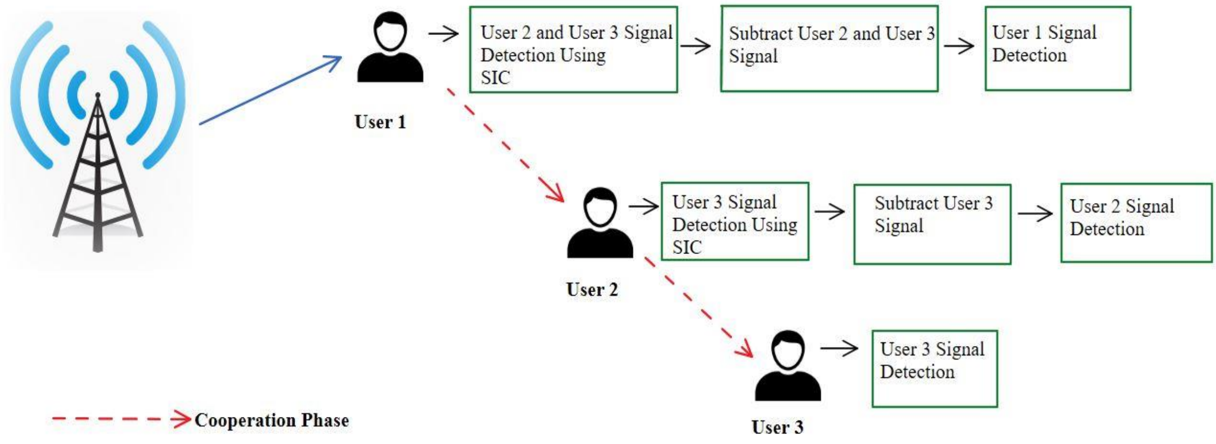

Figure 3.5.1 *Cooperative NOMA with 3 users Case*

3.6 Space Time Block Coding (STBC)

STBC is a mechanism that is used to relay several copies of a data stream through a range of antennas in wireless communications and to manipulate the different versions of the data obtained to increase the spectral efficiency of data transmission. The fact is the transmitted signal must pass through a potentially difficult environment of dispersion, reflection, refraction and can then be further distorted by the receiver's thermal noise, meaning that some of the copies of the data obtained may be closer than others to the original signal. This continuity results in a better probability of using one or more of the copies obtained to decipher the signal received correctly. Space-time coding simply incorporates all the copies of the obtained signal in an optimized way to obtain as much data as possible from each of them [39]. For any number of transmitting antennas for complex constellations, space-time block codes may be developed and these codes again have remarkably simple encoding algorithms based on linear processing at the receiver only [77].

STBC validates Alamouti's discovered strategy of transmission to an arbitrary number of transmission antennas can achieve the maximum promised variety by the antennas for transmitting and receiving [13]. These Alamouti codes maintain the resources of providing a very basic algorithm of maximum probability linear processing-based decoding at the receiver. They have the highest possible transmission rate for actual signal constellations permitted by the space-time coding theory. By following the Alamouti STBC system, the BS conveys the overlaid signals to all users simultaneously [78]. The BS generated linked transmission matrix, the columns of which are orthogonal to each other and therefore coding matrix can be expressed as $\mathbf{G_2} = \begin{pmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{pmatrix}$, here $(.)^*$ denotes the complex conjugate [13]. The symbols to be transmitted during the first interval of time are used in the first row and the second row for the second interval of time. In the first row of G2, s_1 and s_2 represent the superimposed signals that are sent to the users from the first and second antennas of the BS and can be represented as $s_1=\sum_{j=1}^{L} \sqrt{a_j P_s/2}\, x_{j1}$ and $s_2=\sum_{j=1}^{L} \sqrt{a_j P_s/2}\, x_{j2}$. In this case, x_{j1} and x_{j2} are the symbols for j first and second unit energy, a_j denotes users and P_s denotes user j related to power allocation coefficient and transmission power at the BS, respectively.

Outage Probability

If we evaluate the case that the symbol of the jth user cannot transmit the *l*th user where the target SINR in case of jth user is defined as $\gamma_{th,j}$ and $1 \leq j \leq l$, we can define outage probability as [13],

$$P_{\gamma out,l} = P_r\left(\left\{\gamma_{SU_1 \to l} \leq \gamma_{th,1}\right\} \cup \left\{\gamma_{SU_2 \to l} \leq \gamma_{th,2}\right\} \cup \ldots \cup \left\{\gamma_{SU_l \to l} \leq \gamma_{th,l}\right\}\right) \tag{22}$$

The event $\{\gamma_{SU_j \to l} \leq \gamma_{th,j}\}$ for $j \neq L$ can be designated by

$$\left\{\gamma_{SU_1 \to l} \leq \gamma_{th,1}\right\} = \left\{\frac{a_j \frac{\overline{\gamma}}{2} \left\|\boldsymbol{h}_{SU_l}\right\|_F^2}{\frac{\overline{\gamma}}{2} \left\|\boldsymbol{h}_{SU_l}\right\|_F^2 \sum_{k=j+1}^{L} a_k + 1} \leq \gamma_{th,j}\right\} \tag{23}$$

$$= \{\bar{\gamma}||\boldsymbol{h}_{SU_l}||_F^2 \leq \eta_j\}$$

Where, we can find the notation $\eta_j \triangleq \frac{2\gamma_{th,j}}{\left(a_j - \gamma_{th,j} \sum_{k=j+1}^{L} a_k\right)}$ is represented as the tractability of mathematics. Here, if $a_j - \gamma_{th,j} \sum_{k=j+1}^{L} a_k \leq 0$, the user symbol j_{th} cannot be decoded by the user l_{th} [79]. Consequently, under the condition of $a_j - \gamma_{th,j} \sum_{k=j+1}^{L} a_k > 0$, by using equation (23) into (22) We can rewrite the l^{th} user's Outage Probability(OP) as

$$P_{\gamma_{out,l}} = P_l(\bar{\gamma}||h_{sul}||_F^2 < \tilde{\eta}l) = F_{\gamma_{eq,l}}(\tilde{\eta}l) \tag{24}$$

Where the $\tilde{\eta}l = \underset{1\leq j\leq l}{max}(\eta_j)$, In (24), $\gamma_{eq,l} = \bar{\gamma}||\boldsymbol{h}_{SU_l}||_F^2$ is the alternative immediate structured SNR(therefore in ascending order, channel gain are established) at recipient of the l^{th} device. Here, $F_x(.)$ means the cumulative distribution function (CDF) of any arbitrary factor X. Through (23), We could have seen that the OP of the consumer can be accessed from the CDF of the selected SNR $F_{\gamma_{eq,l}}$ at a worth in $\tilde{\eta}l$.

For every user, the precise OP statement here is acquired in closed-form.

3.7 STBC Based C-NOMA

With the exception of all the CNOMA efficiency gain, the biggest drawback on this system being the larger range of SIC is carried out inside the overall process. Therefore the SIC is done on the user equipment (UE) in the downlink, due to the insufficient computational power and battery, the whole method is resource bound. Getting increased the amount of SICs conducted at the UE thus extends the computing upward of the UEs which results very high computational complexities [18]. With this reality in mind, for improving the performance of CNOMA and reducing the system complexity notably, we are investigating a new hybrid model that takes advantage of STBC, and we refer to it as STBC based CNOMA (STBC-CNOMA). The indicated framework significantly decreases the total amount of SICs carried out in this method, therefore reduction in the complexity of the process. In realistic situations, however certain problems need to be discussed in the STBC-CNOMA schemes. For example, the dispersed conception of branches and their versatility reasoning for timing offsets, that are extremely extreme of approaches focused on virtual antenna arrays, including distributed STBC [80],[81]. To keep this in mind, in this paper, we analyze the impacts of imperfect timing, perfect SIC and perfect CSI between 6 users in order to properly assess STBC-CNOMA. We are defining the downlink with *K* users of a contact device, in which the most powerful user will be the 1st user and the weakest user is *K*th user. STBC-CNOMA operates in two stages such as the traditional CNOMA. The first stage is the conventional NOMA stage, while the Cooperation phase is the second stage. The BS transmits a superimposed signal based on NOMA towards the other users, identical to CNOMA, in the first step of the first time slot. The cooperation process consists of time slots K - 1 and is subdivided further two sub-phases: the period of direct cooperation and the stage of STBC cooperation [76].

Our STBC based CNOMA scheme major contributions as follows.

- To the best of our understanding, we are the first presenting a computational structure that involves an arbitrary of 6 users signal model underneath the timing imperfection, perfect SIC, perfect CSI and bit error probability in the channel estimation for the auspicious STBC-CNOMA system.
- For those basic combinations that can be used in the configuration and function of the STBC-CNOMA device, we find dispersion of probability [13] of the signal-to-interference-plus-noise ratio (SINR).
- We quantify the equal contrast with other promising hybrid NOMA models to make comprehensive comparative analysis in terms of BEP computation, energy & spectral efficiency tradeoff and number of SICs requirements as a function of the number of users.

3.7.1 System Model of STBC-CNOMA:

We assume a downlink framework based on STBC mechanism. The superimposed signal is sent by the Base Station (BS) to all devices in its area of coverage. We presume that the link between the user and the BS is a flat fading Rayleigh channel between any two users as in [82], [55]. In general, powerful links of the BS is open to users close to the BS and the strong users are henceforth referred to. Similarly, there are poor channel conditions and consumers lying at the cell side, they are known as week users. The maximum power is provided to the user with the least effective channel scenario, while the user with the decent accuracy channel conditions is allocated the below average power. It is believed, without lack of generality, that the users are aligned as per the channel condition. For example, $|h_1| \geq |h_2| \geq \cdots \geq |h_k|$, Where $|h_k|$ is the BS-to-k$^{\text{th}}$ user channel coefficient, and k is the total quantity of users. U_1 is assumed to be the strong user and the U_k to be the weakest user, where $\{U_1, U_2 \ldots\ldots U_k\}$ is the user set. In two steps, communication via BS to user's happens. BS delivers the superimposed signal to all the users in the first stage, called the direct NOMA stage. By regarding the signals as noise for all the other users, the weak user derives his own signal. Rest of the users use SIC to delete the weak users' interference and handle the signals as noise for other efficient users. The first two strongest users, U_1 and U_2, form an STBC pair in the 2$^{\text{nd}}$ stage, forwarded to as the cooperative NOMA stage, and relay messages for the next two users, U_3 and U_4 by 2×2 STBC transmission. U_3 and U_4 also broadcast messages to U_5 and U_6 user by 2×2 STBC transmission. This two 2×2 STBC method persists until the less effective U_k user is sustained.

Table 3: Table of Notation

Symbol	Definition
$g_{k,j}$[13]	Channel gain between k^{th} and the j^{th} user
γ_k^{ε}	For timing mismatch, ideal SIC and perfect CSI of SINR at the k^{th} user
γ_{th}	Threshold of SINR
p_s[13]	Mean power obtained during the collaboration process of STBC by the recipient
$\epsilon_{k,t}$	Noise obtained during time slot t of the STBC collaboration process at the k^{th} end
$r_{k,t}$	Received signal during time slot t of the STBC cooperation process at the k^{th} end
h_k	Via BS to the k^{th} user, channel gain
λ_g[13]	Component of fading for Gamma distribution factor Z
λ_h[13]	Component of fading for exponential random parameter A
γ	Rate Threshold

Straight NOMA Stage

As seen in the Fig. In the first time slot, the direct NOMA stage is completed as the superimposed message is provided by BS to all K users. User of k^{th} end, in such a way that $1 \leq k \leq$K then to detach it from the superimposed signal, SIC introduces and then identifies its own message.

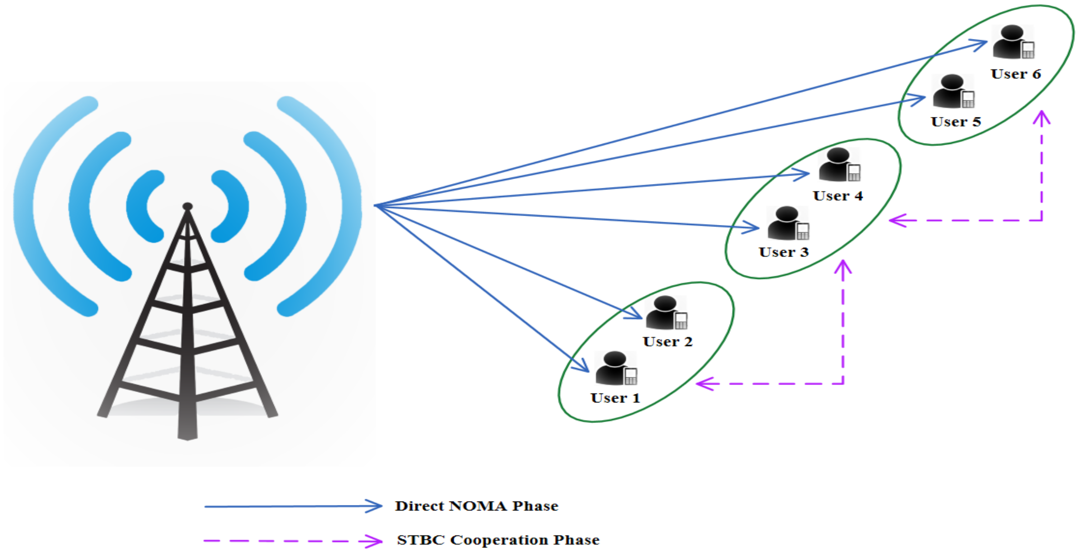

Figure 3.7.1.1 *An illustration of a STBC-CNOMA downlink with six users.*

STBC based Cooperation Phase:

The STBC based step of cooperative transmission is the 2nd stage of the suggested transmission process. As per their channel requirements, users are matched. Two of the first important users produce the very first pairing of users sustained by U_3 and U_4 having the second pair of users. Similarly, U_5 and U_6 having the third pair of users before the M^{th} user pair is made by U_{k-1} and U_k. Here, M=$\frac{K}{2}$ and K is even. When K is impact as odd, U_{K-2} and U_{K-1} build the M^{th} user pair, where $M = \frac{K-1}{2}$.

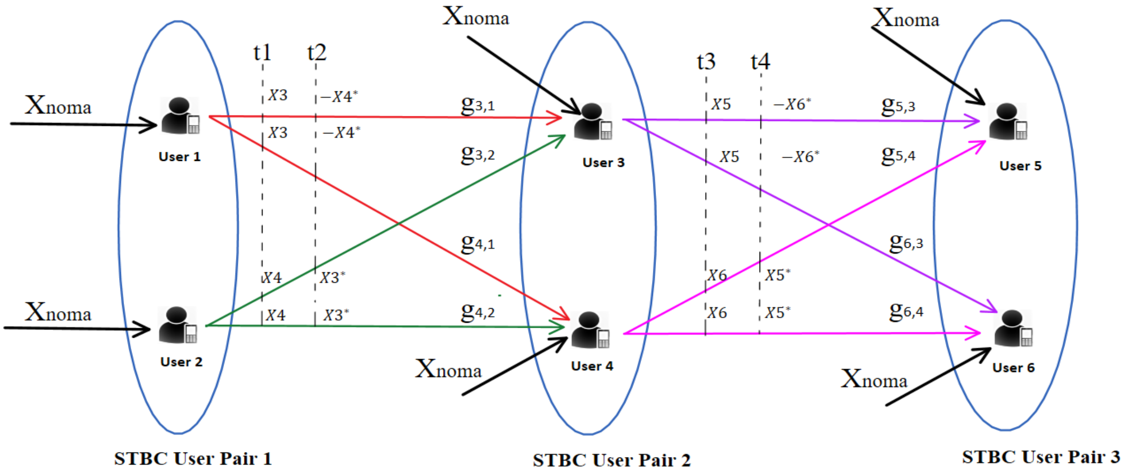

Figure 3.7.1.2 *Cooperation process with two STBC user pairs inside the STBC-CNOMA network*

In this point, by using two distributed 2×2 STBC transmissions, all the devices cooperate with each other. However, for the identification of the symbols, we use 2×2 STBC arrival of the receiving STBC user pair. Two symbols are issued from each STBC user, one each for itself and another for its neighbour. Consequently the decoded symbol is retained for itself by an STBC user, while the other symbol for its neighbour is discarded. BS convey the integrated NOMA signals to all the users in its service region in the first time slot t_0. Therefore, as the first two most influential users have compiled communications for the other users, hence they will go to contribute the STBC cooperation by submitting information in the two additional time slots to the next two users. Thus, t_1 and t_2, U_1 and U_2 relay to users U_3 and U_4 using the Alamouti code during in the slots for second and third period. Similarly, U_3 and U_4 relay the STBC signal to U5 and U6 in the two subsequent time slots, and this process continues until the U_k receives its desired signal.

Imperfect Timing Synchronizing

A two users pair case has discussed on [13], where they briefly explain three impairments such as STBC cooperation stage, imperfect SIC, and channel estimation error. In this segment, via the existence of an imperfection of timing, we examine the STBC-CNOMA scheme to make a fair comparison with other two hybrid NOMA schemes. Fig. 3.7.1.2 illustrates a downlink NOMA network based on STBC for three user pairs. Each consumer receives the Xnoma reinforced NOMA signal again from the base station within the first time slot t_0. As U_1 and U_2 are situated in close proximity to the BS, in addition to the U_3 and U_4 messages, they decode their own messages and relay them to U_3 and U_4 via STBC transmission. Similarly, U_3 and U_4 decode and transmit their own messages to U_5 and U_6 via STBC transmission. During time slot t_1, the U_1 and U_2 send x_3 and x_4 to U_3 and U_4. In slot t_2, U_1 and U_2 send $-x_4^*$ and x_3^* to U_3 and U_4, respectively, at the next period. For U_5 and U_6, the same procedure occurs. During time slot t_3, the U_3 and U_4 send x_5 and x_6 to U_5 and U_6. In time slot t4, U_3 and U_4 send $-x_6^*$ and x_5^* respectively to U5 and U6. Thus, the user pair U3, U4, U5 and U6 will recognizes their corresponding messages.

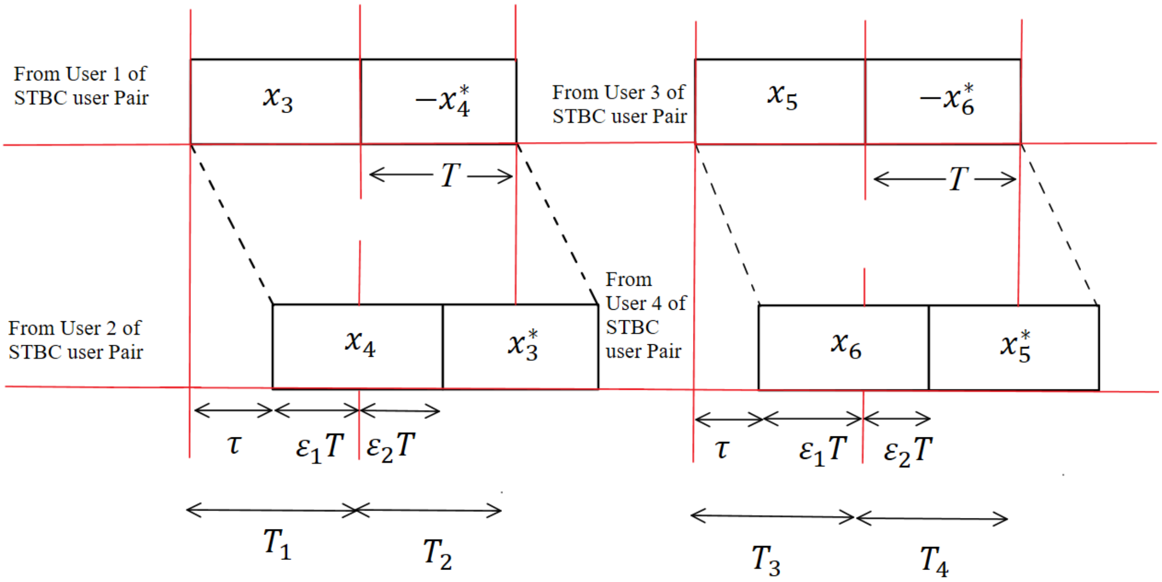

Figure 3.7.1.3 *Received Signal Timing Pattern of Imperfect Timing Synchronization*

Fig. 3.7.1.3 shows the timing pattern with varying circumstances for synchronization. Here we show Transmission of the STBC with timing offset $\tau = \varepsilon_2 T$. In this case, the U_1 and U_2 symbols do not arrive simultaneously and the STBC receiving user pair encounters severe inter-symbol-interference (ISI), which allows the SINR to decrease.

The block of STBC used by U_1 and U_2 is given by [13]

$$S = \begin{bmatrix} x_3 & -x_4^* \\ x_4 & x_3^* \end{bmatrix}$$

The block of STBC used by U_3 and U_4 is given by

$$S = \begin{bmatrix} x_5 & -x_6^* \\ x_6 & x_5^* \end{bmatrix}$$

Thus if U4 and U6 are not synchronized correctly, as seen in Fig. 3, the receiver equations for STBC receiving pair U_3,U_4, U_5 or U_6 at time slots t_1, t_2, t_3 and t_4 are given in the form of [13]

$$r_{3,1} = g_{3,1}x_3 + g_{3,2}\varepsilon_1 x_4 + \epsilon_{3,1} \tag{25}$$

$$r_{3,2} = -g_{3,1}x_4^* + g_{3,2}\varepsilon_1 x_3^* + g_{3,2}\varepsilon_2 x_4 + \epsilon_{3,2} \tag{26}$$

$$r_{4,1} = g_{4,1}x_3 + g_{4,2}\varepsilon_1 x_4 + \epsilon_{4,1} \tag{27}$$

$$r_{4,2} = -g_{4,1}x_4^* + g_{4,2}\varepsilon_1 x_3^* + g_{4,2}\varepsilon_2 x_4 + \epsilon_{4,2} \tag{28}$$

$$r_{5,3} = g_{5,3}x_5 + g_{5,4}\varepsilon_1 x_6 + \epsilon_{5,3} \tag{29}$$

$$r_{5,4} = -g_{5,3}x_6^* + g_{5,4}\varepsilon_1 x_5^* + g_{5,4}\varepsilon_2 x_6 + \epsilon_{5,4} \tag{30}$$

$$r_{6,3} = g_{6,3}x_5 + g_{6,4}\varepsilon_1 x_6 + \epsilon_{6,3} \tag{31}$$

$$r_{6,4} = -g_{6,3}x_6^* + g_{6,4}\varepsilon_1 x_5^* + g_{6,4}\varepsilon_2 x_6 + \epsilon_{6,4} \tag{32}$$

The signal obtained and the ingredient noise detected at the *k*th consumer when time slot t are $r_{k,t}$ and $\epsilon_{k,t}$, respectively. The signals received at U_3, U_4, U_5 and U_6 after the composition are supplied by [13]

$$\tilde{v}_3 = g_{3,1}^* r_{3,1} + g_{3,1} r_{3,2}^* \tag{33}$$

$$\tilde{v}_4 = g_{4,2}^* r_{4,1} - g_{4,1} r_{4,2}^* \tag{34}$$

$$\tilde{v}_5 = g_{5,3}^* r_{5,3} + g_{5,4} r_{5,4}^* \tag{35}$$

$$\tilde{v}_6 = g_{6,4}^* r_{6,3} - g_{6,3} r_{6,4}^* \tag{36}$$

The SINRs of U_3, U_5 and U_4, U_6 can be obtained as (39) and (40) assuming MRC (Maximum Ratio Combining) of the signals obtained in both the immediate NOMA and STBC stages respectively.

Table 4. A benchmark relation of the exact time slots and quantity of transmissions for multiple hybrid NOMA schemes

Application	Quantity of Time slots	Quantity of Transmission
Conventional Cooperative NOMA(CCN) [55]	K	K
Cooperative relaying system using NOMA(CRS-NOMA)[82]	K	K
CRS-STBC-NOMA[83]	2K	4K
CRS-NOMA-ND[6]	K	K
STBC-CNOMA[13]	K-1	2K-3
NOMA-GSSK[17]	K	K
MIMO-NOMA[29]	K	K

Bit Error Probability (BEP)

In this segment, under timing mismatch, perfect SIC and perfect CSI we measure the bit error probability (BEP). The last recipient (recipient K) has the lowest advantage in the channel and therefore it is suffering from impairments and has the worst risk of outage according to other devices, as seen in [76], [18]. For this purpose, we concentrate on User K's outage output (e.g., User 6 in the corresponding segment's example), that will establish a standard for the other users with greater channel gains. An error case happens where the accurate SINR cannot be reached by a recipient to detect the signal. So, the SINR of the users at timing mismatch, perfection of SIC and perfection of CSI can be defined as [13]

$$\gamma_m^{\varepsilon} = \frac{|h_m|^2 P_m}{\sum_{i=1}^{m-1} |h_m|^2 P_i + \sigma^2} + \frac{(|g_{m,m-2}|^2 + \varepsilon_1 |g_{m,m-1}|^2)^2 P_s}{|(\varepsilon_1 - 1) g_{m,m-2}^{*} g_{m,m-1} + \varepsilon_2 g_{m,m-2} g_{m,m-2}^{*}|^2 P_s + (|g_{m,m-2}|^2 + |g_{m,m-2}|^2)\sigma^2} \tag{37}$$

$$\gamma_n^{\varepsilon} = \frac{|h_n|^2 P_n}{\sum_{i=1}^{n-1} |h_n|^2 P_i + \sigma^2} + \frac{(|g_{n,n-3}|^2 + \varepsilon_1 |g_{n,n-2}|^2)^2 P_s}{|(1 - \varepsilon_1) g_{n,n-3}^{*} g_{n,n-2} - \varepsilon_2 g_{n,n-3} g_{n,n-2}^{*}|^2 P_s + (|g_{n,n-3}|^2 + |g_{n,n-2}|^2)\sigma^2} \tag{38}$$

To calculate SINR of 6 users, we worked on last 4 users as they are very much far from BS. Here, m=3rd and 5th user whereas, n= 4th and 6th user case. From [13], they proposed for timing mismatch, perfect SIC, perfect CSI case, the SNR→ ∞, so the outage probability will become as

$$\lim_{SNR\to\infty} \widetilde{P_{out}^{\varepsilon}} \sim \frac{\lambda_h g(SNR)}{\varphi_k - \sum_{i=1}^{k-1} \varphi_i (2^{\gamma}-1)} + g^{\varepsilon}(SNR) \tag{39}$$

Where, $g^{\varepsilon}(SNR) = 2\varepsilon_1 \lambda_g^2 \left(\frac{2^{\gamma}-1}{SNR}\right)^2$ and Rate threshold, $\gamma = log_2(1+\gamma_{th})$

In [13], By way of superposition coding, two sources send two symbols to two users, and each user decodes their symbol through MRC and SIC. Meanwhile, the cumulative number of SICs is conducted by STBC-CNOMA as

$$SIC_{STBC-CNOMA} = \sum_{i=1}^{K-1}(K-i) \tag{40}$$

In (40), It is shown that due to higher SIC numbers, CCN difficulty improves with a greater number of user. In comparison, the number of SICs has not been raised in the STBC-CNOMA cooperation process. Moreover, we equate the number of transmissions in the last column of Table 4, which shows the overhead of communication. CRS-STBC- NOMA has the highest number of communication, as seen in the table. Due to the obvious STBC portion, we will find that for any $K \geq 4$, STBC-CNOMA also needs more transmission numbers compared to the MIMO-NOMA and NOMA-GSSK techniques.

Chapter 4

Simulation Result Analysis & Discussion

We present numerical and simulation outcomes in this section based on the equations mentioned in section 3.3, 3.4 & 3.7. We consider a downlink NOMA systems with 6 users along with one base station. Simulation result will show which hybrid NOMA scheme performs better in order to have low bit error probability (BEP), high energy and spectral efficiency, and low number of SIC (Successive Interference Cancellation) occurrence.

4.1 Comparison of BEP among MIMO-NOMA, NOMA-GSSK & STBC-CNOMA

Figure 4.4.1 shows the simulation result of the Bit error probability (BEP) of MIMO-NOMA, NOMA-GSSK and STBC-CNOMA when the total number of users is 6.

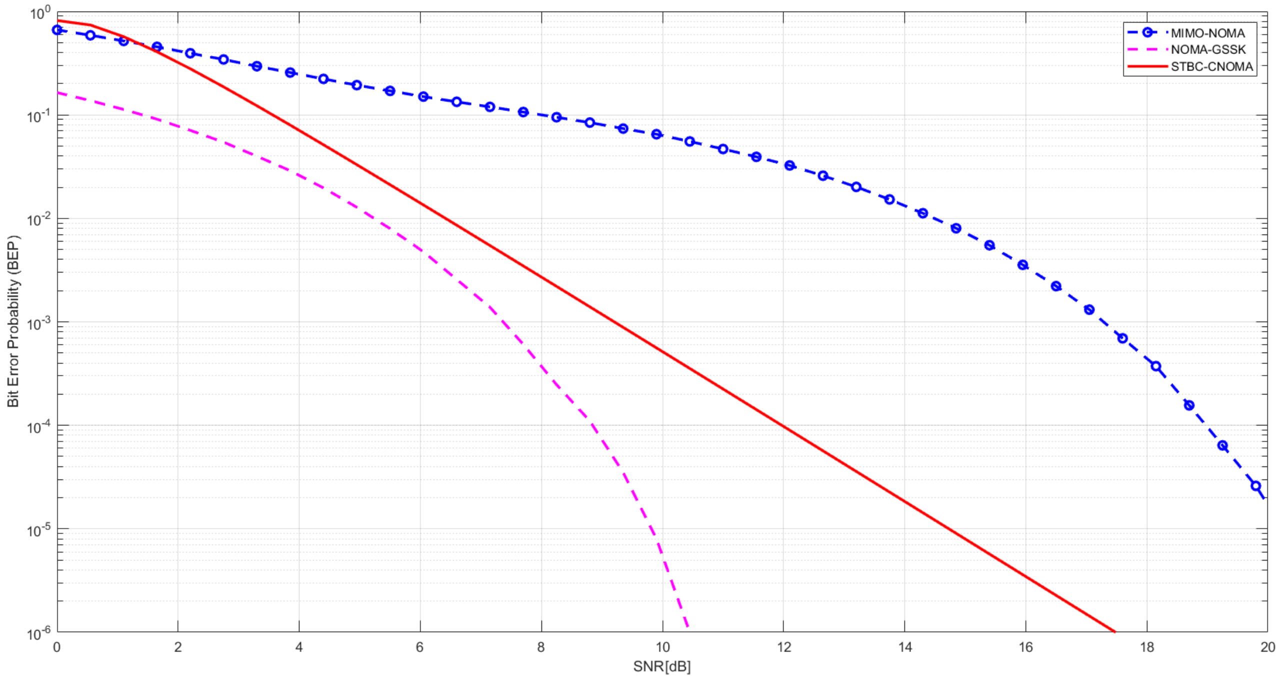

***Figure 4.1.1** Bit error Probability of 6 users case for MIMO-NOMA, NOMA-GSSK and STBC-CNOMA (Imperfect timing synchronization, Perfect SIC, Perfect CSI)*

Thus, we can see from the fig. that as the value of SNR (dB) increases, the decreasing rate of BEP is quite significant for the NOMA-GSSK scheme rather than the other two hybrid NOMA schemes. So, the NOMA-GSSK scheme outperforms the other two NOMA hybrid schemes in terms of BEP in the proposed 6 user's case. Further, when the SNR is increasing the BEP rate is decreasing for STBC-CNOMA. Although it is kind of expected from theory where we found for MIMO-NOMA case the signal will be strong if there is increasing number of antennas is used. For NOMA-GSSK and STBC-CNOMA schemes, the no. of antennas will be equal to the no. of users. But the complexity of the system on STBC-CNOMA is greater than NOMA-GSSK. For a good communication system, BEP should be 10^{-3} and lower than that is considered acceptable [2]. In this case, NOMA-GSSK crosses 10^{-3} when the SNR value is only 7 dB which is extremely good compared to other two hybrid schemes. Whereas, STBC-CNOMA and MIMO-NOMA provides the BEP value of 10^{-3} when the SNR value is 9 dB and 17 dB respectively. To conclude, the reason behind NOMA-GSSK overtakes STBC-CNOMA is imperfect timing synchronization in STBC-CNOMA degrades BEP rates, whereas there is no timing synchronization issues in NOMA-GSSK.

4.2 Comparison of Spectral Efficiency among MIMO-NOMA, NOMA-GSSK & STBC-CNOMA

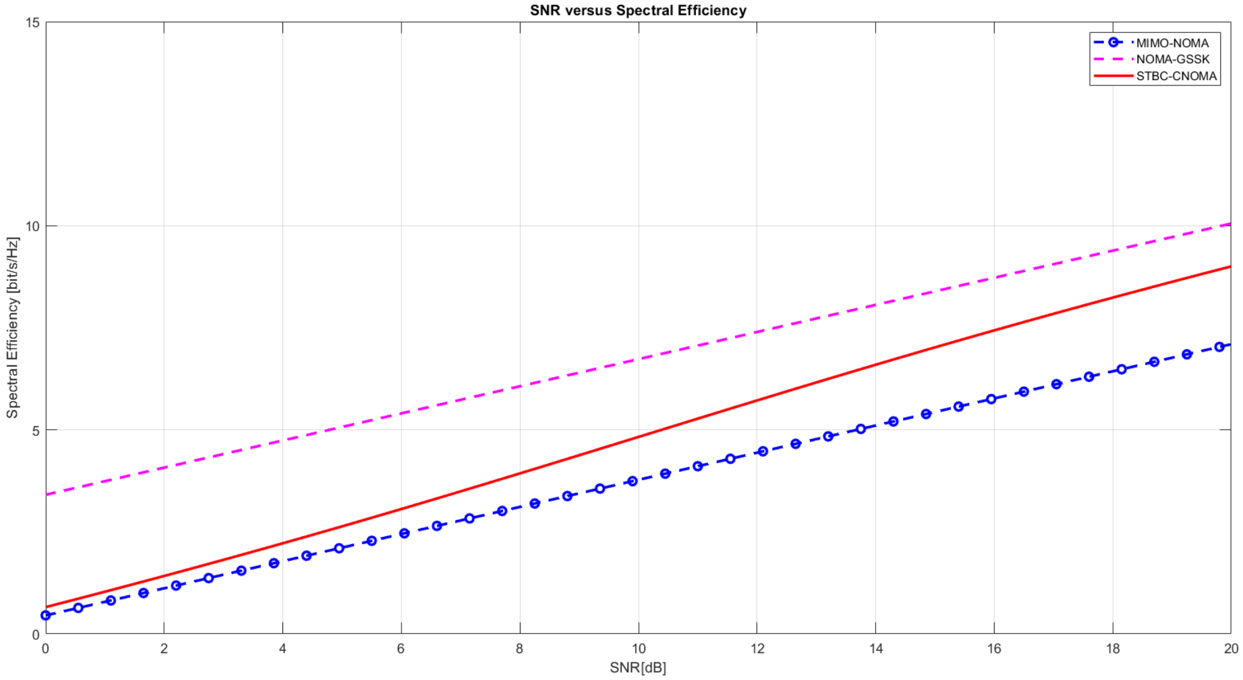

***Figure 4.2.1** Spectral Efficiency of 6 user's case for MIMO-NOMA, NOMA-GSSK and STBC-CNOMA (Imperfect timing synchronization, Perfect SIC, Perfect CSI)*

Figure 4.2.1 Shows the SNR (dB) vs Spectral Efficiency (bit/s/Hz) of MIMO-NOMA, NOMA-GSSK and STBC-CNOMA. The simulation results clearly show that for 6 users' case the spectral efficiency from low to high SNR of NOMA-GSSK is higher than the other two schemes. Whereas, the STBC-CNOMA holds better spectral efficiency than the MIMO-NOMA scheme. For MIMO-NOMA, multiple times of antenna than user number improves spectral efficiency but increases system complexity. It is also observed from the figure that when SNR increases more than 10 dB the difference in spectral efficiency becomes lower gradually between NOMA-GSSK & STBC-CNOMA. The reasons behind NOMA-GSSK performs better because it utilizes spatial domain for cell-edge users. So, for the given number of bandwidth (Spectral Efficiency) the performance of NOMA-GSSK is significantly greater compared to other two schemes.

4.3 Comparison of SIC among NOMA-GSSK, MIMO-NOMA & STBC-CNOMA

Figure 4.3.1 represent the comparison between SIC among NOMA-GSSK,MIMO-NOMA and STBC-CNOMA.

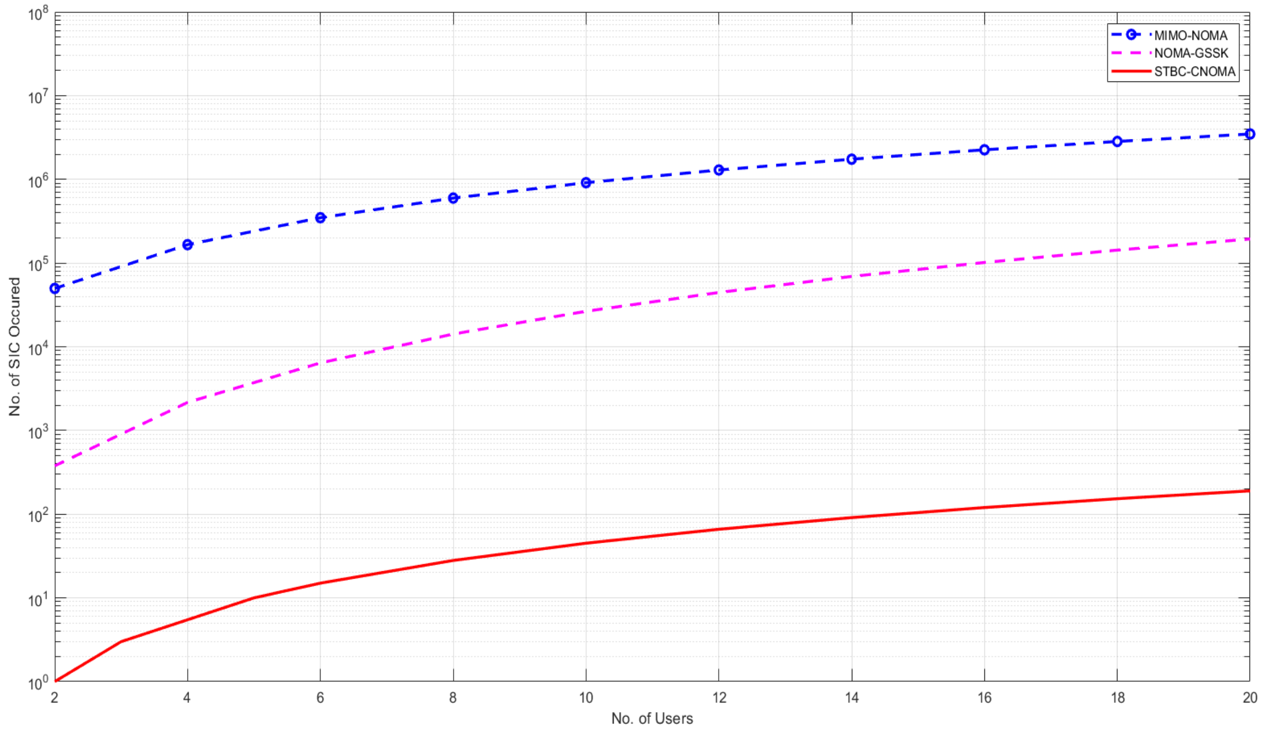

Figure 4.3.1 *SIC comparison among NOMA-GSSK, MIMO-NOMA and STBC-CNOMA*

From Table 4. We came to know that STBC-CNOMA uses less time slots than any other Hybrid Schemes used in NOMA. Though the time slot is less, the number of SIC is also less than any other hybrid NOMA schemes. Also the benefits of Alamouti coding which decreases complexity, hence, number of SIC decreased drastically. In this fig. we can see that the number of SIC performed for increasing number of users is extremely low for STBC-CNOMA than other two hybrid NOMA schemes used here. For our 6 user's case the number of SIC occurred for STBC-CNOMA is 13 (from eq. 38). Whereas, the number SIC for MIMO-NOMA and NOMA-GSSK is significantly very much high in this case. Thus, the decoding complexity issues can be reduced notably by using STBC-CNOMA compared to other two schemes. On the other hand, NOMA-GSSK scheme require very low number of SIC than MIMO-NOMA because NOMA-GSSK hybrid scheme does not perform SIC for cell-edge users.

4.4 Comparison of Energy Efficiency among MIMO-NOMA, NOMA-GSSK & STBC-CNOMA

Figure 4.4.1 indicates the Spectral Efficiency vs Energy Efficiency performance of MIMO-NOMA, NOMA-GSSK and STBC-CNOMA.

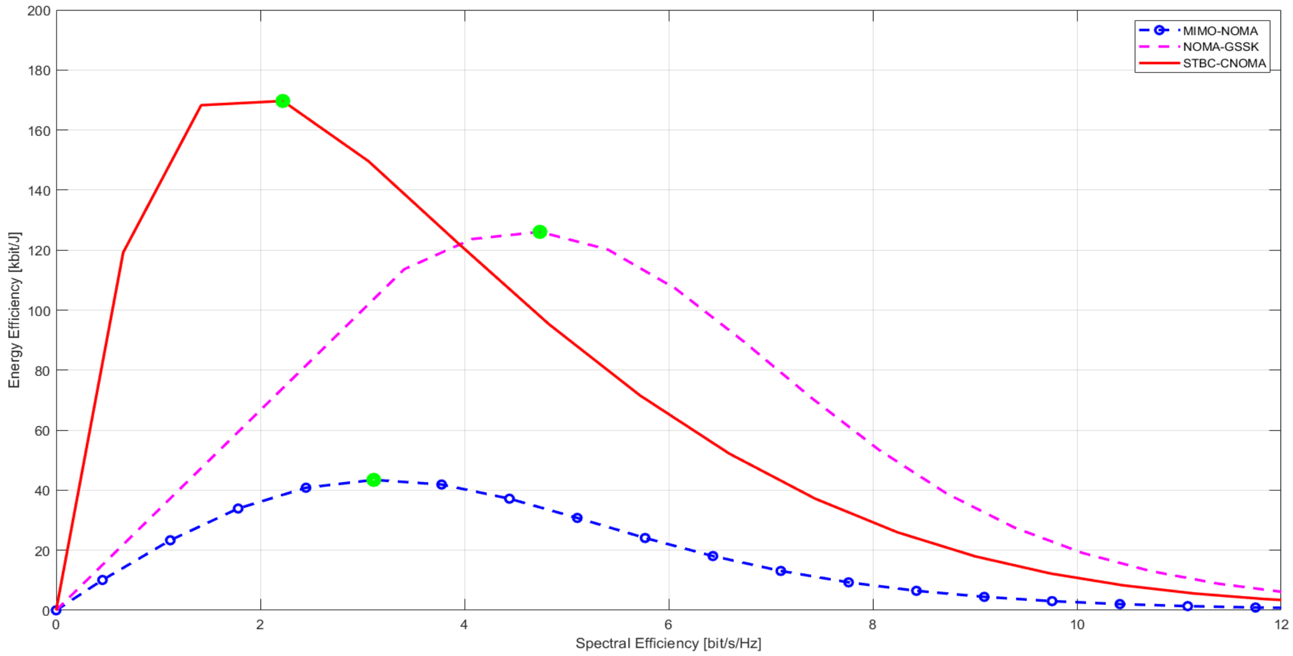

Figure 4.4.1 *Energy Efficiency of 6 user's case for MIMO-NOMA, NOMA-GSSK and STBC-CNOMA (Imperfect timing synchronization, Perfect SIC, Perfect CSI)*

Due to the exponential rise in transmission reliability, both EE (Energy efficiency) and SE (Spectral efficiency) increase initially as the transmission power increases, before they achieve optimum values. But the trade-off between EE and SE begins as the transmission capacity becomes greater. The EE increases when the number of bits transmitted (modulation order) increases as the SE is set to a constant at any necessary value. Increasing SIC means decoding complexity becomes notably high which leads to very high circuit power consumption. Thus, STBC-CNOMA outperforms other 2 hybrid NOMA schemes in terms of Energy efficiency significantly because extremely reduced number of SIC occurrence. NOMA-GSSK is better than MIMO-NOMA in terms of energy efficiency because cell-edge users are divided in space domain instead of power domain, hence transmission power consumption decreased. STBC-CNOMA holds particularly low complexity issues than other two schemes. In figure, the green point holds the highest Energy efficiency for respective hybrid schemes used here. We can observe that STBC-CNOMA holds its highest peak when the spectral efficiency is immediately after 2 bit/s/Hz. However, the MIMO-NOMA and NOMA-GSSK hold the highest energy efficiency when the spectral efficiency is at 3 & 5 (bit/s/Hz) respectively.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

Since NOMA has been acknowledged as an efficient technology to fulfill the demand of 5G and beyond wireless networks, many researchers have proposed integration of promising technology along with conventional NOMA technique in order to upgrade NOMA with an intention to boost diversity, remarkable increase in energy and spectral efficiency with noticeable reduction in SIC occurrence. In order to assess the changes, we analyzed some of the recent innovations of hybrid NOMA schemes. We use the observation in this report for a downlink hybrid NOMA system for six users, of which three users are located at the cell edge. Cell edge users have the lowest possibilities to detect strong desired signals due to poor channel conditions. Cell-edge users were given the spatial domain in NOMA-GSSK to transmit symbol information using an antenna index without performing SIC in the receiver side. Multiple active transmit antennas are used by NOMA-GSSK to boost efficiency. Whereas, to decrease SIC, Cooperative NOMA has been updated with space time block coding. We used STBC-CNOMA to highlight the benefits of Alamouti coding in order to reduce the SIC occurrence remarkably than the other two hybrid NOMA schemes.

Simulation results have been portrayed in terms of BEP, spectral & energy efficiency and SIC occurrence to make rational performance comparison among MIMO-NOMA, NOMA-GSSK and STBC-CNOMA schemes. Our findings show that NOMA-GSSK has the lowest BEP (Bit Error Probability) and the highest spectral efficiency compare to other two schemes. On the other hand, STBC-CNOMA obviously outperforms other two hybrid NOMA schemes in terms of energy efficiency and number of SIC occurrence. In short, it can be demonstrated that

NOMA-GSSK scheme is more suitable for large scale communication systems where extremely low BEP and very high channel capacity are the major concerns. Whereas, for small scale and less complex communication systems such as IoT based small battery powered sensors STBC-CNOMA will be appropriate than other two hybrid NOMA schemes.

5.2 Future Work

In this work, we have investigated thoroughly the performance of hybrid NOMA schemes, which have been proposed in recent research works. The outcomes reveal that hybrid NOMA schemes can successfully mitigate the limitations of conventional NOMA technique. In the foreseeable future, research work can be carried out whether hybrid NOMA scheme or NOMA-OMA combination is more efficient to meet the challenges of conventional NOMA technique in order to fulfill the demand of 5G and beyond wireless communications more effectively. Research work can also be performed to identify simpler hybrid NOMA schemes which may outperform the mentioned schemes one step forward to be considered most prominent hybrid NOMA scheme.

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