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OPTIMIZATION OF SPECTRAL EFFICIENCY OF 5G BY USING NON-ORTHOGONAL MULTIPLE ACCESS (NOMA) BASED ON POWER DOMAIN

Osamah Razzaq JANABI

Master`s Thesis

Supervisor

Asst. Prof. Dr. Mesut ÇEVİK

Istanbul, 2023

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The thesis titled OPTIMIZATION OF SPECTRAL EFFICIENCY OF 5G BY USING NON-ORTHOGONAL MULTIPLE ACCESS (NOMA) BASED ON POWER DOMAIN prepared by OSAMAH RAZZAQ JANABI and submitted on 13 /04/2023 has been **accepted unanimously** for the degree of Master of Science in Electrical and Computer Engineering**.**

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Submission date of the thesis to Institute of Graduate Studies: ___/___/___

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Osamah Razzaq, JANABI

Signature

DEDICATION

First of all, I am grateful to Allah for giving me strength and wisdom throughout all my life and especially to finish this project. I would like to express my sincere appreciation and grateful thanks to the supervisor Asst. Prof. Dr. Mesut Cevik for his valuable suggestions and comments related to this work.

Lastly, I dedicated this to my mother, my wife, brothers and sisters, relatives, and my friends specially Eng.Yassen sadoon, Eng. Ali Abbas and Eng.Nariman they have been encouraging and support me during this study.

ABSTRACT

OPTIMIZATION OF SPECTRAL EFFICIENCY OF 5G BY USING NON-ORTHOGONAL MULTIPLE ACCESS (NOMA) BASED ON POWER DOMAIN

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5G fifth generation has the ability to support a massive number of connected devices with very low latency communications, in addition to high data rate speed and huge coverage area. To deal with the big data information above, it is required that some emerging technologies go forward to become a reality. 5G use a certain segment that make a network perform better in terms of Quality of Service (QoS) with these challenges, so this is a reason behind considering 5G much more than a mobile communication network presented with current and expected transmission techniques. This thesis shows the overview about Multiple Access Techniques (MTA) with its two categories: Orthogonal Multiple Access (OMA) and Non-Orthogonal Multiple Access (NOMA) then describes NOMA segments: power and code domain. After that, we are focusing and investigate on the power domain where we will suppose a certain methodology to enhance SE (spectrum efficiency) and achieve fairness in power allocation for the users in both uplink and downlink NOMA scenarios.

Keywords: 5G, Oma, Noma, Pd –Noma, Cd-Noma. Mta.

TABLE OF CONTENTS

Pages

LIST OF FIGURES

Pages

ABBREVIATIONS

2G	:	Second Generation
OMA	:	Orthogonal Multiple Access
4G	:	Fourth Generation
IOT	:	Internet of Things
QOS	:	Quality of Service
6G	:	Sixth Generation
OFDM	:	Orthogonal Frequency Division Multiplexing
NOMA	:	Non-Orthogonal Multiple Access
3G	:	Third Generation
SIC	:	Successive Interference Cancellation
5G	:	Fifth Generation
TDMA	:	Time Division Multiple Access
GSM	:	Global System for Mobile Communications
UMTS	:	Universal Mobile Telecommunications System
LTE	:	Long-Term Evolution
MA	:	Multiple Access
M-MIMO	:	Massive-Muti Input Multi Output
PD-NOMA	:	Power Domain Non-Orthogonal Multiple Access
LTE-A	:	Long-Term Evolution Advance
CD-NOMA	:	Code Domain Non-Orthogonal Multiple Access

SE	:	System Efficiency
CSI	:	Channel State Information
UE	:	User Equipment
SDR	:	Software-Defined Radio
SP	:	Superposition
PDMA	:	Pattern Division Multiple Access
SCMA	:	Sparse Code Multiple Access
FDMA	:	Frequency Division Multiple Access
LDS	:	Low-Density Spreading
MPA	:	Message Passing Algorithm
BER	:	Bit Error Rate
TDMA	:	Time Division Multiple Access
MUSA	:	Multiuser Shared Access
TDD	:	Time Division Duplexing
CDMA	:	Code Division Multiple Access
FDD	:	Frequency Division Duplexing
MMTC	:	Massive Machine-Type Communications
OOB	:	Out-Of-Band
PIC	:	Parallel Interference Canceler
MMSE	:	Minimum Mean-Squared Error
MUD	:	Multiuser Detection

SC-FDMA	:	Single Carrier–Fdma
PAP	:	Power Allocation Process
SISO-NOMA	:	Single Input- Single Output Noma
GNB	:	In 3GPP-Compliant Implementation of The 5g
AWGN	:	Additive White Gaussian Noise
RF	:	Radio Frequency
PAPR	:	Peak to Average Power Ratio
FDE	:	Frequency Domain Equalization
ICI	:	Inter-Cell Interference
TPC	:	Transmission Power Control
D-OMA	:	Delta-Orthogonal Multiple Access

1. INTRODUCTION

1.1 BACKGROUND

5G is leads some technologies to appeared, such as Internet of Things (IoT), Quantum Computing, Artificial Intelligence, Machine Learning, Robotics, Augmented Reality, Virtual Reality, etc. by offering broadband access across a huge coverage area, high-speed and very low latency communications. Great changes are in perspective – if they happen in our lives in an active way regarding the way of producing, communicating and storing information. 5G use a certain segments that make a network perform better in terms of Quality of Service (QoS) with these challenges, so this is a reason behind considering 5G much more than a mobile communication network presented with current and expected transmission techniques [1] .

The transmission techniques used in the current 5G version are based on Orthogonal Frequency-Division Multiple Access (OFDMA). However, for future updates, Non Orthogonal Multiple Access (NOMA) techniques presents itself as a strong candidate. Non-orthogonal multiplexing of a user using power allocation at the transmitter and Successive Interference Cancellation (SIC) at the receiver and not only outperforms on the orthogonal multiplexing, but is also good at reaching the capacity region of the downlink transmission channel and superior in terms of spectral efficiency. In addition to that, these is various opportunities and challenges associated with NOMA's compatibility with other communication paradigms, Figure1.1 below shows the difference between current 5G version and the promising one [2].

Until now, Orthogonal Multiple Access techniques (OMA) have been used in the different generations of cellular radio communication: GSM (Global System for Mobile Communications), UMTS (Universal Mobile Telecommunications System) and LTE (Long-Term Evolution). Frequency reuse, polarization diversity, carrier sharing in OFDMA are all techniques that make it possible to obtain good network capacity while maintaining reasonable interference levels. However, the transition to 5G, with the need to take into account the deployment of large-scale sensor and machine to machine exchanges, changes the situation and leads to examining the case of NOMA. In NOMA systems, it is tolerated that blocks of time-frequency resources can be superposed on a condition, of course, of being able to process the interference generated effectively on reception as in Figure 1.1 below [3].

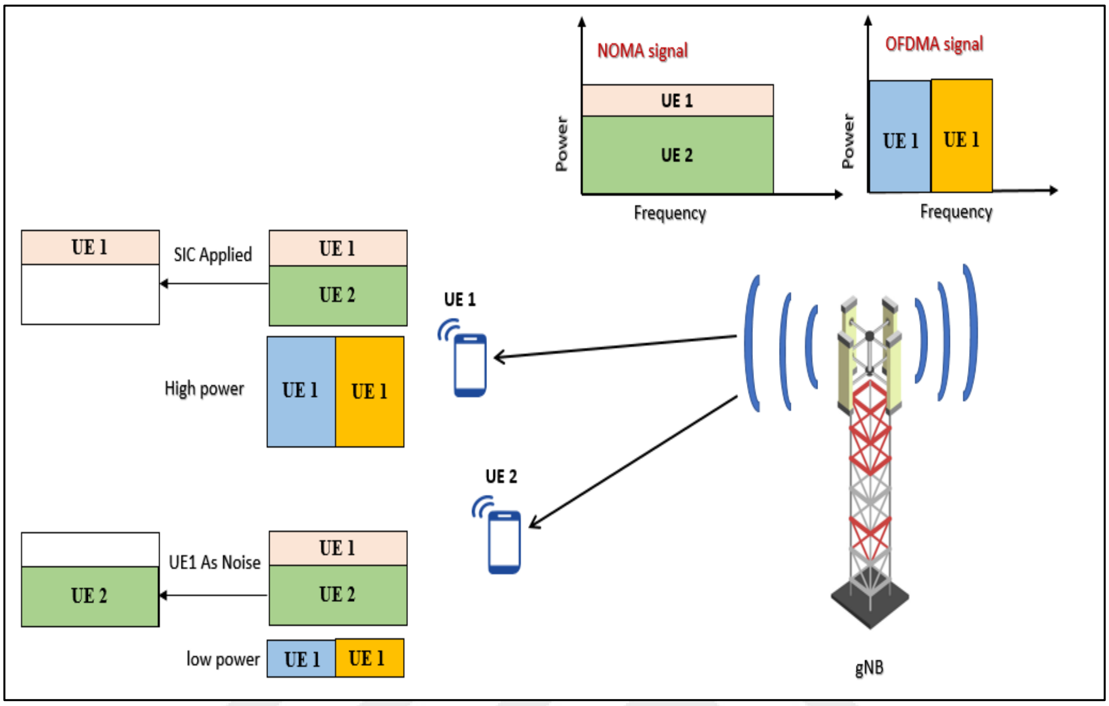

Figure 1.1: Current and Update NOMA Multiple Access Technology [3].

NOMA is an alternative to OMA that does multiplexing in the time domain, frequency domain, or coding domain instead of all three. In other words, NOMA can be interpreted as a "add-on" that has the potential to be compatible with the multiple access (MA) techniques that are now in use. The primary objective of NOMA is to multiplex power domains and/or code domains in order to make it possible for a greater number of users to share the same collection of resources. The acronym NOMA can be broken down into three distinct groups: NOMA in the power domain, NOMA in the code domain, and NOMA multiplexing in several different domains. Every one of these subcategories focuses on a different element that is a part of NOMA. Because NOMA makes it possible to make full use of the limited spectrum resources available, 5G networks may accommodate a significantly greater number of users. This leads to a significant increase in the capacity of 5G networks [3][4].

1.2 HYPOTHESIS

In this thesis, NOMA will be analyzed as a potential multiple access technique to be adopted in future 5G upgrades. The environment will be with power domain, which has the ability to provide greater spectral efficiency and capacity with superposed signals in the transmitters, and low complexity process in receivers compared with code domain. The choice of this technique is due to its great performance in spectral efficiency, flexibility for decoding and user fairness.

1.3 MOTIVATION

Cellular communications over the years have been asserting themselves as the future when it comes to communication. Since the emergence of the first generation, new services have become available and data rates have increased. Services such as video conferencing, online games and mobile television have made it possible for mobile devices to become a constant in everyone's daily lives, with the massive number of connected devices and traffic increasing significantly. In the emergence of 5G, we will have an increase in throughput of up to 10,000 Mbps, with a very low latency (in ms) and more reliability, these characteristics will boost areas such as IoT, Autonomous Driving, Virtual Reality and many others applications.

1.4 PROBLEM STATEMENT

Due to the limitation of spectrum in the space, it is necessary to thinking about new multiple access technique to attain the demand with the available bands. The transmission techniques used in the current 5G version are based on OFDMA associated with m-MIMO and mm-wave. However, NOMA presents a good performance in terms of spectral efficiency and being a potential multiple access technique, which be adopted for future 5G upgrades. This thesis aims to study, in more detail, 5G, PD-NOMA, CD-NOMA. Simulations will be carried out in three scenarios (uplink, base station, and downlink) in the power domain, which tends to gain spectral efficiency with low complexity in receiver side.

1.5 OBJECTIVES AND CONTRIBUTIONS

The general objectives of this thesis are to study MAT, NOMA in 5G.

a. Study spectrum in 5G with most important bands.
b. Study OMA and NOMA, and then compare them from side of capacity.
c. Study the most important CD-NOMA schemes for the 5G standard.
d. Study PD-NOMA and analyze what makes it provide greater spectral efficiency with high capacity.
e. Carry out a set of simulations in three scenarios (uplink, base station, and downlink) with NOMA users and extract analyzes and conclusions from them.

1.6 THESIS ORGNIZATION

The organization of this thesis as below:

a. Chapter 2 is describing the literature survey in power / code domain, then describe OMA, NOMA and code domain in a superficial way.
b. Chapter 3 is where describe our methodology for power domain.
c. Chapter 4 is where we explain simulations and discuss results.
d. Chapter 5, here, we describe the conclusion of our work and describe future works which can be used.
e. References.

2. LITERATURE SURVEY

2.1 LITERATURE SURVEY MAT, AND CD-NOMA

The literature survey arranges as: The overwhelming majority of the survey publications on NOMA that are currently available [5][6][7][8] solely concentrate on the power-domain NOMA. The references [9][10][11] offer a condensed summary of the many different NOMA schemes that are active in the code domain.

Chekwas Ifeanyi Chikezie (2022) [5] discussed the power allocation from side of user's fairness and described it as necessary to improve the scheme further. To attain fair power allocation and striving to enhance the SE (System Efficiency) with a good QoS, this can be useful for the weak users in the prospective RAN (Radio Access Network), so he proposed a new power algorithm that achieve users' fairness, depending on desired CSI and rate requirements. The simulation findings explained that the new power algorithm proposed achieves better performance than other conventional ones.

Bipasha Patnaik (2022) [6] the asserting studies was described on evolution of 5G - NOMA and distinguished the performance between NOMA / OMA technologies. As basic principles of NOMA technique, the throughput is higher for the users who have better channel gain. NOMA optimizes the SE (Spectral Efficiency) of 5G access equipment. When many users had the same channel gains and time but at different levels of power allocated, the request of the desired data will be critical.

N. Iswarya (2021) [7] discussed first, the main fundamentals of NOMA compared with OMA from aspect channel gain. In addition to that, he discussed the SC (Superposition coding) technology of the base station (In downlink scenario), and the SIC on the user equipment (UE), An obvious survey of different SIC protocols executed with ideal/non-ideal CSI was shorted from side of system performance and outage probability. Eventually, cases between distinct practical and ideal SIC technique was performed from aspect of performance gap with NOMA ideal and non-ideal CSI.

YUE QI (2021) [8] he discussed the implement and design NOMA in (SDR - Software-Defined Radio), then the performance was evaluated including real time realization of NOMA key instances, such as Superposition (SP) and Successive Interference Cancellation (SIC) techniques. Furthermore, introduced superimposed signals constellation with different rates of symbols to improve the achievable data rate of the NOMA experimented. With his new designed system, the system can support a different transmission symbol rate, ones with convolutional coding, and without.

Linglong Dai (2015) [9] discussed key features, main principles, and pros/cons for many NOMA schemes for 5G. These can be summarized as: based on spreading sequence such as MUSA (Multi-User Shared Access) and based on coding sequence such as PDMA (Pattern Division Multiple Access), SCMA (Sparse Code Multiple Access) and (LDS) Low-Density Spreading, Furthermore, he provided an obvious comparison of these schemes from side of system performance, receiver complexity and spectral efficiency. After that, highlighting opportunities, challenges, and prospective research for NOMA protocol was done. In order to help the next researchers regarding to field above, He had also described on theoretical work, enhancing spreading design (or codewords) and receiver.

Kun lu, (2017) [10] summarized the features and process of different schemes of NOMA and evaluated its performance. Then he analyzed the differences and similarities of every scheme in the same protocol and their respective features. In addition, he showed that scheme who depend on code domain had better performance than other schemes according to the simulation results but there is a high complexity in Message Passing Algorithm (MPA) decoding. Based on the features of high order modulation, SCMA has higher performance advantages than the other due to design of sparse codebook in multi-dimensional way.

Bichai Wang (2015) [11] discussed main fundamentals and key specifications of 3 ordinary NOMA schemes (MUSA, SCMA, and PDMA). In addition to, uplink Bit Error Rate (BER) effectiveness. Simulation findings appeared that in standard Rayleigh fading channels, SCMA scheme have better finest action due to the near-optimal MPA receiver together with near-optimal sparse code words design, whereas MUSA and PDMA BER results are so near to one another. Furthermore, the PDMA performance analyses at using the factor graph as same as used in SCMA is done, and the last one refer to that both the differences of codebook optimization and factor graph is the reason that makes SCMA overcome PDMA in gain.

2.2 IMPORTANCE OF SPECTRUM IN 5G

Spectrum of radio is a finite natural wealth, where its management requires a thorough perception of its value, and it is a core piece of any wireless communication system. In order to respond 5G segments and NOMA technology, a significant range of new internationally harmonized mobile spectrum in low-mid-high ranges should be assigned to deliver widespread coverage, high data bitrate and support all 5G services [12].

There are three sub-divided categories of spectrum bands (licensed and unlicensed bands) and spectrum management for deployment of 5G, sub-1GHz, 1-6 GHz and above 6 GHz. In Sub-1GHz, due to the propagation properties of the radio signals at these frequencies enable 5G to support widespread coverage areas and deep inside-building penetration in rural, urban, and suburban areas. The band 1-6 GHz offer a good mixture of capacity and coverage benefits for 5G services and has also been used in 3G and for 4G networks. The new radio spectrum are assigned primarily in 3.5 GHz band, with a plan to acquire more spectrum available in the band of 5 GHz [12].

The mid band offers better connectivity in indoor communications and wide range compare with the high frequency's bands. It is an optimal balance between range coverage, capacity, QoS and throughput. In above 6 GHz High-band radio is a hopeful solution for 5G to enhance capacity, quality and data rate speed with low latency by using high bands (e.g. mm Wave bands) where the fastest 5G speeds depend on millimeter wave bands above 24 GHz [13]. Figure 2.1 below show three categories of 5G.

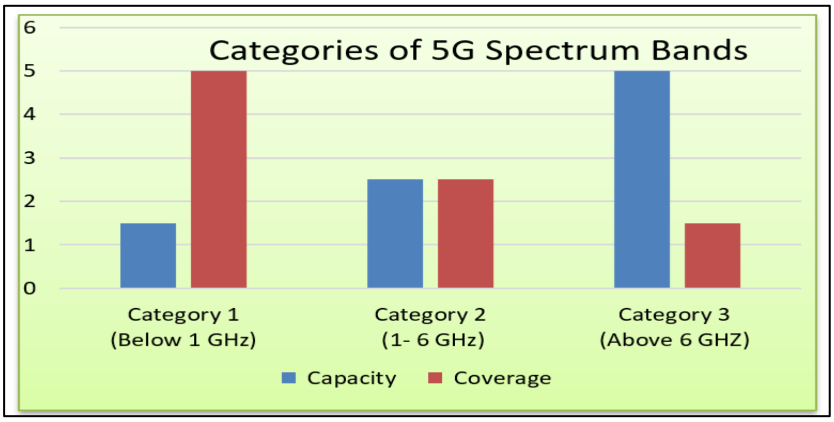

Figure 2.1: Capacity and Coverage of 5G Spectrum Categories [13].

2.3 MULTIPLE ACCESS TECHNIQUES (MAT)

MAT is a system that allow numerous users' equipment (UE's) to effectively use the same communication channel, UE's broadcast their data stream independently via their channel to a certain receiver, this transmission will use full system frequency bandwidth with a restricted power for each user, and the base station will synchronize and coordinate the process of transmission. Then, the signals received will decoded in a consistent way. There are two categories of multiple access techniques: OMA (Orthogonal Multiple Access) and NOMA (Non-Orthogonal Multiple Access) [3][7][14][15][16]. Figure 2.2 below illustrates MAT categories.

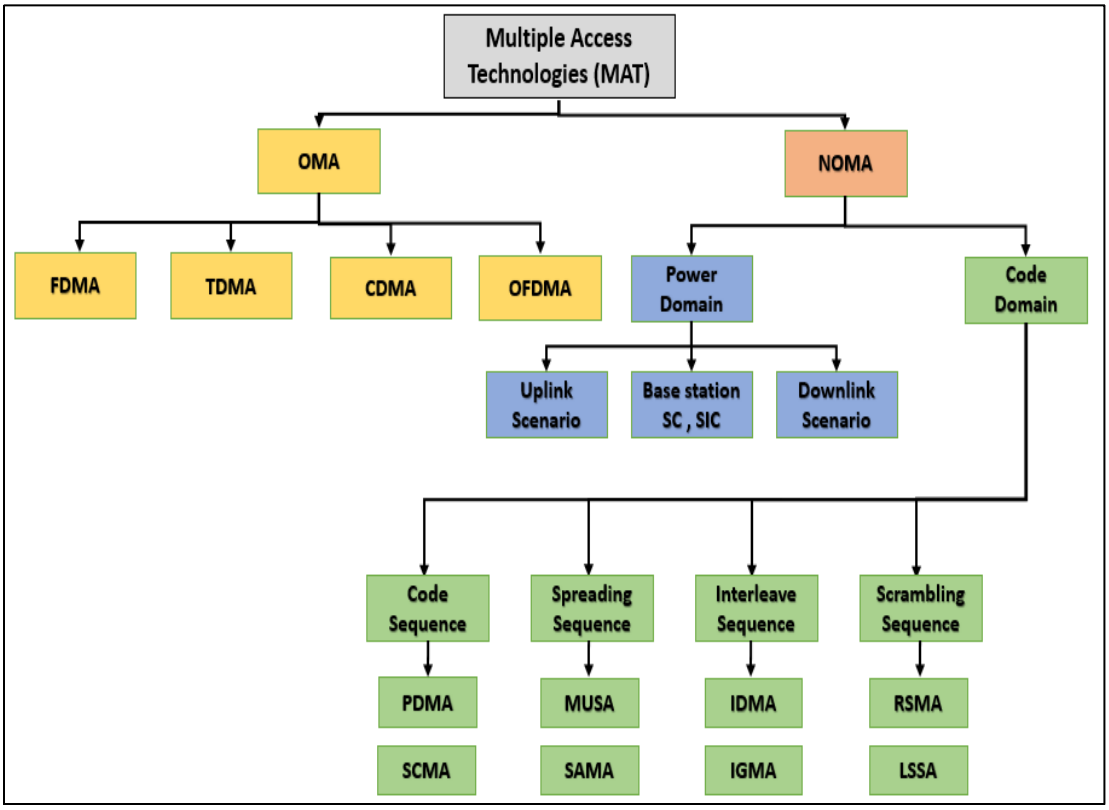

Figure 2.2: MAT Categories [14].

2.3.1 ORTHOGONAL MULTIPLE ACCESS TECHNIQUES (OMA)

OMA, which stands for orthogonal multiple access, is an essential component of all wireless networks, both those that already exist and those that will be built in the future. In digital communication systems, there are three basic techniques of wireless media sharing multiple access, respectively called Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA) and Code Division Multiple Access (CDMA). The principle of TDMA is to divide the time axis into time slots within a repeating pattern called a frame. Within a frame, each user is assigned to one or more time slots, taking care that there are never two users on the same time slot. To establish communication between a sender and a receiver, each of the two uplinks and downlinks is assigned specific time slot positions [6][17].

In FDMA, the total system bandwidth is divided into sub-bands (which do not overlap). Subsequently, each user is assigned a specific frequency sub-band. It should be noted that in general, a mix between TDMA and FDMA is rather used in order to be able to have the widest possible radioelectric resource. Thus, in MF-TDMA (Multi Frequency TDMA), users have access to several frequency bandwidths in the same time slot. The third technique, called CDMA, consists of multiplying each user's data by a faster sequence called a spreading code If the codes assigned to the different users are orthogonal in the sense of the inter-correlation, it is easy to superimpose several users on the same frequency band [6].

The fact that the spreading sequence is clocked at a higher rate than the sequence of the transmitted data results in a widening of the bandwidth for the signals of the users, when we speak about spread spectrum with the CDMA technique. It should also be noted that CDMA is associated either with the FDMA technique (case of the FDD – Frequency Division Duplexing mode of UMTS), or with the TDMA technique (case of the TDD – Time Division Duplexing mode of UMTS) [18].

In addition to that, a new revolutionary multiple access technique has made the success of 4G, it is multiple access by Orthogonal Frequency Division Multiple Access (OFDMA). OFDMA is obviously based on the use of OFDM, a multi-carrier modulation technique which converts a frequency-selective channel into a set of non-frequency-selective channels. However, unlike OFDM where all of the carriers are assigned to one user, in the context of OFDMA the carriers are shared among multiple users. This frequency sharing, associated with a sharing of emissions in the time domain, quite naturally leads to the concept of block of resources (RB: Block Resources) which are time-frequency blocks allocated to different users according to the quality of service (QoS) they require. The OFDMA technique is currently used in wireless LAN, WiMAX (IEEE 802.16) and LTE downlink systems. Figure 2.3 below illustrate different OMA techniques [18].

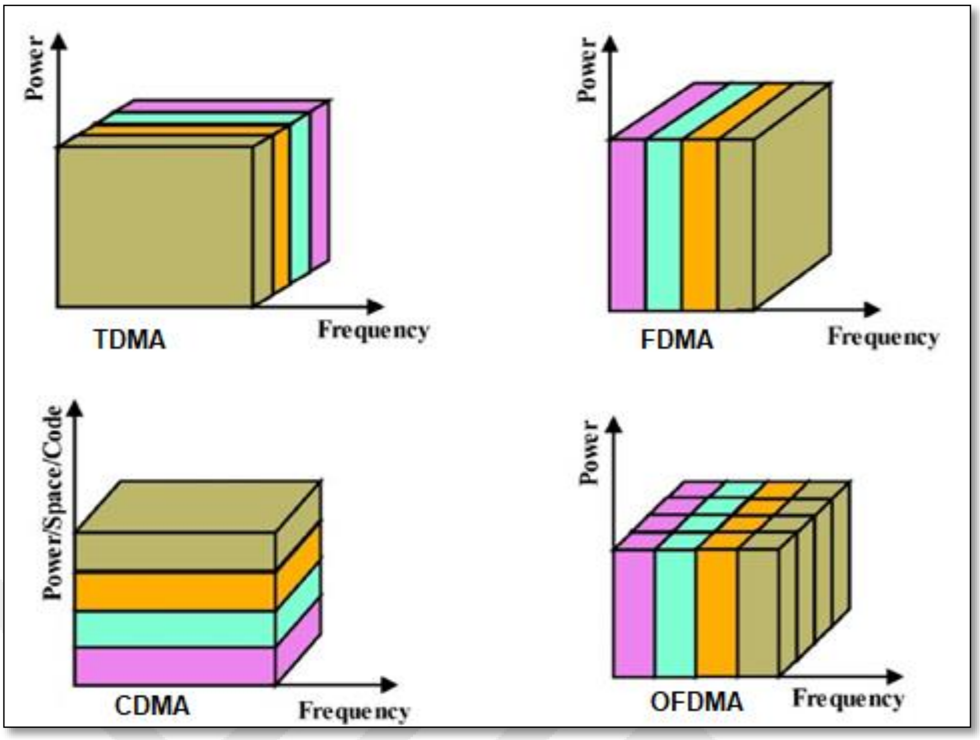

Figure 2.3: Principle of Multiple Access Techniques TDMA, FDMA, CDMA and OFDMA [3] [6].

One of the major advantages of OFDMA lies in its ability to adapt to time fluctuations of the propagation channel. Thus, in the frequency bands where the channel is very attenuated, we can assign resistant modulations with low spectral efficiency to the carriers concerned, while in the areas where the channel is strong, we can assign high efficiency modulations such as (QAM 16-32-64) to the carriers concerned. OFDM is currently a significant solution for broadband transmission due to its ability to reduce delay spread in wireless channels using simple detection techniques. This is one of the reasons why it has become so popular in recent years [19].

CDMA and OFDMA are implemented in 3G and 4G networks, respectively, whilst TDMA and FDMA are implemented in 2G systems. The resources of the system are divided orthogonally in time, frequency, or code domains. As a result of this, there is minimal interference between adjacent blocks, which makes signal simple to detect.

Classical OFDM is not capable of satisfying the needs for 5G networks in many ways because of the restrictions inherent to the technology. If this criterion is not satisfied, there will be significant interference between the nearby sub bands in the case of Massive Machine-Type Communications (mMTC) of 5G. In contrast, sensor nodes in this environment will commonly broadcast data asynchronously over limited bandwidths. In order to reduce the Out-Of-and (OOB) leakage of OFDM signals and fulfill the new requirements of 5G networks, several modulation schemes have been devised. Filtering, pulse shaping, and precoding are only few of the methods that fall under this category [20]. Leakage over the stop band can be successfully removed by a filter that has been carefully built, and it is possible to reduce OOB leakage with only a small amount of work by filtering the frequencies. Even though pulse shaping is a type of subcarrier-based filtering that minimizes subcarrier overlaps even within a single user's band, it frequently exhibits a lengthy tail in the time domain as a result of the Heisenberg-Gabor uncertainty principle. This is because pulse shaping is a filtering method that is based on subcarriers. Another effective strategy for reducing leakage is to send data using precoding before OFDM modulation. This is done in order to avoid data loss. In addition to the measures described above for preventing the propagation of OFDM signals, a variety of novel types of modulation have been proposed for use in 5G networks. These modulation types are intended to be used in conjunction with the 5G networks [17].

2.3.2 NON-ORTHOGONAL MULTIPLE ACCESS TECHNIQUES (NOMA)

NOMA techniques were designed to cope with the increase in the number of connected devices in the context of 5G and beyond. Indeed, these techniques were intended to tolerate a certain level of interference between users, by allocating common resources to several users at the same time, on condition that each of these users could be decoded correctly on reception with the quality of service required. The consequence of complexity of this technique is transferred to the level of the receivers, which must be able to carry out signal processing in order to cancel the interference.

The NOMA technique allows several users to share resources in time and frequency by simple linear superposition or by multiplexing. On the receiver side, the information of the different users (also called User Equipment or UE) can be recovered by advanced receivers such as receivers with interference cancellation or with iterative detection. However, to enable the receiver to detect multi-user signals under good conditions, it is necessary to introduce good separability between the users. This separability can be obtained in the power domain. In this case, the users are assigned different power levels which take into account the quality of their propagation channels. These power differences on reception will allow a receiver with SIC technique to recover all the signals transmitted [21].

This separability can also be obtained in the domain of code. Indeed, by assigning specific spreading sequences to each user, we can design a high-performance receiver capable of decoding all the users. This is the case (for example) of SCMA (Sparse Code Multiple Access) code spreading multiple access systems where the receiver uses a powerful decoding algorithm by belief propagation which best approximates the Maximum of Likelihood. It should also be noted that the separability of the users can be obtained spatially, if sufficiently directional antennas are available. In this case, it is possible to take advantage of the frequency reuse between sufficiently disjoint beams [9].

2.3.3 OMA AND NOMA THROUGHPUT

Several studies in the literature have shown that the NOMA technique with power multiplexing can be very interesting in terms of spectral efficiency and overall throughput compared to OMA techniques considering of course a perfect knowledge of the information on channel status (CSI). Figure 2.4 compares the capabilities of NOMA systems in power multiplexing and OMA systems in the case of two usersIt can be seen that NOMA is very efficient in terms of throughput when the user channels are different. Thus, NOMA is considered as a promising technique for future wireless communication networks [9].

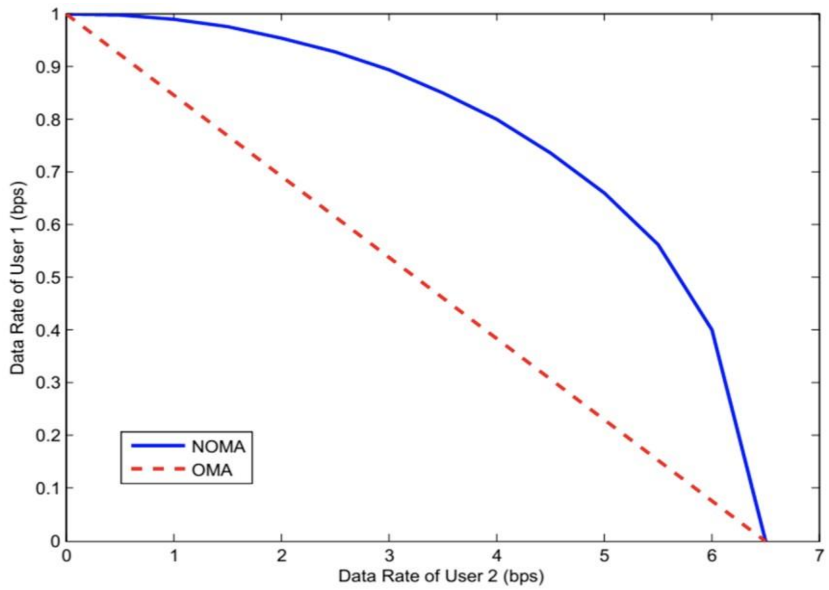

Figure 2.4: Comparison of the Capacity of OMA and NOMA Techniques in the Case of Two Users in the System [9].

2.4 CODE DOMAIN

This section will be devoted to a state of the art relating to the coding multiple access techniques used in the 5th generation. We focus on the NOMA techniques used in 5G which allow the superposition of several users on the same bandwidth in a given time interval. Specifically, we introduce code type of NOMA techniques: multiplexing techniques based on code separation to be able to deal effectively with the interference generated at reception. Multiplexing techniques based on code separation, key features and main basics of three NOMA schemes (Coding, Spreading and interleaving sequences) will be discussed separately with deep investigation for SCMA, PDMA and MUSA [9] [10].

2.4.1 A Code Sequence (CS-NOMA)

2.4.1.1 Sparse code multiple access (scma)

The SCMA technique, based on low-density codes in order to multiplex the users, is based on the LDS-CDMA technique (spectrum spread with low-density codes). This technique presenting many chips equal to zeros and few of chips equal to one, where it combines with a sophisticated multidimensional mapping in order to produce code words which can be processed efficiently on reception by a belief propagation algorithm. The SCMA technique associates the bits of information with low-density code words, extracted from a multi-dimensional codebook, which will be multiplexed into a well-defined group of orthogonal time-frequency resources, as can be seen in Figure 2.5 below. According to SCMA transmission system, the transmission chain is divided into two parts: The Encoder and The Decoder [9] [11].

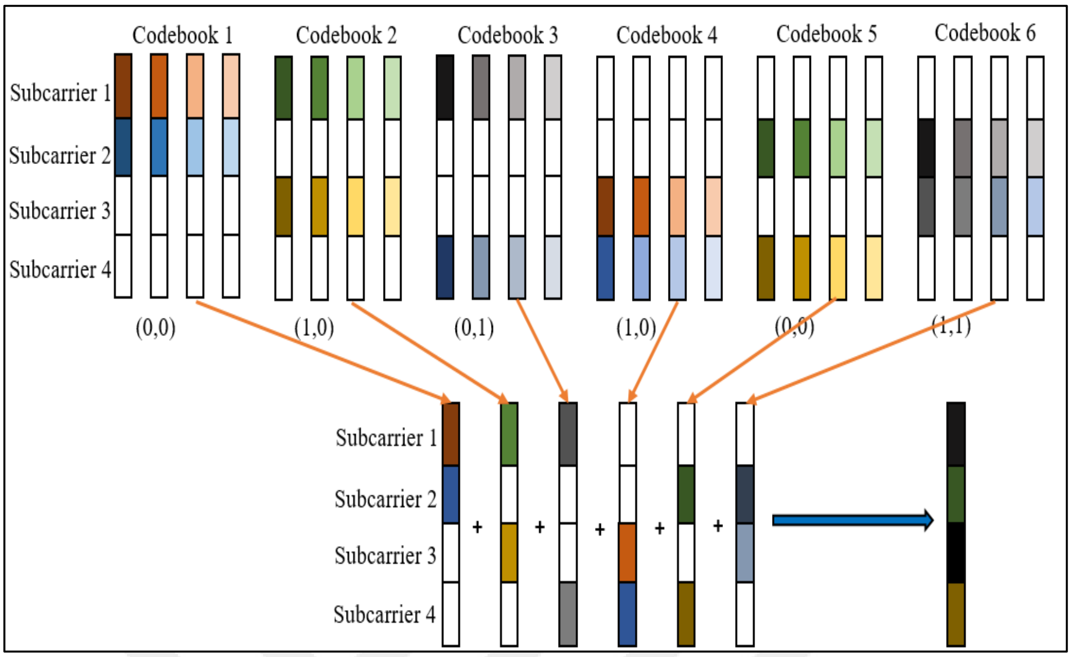

Figure 2.5: Mapping Bits / Code Words [22].

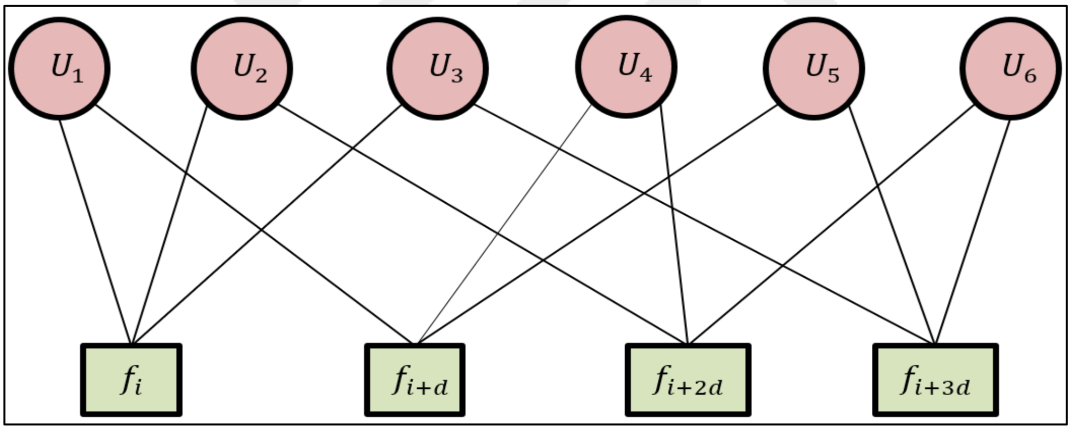

Figure 2.6: Equivalent Factorial Graph [23].

At the level of the encoder, a set of $\log_2 M$ bits must correspond to a code word of size M and of K dimensions, K corresponding to the numbers of sub-carriers available N(non-zero component). The K-dimensional code word is a vector with $N_1 < K_1$ nonzero components. Users cannot transmit data across the subcarriers represented by the other (N – K) null components. In theory, several code words can be allocated to a mutli user, and each code word can be used by several users. Figure 2.5 shows an example SCMA encoder with six layers that each have four code words that are represented as variable nodes and four subcarriers that are represented as function nodes or constraint nodes as in Figure 2.6. In

Figure 2.5, each row represents one dimension, and each column represents a four-dimensional vector. For each group of two bits, there is a list of four code words [23].

The white portions on the code words represent zeros in the corresponding code words. For example, for the list of code words corresponding to the pair of bits (0,0), there are four code words and only the first two lines are non-zero, which means that only subcarriers 1 and 2 are used while that carriers 3 and 4 are off. The design of the alphabet or of the set of multi-dimensional code words is the most delicate part, which conditions the performance of SCMA transmission techniques. Many research works have proposed different methods to obtain multi-dimensional constellations with good separability properties. Generally speaking, designing code words in SCMA systems is done in three steps [11].

a. The first step consists in designing the mapping matrix that will determine the number of layers which will interfere on each sub-carrier. In the example of Figure 2.5, we can see on the construction of the mapping that each layer can interfere with two other layers.

b. The second step consists of constructing the basic multi-dimensional constellation and deducing the corresponding points in the constellation.For this step, firstly it will be necessary to find a basic constellation, which maximizes the Euclidean distances between the points. Then we can apply transformations based on rotation matrices on this starting matrix to duplicate the code words.

c. The third step consists in constructing the code words likely to interfere using operations of conjugation, rotation, permutation. In the example of Figure 2.5, we have six layers of data that correspond to six users, four blocks of time-frequency resources available with the possibility of interfering two other users for each given user and four code words available for each of the six alphabets corresponding to a data layer [22].

Example: the optimization of the code words leads to the following alphabet equations (2.1, 2.2, 2.3, 2.4, 2.5, and 2.6) below [23].The parameters quoted in the table below are respectively:

a. F=4 the number of time-frequency resource blocks available,

b. V=6 the number of data layers (or the number of users who share the four resources),

c. df=3 the number of users who use the same block of time-resources frequency,

d. dv=2 the number of time-frequency resource blocks used by each user (or data layer),

e. M=4 the number of code words in each of the six alphabets.

$$CB_{U1} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ -0.1815 - 0.1318i & -0.6351 - 0.4615i & 0.6351 + 0.4615i & 0.1815 + 0.1318i \\ 0 & 0 & 0 & 0 \\ 0.7851 & -0.2243 & 0.2243 & -0.7851 \end{bmatrix} \quad (2.1)$$

$$CB_{U2} = \begin{bmatrix} 0.7851 & -0.2243 & 0.2243 & -0.7851 \\ 0 & 0 & 0 & 0 \\ -0.1815 - 0.1318i & -0.6351 - 0.4615i & 0.6351 + 0.4615i & 0.1815 + 0.1318i \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (2.2)$$

$$CB_{U4} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0.7851 & -0.2243 & 0.2243 & -0.7851 \\ -0.0055 - 0.2242i & -0.0193 - 0.7848i & 0.0193 + 0.7848i & 0.0055 + 0.2242i \end{bmatrix} \quad (2.3)$$

$$CB_{U5} = \begin{bmatrix} -0.0055 - 0.2242i & -0.0193 - 0.7848i & 0.0193 + 0.7848i & 0.0055 + 0.2242i \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -0.6351 + 0.4615i & 0.1815 - 0.1318i & -0.1815 + 0.1318i & 0.6351 - 0.4615i \end{bmatrix} \quad (2.4)$$

$$CB_{U6} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0.7851 & -0.2243 & 0.2243 & -0.7851 \\ 0.1392 - 0.1759i & 0.4873 - 0.6156i & -0.4873 + 0.6156i & -0.1392 + 0.1759i \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (2.5)$$

Under these conditions, the Tanner graph in Figure 2.7 shows interconnections between the time-frequency resource blocks and the different data layers [24] , which give us in a more detailed form than in Figure 2.5, Figure 2.6.

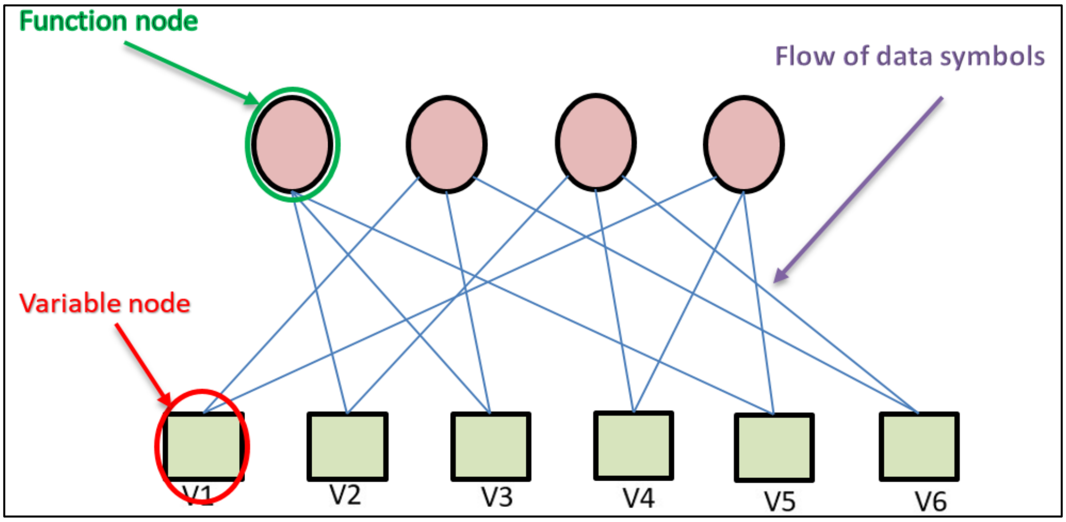

Figure 2.7: Factorial Tanner Plot for the Interconnection Between Users and Resource Blocks [24].

At the level of the decoder, the encoded signal received at the base station after transmitting over Rayleigh channel can be presented as [22].

$$y = \sum_{k=1}^{K} \text{diag}\,(h_k)\,(x_k) + \eta \qquad (2.6)$$

Where?

y Denote to encoded signal received.

h_k Denote to the channel coefficient vector.

x_k Denote to SCMA code word.

η Denote to complex additive white Gaussian noise.

The message-passing algorithm (MPA) or the belief propagation algorithm (BPA) are used to approximate the Maximum Likelihood. There are many factors effects on the computational complexity at the receiver side such as, number of users, size of codebooks, number of complex dimensions and special codebooks structure choosing.

Now, we must update the messages on the level of the nodes of constraint. The constraint node g elaborates the red message towards v1 from the two extrinsic information v2 and v3, illustrated in green on the diagram of the figure 2.8 below. The message transmitted to v1 contains the estimates of g from all the possible values of v1.

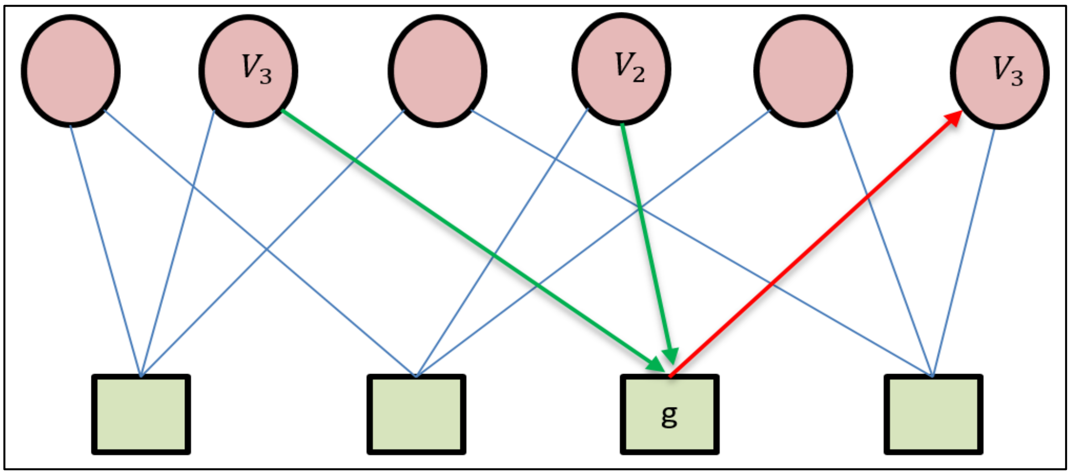

Figure 2.8: First Stage Initialization of Decoder [23].

In the same way, we will update the residual messages at the level of the variable nodes (g1.g2) and thus complete the first iteration of the MPA algorithm as in figure 2.9 below. For this step, After N iterations of this algorithm between the variable nodes and the function nodes, we obtain an estimate of the transmitted code words in the form of the required product. Then we can make a final decision on the transmitted bits [25].

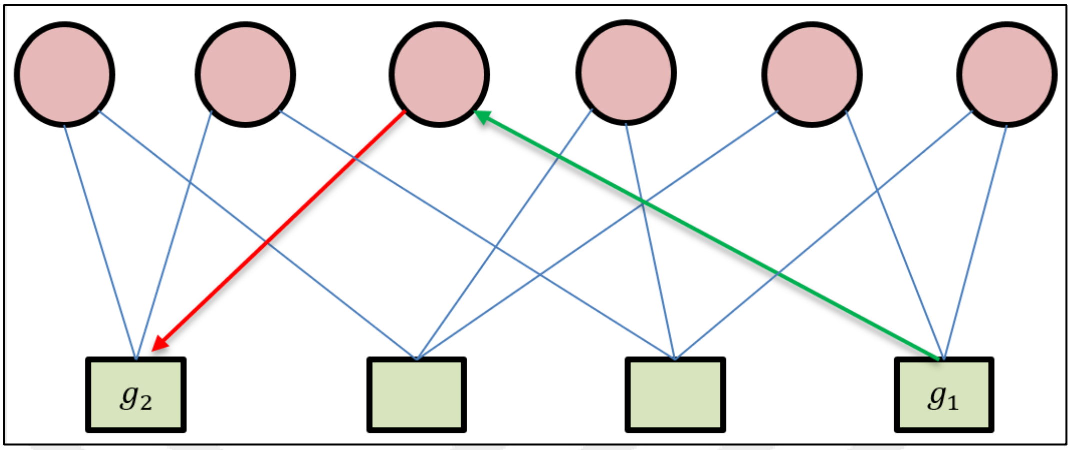

Figure 2.9: Second Stage of Initialization of Decoder [25].

To conclude on this part, we can affirm that the SCMA has a dense multi-user multiplexing which ensures high throughput and massive connectivity. It uses a spectrum spread based on low-density signature sequences combined with a very efficient multi-dimensional mapping, which makes it possible to develop in reception multi-user detection algorithms of the MPA type, which approximate the Maximum Likelihood in a very efficient.

2.4.1.2 A.2 pattern division multiple access (pdma)

Pattern Division Multiple Access (PDMA) is a new non-orthogonal technology designed to best exploit the performance of a successive interference canceller. The PDMA technique separates the users on transmission on the same block of resources by using either different powers or different spreading codes or even by using different propagation channels with multiple antennas. Indeed, any effective combination of these three separation techniques is possible. On reception, detection is used based on a successive interference canceller or an MPA type decoder, which approximates the maximum likelihood (as SCMA technique described previously) [10].

In general, a PDMA transmission system is described by a matrix (pattern matrix) which indicates the distribution of signals in the time or frequency domain. By way of example, we are going to consider the case of a system with K2 users who share N2 (N2 < K2) radio electric resources: these are chips when we are in spread spectrum (CDMA) and frequency bands when we are in OFDMA. Overload factor α is defined as the ratio between the number of users and the number of radio resources, $\alpha = \frac{K}{N}$. The PDMA pattern matrix S is described by:

$$\mathrm{s} = [\mathrm{s}_1, \mathrm{s}_2, \ldots, \mathrm{s}_\mathrm{k}]^T \quad (2.7)$$

Where $s_k = [s_{k1}, s_{k2}, \ldots, s_{kn}]^T$ the pattern of user k. The set of positions where the matrix S is non-zero on the line n corresponds to the contribution (superposition) of the users on the radio electric resource N. Generally, for the SIC receiver to be able to operate under good conditions, it is shown that the pattern matrix S must satisfy the following properties:

a. The number of subsets or user groups having different numbers of non-zero elements must be maximum.

b. Interference within the same group of users must be minimized.

c. The size of each group is maximized considering computational complexity constraints.

In fact, these users have the same number of non-zero elements in the matrix S. The maximum number of users K2, which can be included in a PDMA system with N2 orthogonal radioelectric resources, is given by the formula:

$$K2 = \binom{N2}{1} + C \ldots \binom{N2}{2} = 2^{N2} - 1 \quad (2.8)$$

From these definitions, we can give several examples of construction by distinguishing different three scenarios. We are going to show in these scenarios how the design of the system makes it possible to privilege the detection of users. In the first scenario, one builds a distributed PDMA scheme for all the resources listed in the system while in the second scenario one builds a scheme for a particular localized subset of resources [11].

a. For the first scenario, we propose the following pattern matrices for N= 2 and N= 3 with respectively K= 3 and K= 7 users, as shown in equations 2.9 and 2.10 below:

$$S_{dm}^{(2\times3)} = \begin{bmatrix} ferquency & user1 & user2 & user3 \\ fi & 1 & 0 & \sqrt{2} \\ f_{i+d} & 1 & \sqrt{2} & 0 \end{bmatrix} \quad (2.9)$$

Group 1, size of 1 (c_2^2) *Group 2, size of 2 (c_2^1)*

$$S_{dm}^{(3\times7)} = \begin{array}{c|c|ccc|ccc} ferquency & user1 & user2 & user3 & user4 & user5 & user6 & user7 \\ fi & 1 & 0 & \sqrt{3/2} & \sqrt{3/2} & \sqrt{3} & 0 & 0 \\ f_{i+d} & 1 & \sqrt{3/2} & 0 & \sqrt{3/2} & 0 & 0 & \sqrt{3} \\ f_{i+2d} & 1 & \sqrt{3/2} & \sqrt{3/2} & 0 & 0 & \sqrt{3} & 0 \end{array} \quad (2.10)$$

Group 1, size of 1 (c_3^3) *Group 2, size of 2 (c_3^2)* *Group 1, size of 3 (c_3^1)*

The notation f_i in the matrices above denotes the subcarrier $k$and d is the frequency separation between the carriers allocated to the same user. When d is large enough, it is called distributed PDMA, while for$d$equal to 1, we speak of localized PDMA. PDMA transmission schemes are designed such that each group has a different number of non-zero elements, which is to say that the order of user diversity is different between groups. For example, if we take the case of users with the matrix $S_{dm}^{(3\times7)}$, they can be divided into three groups, each group having a given order of diversity. on First we have group 1 which is composed of the only user 1, this group benefits from a diversity of three (three non-zero terms in the column of user 1). On group two with three users has a diversity order of 2. On group 3 with three users has a diversity order of one (a mutli nonzero element in the column of users 5, 6, and 7). Note that the overload factor α is equal to 150 percent for $S_{dm}^{(2\times3)}$and at 233 percent for $S_{dm}^{(3\times7)}$ [10].

b. In the second scenario, we construct a localized PDMA scheme using adjacent channel correlation and constructing a PDMA matrix to minimize interference.

$$S_{dm}^{3\times7} = \begin{array}{c|c|ccc|ccc} ferquency & user1 & user2 & user3 & user4 & user5 & user6 & user7 \\ fi & 1 & 0 & \sqrt{3/2} & \sqrt{3/2} & \sqrt{3} & 0 & 0 \\ f_{i+d} & 1 & \sqrt{3/2} & 0 & \sqrt{3/2} & 0 & 0 & \sqrt{3} \\ f_{i+2d} & 1 & \sqrt{3/2} & \sqrt{3/2} & 0 & 0 & \sqrt{3} & 0 \end{array} \quad (2.11)$$

Group 1, size of 1 (c_3^3) *Group 2, size of 2 (c_3^2)* *Group 1, size of 3 (c_3^1)*

As can be seen from the matrix 2.11 above, user 1 is orthogonal to users 2, 3 and 4, and it has a weak correlation with users 5, 6 and 7. On the other hand, users 2, 3 and 4 present a fairly strong inter-correlation (stronger than user 1) with users 5, 6 and 7. At the level of the demodulator, the user 1 who will be detected first because he presents the highest order of diversity. It will then be the turn of users 2, 3 and 4 to be detected with a diversity order equal to 2. Finally, it is users 5, 6 and 7 who will be detected at the end because they have the diversity order the weakest. The same remarks can be made for the system proposed in $\boldsymbol{S}^{(}{}_{dm}{}^{2\times3)}$.

As far as the decoding algorithms are concerned, it is often preferred, as in the case of SCMA, the use of multi-user detector based on belief propagation algorithm. As an example, we illustrate in Figure 2.10 below the bipartite graph corresponding to the transmission scheme of the matrix $\boldsymbol{S}^{(}{}_{dm}{}^{3\times7)}$.

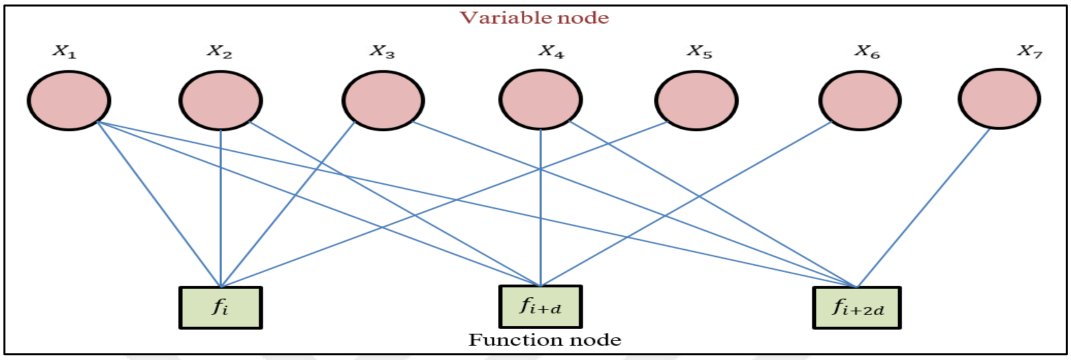

Figure 2.10: Bipartite Graph Equivalent to The Matrix Transmission Scheme $S^{(}{}_{dm}{}^{3\times7)}$ [25].

Again, the variable nodes correspond to the different users and the function nodes or constraint nodes correspond to the physical resources (frequencies) to be allocated to the different users. The belief propagation algorithm consists (as in the case of SCMA) in iteratively updating extrinsic information at the output of the variable nodes and function nodes by calculating logarithmic likelihood ratios.

For a system, with K users the vector of symbols received at the base station can take the following form :

$$Y = Z\,x + N \tag{2.12}$$

$$Z = H \odot S \tag{2.13}$$

Where?

y Denote to symbols received.

x Denote to data symbol.

N Denote to complex (AWGN) additive white Gaussian noise.

H Denote to the channel coefficient vector.

S Denote to PDMA matrix.

We have by definition: $H = [h_1, h_2, \ldots, h_k]^T$ and Z represents the equivalent channel matrix for all users $\boldsymbol{x} = [x_1, x_2, \ldots, x_k]^T$. The symbol ʘ denotes the element-by-element matrix product, also called the Hadamard product. Classically, Thus, for the PDMA system of type $\boldsymbol{S}^{(2\times3)}_{dm}$, we can write:

$$y = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \end{bmatrix} \odot \begin{bmatrix} 1 & 0 & \sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \tag{2.14}$$

Another example in the case of a QPSK modulation. Type system abilities $\boldsymbol{s}^{(4\times6)}_{dm}$ are then illustrated in equation 2.15 below:

$$S_{dm}^{(4\times6)} = \begin{matrix} user1 & user2 & user3 & user4 & user5 & user6 \\ \sqrt{4/3} & 0 & \sqrt{4/3} & \sqrt{2} & \sqrt{2} & 0 \\ \sqrt{4/3} & \sqrt{4/3} & 0 & \sqrt{2} & 0 & \sqrt{2} \\ \sqrt{4/3} & \sqrt{4/3} & \sqrt{4/3} & 0 & \sqrt{2} & 0 \\ 0 & \sqrt{4/3} & \sqrt{4/3} & 0 & 0 & \sqrt{2} \end{matrix} \tag{2.15}$$

Regarding the system $\boldsymbol{S}^{(4\times6)}_{dm}$, we have the equivalent pattern matrix, shown above. It should be noted that both systems $\boldsymbol{S}^{(2\times3)}_{dm}$ and $^{(4\times6)}_{dm}$ have the same overload rate, which is equal to 150%.

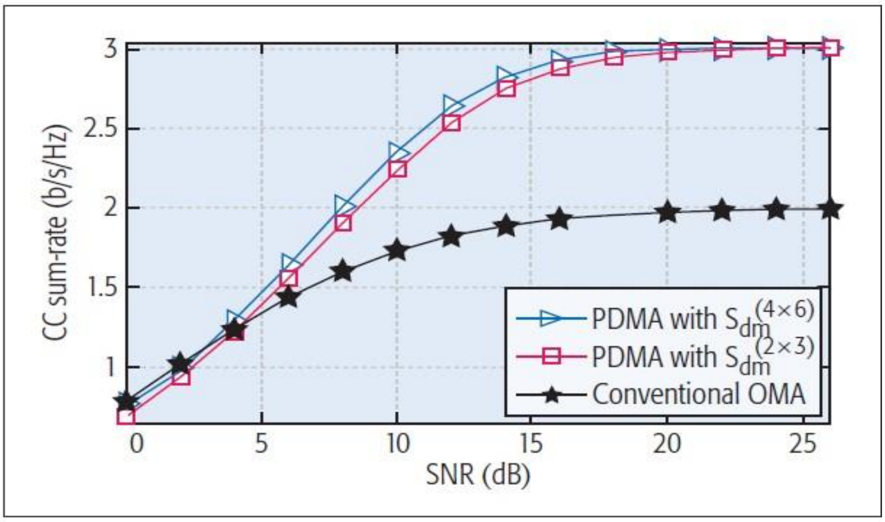

Figure 2.11: Sum-Rate Capacity of Pdma Schemes and Comparison with Oma Systems [11].

Figure 2.11 above, the two PDMA schemes (distributed and localizer) make it possible to obtain a spectral efficiency of 3 bits/s/Hz at high SNR, which gives the PDMA a capacity increase of 50% compared to the OMA system. The sum-rate capacity of the system $\boldsymbol{S}^{(2\times3)}_{dm}$ is slightly lower than that of the system $\boldsymbol{S}^{(4\times6)}_{dm}$ (difference of around 3%) because the average diversity order of users in the system $\boldsymbol{S}^{(2\times3)}_{dm}$ is lower than that of the system

$\boldsymbol{S}^{(}{}_{dm}{}^{4\times6)}$. However, the complexity of the multiuser decoding algorithm is ϑ ($|X|^{df}$) , so in the case of the system $\boldsymbol{S}$ $^{(}{}_{dm}{}^{4\times6)}$ is or ϑ ($|X|^4$) and ϑ ($|X|^2$) for the system $\boldsymbol{S}^{(}{}_{dm}{}^{2\times3)}$ (df = no .of users distributed in each resource, x = no. of codewords).

In conclusion, we can state that PDMA is a multiple access method that aims to create different orders of diversity between users. These imbalances are taken advantage of the multi-user detector which will first detect the users with the high order of diversity and then detect the users with a lower degree of diversity. The algorithm most often used is, as for SCMA, the belief propagation algorithm. However, its high complexity, in ϑ ($|X|^{df}$) still makes it difficult to implement for systems with massive deployment (i.e. with a large number of users).

2.4.1.3 Spread-based noma techniques / multiuser shared access (musa)

MUSA multiple access was developed specifically for mass IoT deployment. It combines packet transmissions in “grant free” mode with the use of spectrum spreading and multi-carrier modulations. The spreading sequences used are of short length but are calculated in an extended alphabet with complex chips. The increase in the capacity of the system here will very much depend on the ability of the SIC receiver to properly separate the users. In other words, it will be necessary to set up algorithms for optimal management of the transmission power to allow proper operation of the SIC receiver. MUSA do not use LDS-based spreading codes and use receivers such as SIC or PIC (Parallel Interference Canceler) [9][10].

We consider here the case of an uplink communication system with J users who transmit on Korthogonal carriers. Active users share the available resources according to the MUSA scheme in "grant free" mode. The user information bits are grouped into vectors in order to transform them into complex modulated symbols with, for example, N-PSK modulation. All of the signals multiplexed on the$K$subcarriers can be written in the following form:

$$Y = G\, P^{\frac{1}{2}}\, x + N \qquad (2.16)$$

Where P=$diag$ (p1, p2... pJ) represents the power allocation matrix and x=$[x_1 , x_2 , \ldots , xJ\ ]^T$ is the vector of modulated symbols transmitted. We suppose that E $[xx^H]$ =$\boldsymbol{I}_J$ and finally G is the equivalent matrix of the channel which takes into account the spreading sequences [24].

$$G = H \Theta S \tag{2.17}$$

where the matrices $\boldsymbol{H}$ and $\boldsymbol{S}$ represent the contributions of all the J users: H=[h_1, h_2,..., h_j], S=[s_1, s_2..., s_j] , and where Θ denotes the Hadamard product of the matrices element by element, we have in this case:

$$g_{kj}=h_{kj}\ s_{kj} \tag{2.18}$$

Now we concatenate the set of different y_k vectors with K_k in a mutli vector y=(y_1, y_2, ,..., y_k) T of size N.

$$G=\begin{bmatrix} y_1 \\ y_2 \\ . \\ . \\ y_k \end{bmatrix}_{KN,\times 1} = \begin{bmatrix} G_1 \\ G_2 \\ . \\ . \\ G_k \end{bmatrix}_{KNr\times 1} \begin{bmatrix} \sqrt{p_1} & 0 & \dots & 0 \\ 0 & \sqrt{p_2} & \dots & 0 \\ . & . & & . \\ . & . & \dots & . \\ 0 & 0 & \dots & \sqrt{p_3} \end{bmatrix}_{j\times j} \begin{bmatrix} x_1 \\ x_2 \\ . \\ . \\ x_k \end{bmatrix}_{j\times 1} + \begin{bmatrix} n_1 \\ n_2 \\ . \\ . \\ n_k \end{bmatrix}_{KNr\times 1} \tag{2.19}$$

$$G=\begin{bmatrix} G_1 \\ G_2 \\ . \\ . \\ G_k \end{bmatrix}_{KNr\times j} = \begin{bmatrix} H_1S_1 \\ H_2S_2 \\ . \\ . \\ H_KS_K \end{bmatrix}_{KNr\times j} = \begin{bmatrix} H_1 & 0 & \dots & 0 \\ 0 & H_2 & \dots & 0 \\ . & . & & . \\ . & . & \dots & . \\ 0 & 0 & \dots & H_K \end{bmatrix}_{KNr\times kj} \begin{bmatrix} S_1 \\ S_2 \\ . \\ . \\ S_k \end{bmatrix}_{KJ\times J} \tag{2.20}$$

We finally obtain the equivalent mathematical model:

$$Y=G\ P^{\frac{1}{2}}\ x+ N \tag{2.21}$$

$$G = H \Theta S \tag{2.22}$$

This mathematical equivalent model makes it possible to develop transmission power allocation optimization algorithms. After each iteration, the j^{th} matrix column $\boldsymbol{G}$, corresponding to the user$j$decoded, is deleted and the Minimum Mean-Squared Error (MMSE) matrix is recalculated. This process is repeated until all users are decoded. The SIC receiver offers low decoding complexity compared to other Multiuser Detection (MUD) algorithms, namely the message passing algorithm or the maximum a posterior algorithm because here we are content to use a simple receiver with interference cancellation of SIC type. However, the performance of the SIC depends on the powers received by the users and the receiver is more efficient when the powers received are sufficiently different [11] [24].

3. PROPOSED METHODOLOGY

3.1 INTRODUCTION

Emerging technology solutions should be available to accommodate the 5G mobile aspects through the next 10 years. In MAT, we need to enhance (QoS), get low latency and increase capacity for users are required to increasing the volume of mobile data traffic. One of the future MAT for 5G cases is NOMA. In OMA, only one user equipment can use the same radio frequency band, in the same time. Whilst, NOMA can support multiple user equipment (UE) with the same sub band in power domain with different power allocation for the multiplexed UE, then applied successive (SIC) at the receiver side for user separation. NOMA technique can be performed in both DL/UPLINK scenarios [4]. In this chapter, we will suppose a certain methodology for both uplink and downlink NOMA scenarios, in order to enhance SE and user fairness.

3.2 POWER DOMAIN

The NOMA second family is based on power coefficients to separate the user signals superimposed in a NOMA frame. This second family of NOMA techniques has the advantage of having low complexity in RX side because the only processing required is the execution of the SIC. Thus, we will use spread spectrum to multiplex many users depending on the power level, and not obliged to use spread spectrum on the same time or the same frequency. This family of NOMA techniques is called PD-NOMA (Power Domain Non-Orthogonal Multiple Access) [3].

NOMA can used in both uplink and downlink scenarios, to decode the signal in this technique, power allocation multiplexing at the transmitters then SIC at the receivers will be used. In the downlink protocol (in a simple way), a higher power coefficient is allocated for cell edge user (UE2) than the cell center user (UE1). Subsequently, on reception, UE2 decodes the received signal considering the signal from UE1 as interference; however, UE1 firstly will decode the signal of UE2 because it is a strong signal, subtract this from the whole signal and decode the UE1 signal.

In uplink, numerous users can use the same sub band (subcarrier) to transmit his message and that we will increase the throughput of the system. If the signals received are near enough apart, say the signal of UE1 is stronger than that of UE2 [26].

The base station starts by decoding the signal of the UE1 considering the second signal as interference. Then subtract the signal of the first user from the all signal received to get UE2 signal by decoding it. As interesting as this approach, there will be several challenges such as the perfect knowledge of the channel to perform the SIC, the power control to determine the power coefficients to be used for each user, the arrangement of the users in clusters, the sharing of power coefficients between transmitters and receivers [6].

3.3 SUCCUSIVE INTERFEENCE CANCELLATION (SIC)

After applying superposition technique in transmitter section to multiplex all signals with different power allocation factors (PAF). We need to apply a certain technique in receivers of 5G communication network in order to decode more than one signal by recognizing them depending on their differentiate in power levels, this technique called successive interference cancellation (SIC). Where the SIC will decoding the strong signal first, then the weak signal.

To retrieve the data of the near user from the whole signal for the system consist of two users (near and far), that’s required five steps as below:

a. Estimate CSI (channel equalization).
b. Considering the weak signal as a Gaussian noise (low power allocation).
c. Filter, demodulate the strong signal from whole signal, and according to the information with gNB these data is not for this user, so it is necessary to reconstruct the strong signal again.
d. Subtract reconstructed signal from the whole signal.
e. Filter, demodulate and decode the signal with low power allocation to obtain the estimated signal.

While to retrieve the data of the far user, it is not required to use SIC technique, we can directly filter, demodulate, and decode the far user signal because it has high power allocation. This scenario is illustrated in Figure 3.1 below:

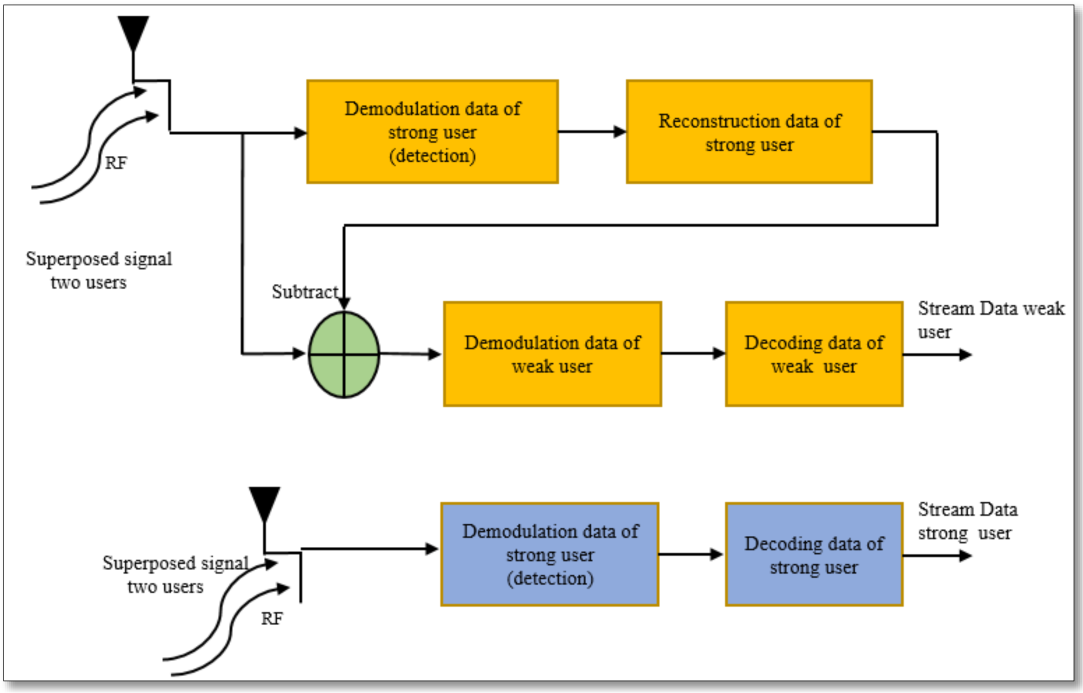

Figure 3.1: SIC Technique for Two Users (Strong and Weak) [15].

SIC can apply in user equipment (downlink scenarios) and in the base station or gNB (uplink scenario). In downlink scenario (at the user equipment), the number of applied SIC technique, depend on the number of users, for example, if we have four users in the receiver side as in Figure 3.2 below, the procedure of applying SIC will be as the following:

At the first user (near user) , we need to apply SIC three time to retrieve the data of user 1, while in the second user two times because the data of user 1 was retrieved, then we need to use SIC only one time to retrieve the data of user 3. Finally, In NOMA technique, we never need to use SIC technique in the last user, because the last user has the highest power allocation, so we can directly retrieve his data easily by dealing with other signals as a noise.

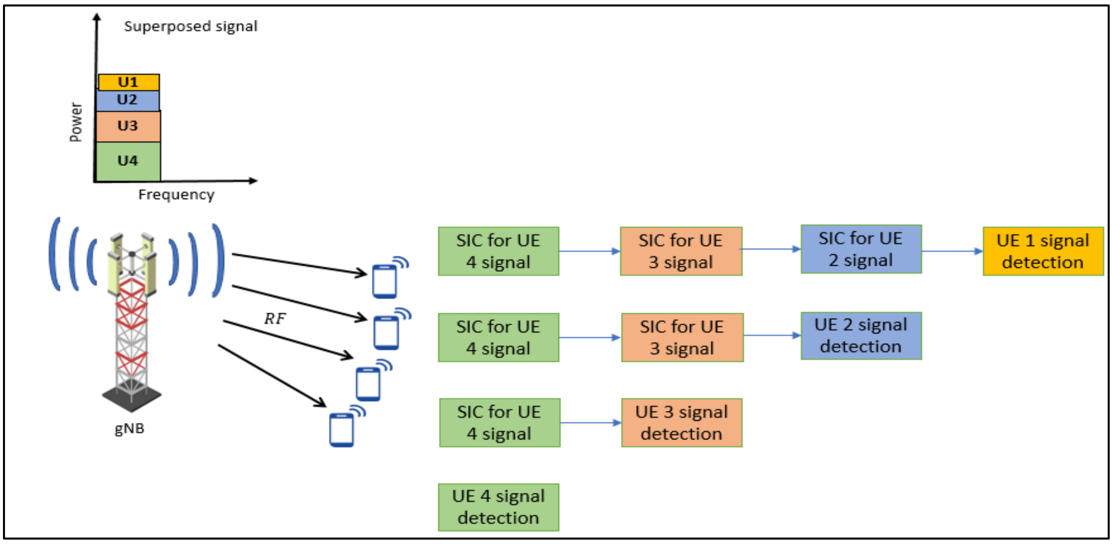

Figure 3.2: SIC Technique for Four Users (Decreasing Order of Power) [16].

3.4 PROPOSED METHODOLOGY

We will investigate the performance of (PD -NOMA) in order to examine the NOMA spectrum efficiency in three supposed scenarios (TX, Base Station, Rx) of 5G technology. Furthermore, to know in more details all the 5G related ingredients in NOMA, such as Single Carrier–FDMA (SC-FDMA). Power Allocation Process (PAP), Superposition Coding (SC), reconstruction data and SIC. The proposed system model consist of single antenna transmitter users, single antenna base station, and single antenna receiver users in both uplink and downlink sections. SISO-NOMA (Single Input- Single Output NOMA) 2 x 2 users supposed to transmit their stream data to other two users in the receiving end respectively, through gNB (gNB or gnodeB in 3GPP-Compliant Implementation of the 5G-New Radio Base Station). Forthermore, the impact of AWGN (Additive White Gaussian Noise) channel is analyzed and simulated in Mat lab version 2017 [16].

The proposed system is shown in (Figure 3.3) below:

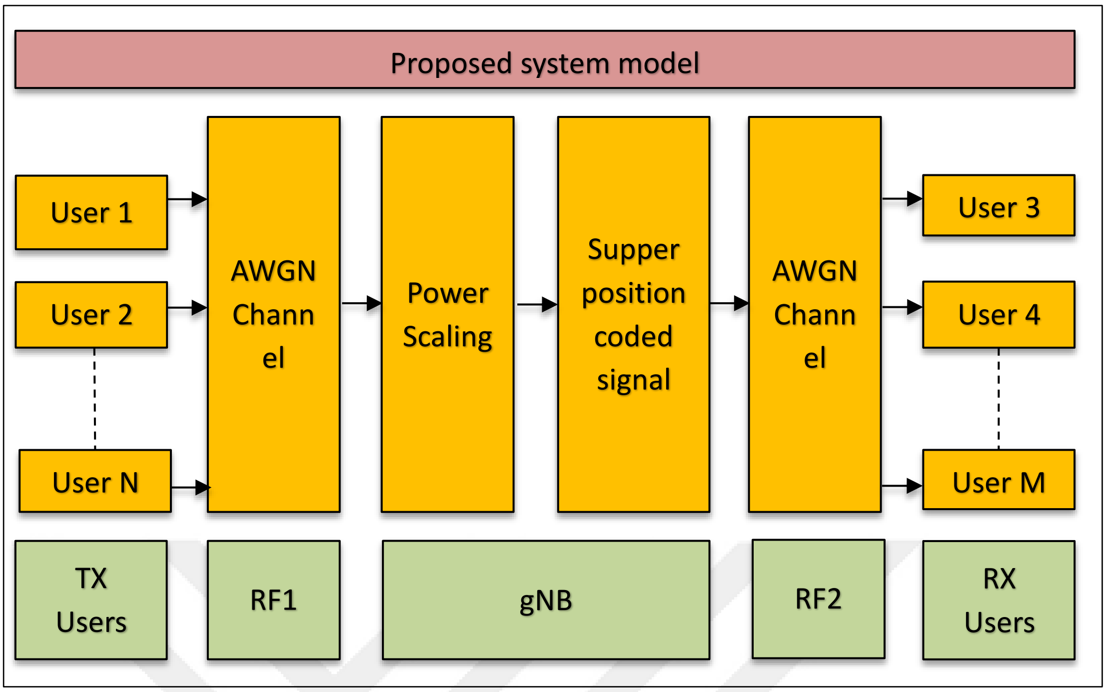

Figure 3.3: The Proposed System Model [27].

Where it is consisting of five segments namely transmitter (TX), radio frequency1 (RF1), Base Station (gNB), radio frequency 2 (RF2), and Receiver (RX). We assume N is the number of UEs which broadcast its data to the gNB through RF_1 and AWGN channel (uplink). Moreover, let the number of UEs that receive stream data from transmitter users through gNB with RF_2 and AWGN channel (downlink) is M. Considering the users N &M within the coverage of gNB (center-cell users and edge-cell users) with different distances. So, the Maximum transmit power level of (Pmax.) will be scaled top levels, p is a value from zero to Pmax. Where the summation of p1, p2, ….pn must be equal to Pmax. In the same way in gNB, the maximum transmitted power will be divided unequally to the users due to their proximity distances to the gNB.

The stream data signal of UE1 and UE2 is modulated in the transmitter section and send modulated data to the gNB in the uplink scenario. In the gNB, power-scaling allocation is applied according to the distance of UE3 and UE4 to gNB, after that superposition coding process is executed for the two modulated signals. Then the gNB will transmit the processed data to required recipient users to demodulate it and performs SIC technique to retrieve the desired stream data signal [26][27][28].

3.4.1 TRANSMITTER SECTION

The power limitations of (UE) is one of the vital parts in uplink scenario. This is a reason behind that make SC-FDMA is more suited in LTE and (LTE-A) Long-Term Evolution Advance technologies than conventional OFDMA according to low PAPR (Peak to Average Power Ratio) characteristics. Therefore, if we need to get low PAPR, UEs require many resource allocations in consecutive way.

SC-FDMA is inspired from 4G - OFDMA technique which is a suitable for uplink scenarios. It is using the basics of OFDMA TX/RX resource blocks but in different levels. For brevity, SC-FDMA is the single carrier modulation for multiuser with Frequency Domain Equalization (FDE). The substantial target of SC-FDMA is to perform transmission process at lower PAPR than the OFDMA. So, to reduce the distortion of signals with high PAPR we needs a highly linear power amplifiers, the design of access equipment is limited and in nowadays need more power so the linearity in the amplifier can only be handled with a large backoff from their peak power [18].

The system model of combination of two supposed NOMA users with SC-FDMA in uplink scenario, shown in Figure 3.4 below. Where all the users are connected to a certain cell in gNB. We assume the number of these users be (n=2). Then we consider each user has a single transmit antenna, and (x) is the independent random data generated by these users where the information data consist of (b) number of bits. these data will modulate using specific modulation type (BPSK, QPSK, 16 QAM and 64 QAM), after that every user will transmit his data stream by using its own a single antenna through the same radio frequency 1 RF_1 (3.5GHz) band as mentioned in chapter 2. Moreover, the transmitted power r_n of two users is constrained due to the limitation of batteries capacity of each user and can expressed as:

$$r_n = \sqrt{P_n}\, x_n \qquad n = 1, 2 \ldots.., N \tag{3.1}$$

So, $$r_1 = \sqrt{P_1}\, x_1 \text{ Transmitted power of user1} \tag{3.2}$$

$$\mathrm{r}_2 = \sqrt{\mathrm{P}_2}\, \mathrm{x}_2 \text{ Transmitted power of user2} \tag{3.3}$$

$$x_n = b_1\, b_2\, b_3 \ldots..\, b_n$$

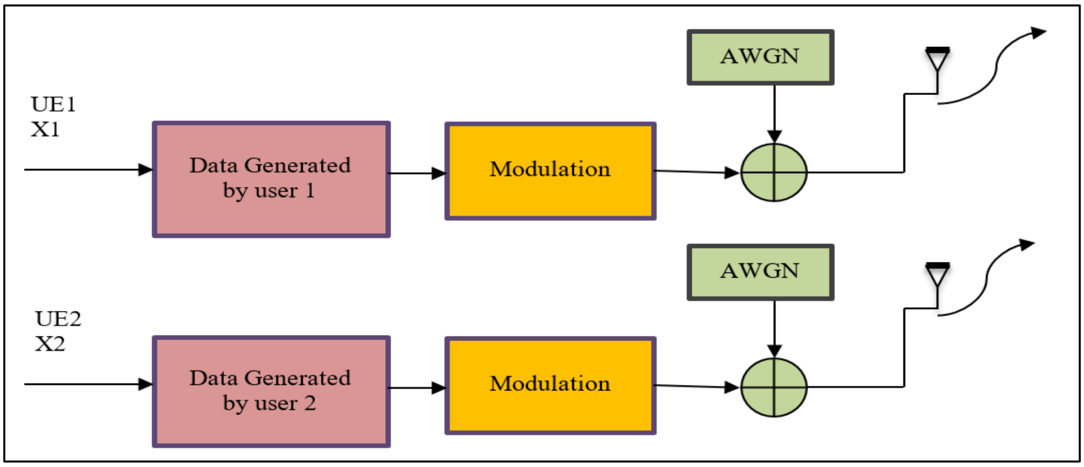

Figure 3.4: NOMA Uplink with SC-FDMA [29].

If we consider the available bandwidth (B) for our proposed system is (1.5MHz) and it is divided into a set of subcarriers (m). Each subcarrier contains one or more resource block according to SC-FDMA technique. So if we have six subcarrier, that mean each resource block will be (250 KHz) in frequency domain. According to that, gNB can non-orthogonally multiplex multiple two uplink transmitter users in the same sub band with different scaling power levels with the same time by controlling the transmitted power of these users and applying SIC technique [3][29] [30] as showed in Figure 3.3.

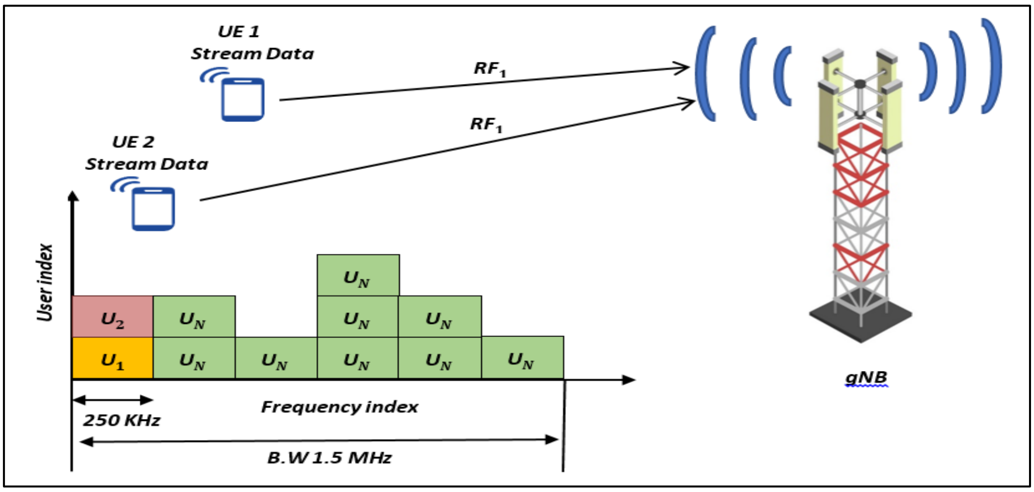

Figure 3.5: Two-Uplink Transmitter Users in The Same Sub Band [30].

At the gNB side, gNB can serve many users equipment in each sub band with single receive antenna, we denote to max. multiplied user number in each sub band by (Nmax), finally, the component of AWGN should be add to the whole signals. In order to get low PAPR for uplink scenario, we suppose the Nmax consecutive sub band allocation is 1-3 as shown in Figure 3.5, In descending order we assume the UE1 is close to gNB, with SINR

(3.4)

is 30dB, and the other UE2 is far, with SINR 15 dB, so the overall signal received by gNB can be written as:

$$r_s = \sum_{p=1}^{N} h_p \, x_p \, \sqrt{P_p} + I + \eta$$

Where?

N=2, P=1, 2

h_p Denote to the channel estimation from UE_N to gNB.

x_p Denote to transmitted data information for UE_N.

P_p Denote to transmitted power forUE_N.

I Denote to Inter-Cell Interference (ICI).

η Denote to AWGN observed at gNB.

There are two cases in uplink scenario we will describe them as in below:

Case 1: If the two users transmit their data with the same power and different channel condition.

Let's consider that the two users above transmit their signals with same power, but the UE1 has a strong channel condition$|h1|^2 > |h2|^2$ [31], the whole signal in equation 3.1 can be written as:

$$r_s = DATA\ UE1 + DATA\ UE2 = h_1\sqrt{P}x_1 + h_2\sqrt{P}x_2 + I + \eta \qquad (3.5)$$

The gNB will deal with the $h_2\sqrt{P}\, x_2$ as interference component and can directly retrieve the data information of the dominant UE1 by decoding it. Then SIC should be applied to retrieve the data of UE2. That is mean the gNB can successfully distinguish the data stream of the two superposed users if these is a distinct far in distance from each other, on other words, gNB depend on the inherent differences in the channel statements on power domain not by applying SC as in downlink NOMA Scenarios [32].

Concerning to the data rate, the near user firstly decoded by dealing with the far user as interference. so, achievable data rate at gNB for strong user and weak user respectively [5] [33] as below:

$$R_1 = \log_2\left(1 + \frac{p|h_1|^2}{p|h_2|^2 + \sigma^2}\right) \qquad (3.6)$$

$$R_2 = \log_2\left(1 + \frac{p|h_2|^2}{\sigma^2}\right) \quad (3.7)$$

Where?

P_1 Denote to transmission power of near user.

P_2 Denote to transmission power of far user.

h_1 is the fear user's coefficient for Rayleigh fading channel.

h_2 is the near user's coefficient for Rayleigh fading channel.

σ Denote the noise power.

Case 2: If the two users transmit their data with the same power and the same channel condition.

- In order to balance the transmitting power of users to connect to the serving gNB, and the other neighbors gNBs, we can use algorithm called Transmission Power Control (TPC), which mitigates external interference to the gNBs. Firstly, the TPC algorithm is used to fractionally compensate of the experienced pathloss of the users. Then, the transmission power for each UEs in the NOMA UE group can be determined according to equation below [30]:

$$P_n = min\left(\frac{P_n^{LTE}}{\sum_{l \in s} P_l^{LTE}} \cdot \beta \ \max_{l \in s} P_l^{LTE} , P_n^{LTE}\right) \quad (3.8)$$

Where?

P_n Denote to transmission power.

s Denote to NOAM user group.

l Denote user index in the NOMA user group.

β Denote a predefined parameter for optimization.

The gNB will share the information of modulation types such as (BPSK, QPSK) and the power coefficient factors and with all UEs located within its coverage area in order they can perform SIC and decode their data stream correctly.

3.4.2 BASE STATION SECTION

In architecture of 5G, every UE associate with in the coverage of particular serving Base Station, will sends a recurrent measurement report to the gNB to share its location and signal strength with the Base Station. With this information, the gNB will compute the required transmitting power factor to communicate with the UEs in the downlink scenario.

a. Successive Interference Cancellation (SIC) Technique

At gNB, initially the noise component $(i + \eta)$ received along with r_s is removed using suitable filter. Then the process of SIC will be as in the following steps:

a. The gNB deteعcts the signal of UE1 due to the higher channel gain compared with the UE2, considering UE2 signal as interference.

b. After detecting process of the first signal, gNB subtracts the signal detected of UE1 from the whole received signal, to get the UE2 signal [33] as shown in Figure 3.6 below:

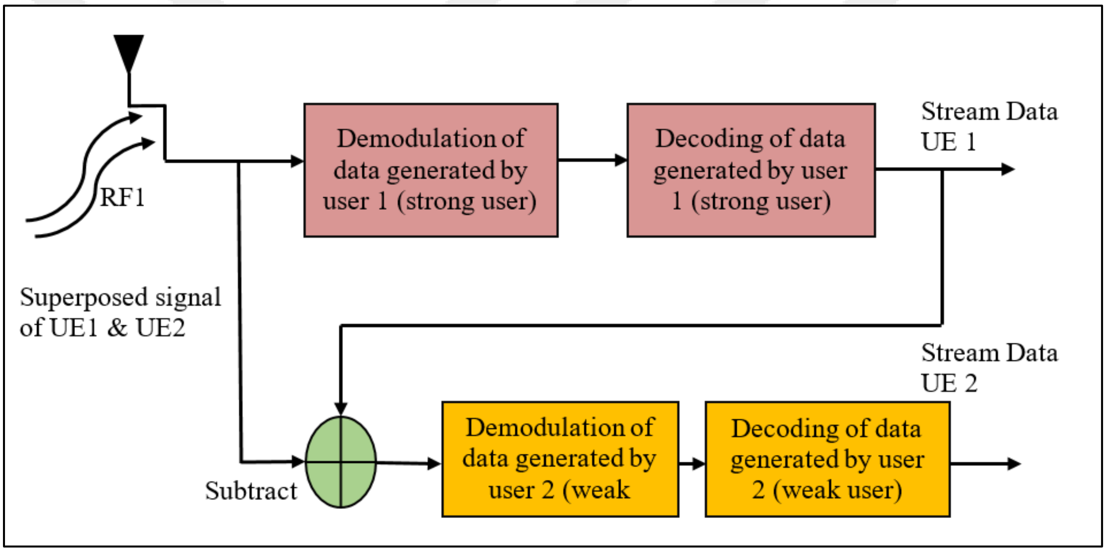

Figure 3.6: SIC Process at GNB.

b. Superposition Coding (SC) Technique

This technique will apply at the gNB in order to multiplex the all signals with different power allocation factors (PAF) as follow, after the SIC process, The data stream of UE 1 and UE2 will be encoded and modulated again into complex-valued symbols in a separable way by using a certain type of modulation (BPSK, QPSK 16QAM and 32QAM.etc), as in Figure 3.7 below. Furthermore, UE1 will up samples with k samples for each symbol then applies pulse shaping filter P1(n), in the same way UE2 will up samples with k samples for each symbol the pulse shaping filter P2(n) will apply, where n represents the input index. For each user, the sequence of signal in used channel will refer toK_j, where j will be equal to (1, 2). [8] [16]. Then, a fraction β from 0 to 1 value of the total power P is allocated to UE3 (Which will received the data of UE1) , and the remaining value of the power will assigned to UE4 (Which will received the data of UE2) according to their location to gNB [26].

The total transmitted signal P_t of UE3 and UE4 with various power allocation levels, can be written as below after superposed in the PD:

$$P_t = \sqrt{\beta}\, x_1 + \sqrt{1-\beta}\, x_2 \qquad (3.9)$$

Where?

β Denote to power allocation coefficient (0 - 1).

$1-\beta$ Denote to the residual value of the power (0-1).

x_1 Denote to transmitted data information for UE_1.

x_2 Denote to transmitted data information for UE_2.

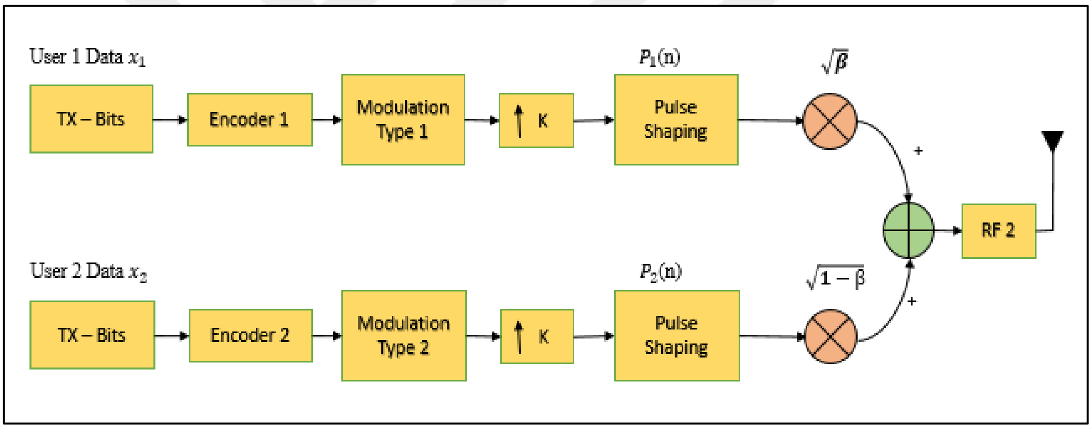

Figure 3.7: SC, Up Sampling, and Power Scaling at GNB.

Through radio frequency RF_2 (3.5GHz) band, the superimposed signal is transmitted to the two supposed users (UE3, UE4).

3.4.3 Receiver Section

Only at UE1, SIC technique will be applied to superposed data signals where power allocation factors were assigned according to gNB protocol. In generally, low power is allocated to the strong channel estimation users, whereas high power must be allocated to the weak channel estimation users [3] [15] [28] as shown in Figure 3.8 below :

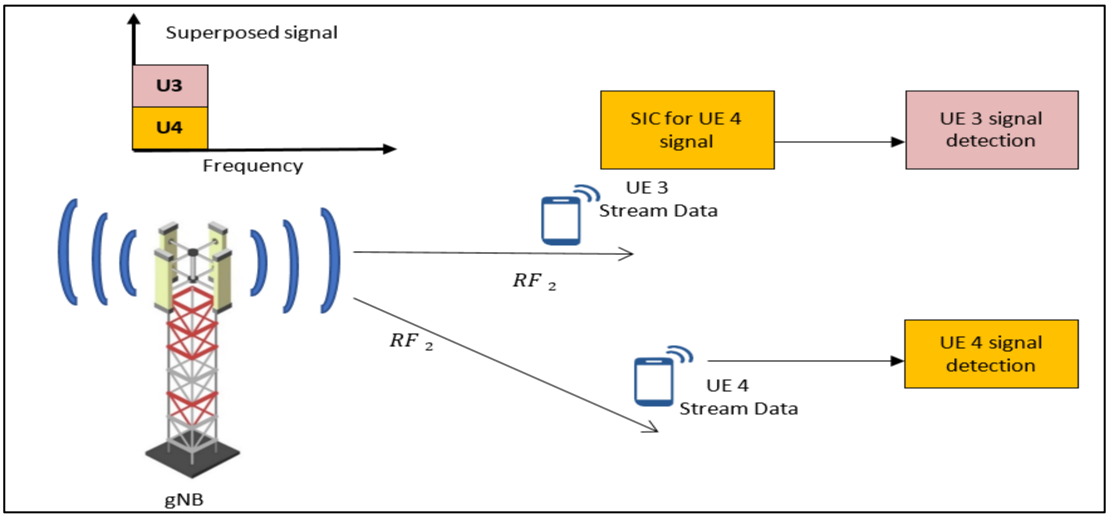

Figure. 3.8: Representation Downlink Scenario with Power Allocated for UE3 &UE4.

User Equipment 3 (UE 3)

UE 3 will decode the signal of the UE4 firstly, because he has a strong channel to transmit, [8][34]. The total signal received at this used can be given as:

$$y_3 = L_3 X + f_3 = L_3\sqrt{\beta}\, X_1 + L_3\sqrt{1-\beta} X_2 + f_3 \quad (3.10)$$

Where?

L_3 Denote to the complex channel estimation from gNB to UE3.

x_1 Denote to transmitted data information for UE3 from UE1.

x_2 Denote to transmitted data information for UE4 from UE2.

f_3 Denote to ICI and AWGN observed at UE3.

To recover the data of the UE3 from the whole signal y1, that's required 5 steps as below.

a. Estimate CSI (channel equalization).

b. Considering $L_3\sqrt{\beta}\, X_1$ and $f3$ as a Gaussian noise because it is a weak signal (low power allocation).

c. Filter and demodulate type 2 the data signal of UE4 from *y1*, and according to the information with gNB these data is not for the this user, So it is necessary to reconstruct UE4 signal again using modulation type 2 and up sampling k2 to obtain $\hat{y}_4$.

$$\text{So,} \quad \hat{y}_4 = \hat{L}_3\sqrt{1-\beta}\, \hat{x}_2 \quad (3.11)$$

d. Subtract $\hat{y}_1$ from the received signal *y1*:

$$y_3^* = y_3 - \hat{y}_4 = L_3\sqrt{\beta}\, X_1 + L_3\sqrt{1-\beta} X_2 - \hat{L}_3\sqrt{1-\beta}\, \hat{x}_2$$
$$= L_3\sqrt{\beta}\, X_1 + \sqrt{1-\beta}\left(L_3 X_2 - \hat{L}_3 \hat{x}_2\right) \quad (3.12)$$

The component $\sqrt{1-\beta}\left(L_3X_2 - \hat{L}_3\hat{x}_2\right)$ equal to zero when CSI and $\hat{x}_2 = x_2$.

e. Decode and demodulate type 1 the signal of UE3 ($L_3\sqrt{\beta}\, X_1^*$)and obtain the estimated signal X_1^* which sent by the UE1 [34] [35] .This scenario is illustrated in Figure 3.9 below.

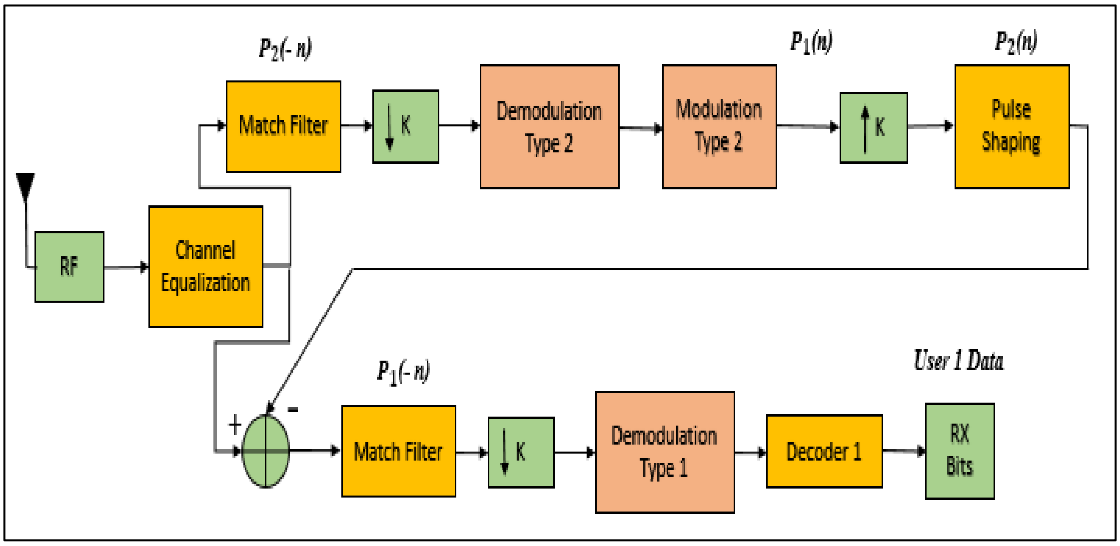

Figure 3.9: SIC Applied and Data Retrieved at UE3 [40].

User Equipment 4 (UE 4)

Referring to the complex channel estimation for UE4 as L4, and assume, , $|L_3|^2 > |L_4|^2$ [8] The received signal at this user is :

$$y_4 = L_4 X + f_4 = L_4\sqrt{\beta}\, X_1 + L_4\sqrt{1-\beta} X_2 + f_4 \quad (3.13)$$

Where?

L_4 Denote to the complex channel estimation from gNB to UE4.

f_4 Denote to ICI and AWGN observed at UE4.

- The weaker UE4 decodes its data and from y_4 (considering $L_4\sqrt{\beta}\, X_1$ and f_4 as Gaussian noise). Let $\hat{L}_4$ be UE4 estimated channel. So, the signal recovered of UE4 as below:

$$y_4^* = L_4\sqrt{1-\beta}\, x_2^* \quad (3.14)$$

Channel equalization, filtered by using the matching filter $P_2(-n)$, down sampled with k, and demodulated type 2 applied to the signal to recover UE4 data streams which sent by the UE2 as illustrated in Figure 3.10 below:

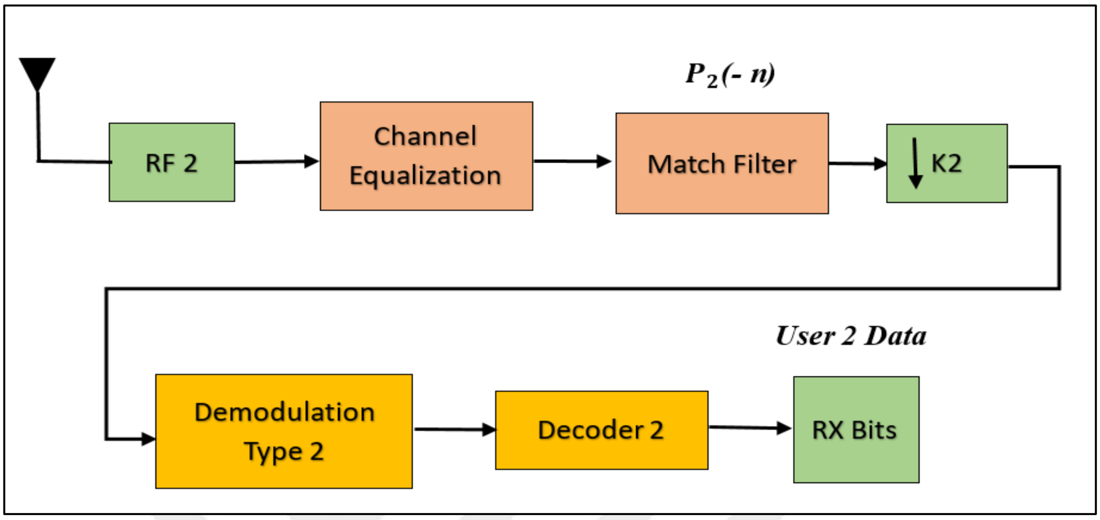

Figure 3.10: Data Retrieved at UE4 [42].

4. SIMULATION AND DISCUSS RESULTS

4.1 SIMULATION OF PROPOSED SYSTEM MODEL WITH BPSK MODULATION

In PD – NOMA, lets investigate in following our proposed network for uplink and downlink scenarios and analyze the results by using in Mat lab version 2017. The proposed network model is shown in Figure 4.1 below:

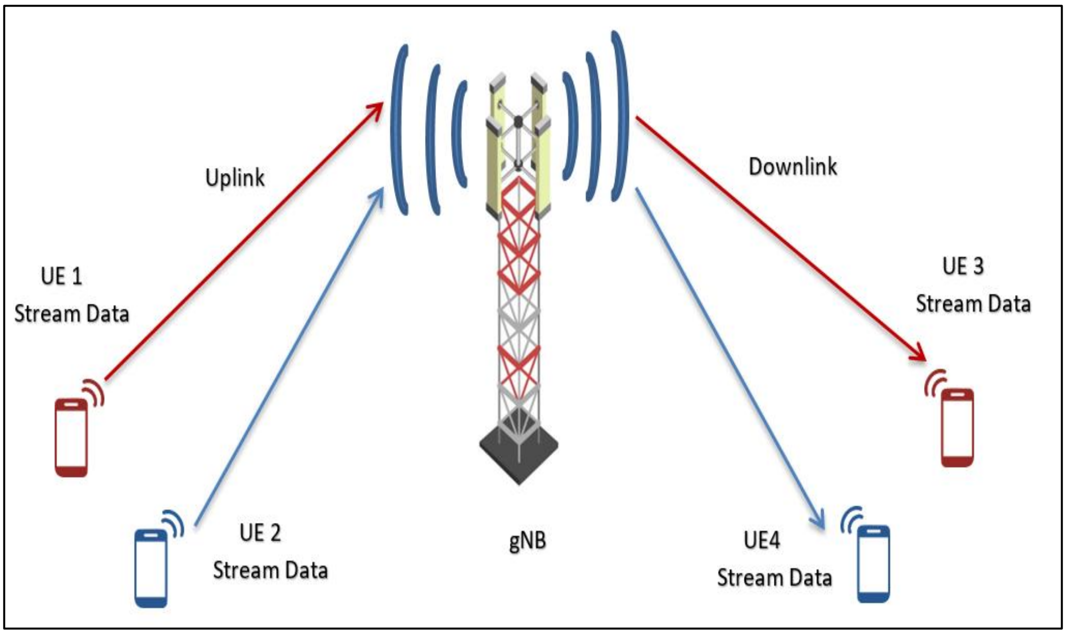

Figure 4.1: NOMA Proposed Network.

Our proposed network consists of four users (N=2, M=2) in both transmitting and receiver sections (two users for transmitter section and the rest for receiving section). Then we consider UE1 and UE2 has four bits transmitted data information as given below:

a. UE1 = 0101

b. UE2 = 1001

Let us modulate data signal above, by using supposed Binary Phase Shift Keying (BPSK) modulation, then we get:

a. UE1 = $[-1 \quad +1 \quad -1 \quad +1]$

b. UE2 = $[+1 \quad -1 \quad -1 \quad +1]$

Now, we need to allocate power for UE3 and UE4 depend on the data measurement reports between the gNB and the users, Let P1 & P2 are the power assigned levels for the near & far users respectively. Then we assumed their values to be *P1 = 0.3* watts and *P2 = 0.7* watts to attain the condition P_{MAX} = *P1 + P2 = 1* watts.

We suppose SNR (Signal to Noise- Ratio) in downlink section AWGN channel is between (0-30dB), after applying scaling power process to the users, the power scaled will be as following

$\sqrt{P_1} = \sqrt{0.3} = 0.54$ and also, we outcome other results $\sqrt{P_2} = \sqrt{0.7} = 0.83$

Thus, the superposition code generated for both two users is given by equation 4.1 below:

$$Z = UE1 + UE2 \tag{4.1}$$

Where?

$$UE1 = \sqrt{P_1} * UE'1 = 0.54 \; [-1 \quad +1 \quad -1 \quad +1]$$

$$= [-0.54 \quad +0.54 \quad -0.54 \quad +0.54] \tag{4.2}$$

$$UE2 = \sqrt{P_2} * UE'2 = 0.83 \; [+1 \quad -1 \quad -1 \quad +1]$$

$$= [+0.83 \quad -0.83 \quad -0.83 \quad +0.83] \tag{4.3}$$

Sub. Equ.4.2, 4.3 in equ.4.1, we get:

$$Z = 0.54 \, [-1 \quad +1 \quad -1 \quad +1] \quad + \quad 0.83 \, [+1 \quad -1 \quad -1 \quad +1]$$

$$= [+0.29 \quad -0.29 \quad -1.37 \quad +1.37] \tag{4.4}$$

At the receiver side, we assume that UE3 is the center cell user who dominant according to it is location to the gNB (short distance), whilst UE4 is considered edge cell user according to its located to the gNB (larger distance). The gNB will assign higher power allocation factor to UE4 (0.7) than user UE3 (0.3) where P2 ≥ P1 according to NOMA protocol. After that by using SIC technique, we can get the data stream of UE3 which sent to it from UE1,

At UE3;

$$\text{Retrieved Data} = Z - \sqrt{P_2} \; * \; UE'2$$

$$= [+0.29 \quad -0.29 \quad -1.37 \quad +1.37] \; - \; \sqrt{0.7} \; [+1 \quad -1 \quad -1 \quad +1]$$

$$= [-0.54 \quad +0.54 \quad -0.54 \quad +0.54] \tag{4.5}$$

$$Z = \sqrt{P_1} * UE1 + \sqrt{P_2} * UE2 \quad (4.6)$$

$$UE'2 = \frac{Z - \sqrt{P_1} * UE'1}{\sqrt{P_2}} \quad (4.7)$$

At the UE4

We can directly retrieve the data information by deal with the signal from $\sqrt{P_1}$ * UE1 as a noise, So the shape of data as $[+1 \quad -1 \quad -1 \quad +1]$.

Figure 4.2 shows the information waveform of UE1 and UE2. We use BPSK modulated type as representative is given in Figure 4.3. Then Figure 4.5 illustrates the scaled data version of the signals in the gNB. the superposition coded signal is given in Figure 4.6. Figure 4.7 the retrieved data using SIC is presented.

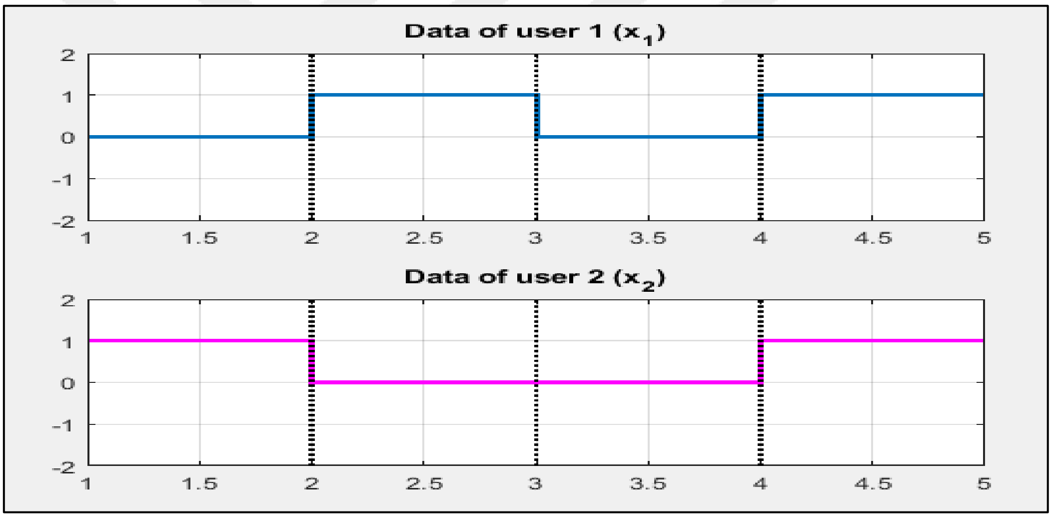

Figure 4.2: Four Bits User Data Representation.

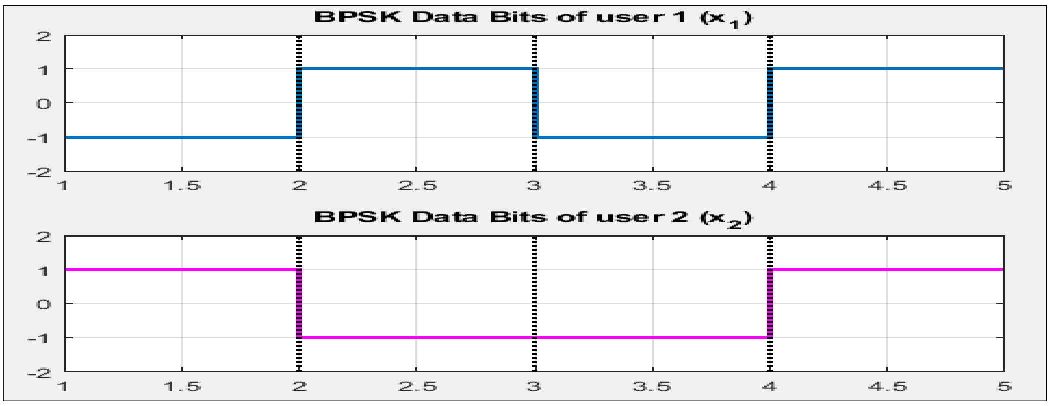

Figure 4.3: BPSK Modulation of UE1&UE2.

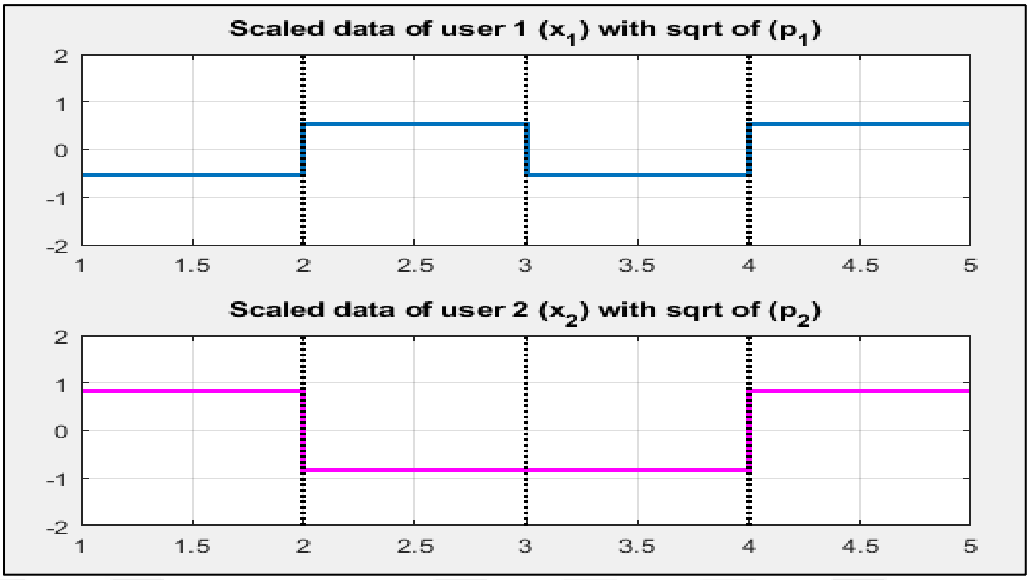

Figure 4.4: Power scaled signal of UE1&UE2.

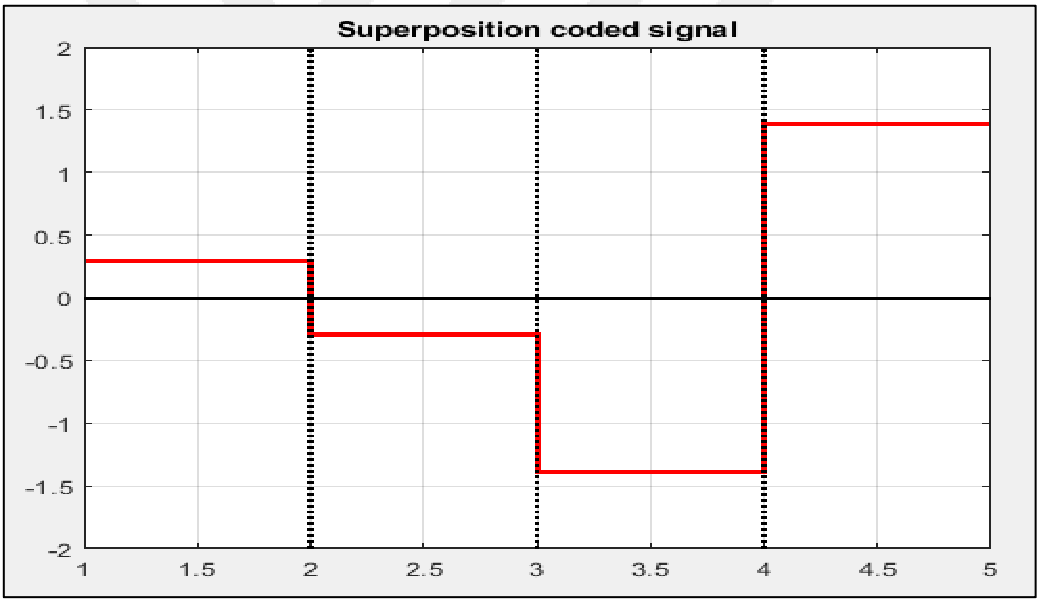

Figure 4.5: Superposition Coding of the Signal.

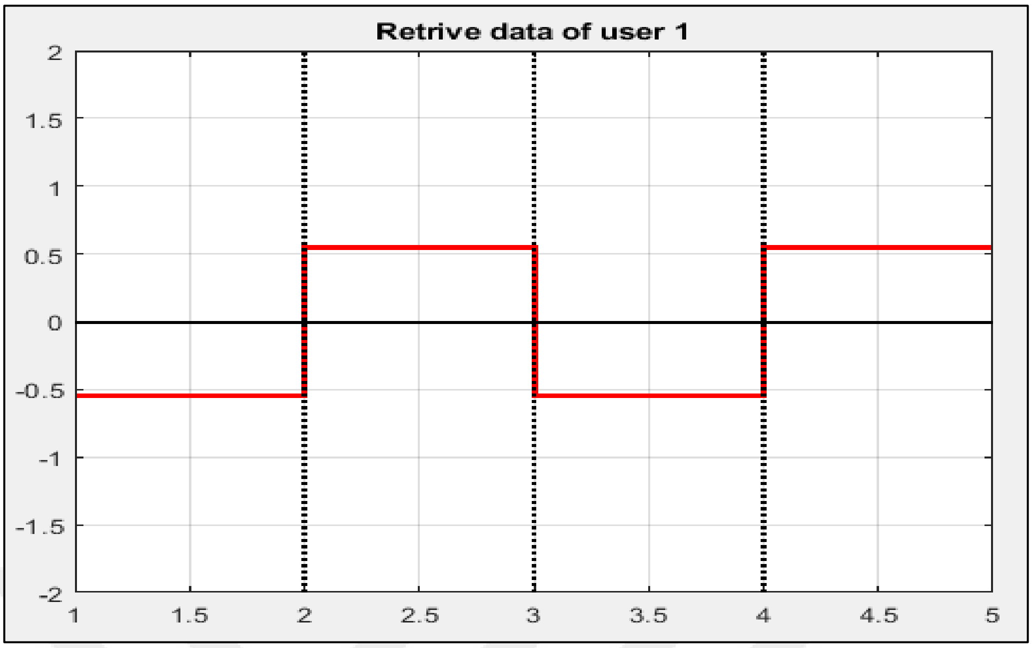

Figure 4.6: Retrieve Data of User 1 at User 3.

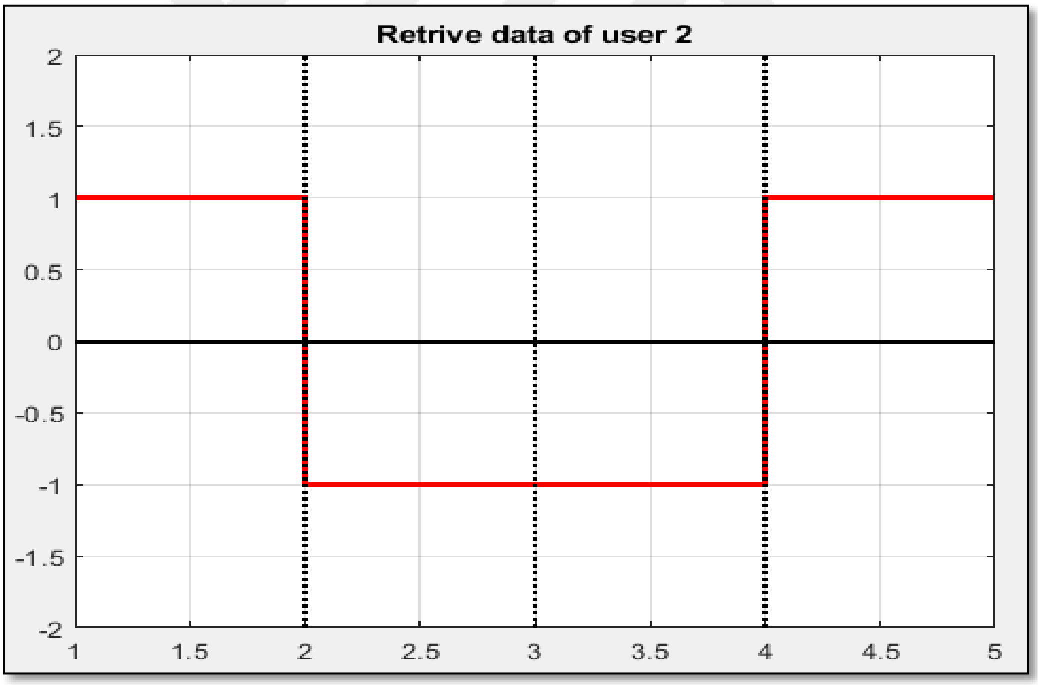

Figure 4.7: Retrieve Data of User 2 At User 4.

4.2 DOWNLINK SIMULATION OF PROPOSED SYSTEM MODEL WITH BER/ SNR COMPARISON

Here we will discuss the BER/ SNR for two users (UE3, UE4) as the following:

$X_3 = [1 \quad 1]$ and $X_4 = [0 \quad 1]$ Supposed data of user 3 and 4.

$\grave{X}_3 = [+1 \quad +1]$ $\grave{X}_4 = [-1 \quad +1]$ After BPSK Mod.

$\beta_1 = \sqrt{0.3}$ and $\beta_2 = \sqrt{0.7}$ Supposed PAC for user 3 and 4.

$P_T = \beta_1 \ \grave{X}_3 \ + \ \beta_2 \grave{X}_4$ Superposed Signal.

$y_3 = L_3\sqrt{\beta_1}\,\grave{X}_3 + L_3\sqrt{\beta_2}\,\grave{X}_4 + f_3$ Received channel at user 3+ AWGN.

Then, we estimated data of user 4 firstly, take a decision, reconstruction it again, then subtracted it from the y_3 so we got:

$y_3^* = L_3 \sqrt{\beta_1} \ X_3^*$

We demodulated and decoded data of user 3, so we got X_3^*

$y_4 = L_4\sqrt{\beta_1}\,\grave{X}_3 + L_4\sqrt{\beta_2}\,\grave{X}_4 + f_4$ Received channel at user 4+ AWGN.

Due to higher PAC for this user, so directly we demodulated and decoded data of user 4, and we got X_4^*

$y_4^* = L_4 \sqrt{\beta_2} \ X_4^*$

Now, we can Compare the decoded bits (X_3^* , X_4^*) with the transmitted bits (X_3 , X_4) to estimate BER as figure 4.10 below using the inbuilt biterr function of MATLAB.

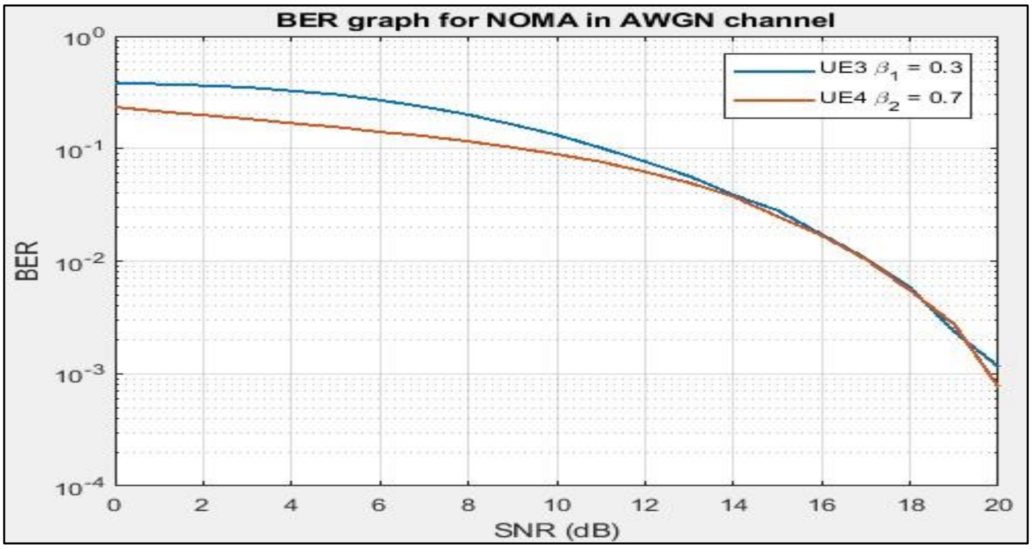

Figure 4.8: NOMA BER/ SNR Graph in AWGN Channel.

From the Figure 4.8 above, we note that UE3 and UE4 had the same BER at high power (more than 14 dB), while at the low power (less than 14 dB), UE4 had better BER than UE3.

Parameter Used in Simulation:

a. $SNR = 0 : 20\ dB$ SNR range.

b. $N = 10^5$ Number of monte carlo simulation.

4.3 DOWNLINK SIMULATION OF PROPOSED SYSTEM MODEL WITH BER/DBM COMPARISON

Here we will discuss the BER/ Transition power for two users (UE3, UE4) as the following:

$X_3 = [1 \quad 1]$ and $X_4 = [0 \quad 1]$ Supposed data of user 3 and 4.

$X_3^{`}$ , $X_4^{`}$ After QPSK Mod.

$\beta_1 = \sqrt{0.3}$ and $\beta_2 = \sqrt{0.7}$ Supposed PAC for user 3 and 4.

$P_T = \beta_1 \; X_3^{`} \; + \; \beta_2 \, X_4^{`}$ Superposed Signal.

$y_3 = \sqrt{P}\ (L_3\sqrt{\beta_1}\, X_3^{`} + L_3\sqrt{\beta_2}\, X_4^{`}) + \sigma_3$ Received channel at user 3 + noise power

Then, we estimated data of user 4 firstly, take a decision , reconstruction it again, then subtracted it from the y_3 so we got:

$y_3^* = \sqrt{P}\ L_3 \sqrt{\beta_1}\, X_3^*$

We demodulated and decoded data of user 3, so we got X_3^*

$y_4 = \sqrt{P}\ \left(L_4\sqrt{\beta_1}\, X_3^{`} + L_4\sqrt{\beta_2}\, X_4^{`}\right) + \sigma_4$ Received channel at user 4 + noise power

Due to higher PAC for this user, so directly we demodulated and decoded data of user 4, to got X_4^* .

$$y_4^* = \sqrt{P}\, L_4 \sqrt{\beta_2}\, X_4^*$$

Now, we can Compare the decoded bits (X_3^* , X_4^*) with the transmitted bits (X_3 , X_4) to estimate BER as figure 4.10 below using the inbuilt biterr function of MATLAB.

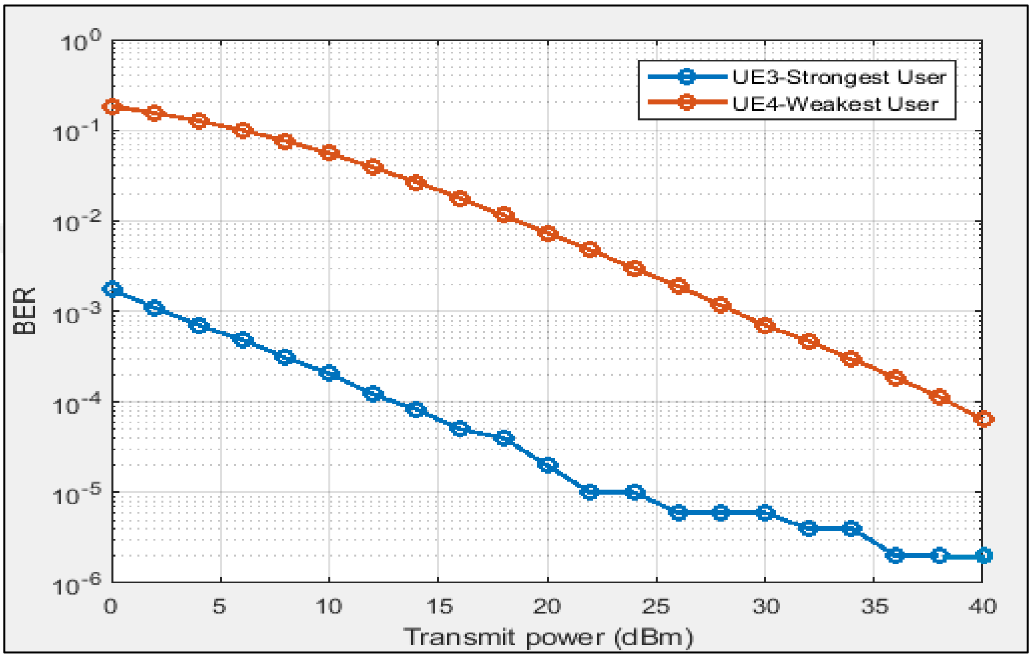

Figure 4.9: NOMA BER/ Transition Power Graph (dBm).

From the plot above, we note that UE3 had better BER than UE4 in both high and low transmitted power.

Parameter Used in Simulation:

a. df =500m, Distance to base station for far User.

b. dn = 100m, Distance to base station for Near User.

c. B.w = 10 MHz, The bandwidth used.

d. Pt = 0:2:40 dBm, Power transmitted.

4.4 UPLINK SIMULATION OF PROPOSED SYSTEM MODEL WITH OUTAGE PROBABILITY

We will study outage probability for our proposed model in uplink where multiplexing in power domain is applied depending on the inherent differences in channels condition (the two users transmit their data with same power with different channel condition) as below:

We suppose that UE1 at 100m distance from the base station & UE2 is 500m. Then the UE1 at 300m distance & UE2 is 500m, let's consider that the two users above transmit their signals with same power (P), but the UE1 has a strong channel condition $|h1|^2 > |h2|^2$,

The near user's signal is decoded first, by treating the far user's signal as interference. Then, the far user's signal is decoded by applying SIC technique, Therefore, signal to interference noise ratio (SINR1,2) and the achievable rate (R 1,2) at the BS to decode the near and far users as below, and the Outage condition is R_1 , R_2 < 0.5 (target rate).

$$SINR_{user\ 1} = \frac{P|h_1|^2}{P|h_2|^2 + \sigma^2} \tag{4.8}$$

$$R_1 = \log_2\left(1 + \frac{P|h_1|^2}{P\ |h_2|^2 + \sigma^2}\right) \tag{4.9}$$

$$SNR_{user\ 2} = \frac{P|h_2|^2}{\sigma^2} \tag{4.10}$$

$$R_2 = \log_2\left(1 + \frac{P|h_2|^2}{\sigma^2}\right) \tag{4.11}$$

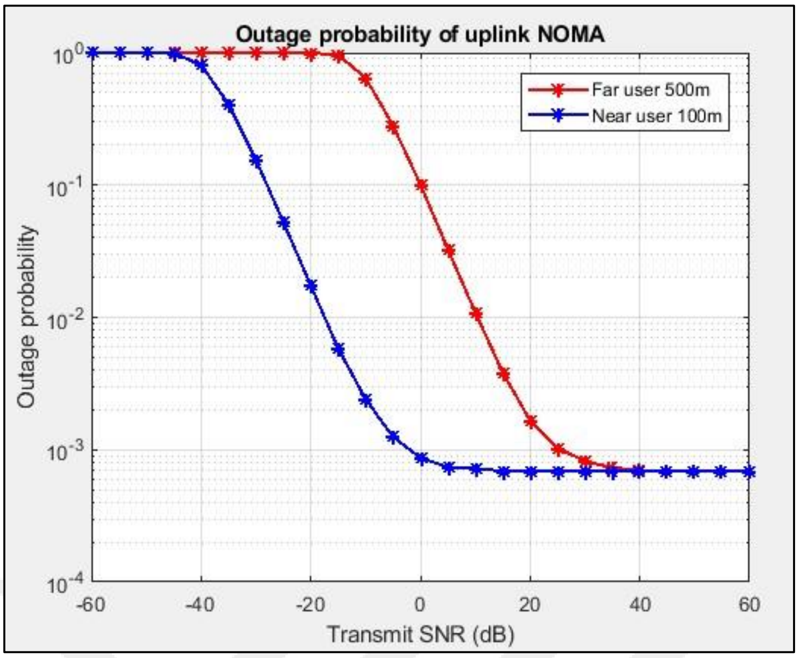

Figure 4.10: Outage Probability of Pair Users (100, 500m).

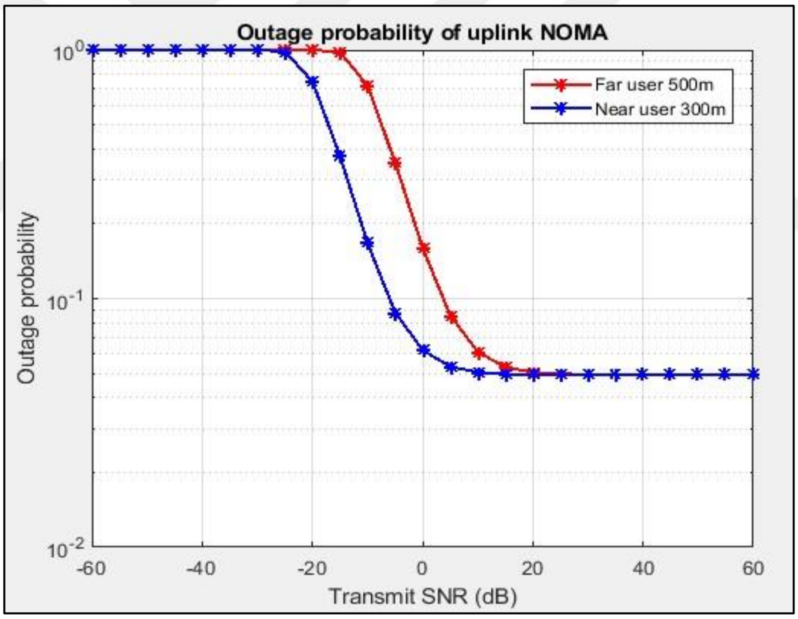

Figure 4.11: Outage Probability of Pair Users (300, 500m).

According to the result shown in Figure 4.10, and Figure 4.11 above. The lesser outage probability is for the pair users (100, 500m). While the high outage probability is for pair users (300, 500m), and this is because of there is a distinct enough distance in pair users 100, 500m (400m) whereas there is only (200m) distance between the pair users (300, 500m). For example, at 40dB transmit power, the outage probability about less than 10^{-3}

for both pair users (100, 500m) while in pair users (100, 500m) the outage probability between 10^{-1} and 10^{-2} as in figures mentioned above.

Parameter Used In Simulation:

a. dn = 100m, 300m , Distances to base station UE1.

b. df = 500m , 500m, Distances to base station UE2.

c. B.w = 10 MHz, The bandwidth used.

d. Pt = - 60: 5: 60 dBm, Power transmitted.

e. N = 10^5 Number of monte carlo simulation.

f. rf = 0.5 , rn = 0.5 Target rates of outage probability.

5. CONCLUSION AND FUTURE WORKS

5.1 CONCLUSION

There are fewer review papers than there were in the past when comparable arguments were held regarding a wide variety of access modalities for 5G networks. The current debates are more focused on 6G (refers to the sixth generation of technology used for wireless network) examination as a particular technology or technique. Comparisons were made between the communication network topologies of 5G and 6G. Based on the findings of these comparisons, modifications were made to the 5G NOMA protocol, and an appropriate 6G protocol was developed and the scholarly works cited as references provide an explanation of the structural and technological changes, as well as the economic gains, that would result from the transition from 5G to 6G.

In this thesis, we conclude NOMA with SC-FDMA in uplink scenario can attain better performance in far and near than SC-FDMA alone. So that it led to consider NOMA is a candidate RAT for future 5G in uplink section. Furthermore, in uplink scenario, it was required a big difference in channel gain when the channel conditions at the far user is weaker.

At a perfect channel estimation condition, it was investigated the power scaling of four-user downlink / uplink SISO-NOMA. NOMA with a perfect resource allocation (frequency and time) can outperform OMA in terms of user fairness sand spectral efficiency. NOMA can realize overloading easily by using controllable interferences but with increasing complexity at receiver.

This is a reason that makes NOMA fulfilled the massive connectivity and spectral efficiency of 5G aspects. In addition, in terms of system capacity, overall, NOMA has seemed to be an effective technique compared to OMA. In particular, NOMA technique has been shown that it can enhance the spectral efficiency of wireless communication. In short, NOMA can attain the following important features: 1) user capacity, 2) low latency, 3) data speeds, 4) Spectral efficiency, and 5) user faintness. Finally, from the reasons mentioned above, we conclude that the strongest candidate for the future 5G mobile network until now is NOMA technique.

5.2 FUTURE WORKS

a. The successful NOMA implementation is still suffer from several challenges. These challenges are power limitation in the transmitters, computational power is required to apply SIC algorithms especially for massive user's numbers, which required high data rates and Sensitivity of SIC technique to mitigate the errors of fading channels. The power consumption and implementation complexity can be reduced by emerging a new techniques such as MIMO (multiple- input-multiple-output) and mMIMO (massive multiple- input-multiple-output) that introduce the same performance in our SISO-NOMA but with less complexity, decreaing the error of decoding, and increase the reliability which make it more suitable for implementation.
b. Spectrum can be utilized in a more effective manner in NOMA by overlapping sub bands carriers, this is occurred by using Delta-orthogonal multiple access (D-OMA). Where it is possible to retain a greater number of groups without requiring an increase in the overall spectrum allocation (without need for increased bandwidth).
c. Future research for wireless communication systems can be focused on throughput and fairness (main target of NOMA) by new proper power allocation strategies with low complexity.
d. Transmit power control (TPC) and performance of proposed algorithm for uplink NOMA can be enhanced in future research.
e. Future research can focus on the security side because the data of users is available in most of the users.

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