REPUBLIC OF IRAQ
MINISTRY OF HIGHER EDUCATION
AND SCIENTIFIC RESEARCH
AL-FURAT AL-AWSAT TECHNICAL UNIVERSITY
ENGINEERING TECHNICAL COLLEGE - NAJAF

Performance Enhancement of Non-Orthogonal Multiple Access (NOMA) Based on Optimization Techniques

AHMED JASIM MOHAMMED YOUNIS

(M. Sc. In Communications Techniques Eng.)

2022

Performance Enhancement of Non-Orthogonal Multiple Access (NOMA) Based on Optimization Techniques

THESIS
SUBMITTED TO THE (COMMENICATION TECHNIQUES ENGINEERING DEPARTMENT) IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF (MASTER DEGREE)

BY

AHMED JASIM MOHAMMED YOUNIS

Supervised by

Prof. Dr. Ahmed Ghanim Wadday

February /2022

بسم الله الرحمن الرحيم

«أنظر كيف فضلنا بعضهم على بعض وللآخرة أكبر درجات وأكبر تفضيلا»

صدق الله العلي العظيم

سورة الإسراء – الآيه 21

Supervisor Certification

I certify that this thesis titled **" Performance Enhancement of Non-Orthogonal Multiple Access (NOMA) Based on Optimization Techniques "** which is being submitted by **Ahmed Jasim Mohammed Younis** was prepared under my supervision at the Communication Techniques Engineering Department, Engineering Technical College-Najaf, AL-Furat Al-Awsat Technical University, as a partial fulfillment of the requirements for the degree of Master in Communication Engineering.

Signature**:**

Name**: Prof. Dr. Ahmed Ghanim Wadday**

(Supervisor)

Date: / / 20

In view of the available recommendation, I forward this thesis for debate by the examining committee.

Signature:

Name**: Prof. Dr. Ahmad T. Abdulsadda**

(Head of comm. Tech. Eng. Dept.)

Date: / / 20

Committee Report

We certify that we have read the thesis titled **" Performance Enhancement of Non-Orthogonal Multiple Access (NOMA) Based on Optimization Techniques "** submitted by **Ahmed Jasim Mohammed Younis** and as an Examining Committee, examined the student's thesis in its contents. In our opinion, it is adequate for an award of a degree of Master in Communication Engineering.

Signature:
Name: **Dr. Ahmed Ghanim Wadday**
Degree: Prof.
(Supervisor)
Date: / / 2022

Signature:
Name: **Dr. Mohanad Ahmed Al-Ibadi**
Degree: Lecturer
(Member)
Date: / / 2022

Signature:
Name: **Dr. Hadi Athab Hamed**
Degree: Assistant Prof.
(Member)
Date: / / 2022

Signature:
Name: **Dr. Adnan Hussein Ali**
Degree: Prof.
(Chairman)
Date: / / 2022

Approval of the Engineering Technical College- Najaf

Signature:

Name: **Assistant. Prof. Dr. Hassanain G. Hameed**

Dean of Engineering Technical College- Najaf

Date: / / 2022

Linguistic Certification

This is to certify that this thesis entitled **" Performance Enhancement of Non-Orthogonal Multiple Access (NOMA) Based on Optimization Techniques "** was reviewed linguistically. Its language was amended to meet the style of the English language.

Signature:

Name: **Asst. prof. Dr. Raed Dakhil Kareem**

Date: / / 2022

Abstract

One of the most strongly nominated wireless access technologies for use in the next generation of wireless communications is Non-orthogonal Multiple Access (NOMA). When a comparison is made between one of the orthogonal multiple access (OMA) technologies, for example, the orthogonal frequency division multiple access (OFDMA) technology, we note that NOMA offers a set of good characteristics such as massive connectivity, high reliability with low latency and efficient spectrum resource management. The main working principle of NOMA is to serve more than one user using the same wireless resources in terms of time and frequency. The resource allocation (RA) of the NOMA system (power allocation), fairness among users, interference management and improving the throughput of the system are the important challenges because is operating under a considerable group of constraints that prevent harmful for the user that have a poor channel condition.

Among the challenges and problems facing NOMA are increasing the sum rate and maintaining an appropriate level of fairness in allocating Power among users. As a result, In this thesis wireless system model to maximize users' sum rate was proposed by allocating appropriate power. This model consists of a central cell and a group of six neighboring cells in a cellular system with cross-tier interference and two algorithms to improve the total sum rate.

This thesis used three scenarios; In the first scenario, OMA technology was applied. The second scenario applies the NOMA technique using the GA genetic algorithm. In contrast, the third scenario involves the application of NOMA technology using the Gray Wolf Optimization GWO algorithm to the proposed system. Users' sum rates were used as a metric for evaluating the algorithms performance in simulation scenarios. In addition, the performance was compared in the presence and absence of interference from neighboring cells. The results showed that the proposed method (NOMA using GWO) is better than OMA and NOMA using GA in terms of user sum rate and fairness. The highest total rate obtained from the system is (258.0092 Mbps). The results were simulated using MATLAB 2021a.

Acknowledgment

In the name of Allah, the Most merciful, the most beneficent

In the beginning .. and before all .. I thank God Almighty for giving me the ability to complete this thesis.

I would like to extend my thanks and gratitude to the supervisor of this thesis, **Professor Dr. Ahmed Ghanim Wadday**, for the time and interest shown to me.

Also, I am pleased to extend my sincere thanks to **Prof. Dr. Ahmad T. Abdulsadda** Head of communication Technical Engineering Department.

Special thanks to **Assistant Professor Dr. Hayder Jawad Albattat** and **Mr. Muhannad Adnan Al-Jaafari** for their time, effort and guidance that helped me complete my work.

My special thanks to my dear friend **Youssef Maher Al Nuaimi** for his help.

Dedication

Gratefully dedicated ... to my sources of inspiration, to my dears **father and mother**...

To my dear martyr brother (**Mohammed Jasim Mohammed Younis**), whose separation caused a deep wound in our hearts….

To **my dear brothers and sisters** who supported me in very difficult days...

To **my dear wife** for her outstanding support and encouragement....

Finally...to **my two beautiful small daughters** who give me hope and strength…

Declaration

I hereby declare that the work in this thesis my own except for quotations and summaries which have been duly acknowledged.

21 February 2022 Ahmed Jasim Mohammed Younis

Table of Contents

List of Tables

List of figures

List of Abbreviations

AI: Artificial Intelligence.

AMC: Automatic Modulation classification.

APF: Adaptive Proportional Fair.

AWGN: Additive white Gaussian noise.

BCs: Broadcast channels.

BS: Base station.

CDMA: Code division multiple access.

CD-NOMA: Code Domain-NOMA.

CSI: Channel status information.

CC: central cell.

D-NLUPA: Divide -the next largest difference based User Pairing algorithm.

DL: Deep Learning.

FCC: Federal Communications Commission.

FDMA: Frequency division multiple access.

FRA: Future Radio Access.

GOS: Global Optimal Search.

GA: Genetic Algorithm.

GWO: Grey Wolf Optimization.

HSPA: High-Speed Packet Access.

IoT: Internet of Things.

IPSA: Ideal partner search algorithm.

LTE: Long-Term Evolution.

MIMO: Multiple input multiple output.

MAI: Multiple access interference.

MACs: Multiple access channels.

NOMA: Non-orthogonal Multiple Access.

NOS: number of sub channels.

OMA: Orthogonal multiple access.

OFDMA: Orthogonal frequency division multiple access.

PN: pseudo-noise.

PD-NOMA: Power Domain –NOMA.

QoS: Quality of service.

RSPA: Random subcarrier and power allocation.

RA: Resource allocation.

SC-FDMA: Single Carrier- Frequency division multiple access.

SC: Superposition Coding.

SIC: Successive interference cancelation.

SINR: Signal-to-interference-noise-ratio.

TDMA: Time division multiple access.

TD-CDMA: Time Division- Code Division Multiple Access.

TD-SCDMA: Time Division-Synchronous Code Division Multiple Access.

USMA: User-Sub channel matching algorithm.

UG: User grouping.

3G: Third generation.

3GPP: Third generation Partnership Project.

4G: Fourth generation.

5G: The fifth generation.

Chapter One

Chapter One: Introduction and Literature Review

1.1 Introduction

Various multiple access schemes have been introduced for previous and current generations of cellular mobile communications. These schemes include frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), and orthogonal frequency division multiple access (OFDMA). These multiple access technologies, based on their method of managing wireless resources between users, are considered orthogonal access technologies. Single Carrier SC-FDMA or OFDMA is used in 3.9 and 4th generation (4G) mobile communication systems such as Long-Term Evolution (LTE) and LTE-Advanced, which are standardized by the 3rd Generation Partnership Project (3GPP) [1-3]. Orthogonal multiple access (OMA) was a reasonable choice for achieving high system-level throughput [4]. Thus, the 3GPP has recently convened a meeting to discuss the future evolution of Long term evolution LTE. It is necessary to go to realistic solutions that rise to the level of future challenges in wireless networks in order to ensure continuity during the next decade in 3GPP radio access technologies [5].

A combination of multiple approaches would be required to meet such demands, namely techniques for spectrum efficiency enhancement and efficient use of frequency bands. In this aspect, one of the essential things in 3GPP is to improve the spectrum efficiency well and enhance it, which is done by new radio access techniques. Although achieving a further threefold increase in spectrum efficiency over the LTE baseline for Future Radio Access FRA may be difficult. Since LTE already outperforms 3G High-Speed Packet Access (HSPA) in terms of spectrum efficiency by a factor of three to four. The target gain will be ten times greater than that of 3G HSPA; For example, a significant increase in capacity can be achieved if other methods are used, such as network densification can be up to 500 fold up [6].

The use of interference cancellation to improve the spectrum efficiency of non-orthogonal multiple access (NOMA) schemes is a promising new multiple access scheme for future radio access (FRA) [7]. There are many advantages and characteristics that NOMA enjoys. In general, NOMA techniques can be classified into Two Sections Code Domain NOMA (CD-NOMA) and Power Domain NOMA (PD-NOMA) [8]. This thesis will study the power field in detail. To maximize system throughput, optimization algorithms are proposed, such as Genetic Algorithm GA and Grey Wolf Optimization Algorithm GWO.

1.2 Problem Statement

Now and With the increasing number of users, it has become necessary to switch to the new technique with better performance and better ability to handle more users. In the case of multiple access, communications techniques can make efficient use of limited spectrum resources. One of the most important multiple access methods that show high efficiency in managing spectrum resources and high throughput based on different studies is NOMA.

Power allocation and control is critical factor in increasing the capacity of wireless networks, particularly in NOMA systems, due to their direct impact on the user's sum rate. It is necessary to consider these wireless resources while studying the performance of the NOMA system.

The main problem addressed in this thesis is to increase the sum rate of each user within the downlink NOMA system with the possibility of achieving fairness in the allocation of power using the scale of the sum rate obtained by each user.

1.3 Literature review

To complete the components of the thesis, many related works to the topic of NOMA have been studied and include them as follows :

In [9], Boya *et al*. (2014) the problem of resource allocation in the downlink NOMA network was studied through the allocation of power and sub-channels, taking into account the balance between the number of users and the maximization of the total rate. To solve this problem, the User-Sub channel matching algorithm (USMA) was proposed, which is a modified and low complexity algorithm that has the ability to balance the number of users and sub-channels and form a stable match. Through the simulation results, it was found that the number of users who subscribed to the same channel significantly affected the overall sum rate. Also, the overall rate of users in the case of using NOMA technology with the proposed algorithm is much higher than in the case of using OFDMA technology, regardless of the number of users or sub-channels. In [10], Jianyue *et al*. (2017). NOMA downlink power allocation was studied to maximize the overall user rate while adhering to Quality of Service (QoS) constraints. Effective methods for power distribution and sub-channel allocation were jointly proposed by exploiting the dynamic matching algorithm coupled with the optimal power allocation. The results showed that the proposed method for optimizing the joint resources achieved near-optimal performance compared to OFDMA schemes. In [11], Islam *et al*. (2017) ,as detailed study was carried out on the work of wireless resource allocation algorithms in the downlink NOMA system. Through this study, it was found that these algorithms have a critical role in increasing NOMA throughput. In order to achieve fairness among users with high system throughput, the Divide -the next largest difference based User Pairing algorithm D-NLUPA was proposed. A comparison was made between MIMO-OMA and MIMO-NOMA. The results showed the superiority of MIMO-NOMA in throughput and outage probability. In [12], Chin-Liang *et al*. (2018) the resource allocation were investigated in an OFDMA-based NOMA downlink system with a base station and an even number of users. Where every 2 users were shared together in certain sub-channels. The optimum power is assigned to both users who share the same sub-channel, and this allocated power is subject to a minimum user capacity. A water-filling algorithm has been proposed to allocate energy and amplify gains across different subcarriers while meeting the constraints of user fairness. Simulation results show that the proposed scenario overcomes the traditional OFDMA in terms of providing better system capacity. In [13], Ken *et al*.(2019), The problem of wireless resource management was specifically studied, the problem of allocating power to achieve a balance between increasing the overall total rate of the system, taking into account the retention of the user's minimum limit in the NOMA system. To provide a solution to the problem of matching the sub-channel with the number of users and allocating the optimum power, the Global Optimal Search (GOS) algorithm is proposed. The proposed algorithm achieved an increase in the throughput of the system, but it was not the optimal solution because its high complexity. In this case, an algorithm with low complexity was proposed, the Adaptive Proportional Fair (APF) algorithm. In [14], Estela *et al*. (2019) the optimal relationship between the channel conditions of two NOMA downlink users was studied in terms of maximizing the overall rate of the system. To solve the problem of allocating the sub-channel to the users, the ideal partner search algorithm (IPSA) is proposed to select the most suitable partner for each user on the same sub-channel. Where it was found through this study that any difference between the states of channels for two users significantly affects the performance of the system. This difference is highly dependent on the conditions of each channel. The simulation results showed that the proposed algorithm overcame many methods, as it overcame the random subcarrier and power allocation (RSPA) and user grouping (UG) in terms of the number of users in the system, achievable total rate and BER. In [15], Amanjot *et al*. (2019) The power allocation problem in the NOMA-OMA downlink hybrid network has been studied. Two users are paired up with a random mechanism, one with good channel conditions and the other with poor channel conditions. These pairs compete with each other for the appropriate transmitter power transmitted by the BS to achieve the highest overall rate. This process is repeated for each pair to get its appropriate transmitted power from the base station. Simulation results show that the proposed scheme leads to a good overall rate when compared to schemes using OMA alone or NOMA alone. In [16], Marie *et al*. (2020) the use of new strategies for power allocation and sub-channels were studied in the non-orthogonal multiple access scenario. The goal of these strategies is to reduce spectrum usage while maintaining the required data rate for each user. These strategies include user pairing selection optimal or sub-optimal power allocation; a non-orthogonal hybrid scheme has been introduced. This hybrid scheme enables dynamic switching to orthogonal signals when non-orthogonal access does not improve the data rate achieved for each sub band and dynamic switching from NOMA to orthogonal signals. But one of the drawbacks of these strategies is the high complexity due to the frequent use of the Successive Interference Cancellation SIC at the receiver side, including orthogonal and non-orthogonal access. As a result, there are studies and research to reduce its complexity and maintain the level of overall sum rates for users. In [17], Mohammed *et al.* the problem of joint power distribution and antenna selection (J-PA-AS) for downlink clustered non-orthogonal multiple access (NOMA) networks is studied. In particular, the goal is to perform antenna selection for each user group and allocate transmit power to its users in order to maximize the network's total rate, while meeting Quality of Service (QoS) requirements. In turn, a low-complexity two-stage algorithm is proposed, in which the first stage optimally solves the problem of distributing the power of the sum-rate to the maximum for each pair (antenna, user group). In the second stage, antenna selection was optimally resolved in polynomial complexity via Kuhn-Munkres with the KMB backtracking algorithm. The simulation results are presented to validate the proposed algorithm, which has been shown to give the optimal network sum rate efficiently, and in comparison with the optimized J-PA-AS scheme (resolved via a global optimization package), and superior to other scaling schemes. The effect of spatial diversity on the network aggregate was also highlighted, as it turned out that the more antennas in the base station, the higher the network aggregate rate, and the lower the outage ratio. In [18], Shweta *et al.* user association UA and power allocation PA problems were jointly addressed with the goal of maximizing the sum-rate of the MIMO-enabled mega-delivery network while exploiting NOMA and full-duplex techniques. Based on the proposed framework, the hitch and jumper rate equations with imperfect channel state information CSI have been formulated. Furthermore, the total rate is maximized with minimal service quality and delivery limitations during accounting fairness issues. Initially, a non-convex problem is formulated and then a corresponding solution is obtained by dividing it into several convex sub-problems. The simulation results showed a significant improvement in the sum rate using the proposed algorithm on the current schemes. Finally, in addition to the number of antennas and the number of SBS stations, the results showed the dependence of the total rate on the self-cancellation factor and the minimum transmission rate. In the future, the common UA and PA problem of multiple antennas in each SBS with defective CSI and more than one MBS in the network will be investigated which will make it more suitable for future practical applications. Besides, the energy efficiency measure of the proposed framework was evaluated and optimized to study the trade-off between power consumption and spectral efficiency (SE) to improve system performance. In the few existing literature, channel correlation is useful for massive MIMO technology with the help of NOMA technology. Hence, improving the performance of the proposed framework can also be studied while considering channel correlation in the future to make the study more robust for real-time deployment. Table 1-1 briefly shows the related works that were explained above.

Table 1.1: The related works

No.	Title of related work	Year	Transmission scenario	Max. users in each sub channel	No. of antennas	No. of cells	Cal. External interference
1	Radio Resource Allocation for Downlink Non-Orthogonal Multiple Access (NOMA) Networks using Matching Theory	2014	Downlink	More than two users	Single	Single-cell	No
2	Multichannel Resource Allocation for Downlink Non-Orthogonal Multiple Access Systems	2017	Downlink	Two	Single	Single-cell	No
3	Resource Allocation for Downlink NOMA Systems: Key Techniques and Open Issues	2017	Downlink	More than two users	Multiple antennas	Single	No
4	Low-Complexity Resource Allocation for Downlink Multicarrier NOMA System	2018	Downlink	Two	Single	Single	No
5	Spectrum Resource and Power Allocation With Adaptive Proportional Fair User Pairing for NOMA Systems	2019	Downlink	Two users	Single	Single	No
6	A Fast Algorithm for Resource Allocation in	2019	Downlink	Two users	Single	Single cell	No

	Downlink Multicarrier NOMA				antenna		
7	Power allocation for downlink multiuser hybrid NOMAOMA systems: An auction game approach	2019	Downlink	Two users	Single antenna	Single cell	No
8	New Optimal and Suboptimal Resource Allocation Techniques for Downlink Non-orthogonal Multiple Access (NOMA)	2020	Downlink	Two	Single	Single	No
9	Joint Power Allocation and Antenna Selection for Network Sum-Rate Maximization in Clustered Downlink NOMA Networks	2021	Downlink	Two	Multi antenna	Single cell	No
10	Low-Complexity Joint User and Power Scheduling for Downlink NOMA over Fading Channels	2021	Downlink	Two	Single antenna	Single cell	No
11	Performance Enhancement of Non-Orthogonal Multiple Access (NOMA) Based on Optimization techniques	2022	Downlink	Multiple users	Single antenna	Multi cell	Yes

1.4 Thesis Objectives

The specific objectives of this thesis are:

1. To build a downlink NOMA system using Matlab simulation.

2. To suggest Algorithms that achieve a high sum rate for the user, taking into account the fairness among them.

3. To Make a comparison between NOMA using the proposed algorithms and OMA in terms of the sum rate.

1.5 Thesis Contributions

This thesis aim to provide a better performance of NOMA downlink through several essential contributions to improve system performance are as follows:

1. Implementation of GA and GWO Algorithms in the downlink NOMA system.

2. Allocation of power between users in the NOMA system using GA and GWO Algorithms. In addition, the minimum and maximum number of users sharing the same channel has been included as part of the optimization problem.

3. Calculating the effect of interference between users and BSs of neighboring cells on the total rate of the system.

4. Investigate the system's performance in the presence of different numbers of users and sub-channels.

1.6 The structure of the thesis

This thesis contains five chapters. The first chapter provides an introduction, problem statement, Literature review, thesis objective, and thesis contributions. The rest of the thesis is organized as follows :

Chapter Two: Displays multiple access technologies, The difference between orthogonal and non-orthogonal multiple access techniques, General description of non-orthogonal multiple access technologies in the cases of uplink and downlink And finally, the optimization techniques used in this thesis.

Chapter Three: This chapter includes, describing the proposed system model and optimization problem formulation.

Chapter Four: Shows the simulation results for the proposed optimization techniques.

Chapter Five: It includes the most important conclusions reached through the thesis with ideas and proposals for future research directions.

Chapter Two

Chapter two: Theoretical Background

2.1 Non Orthogonal Multiple Access (NOMA) Technique

One of the best ways to increase bandwidth, data rate, and network capacity in wireless systems is to use multicarrier transmission [19]. Since the network nodes (cells) and users can simultaneously transmit and receive data via the shared medium (i.e., channel) with the minimum level of interference [20], subsequent generations of mobile communications have employed several multiple access techniques for data exchange between a base station (BS) and users.

In addition to the new promising multiple access technique for the fifth generation of wireless systems, this chapter provides an overview of the fundamentals of multiple access techniques used in each generation of mobile technologies.

2.2 General overview of multiple access techniques

In this section, the most prominent multiple access technologies that have been used in each of the different generations of wireless communications will be presented. Include: FDMA, TDMA, CDMA, and OFDMA.

2.2.1 Frequency Division Multiple Access (FDMA)

The oldest communication technique used in broadcasting, land-mobile two-way radio, and other applications is FDMA (frequency division multiple access). It all starts with a frequency band assigned by the FCC (Federal Communications Commission). The FCC issues licenses to operate wireless communication systems in specific frequency bands. These frequency bands are further subdivided into channels and assigned to users. Figure 2-1 depicts the fundamental principle of a typical FDMA technique. As illustrated in the picture, the FCC-allocated frequency band is divided into multiple frequencies, referred to collectively as channels. Each channel has a unique user allocated to it. The channel is occupied for the duration of the call in this technique. FDMA has been used for 1G wireless system [21].

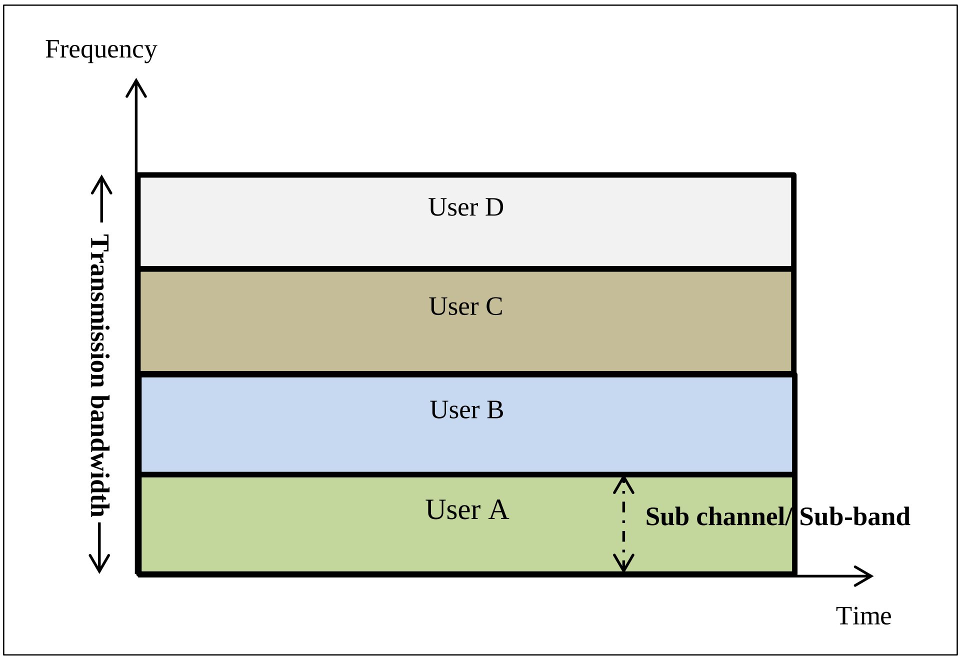

Figure 2-1 Frequency division multiple access (FDMA) [22].

2.2.2 Time Division Multiple Access (TDMA)

Time-division multiple access is a multiple access scheme, which is widely used in broadband satellite systems and the GSM cellular mobile systems. In time-division multiple access (TDMA), the available channel bandwidth in its entirety is used by every user, but the users take turns in making use of the channel in a timely manner. In other words, the channel is sequentially time-shared among many users through non-overlapping time slots in a circular manner (i.e., one after the other). It was used in 2G cellular networks. [23], as showed in figure 2-2.

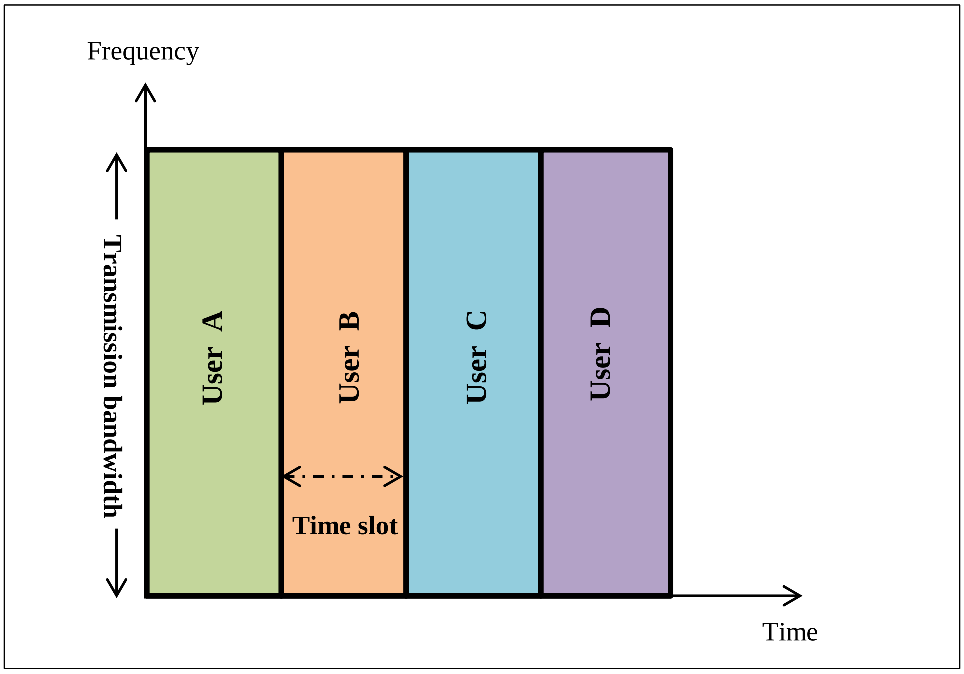

Figure 2-2 Time Division Multiple Access (TDMA) [22].

2.2.3 Code Division Multiple Access (CDMA)

Code-division multiple access (CDMA) is a channel access method used by various radio communication technologies. CDMA is an example of multiple access, where several transmitters can send information simultaneously over a single communication channel. This allows several users to share a band of frequencies (see bandwidth). To permit this without interference between the users, CDMA employs spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code).

CDMA optimizes the use of available bandwidth as it transmits over the entire frequency range and does not limit the user's frequency range. Figure 2-3 depicts the fundamental principle of a typical CDMA technique.

It is used as the access method in many mobile phone standards. IS-95, also called "cdmaOne", and its 3G evolution CDMA2000, are often simply referred to as "CDMA", but UMTS, the 3G standard used by GSM carriers, also uses "wideband CDMA", or W-CDMA, as well as Time Division- Code Division Multiple Access (TD-CDMA) and Time Division-Synchronous Code Division Multiple Access (TD-SCDMA), as its radio technologies [24].

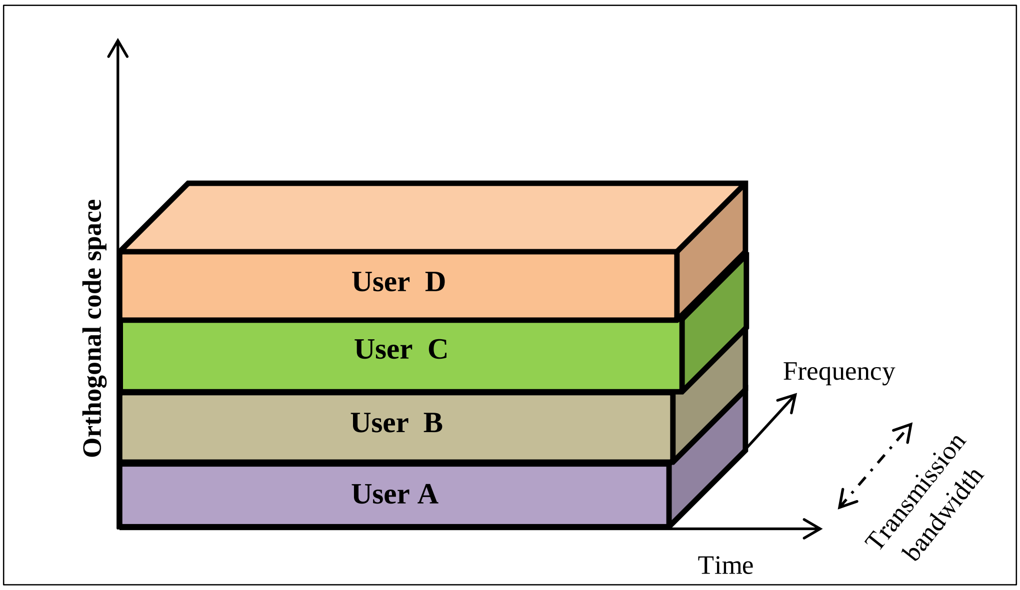

Figure 2-3 Code Division Multiple Access (CDMA) [22].

2.2.4 Orthogonal Frequency Division Multiple Access (OFDMA)

FCC (Federal Communications Commission) provides licenses to operate wireless communication systems over given bands of frequencies. These bands of frequencies are finite and have to be further divided into smaller bands (channels) and reused to provide services to other users. This is governed by the International Telecommunication Union (ITU). OFDMA is a relatively new wireless communication standard used in 4G WiMAX (Worldwide Interoperability for Microwave Access) and 4G LTE (Long-Term Evolution) protocol. It may be noted that WiMAX is an IEEE 802.16 standard, while LTE is a standard developed by the 3GPP group. Both standards are surprisingly similar and bandwidth-efficient. OFDMA is used in the 4G cellular standard. Both LTE and WiMAX standards use several common technologies with subtle differences. The main common technology is orthogonal frequency-division multiple access (OFDMA). In WiMAX, OFDMA is used on both the downlink and the uplink, whereas in LTE it is used only on the downlink. Figure 2-4 depicts the fundamental principle of a typical OFDMA technique. However, the technology used in the uplink of LTE, single-carrier frequency division multiple access (SC-FDMA), is nothing but a simple modification of OFDMA [25,26].

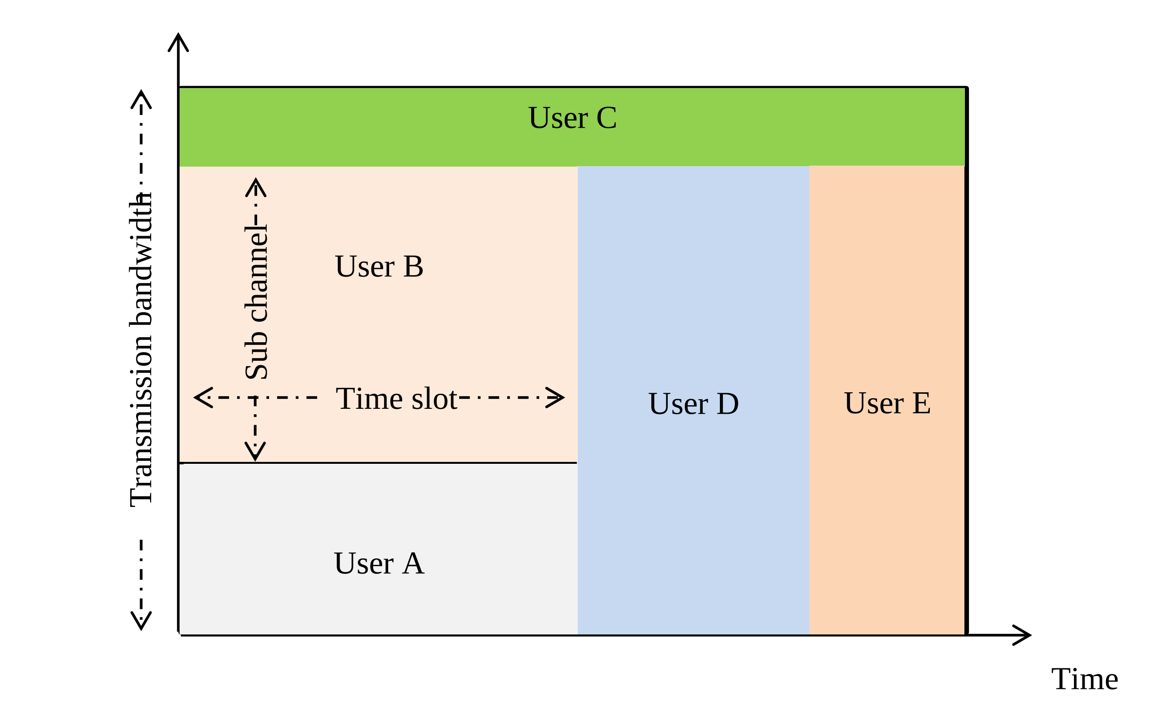

Figure 2-4 Orthogonal Frequency Division Multiple Access (OFDMA) [22].

2.3 Multiple access approaches that are orthogonal versus non-orthogonal

Multiple access techniques are the key part of radio access technologies for cellular communications. These techniques can be classified into orthogonal and non-orthogonal multiple access methods.

In orthogonal multiple access techniques (OMA), signals transmitted by different users are orthogonal to each other either in frequency, time, or code domains in order to mitigate the multiple access interference (MAI) effects. This principle has been simply employed in FDMA, TDMA, CDMA, and OFDMA [27].

OMA has failed to meet the rigorous needs of future communication systems, which include great spectrum efficiency, huge connection with a variety of QoS, low latency, and user fairness [28]. Considering all of these needs, it's no surprise that new and promising communication systems consider them a problem. As a result, Non-Orthogonal Multiple Access (NOMA) is presented as one of the potential technologies that can be used to meet the new demands [29].

In the field of wireless communications networks, NOMA is a viable technique for building new radio access for the fifth generation (5G) of wireless networks [30]. Figure 2-5 shows the difference in the amount of power allocated to each user in both OMA and NOMA techniques. Through the combination of the notion of Superposition Coding (SC), which is used on the transmitting side, and the (SIC) principle, which can be used on the receiving side , NOMA can achieve high spectral efficiency [31].

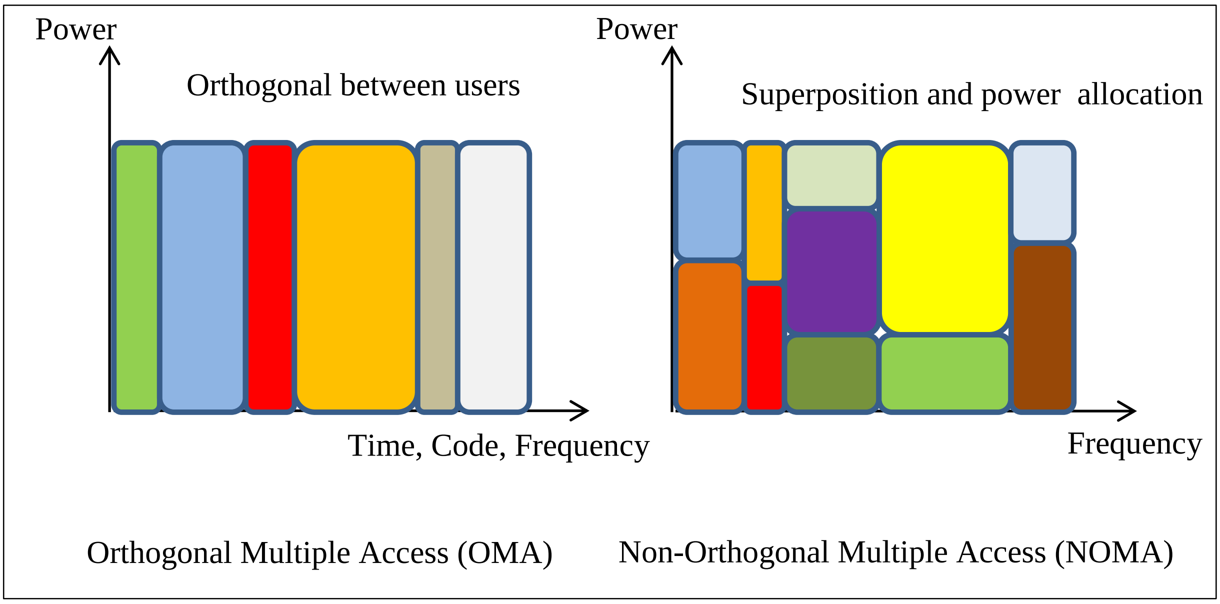

Figure 2-5 Allocation of resources in multiple access approaches that are orthogonal and non-orthogonal [27].

While the number of devices connected to wireless mobile communication systems has increased dramatically in recent years, spectrum resources remain extremely constrained. As a result, reusing them a few times for various users and applications is one way to alleviate the spectrum access problem. Additionally, as demand for the Internet of Things (IoT) has grown, the imperative to link every person and thing to the network has grown [28].

Current wireless communication systems have some restrictions, which limit any future advances necessary to meet the criteria for future wireless communication systems. This motivation drives researchers to develop appropriate techniques and possibly incorporate them into the next generation of wireless communication systems in order to meet emerging requirements such as extremely high spectral efficiency, extremely low latency, massive device connectivity, high achievable data rate, user fairness, high throughput, support for diverse quality of service (QoS), energy efficiency, and low cost [32].

In reality, OMA approaches have encountered a number of difficulties. One of these issues is the insufficient number of supported users, which is restricted by the number of orthogonal resources that are available [33].

The spectral inefficiency of OMA is another problem that it must contend with [34]. It enables customers experiencing bad channel conditions to reserve one of the few bandwidth resources available in the event that the user has high-priority data to send or has not been served in a lengthy period of time. Because of this issue, the whole system's spectral efficiency and throughput are significantly impacted [35].

Regarding user fairness, low latency, and massive connectivity in OMA, for example in OFDMA with scheduling, a high priority for serving is returned to the user with a good channel condition, while the user that has bad channel condition should wait for access. That finally causes a fairness problem and high latency.

Due to the aforementioned restrictions, OMA is insufficiently applicable and acceptable to supply the characteristics required by future generations of wireless communication systems. As a result, experts have proposed NOMA as a strong option for the next generation of wireless systems' multiple access technique [36].

Specifically, two fundamental terms have been addressed: (SC) and (SIC). These terms have been addressed in order to make non-orthogonal multiple access practical to implement. In order for distinct users to be superimposed in either the power-domain or the code-domain, NOMA makes use of the notion of superposition coding on the transmitting side. Figure 2-6 shows the main principle difference between the Oma and Noma techniques. This is possible since these users are sharing frequency or spreading code at the same time. Users inside the system can be allocated to many groups at the same time, allowing for greater flexibility. Due to the implementation of NOMA in each group, the orthogonal bandwidth resources have been allotted to the groups that have been formed. In order to recognize and decode received messages, successive interference cancellation is used at the receiving end [37, 38].

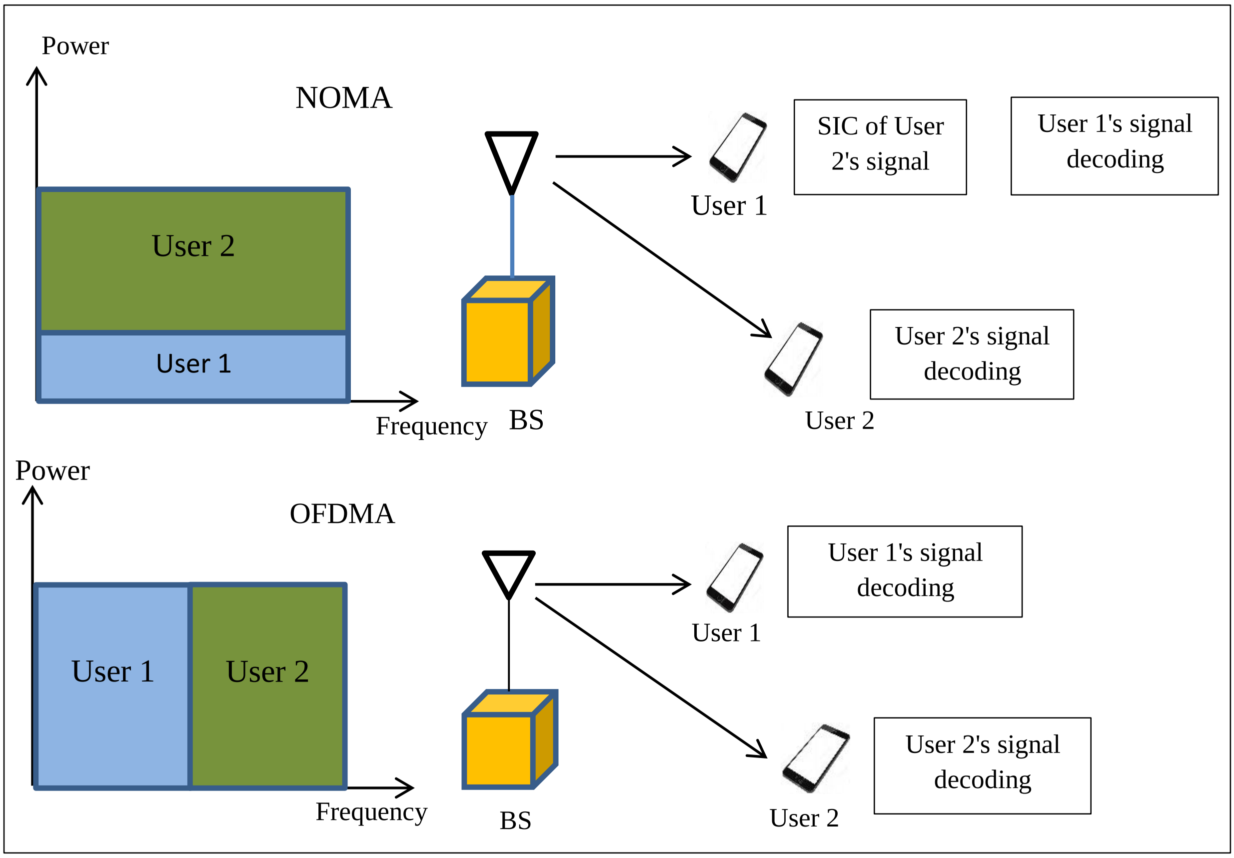

Figure 2-6 A comparison between the NOMA and the OFDMA [39].

On the other hand, NOMA can be divided into two categories: Code Domain CD NOMA and Power Domain PD NOMA [7]. In (PD-NOMA), Users are assigned different power levels depending on power allocation algorithms, which in turn depend on the user's channel circumstances to achieve the highest benefit in system performance. Because the power allocation procedure is also utilized to segregate various users, multi-user interference cancellation can be performed using the notion of SIC [29].

2.4 NOMA's Advantages

When a comparison was made between NOMA and OMA based on different studies, then it was proved that NOMA overcame OMA in terms of the efficiency of the using the spectrum, as it was more efficient in the case of the downlink by a percentage that reached 30%, while the percentage reached 100% in the case of the uplink [28] for that. NOMA has been considered as one of the most efficient multi-access techniques in the optimal use of the spectrum. NOMA has the characteristics and advantages that make it able to overcome the challenges that faced OMA as well as meet the requirements of the next generation of wireless communications systems [40,41]. Below are some of the features that enabled NOMA from overcoming OMA :

Spectral efficiency and throughput : Because each user is assigned a specific frequency resource regardless of whether they have excellent or poor channel conditions in OMA, the overall system has low spectral efficiency and low throughput, which is a problem in OFDMA and other OMA techniques [28]. In NOMA, the same frequency resource is simultaneously allocated to many mobile users with a different power assignment to each of them [42]. A weak user can use the same frequency resource assigned to the strong user, and SIC operations can detect interference in the receivers of both users. Thus, there will be a significant rise in the probability of achieving greater spectral efficiency and high throughput, as shown in Figure 2-7.

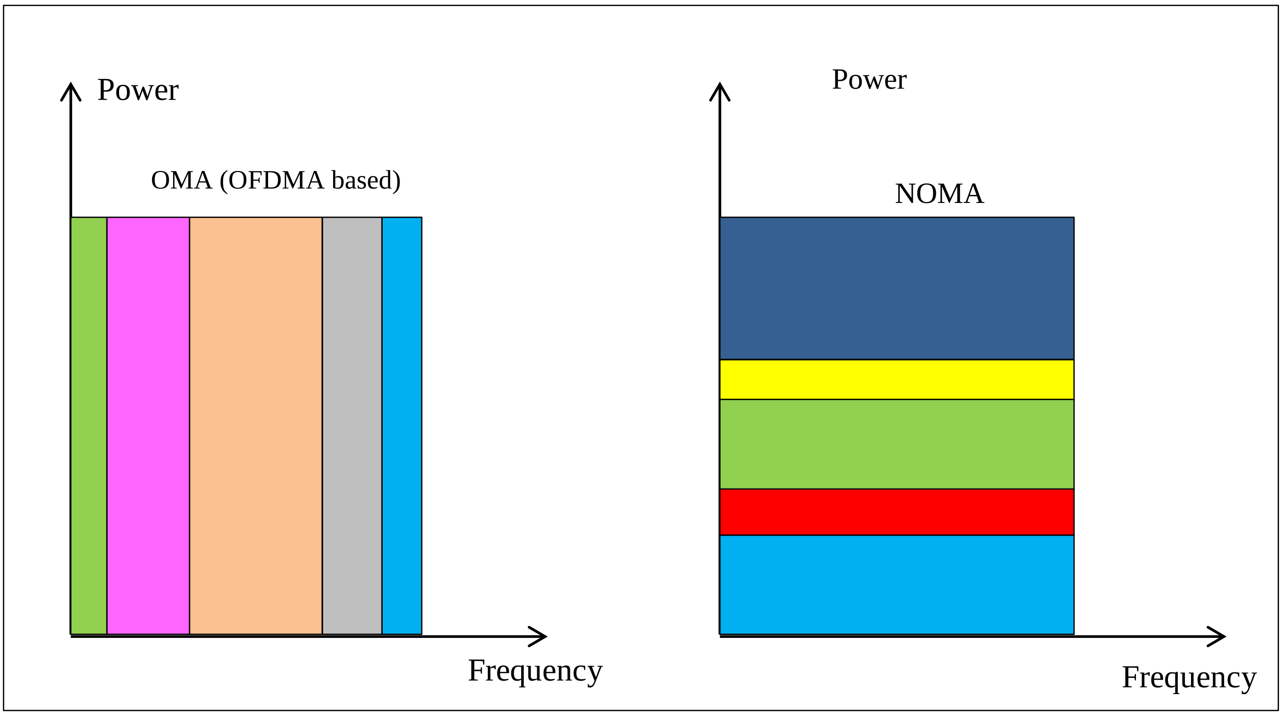

Figure 2-7 An illustration of the differences between OMA and NOMA [43]

Fairness of user : The problem of fairness between users in the distribution of wireless resources when using OFDMA technology (one of the OMA technologies) appears if two users are assumed within the system, one with good channel conditions and the other with poor channel conditions. In this case, service priority will be given to the first user [44]. On the other hand, unlike OFDMA, in the case of using NOMA, the service mechanism differs, as it serves both users at the same time, and thus this mechanism leads to achieve user fairness and increasing system throughput [6].

Compatibility: In contrast to OMA, NOMA does not require major modifications in the architecture to be compatible with future communication frameworks. For example, it is included in the (3GPP LTE Release 13) Long-term evolution Advanced 3G Partnership Project [45].

Massive connectivity: Because NOMA resource distribution is non-orthogonal, the number of supportable users/devices is not strictly restricted by the number of orthogonal resources available. As a result, NOMA can provide enormous connectivity by greatly expanding the number of simultaneous connections. [39].

Low transmission latency and signaling cost: Access-grant requests are used by OMA to communicate between users and BS [46]. The user must make a scheduling request to the BS to initiate communication. When the BS receives the request, it schedules the uplink transmission and responds to the user by issuing a clear-to-send signal to certify the link is clear. As a result, there is a significant increase in transmission latency and signaling overhead. With this much latency, 5G cannot be relied on to provide widespread connectivity. In particular, the LTE access grant operation takes around 15.5 ms before data transmission [39]. As a result, the radical requirement of a user delay of less than 1 ms cannot be easily met [47]. For NOMA uplink communication, the transmitter uses multiple access without requests to grant access. To put it another way, NOMA was implemented with significantly decreased transmission latency. Using SIC on a more significant number of users, on the other hand, can result in increased latency [48].

Table 2-1 NOMA and OMA are being compared [27].

	Advantages	Disadvantages
OMA	• Low complexity in the receivers	• It has a lower spectral efficiency • Supports a limited number of users (fewer) • Not achieving justice
NOMA	• It has a higher spectral efficiency • Provides a high connection density • achieve user fairness • lower transmission latency • Higher quality of service QoS	• High complexity in the receivers high sensitivity to channel uncertainty

2.5 General description of NOMA in downlink and uplink

This section demonstrates the fundamental concepts of NOMA, both in the downlink and uplink directions. Whether upward or downward, NOMAs are subsets of multiple access channels (MACs) or broadcast channels (BCs). Due to the critical importance of these multiple access techniques in the next generation of communication techniques, was present the NOMA principles in two parts, one for downlink and one for uplink. The first section will cover the fundamentals of NOMA in the downlink, while the second section will demonstrate NOMA principles in the uplink.

2.5.1 Downlink NOMA

On the downlink NOMA network, the transmission side is illustrated in Figure 2-8. As shown in this diagram, this network is comprised of two users that are served by a base station that has a single transmitter antenna and a single receiving antenna.

In a downlink scenario, in general, the base station broadcasts superposition of n signals to users by a selection of their different power levels. The BS sends a signal to the user n (n =1,2,…,N), which is represented by s_n and transmission power p_n. Summation of p_n (n=1,2,….N) is equal to p_{total}.

The transmitted signal can be represented by the formula:

$$x = \sum_{n} \sqrt{p_n}\, s_n \qquad n = 1,2, \ldots\ldots, N \qquad (2.1)$$

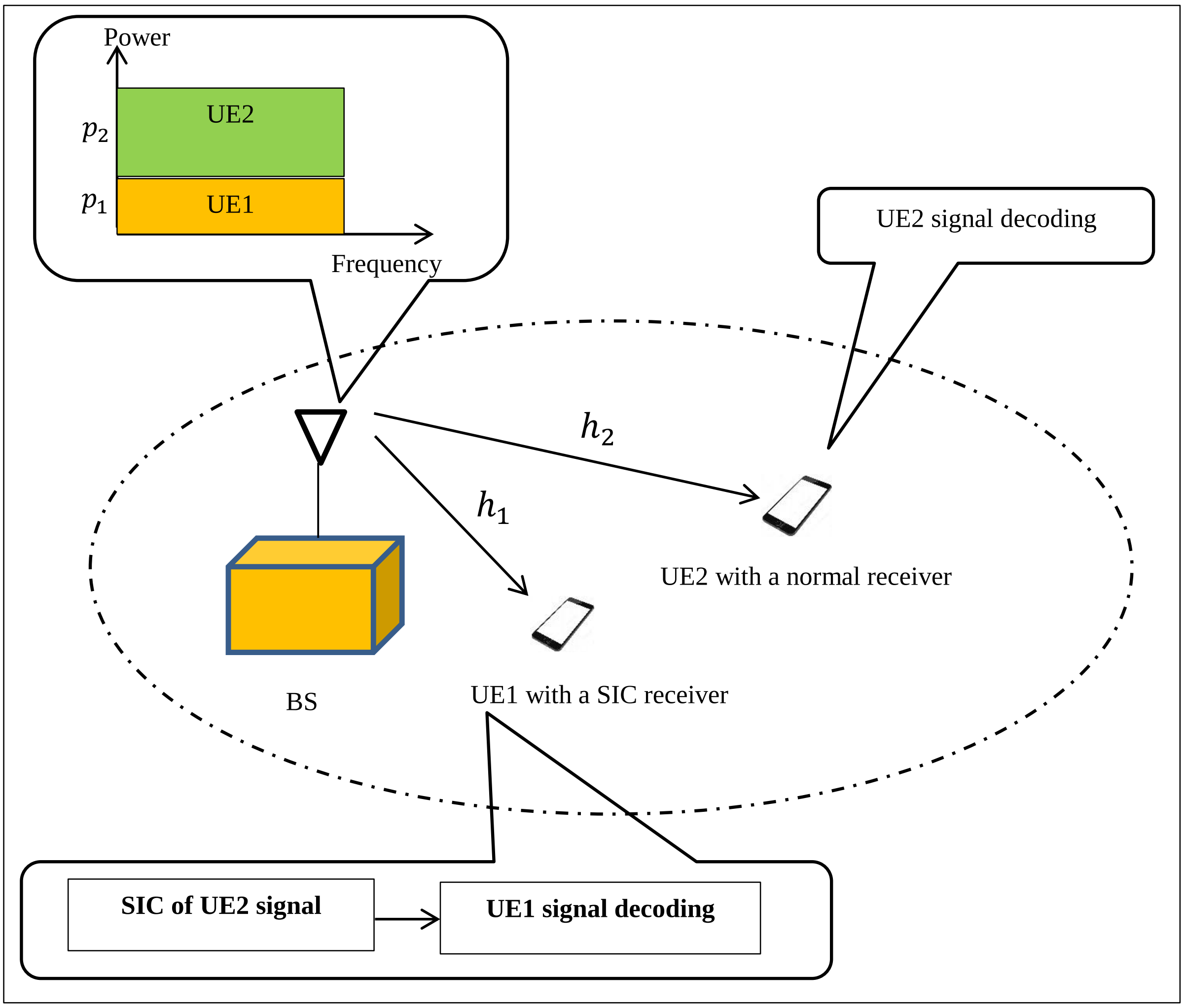

Figure 2-8 NOMA downlink scheme with power assignment diagram [49].

Then, the signal received by the user n can be represented by the formula:

$$y_n = h_n x + w_n \qquad n = 1,2, \dots \dots \dots, N \qquad (2.2)$$

where h_n denotes the complex channel coefficient between the base station and the user n, w_n denotes Additive White Gaussian Noise at the user n including noise variance σ_n^2.

The successive interference cancellation method is applied at the user terminal in order to eliminate the influence of the undesirable received signal components. SIC decoding order is determined by the position of users in the list, which is ordered according to the quality of channel $\frac{|h_n|^2}{\sigma_n^2}$, Based on this order, each user can decode its signal correctly and avoid interference caused by signals from other users [35].

Typically, users with low quality channels should have greater power levels given to them in order to improve their received signal-to-interference-noise-ratio (SINR) and ensure good detection reliability. The converse method is used by users with a higher quality of channels. They have a high possibility of accurately detecting their data, despite the fact that they require less power. Because of this, the SIC method can be used in their receivers [50]. assuming that

$$\frac{|h_1|^2}{\sigma_1^2} > \frac{|h_2|^2}{\sigma_2^2} > \cdots > \frac{|h_n|^2}{\sigma_n^2} \qquad (2.3)$$

Distribution of allocated power among the users can be arranged as:

$$p_1 < p_2 < \cdots < p_N \qquad (2.4)$$

Further, in the case of two users as shown in Figure 2-8, it was assumed that the quality of channel of the first user is better of the second user, and thus $\frac{|h_1|^2}{\sigma_1^2} > \frac{|h_2|^2}{\sigma_2^2}$ and $p_1 < p_2$. In NOMA networks, in the downlink state, SIC operations are performed by the user. These operations implement by adopting a descending order according to the channel quality of the user, and since the quality of the channel of the strong user is the best, it is he who performs the operations of the SIC. This is done first by detecting the weak user's signal, then subtracting it from the total signal received, then the strong user obtaining his own signal. [35], as shown in Figure 2-9. Thus, the throughput R_1 of user 1 can be expressed as follows:

$$R_1 = \log_2\left(1 + \frac{P_1|h_2|^2}{\sigma_1^2}\right) \tag{2.5}$$

whereas, for the user 2 it is:

$$R_2 = \log_2\left(1 + \frac{P_2|h_2|^2}{(p_1|h_1|^2 + \sigma_2^2)}\right) \tag{2.6}$$

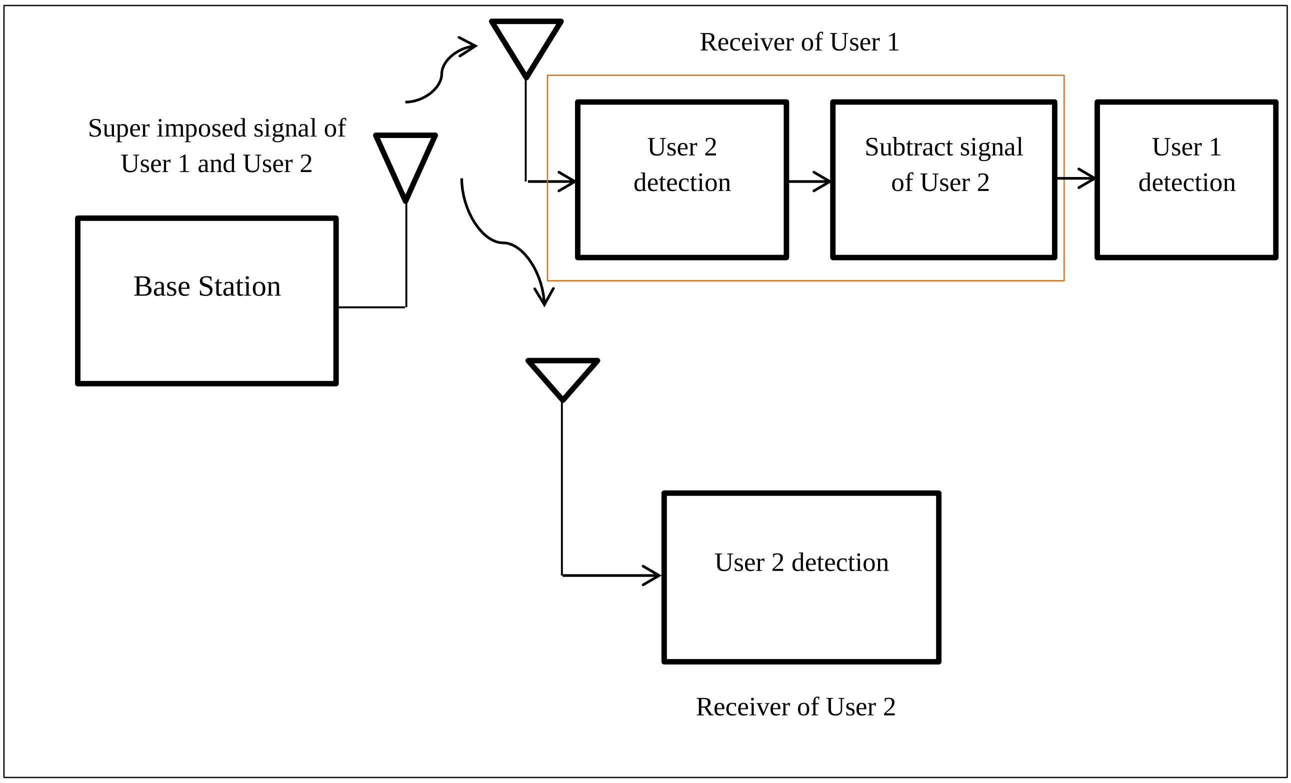

Figure 2-9 Diagram for the SIC decoding process at the user's terminals [51].

2.5.2 Uplink NOMA

This section provides an overview of uplink NOMA, including its fundamental ideas, existing schemes, and performance. The uplink NOMA operates in a manner quite distinct from the downlink NOMA.

In the uplink NOMA, each user broadcasts its own unique signal s_n to BS using the same radio frequency range shared by numerous users, as illustrated in Figure 2-10. In this situation, the transmitted and received signals respectively can be expressed as follows:

$$x_n = \sqrt{p_n} s_n \qquad n = 1,2,\ldots,N \tag{2.7}$$

$$y = \sum_n h_n x_n + w_n \qquad n = 1,2,\ldots.,N \tag{2.8}$$

where h_n denotes the complex coefficient of the channel between the BS and the user n, w_n denotes the AWGN at the BS.

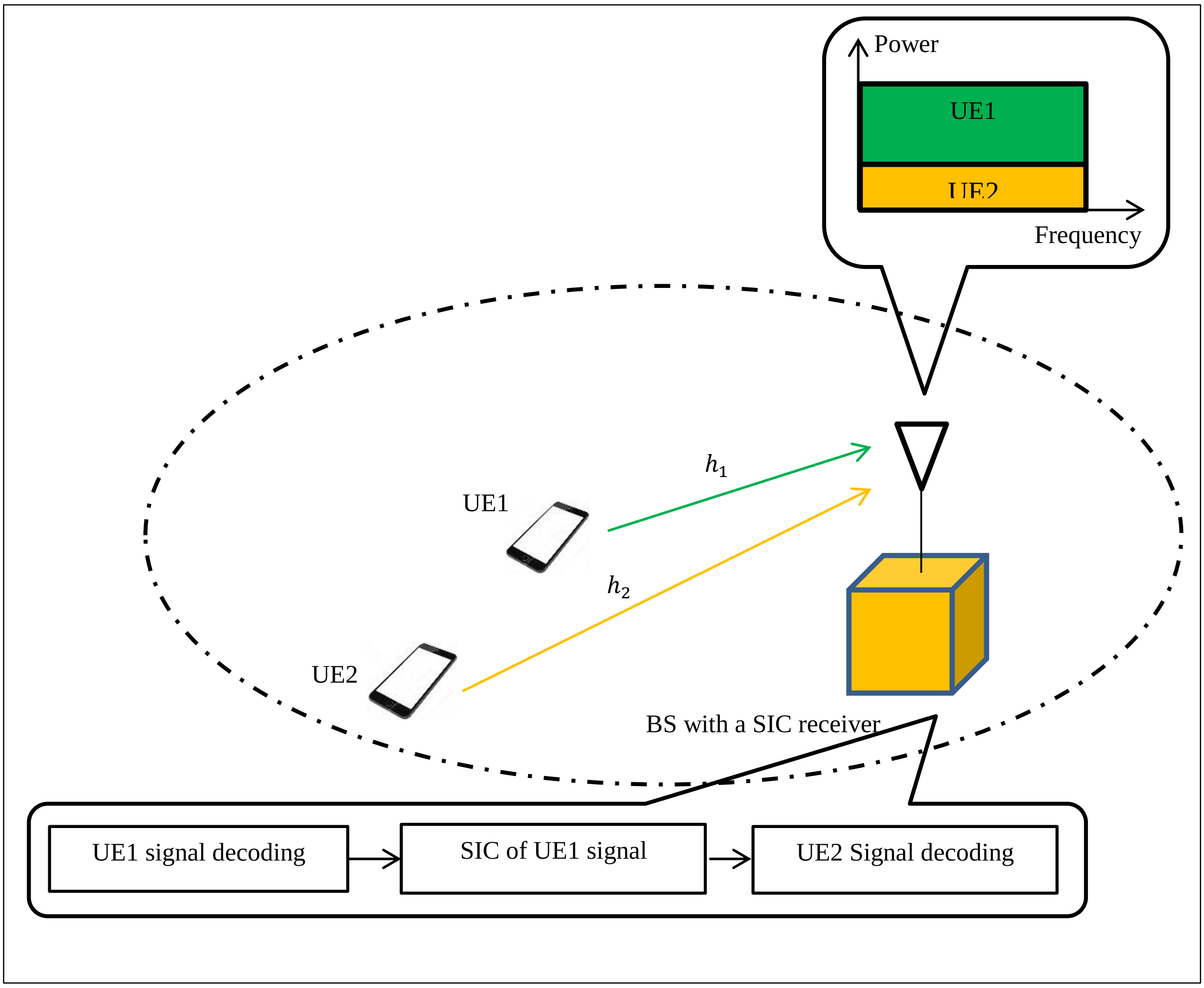

Figure 2-10 Schematic of the uplink NOMA with allocated power [51].

It is assumed that

$$\frac{|h_1|^2}{\sigma_1^2} > \frac{|h_2|^2}{\sigma_1^2} > \cdots > \frac{|h_N|^2}{\sigma_n^2} \qquad (2.9)$$

Thus, the allocated power levels for the users are assumed as:

$$p_1 > p_2 > \cdots > p_N \qquad (2.10)$$

The amount of transmitted power per user is restricted by the amount of maximum battery power available to the user. If the channel gains of all users are sufficiently distinct, they will be able to utilize their battery power independently up to the maximum. When the channel gains get too close to each other, the power control can be used to improve the performance of users who have better channel gains while keeping the performance of users who have weaker channel gains [52, 53].

The concept of SIC decoding in the uplink NOMA is quite different from that in the downlink. The optimal order of SIC decoding is based on the order of decreasing of quality of channel $\frac{|h_n|^2}{\sigma_n^2}$ [54].

In NOMA's uplink, the signal is detected in two stages: In the first stage, the base station detects the signal of the strong user s_1, which is the first user who has a higher channel gain than the second user, in case of interference caused by the second user. In the second stage after the process of detecting the first signal s_1, the receiver subtracts this signal from the total signal that was received, and then detects the second user's signal s_2[7], as shown in figure 2-11.

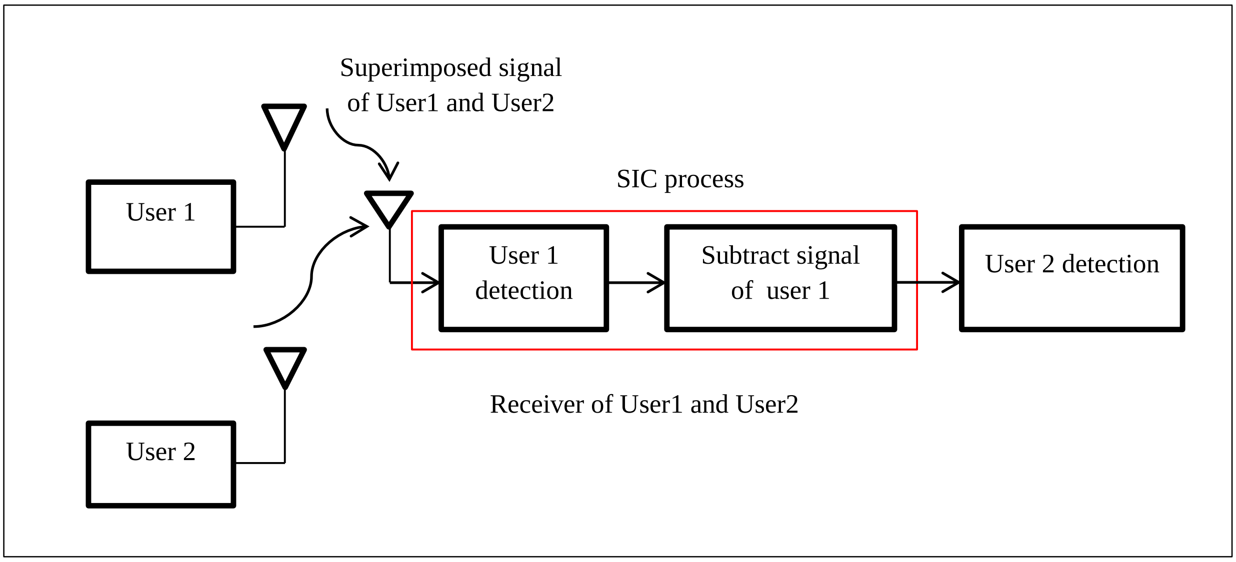

Figure 2-11 Scheme of SIC decoding process at BS [51].

As a result, we can obtain the individual data rates for user 1 and user 2 as follows:

$$R_1 = \log_2\left(1 + \frac{p_1|h_1|^2}{p_2|h_2|^2 + \sigma_1^2}\right) \qquad (2.11)$$

$$R_2 = \log_2(1 + \frac{p_2|h_2|^2}{\sigma_2^2}) \qquad (2.12)$$

2.6 Optimization techniques

In this thesis, two approaches of improving the performance of the proposed NOMA system will be used to improve the overall sum rate of the system by allocating the appropriate power for each user, taking into account the fairness in this allocation:

2.6.1 Genetic Algorithm

GA was inspired by the Darwinian theory of evolutionary , in which the survival of fitter creatures and their genes were simulated. GA is a population-based algorithm. GA evaluates the fitness of each individual in the population using a fitness (objective) function. For improving poor solutions, the best solutions are chosen randomly with a selection (e.g. roulette wheel) mechanism [55, 56].

The GA algorithm is stochastic, so one might ask how reliable it is. What makes this algorithm reliable and able to estimate the global optimum for a given problem is the process of maintaining the best solutions in each generation and using them to improve other solutions. As such, the entire population becomes better generation by generation. This algorithm also benefits from mutation. This operator randomly changes the genes in the chromosomes, which maintains the diversity of the individuals in the population and increases the exploratory behavior of GA. Similar to the nature, the mutation operator might result is a substantially better solution and lead other solutions towards the global optimum [57].

GA enables us to tackle unconstrained, bound-constrained, and general optimization problems [58]. There are five stages in implementing a genetic algorithm, namely: initial population, fitness function, selection, crossover, and mutation. Selection, crossover and mutation are called reproduction operators [59]. Figure 2-12 shows a flowchart illustrating the genetic algorithm. In addition, Algorithm 1 presents the steps for implementing this algorithm.

2.6.1.1 Initial population:

The starting population is often a population of randomly generated solutions or individuals [59].

2.6.1.2 Fitness function:

Also called fitness value, it is a suitable mechanism for determining the best solution to a problem or determining the best chromosome. Where a fitness value is determined for each chromosome. Whereas a lower value indicates that the solutions or chromosomes are not suitable, a higher value indicates that it is well suited [60].

2.6.1.3 Selection:

It is a genetic factor that is used for the selection process of the parents who will survive in order to produce the next generation. In most cases, the fathers with the highest fitness values for mating are selected. The main objective of this selection process is to give encouragement to individuals of high fitness to adapt in order to be selected for the next generation [61].

2.6.1.4 Crossover:

It is the process by which new solutions are generated from the current population by collecting genetic information from the original chromosomes to then produce a new population or offspring [59].

2.6.1.5 Mutation:

With a mutation probability mutate new offspring at each position in chromosome. Similar to the case of crossover, the choice of the appropriate mutation technique depends on the coding and the problem itself. Mutation has the greatest effect in treating locality of crossover. It gets random solution that may lead GA to the global optimum [58].

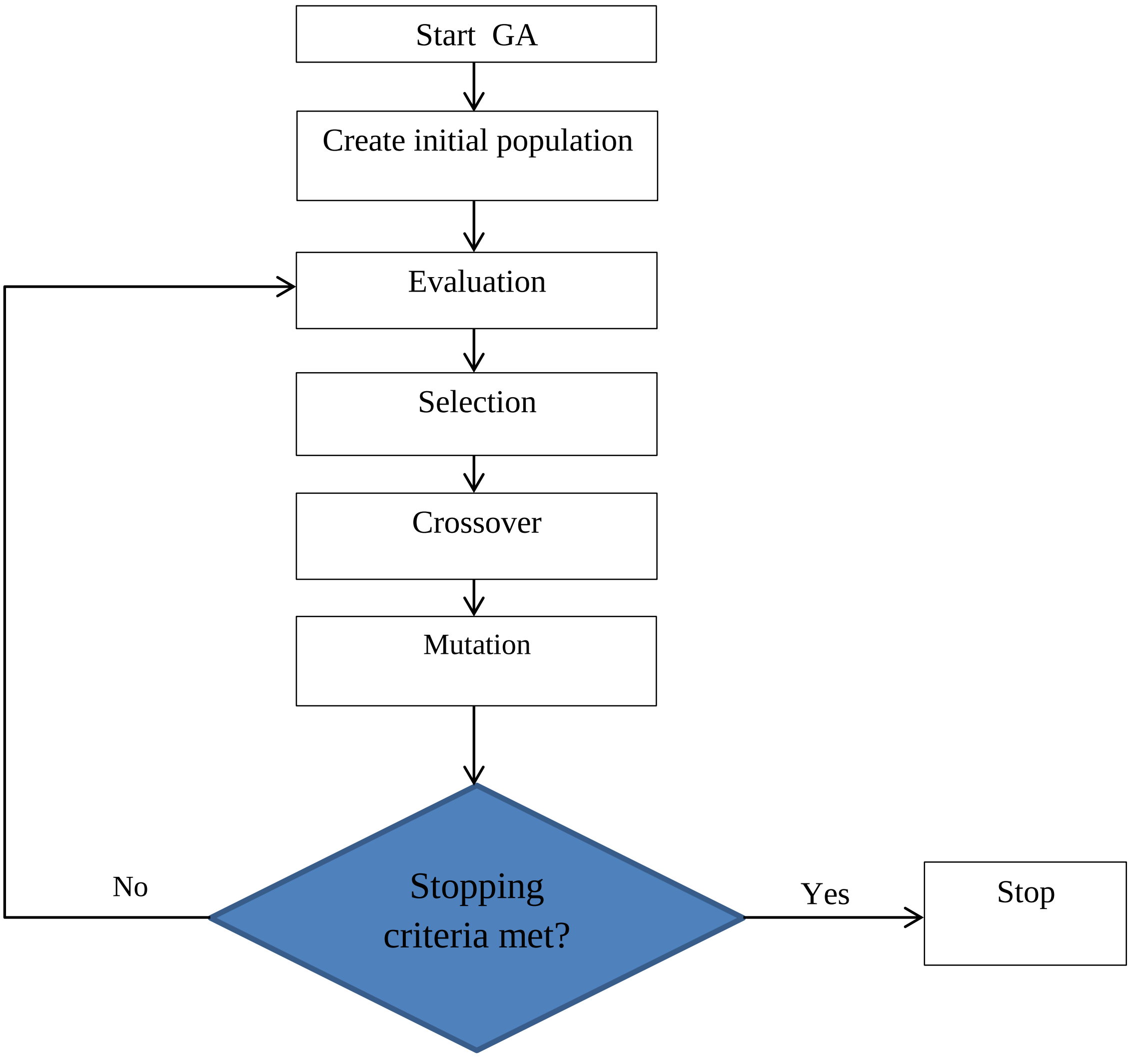

Figure 2-12 Steps of a simple genetic algorithm [58].

2.6.2 Pseudo-code of the standard Genetic Algorithm

Algorithm 1

1: Input : *N* : Population size; *Pc* : Crossover rate; *Pm* : Mutation rate.

2: Output : Best Chromosome.

3: ***t*** **_ 0**

4: Initialize arbitrarily the initial population P(t)

5: while (not termination condition) **do**

6: Evaluate P(t) using a fitness function

7: Select $P(t)$ from $P(t-1)$

8: Recombine $P(t)$

9: Mutate $P(t)$

10: Evaluate $P(t)$

11: Replace $P(t-1)$ by $P(t)$

12: t _ $t + 1$

13: end

2.6.3 Grey Wolf Optimization (GWO)

2.6.3.1 Introduction

It is an improved algorithm and the nature of its work is inspired by nature, specifically from the behavior of grey wolves in how they hunt their prey [62].

Grey wolves are considered from the Canidae , and they are from the main predators, that is, they are at the top of the food pyramid. Most of the time, they prefer to live in a herd, and the herd consists of 5 to 12 wolves. One of the things that is very important is that they have a strict social hierarchy [62]. as shown in Figure 2-13.

Leaders are called alpha (α) and they are both male and female. The alpha is mostly responsible for making critical decisions such as where to sleep when, wake up and hunting decisions. Alpha decisions apply to the entire group. An interesting thing is that Alpha is not necessarily the strongest member of the group, but rather the most efficient at managing the group, which means that the importance of the herd lies in its organization and management, not in its strength [63].

(β) is the second level in the group hierarchy. It comes after alpha and replaces it in the event of his death or absence. His role can be likened to that of an advisor in making all critical decisions [64].

The third level is wolf (Delta □). Delta includes fishermen, rangers, and scouts. They are responsible for protecting the boundaries of the pack, alerting them of upcoming danger, and caring for sick and wounded wolves [62].

The latest level is the wolf (omega Ω) and is considered the scapegoat for the group. His presence is important in the group, as the groups were witnessing internal fighting in the event of his loss. Sometimes she plays the role of nannies in the group [65].

Here are the three main steps in the process of hunting gray wolves

1. Identifying, following and approaching the prey

2. Encircling the prey

3. Attacking the prey.

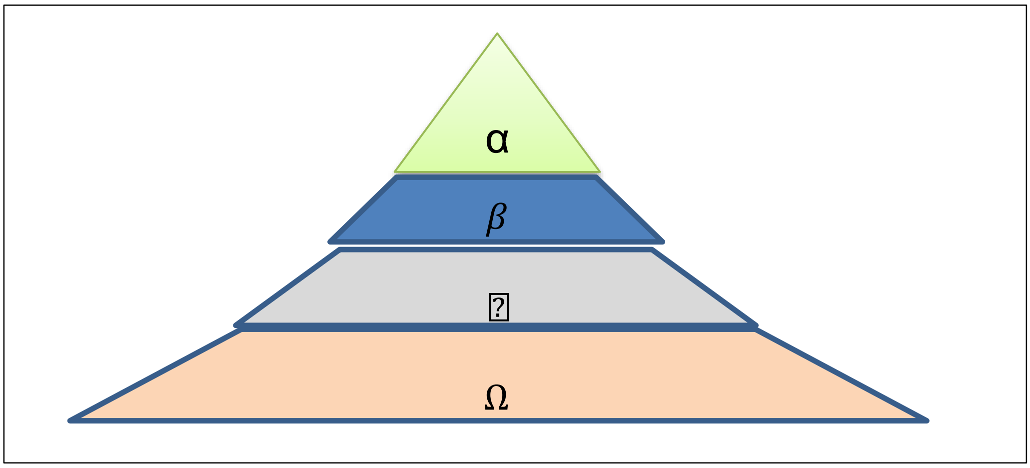

Figure 2-13 Gray wolf group hierarchical diagram [62]

2.6.3.2 The Flowchart of GWO Algorithm

Figure 2-14 shows the working steps of the Gray Wolf Algorithm GWO in detail. Also, the implementation steps of GWO is explained in Algorithm 2.

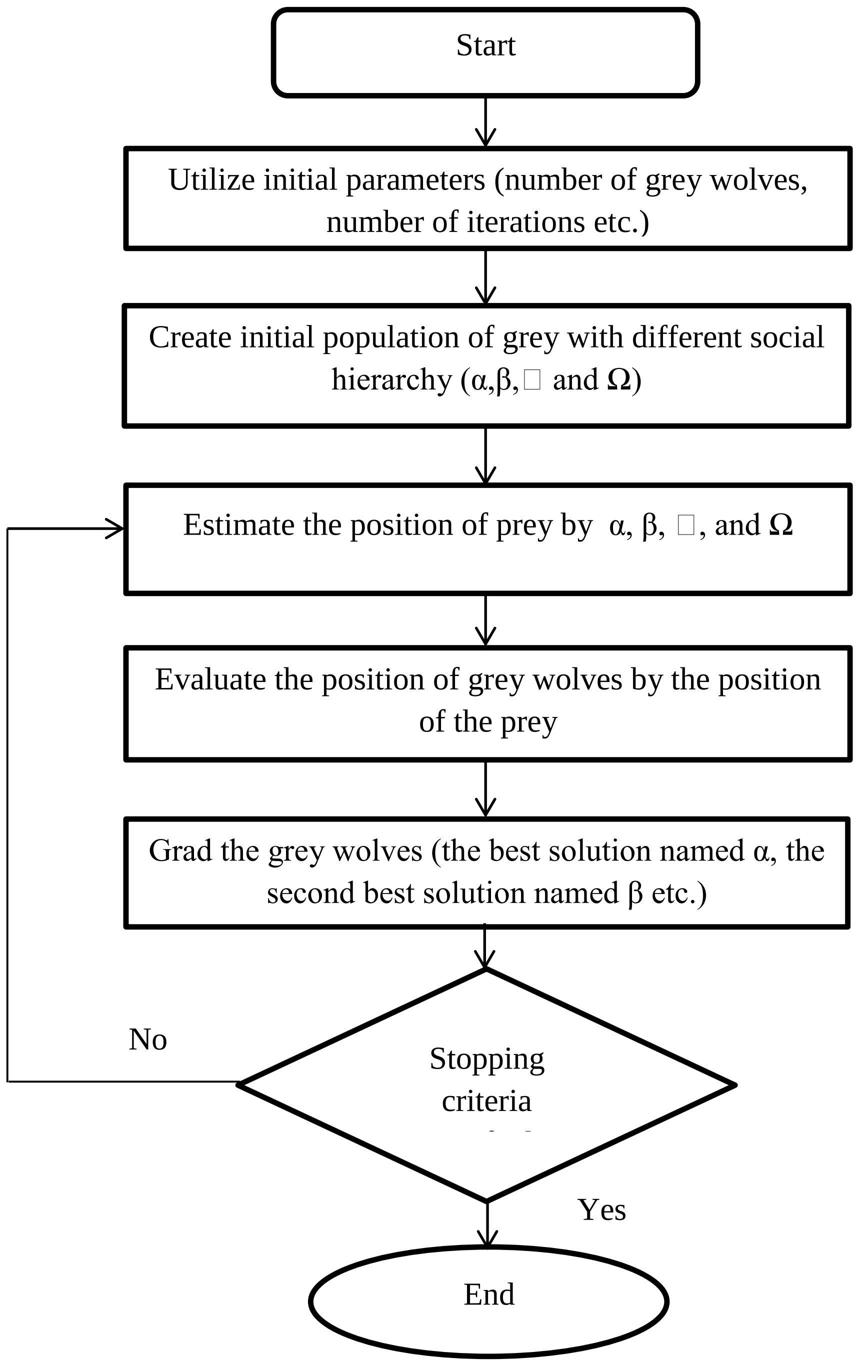

Figure 2-14 Flowchart of Grey Wolf Optimization GWO Algorithm [66].

2.6.3.3 Pseudo code of GWO Algorithm:

Algorithm 2

Begin

Initialize the population of grey wolves *Xi* (*i* = 1, 2, ... , *n*)

Initialize *a*, *A*, and *C*

Calculate the fitness values of search agents and grade them. ($X\alpha$= the best solution in

the search agent, $X\beta$= the second best solution in the search agent, and $X\delta$= the third

best solution in the search agent)

t= 0

While (t < Max number of iterations)

For each search agent

Update the position of the current search agent by Equation (3.6)

End for

Update *a*, *A*, and *C*

Calculate the fitness values of all search agents and grade them

Update the positions of $X\alpha$, $X\beta$, and $X\delta$

t= t+1

End while

End

Chapter Three

Chapter Three: System model and optimization techniques

3.1 Introduction

Due to the huge increase in the demand for spectrum through the need for massive connectivity in future generations of wireless communications, capacity improvement, radio resource allocation and interference management are being considered to meet these demands. NOMA is one of the most promising technologies that can be adopted in the 5G and beyond for the task of managing the optimal use of the spectrum band. Optimizing the overall sum rate of the NOMA network is the objective function in this chapter. The optimization problems addressed in this chapter are: Allocation of power, taking into account fairness among users in the wireless resource allocation process.

In this thesis, GA and GWO Algorithms are adopted to solve the optimization problems required to improve the user sum rate in the proposed model.

3.2 The proposed system model

The proposed system consists of a central cell, in addition to six adjacent cells surrounded by a circular pattern. Each cell contains a single BS, as shown in Figure 3-1. In the central cell, signals are sent to the users deployed in the cell via the base station and are expressed by $n = \{1, \ldots., N\}$. All users are scattered within the central cell in a circular area, and all devices (BS and users) have one Omni-directional antenna. The sub-channels resulting from the bandwidth splitting process performed by the BS are expressed by $k = \{1, \ldots. , K\}$. The total system bandwidth is expressed by B, while the bandwidth of a single sub-channel is expressed by $B_s = B\ /\ K$. One user can receive the signal sent by the BS through multiple sub channels, and multiple users can be served through one sub-channel at the same time according to the principle of work of the NOMA system. The interference in the common sub-channel will be very strong because more than one user is sent on the same channel at the same time. It is considered that the base station is fully aware of the channel state information CSI. The BS allocates each user a different power by relying on the channel state information CSI of the sub channel. Users on the same k sub-channel are denoted by M. The signal sent from the BS is signified as :

$$x = \sum_{n \in M} \sqrt{P_{k,n}}\ s_n \qquad (3.1)$$

In the above equation signified by $p_{k,n}$ is the power that is allocated to the user n , s_n represents the message of the user.

Assuming that all users within the central cell CC and BS are equipped with one antenna, the signal received by user n is expressed as:

$$y_{k,n} = h_{k,n} x_n + w_n \qquad (3.2)$$

The above equation indicates the following: $w_n \sim \mathcal{N}(0, \sigma^2)$ stands for the Additive White Gaussian Noise, the noise variance represented by σ^2. Whereas, $\frac{|h_{k,n}|^2}{\sigma^2}$ indicates the quality of the channel. In NOMA networks, in the downlink state, SIC operations are performed by the user. It includes the implementation of these operations by adopting a descending order according to the channel quality of the user, and since the quality of the channel of the strong user is the best, it is he who performs the operations of the SIC. The SIC process is implemented by the near user (the strong user) in several steps. In the first step, it detects the signal of the far user (the weak user) and then subtracts it from the received signal, then the strong user gets its own signal.

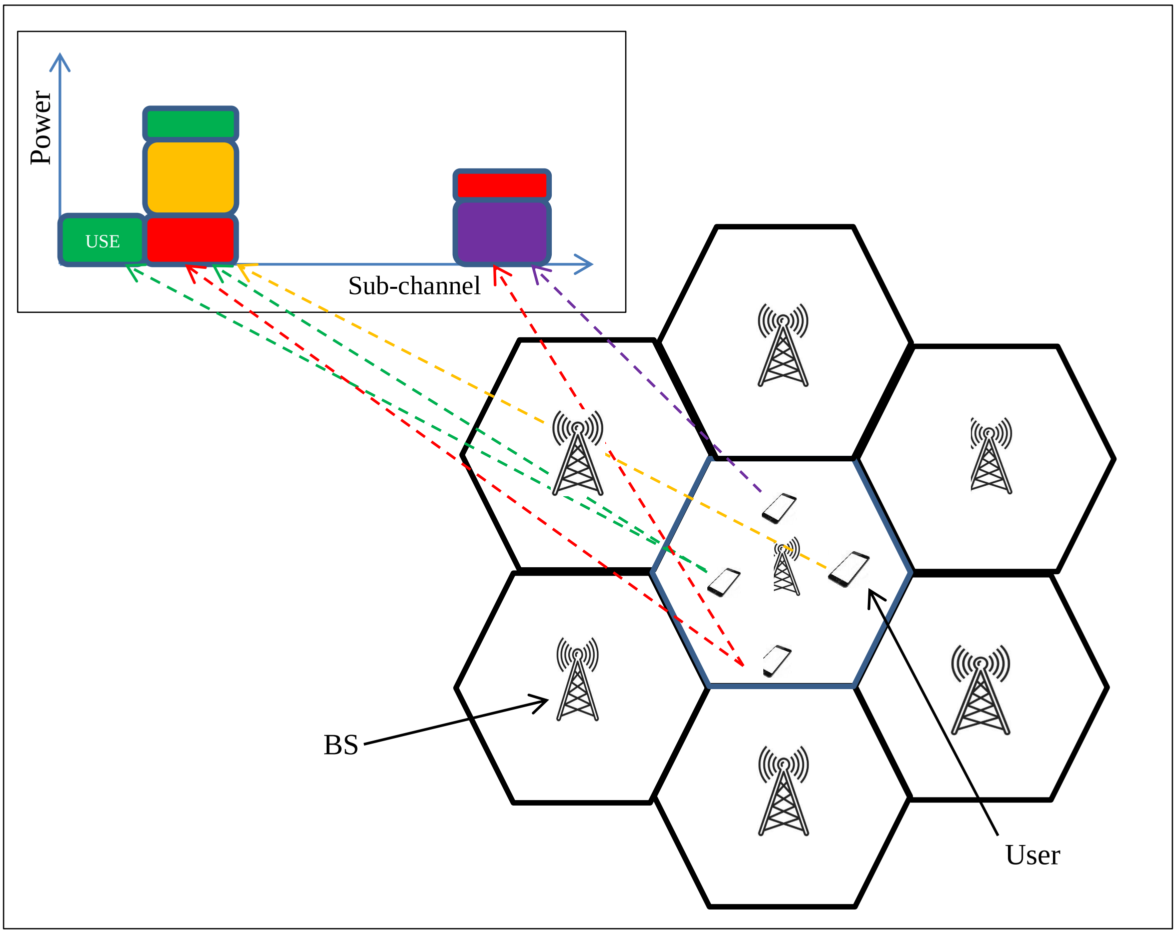

Figure 3-1 System model of the proposed NOMA system.

3.3 Formulation of the optimization problem

To perform the process of improving user sum rate and resource allocation, users who are sent on the same sub channel are denoted by M, so the throughput obtained by the user n can be expressed by

$$R_k = \sum_{n \in M} B_k \log_2(1 + \frac{p_{k,n}|h_{k,n}|^2}{I_o + I_{k,n} + \sigma^2}) \qquad (3.3)$$

$I_{k,n}$ Represents the interference between the users inside the CC.

I_o It represents the interference caused by the base stations of neighboring cells.

In order to reach a good optimization to maximize user throughput, the number of users is determined on the M sub-channels, where it is considered that all the sub-channels are available to all users with the allocation appropriate power for each user and determine the upper and lower limits of the users in the sub-channels $M_l \leq M \leq M_u$, where M_u refers to the maximum number of users on the sub channel while M_l indicates the minimum for it.

$$I_{k,n} = \sum\nolimits_{n \in N} p_{k,n}|h_{k,n}|^2 \qquad (3.4)$$

$$I_o = \sum_{i=1}^{6} p_{Bso}(i)|h_{Bso,n}(i)|^2 \qquad (3.5)$$

$$p_{k,n} = allocated\ power\ to\ user\ n\ on\ sub - channel\ k.$$

$$p_{Bso} = External\ Base\ Station\ power.$$

Equation 3.6 represents the objective function of maximizing the sum rate for each user within the proposed system:

$$\max_{p_{k,n}} \sum_{k\in K}\sum_{n\in M} B_k \log_2\left(1+\frac{p_{k,n}\left|h_{k,n}\right|^2}{I_o+I_{k,n}+\sigma^2}\right) \tag{3.6}$$

$$C_1 : \sum_{n\in M}\sum_{k\in K} p_{k,n} \le P_{total} \tag{3.7}$$

$$C_2 : M_l \le M \le M_u \tag{3.8}$$

$$C_3 : R_n > R_{n,min} \tag{3.9}$$

Because of the limited power that the BS transmits, it must be optimally distributed over the sub-channels. A set of constraints was used to include them in the processes of improving the throughput of the NOMA system, where the constraint C_1 is included in order to achieve the optimal distribution of power and adherence to it by the power distribution variable $P_{k,n}$. The process of determining the number of users in esch sub-channel is captured by constraint C_2. As for the data rate obtained by the user, it is processed in constraint C_3. The problem is non convex, due to the presence of C_3 .

In order to obtain results in implementing the improvement steps that were followed above, the following are the steps that illustrate the throughput improvement processes that took place on the NOMA system.

1. In order to implement the above optimization processes, the GA and GWO Algorithms were proposed, which are classified among the optimization algorithms, as their working principle is inspired by nature.

2 . Dividing the main optimization problem, which is the total sum rate optimization problem, into two sub-problems: power allocation and taking into account the fairness in this distribution.

Chapter Four

Chapter Four: Simulation Results and Discussion

4.1 Introduction

This section presents the parameters of the proposed strategies in Table 4.1. The NOMA-GA and NOMA-GWO strategies are then compared with OMA in different scenarios. The first scenario occurs when there is interference caused by cells adjacent to the central cell using different numbers of users (4, 8, 12 and 16). The same number of users will used in the second and third scenarios without interference from neighboring cells. The results were calculated and plotted using MATLAB 2021a.

TABLE 4-1 Simulation Parameters.

Parameter	Value
Cell radius	200 m
Total Bandwidth (B)	5*MHz*
Total power (P_t)	1 watt
Fading	Rayleigh flat fading
Noise power spectral density	-173 dBm/Hz
Number of users	4, 8, 12, 16
Number of sub-channels	2, 3, 4, 5, 6, 7, 8, 9,10

4.2 The results

4.2.A. Scenario One: Results in the case of external interference

In this section, the total sum rate will be calculated if the interference caused by the base stations of the six neighboring cells on the model proposed in this thesis is taken into account, using three schemes to show the difference when using each scheme, as shown below:

1. In the case of 4 users:

Figure 4-1 shows the difference in the sum rate obtained by the user in different cases when applying the OMA, NOMA-GA, and NOMA-GWO methods indicated by the blue, red, and green curves, respectively. This figure shows that the highest sum rate obtained in OMA technology when the number of sub channels NOS was 3, with a total rate of 46.7740 Mbps. Whereas in the case of using NOMA-GA, the highest total rate obtained was when the NOS was 8, and the total rate was 56.0329 Mbps. Whereas, NOMA-GWO got the highest overall rate when the NOS was 8 and the total rate was 63.9497 Mbps. As such, NOMA-GWO achieved the highest sum rate against all methods.

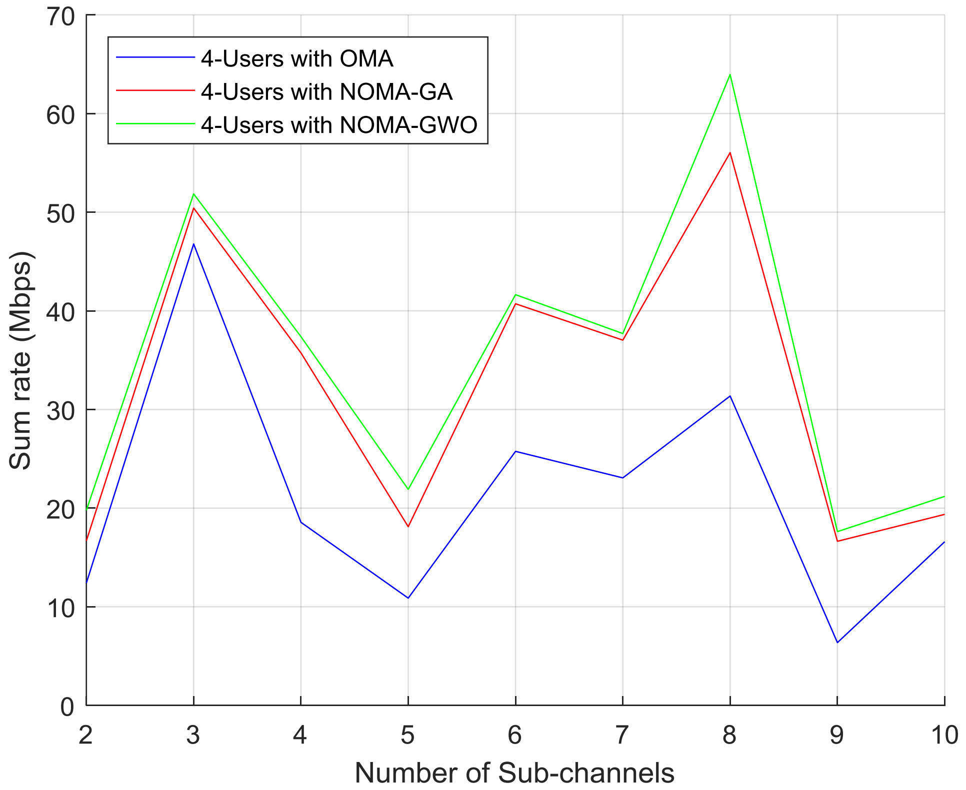

Figure 4-1 The sum rates in the case of 4 users with external interference.

Each curve in Figure 4-1 represents the user's sum-rate values in each of the above scenarios, and these values rise and fall in each case depending on the quality of the channel. Whereas, in the case of generating random fading channels that have high quality, the sum rate values increased. In the case of having a lower quality channel, this value decreases, considering that the interference caused by the BSs to neighboring cells is also variable depending on the quality of the channel in each case. As a result, we saw a change in the level of the curves in each case.

The table 4-2 shows the sum rate values of each sub channel in the case of 4 users and 10 sub channels using OMA, NOMA-GA and NOMA-GWO techniques.

Table 4-2 The sum rate values of each sub channel in the case of 4 users with external interference.

Sub channels	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	4.0644	2.1027	1.8821
2	1.1993	1.3545	1.9310
3	0.8574	0.1893	2.1024
4	0.5150	4.5930	1.3689
5	2.0061	0.7117	1.5240
6	1.3684	2.2018	2.9096
7	0.4392	3.0961	0.8788
8	0.0813	0.2885	2.0934
9	5.8534	2.0594	2.9245
10	0.2096	2.7556	3.5767
Sum of the values	**16.5941**	**19.3526**	**21.1914**

The table 4-3 shows the sum rate values of each user in the case of 4 users and 10 sub channels using OMA, NOMA-GA and NOMA-GWO techniques.

Table 4-3 The sum rate values of each user in the case of 4 users with external interference.

Users	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	7.9231	10.4908	9.5114
2	5.7774	4.7100	5.0010
3	1.2966	3.3111	3.5816
4	1.5970	0.8407	3.0974
Sum of the values	**16.5941**	**19.3526**	**21.1914**

The table 4-4 shows the power values, of each sub channel in the case of 4 users and 10 sub channels using the NOMA technique with the Genetic Algorithm NOMA-GA and NOMA with Grey Wolf Optimization Algorithm NOMA-GWO.

Table 4-4 The power values of each sub channel in the case of 4 users with external interference.

Sub channels	NOMA-GA power (watt)	NOMA- GWO power (watt)
1	0.1166	0.1
2	0.0750	0.13
3	0.0666	0.04
4	0.0142	0.01
5	0.1331	0.14
6	0.1476	0.01
7	0.0833	0.02
8	0.1342	0.26
9	0.1142	0.17
10	0.1142	0.12
Sum of the values	**0.999**	**1**

The table 4-5 shows the power values of each user in the case of 4 users and 10 sub channels, using the NOMA-GA and NOMA-GWO.

Table 4-5 The power values of each user in the case of 4 users with external interference.

Users	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.1822	0.1312
2	0.3000	0.3
3	0.3533	0.3488
4	0.1635	0.22
Sum of the values	**0.999**	**1**

2. In the case of 8 users :

Figure 4-2 shows the achievable user sum rate difference in different cases when applying the OMA, NOMA-GA and NOMA-GWO methods shown with blue, red and green curves, respectively. The figure also shows that the highest sum rate was obtained in the case of OMA technique when the NOS was 2, where the sum rate became 32.8395 Mbps. Whereas in the case of NOMA-GA, the highest rate was obtained when the NOS was 9, the total rate was 52.1354 Mbps. In the case of NOMA-GWO, the highest total rate was obtained when the NOS was 9 so that the total rate became 62.6032 Mbps. As such, NOMA-GWO achieved the highest sum rate against all methods used.

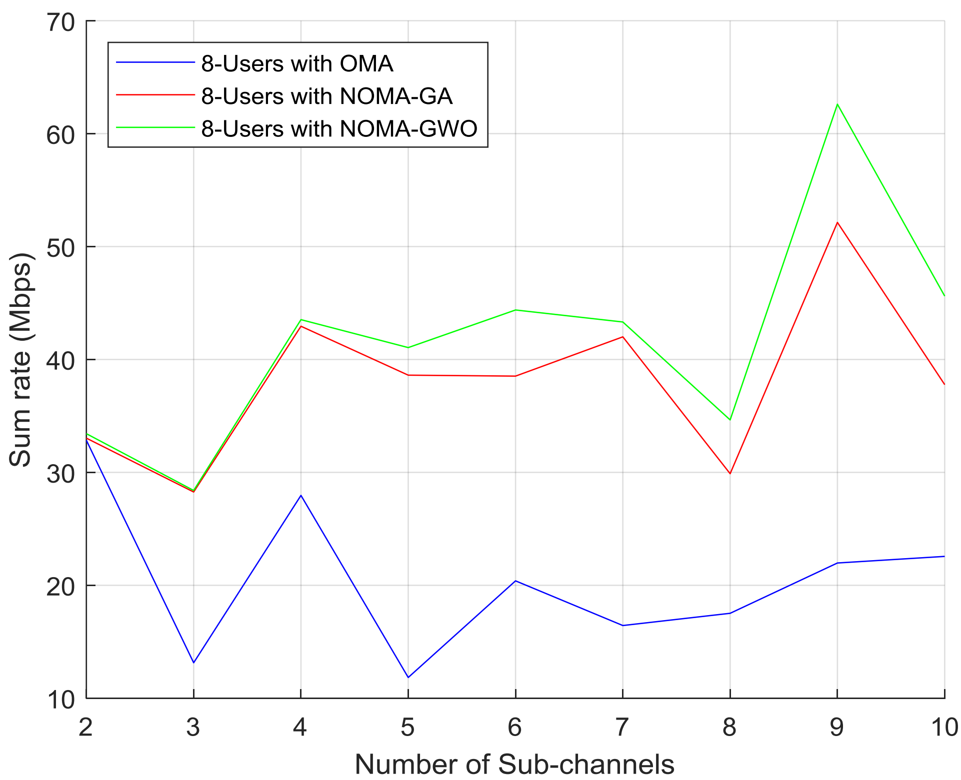

Figure 4-2 The sum rates in the case of 8 users with external interference.

For existing curves in Figure 4-2, The value of the sum rate of the user has begun to increase or leasing in each case as a result of the same reasons mentioned in figure 4-1.

The tables 4-6 and 4-7 show the values of the sum rate for each sub channel and user, respectively, in the case of 8 users and 4 sub channels using OMA, NOMA-GA and NOMA-GWO techniques.

Table 4-6 The sum rate values of each sub channel in the case of 8 users with external interference.

Sub channels	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	0.9636	11.3408	10.3242
2	6.2320	15.7022	12.6570
3	6.1345	6.3911	6.2394
4	14.631	9.5064	14.3042
Sum of the values	**27.9611**	**42.9405**	**43.5248**

Table 4-7 The sum rate values of each user in the case of 8 users with external interference.

Users	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	0.4348	2.6290	3.4187
2	5.9798	1.0878	2.9509
3	0.0796	0.0238	0.4907
4	14.152	31.238	14.0836
5	0.5284	0.1688	2.0456
6	0.2522	3.8123	8.8090
7	6.0554	3.2055	5.4161
8	0.4789	0.7753	6.3102
Sum of the values	**27.9611**	**42.9405**	**43.5248**

The table 4-8 shows the power values, for each sub channel in the case of 8 users and 4 sub channels using the NOMA-GA and NOMA-GWO.

Table 4-8 The power values of each sub channel in the case of 8 users with external interference.

Sub channels	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.3166	0.3375
2	0.0875	0.0527
3	0.3825	0.3069
4	0.2125	0.3027
Sum of the values	**0.9991**	**0.9998**

The table 4-9 shows the power values for each user in the case of 8 users and 4 sub channels using the NOMA-GA.

Table 4-9 The power values of each user in the case of 8 users with external interference.

Users	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.2083	0.3125
2	0.05	0.0411
3	0.0605	0.0325
4	0.1	0.1
5	0.0403	0.0554
6	0.25	0.25
7	0.115	0.125
8	0.175	0.0833
Sum of the values	**0.9991**	**0.9998**

3.) In the case of 12 users :

Figure 4-3 shows the difference in the user achievable sum rate in different cases when applying the OMA, NOMA-GA and NOMA-GWO methods indicated by blue, red and green curves respectively. The figure below shows that the highest sum rate was obtained in OMA technique when the NOS was 5, where the total rate became 39.1593 Mbps. Whereas in the case of NOMA-GA, the highest rate was obtained when the NOS was 5, the total rate became 79.4627 Mbps. In the case of the NOMA-GWO application, the highest total rate was obtained when the NOS was 5, where the total rate became 87.1316 Mbps. NOMA-GWO achieved the highest sum rate against all the used methods.

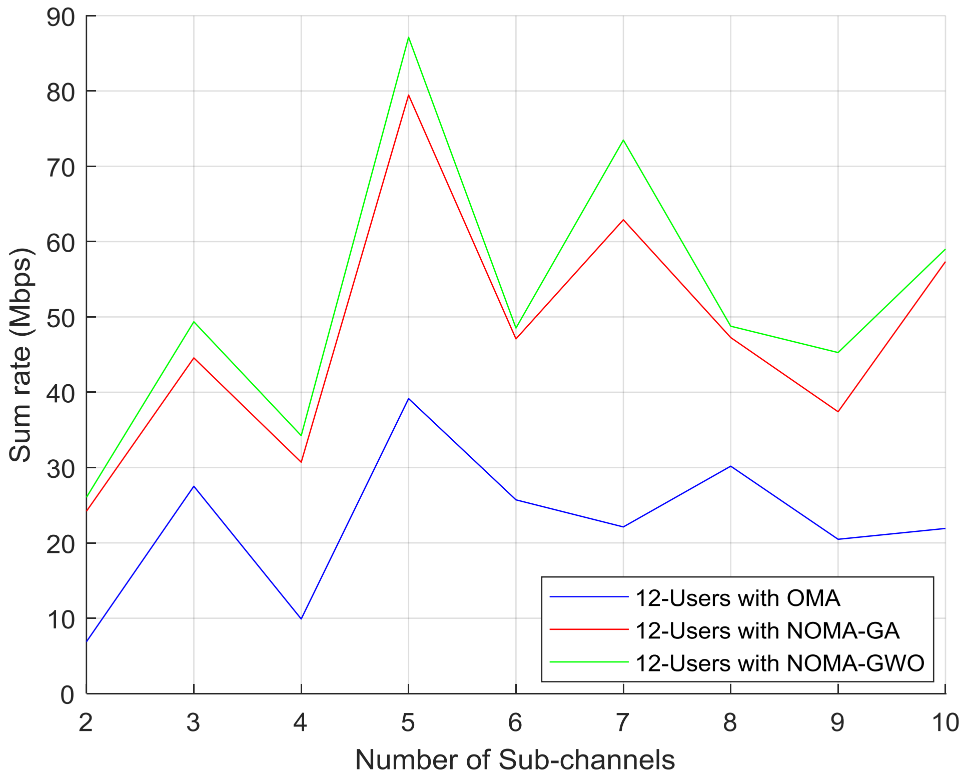

Figure 4-3 The sum rates in the case of 12 users with external interference.

For existing curves in Figure 4-3, The value of the sum rate of the user has begun to increase or leasing in each case as a result of the same reasons mentioned in figure 4-1.

The tables 4-10 and 4-11 show the sum-rate values for each sub channel and user, respectively, in the case of 12 users and 4 sub channels using the OMA, NOMA-GA and NOMA-GWO techniques.

Table 4-10 The sum rate values of each sub channel in the case of 12 users with external interference.

Sub channels	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	1.4976	2.7994	3.4697
2	6.9549	4.3216	10.5041
3	1.1864	10.621	8.7405
4	0.2616	12.9691	11.5113
Sum of the values	**9.9005**	**30.7111**	**34.2256**

Table 4-11 The sum rate values of each user in the case of 12 users with external interference.

Users	OMA-rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	0.0448	1.9204	0.3672
2	1.1896	0.6139	1.1265
3	0.3135	4.2066	3.8819
4	0.2408	2.4572	0.2104
5	1.1347	0.0712	2.6165
6	5.7163	4.9370	8.8419
7	0.4176	0.1290	0.4171
8	0.0171	0.0049	1.4393
9	0.3080	14.2873	11.399
10	0.0889	0.0157	1.7510
11	0.4252	1.9185	1.0163
12	0.004	0.1494	1.1585
Sum of the values	**9.9005**	**30.7111**	**34.2256**

The table 4-12 shows the power values for each sub channel in the case of 12 users and 4 sub channels using the NOMA-GA and NOMA-GWO.

Table 4-12 The power values of each sub channel in the case of 12 users with external interference.

Sub channels	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.2419	0.2
2	0.2569	0.275
3	0.3090	0.225
4	0.1916	0.3
Sum of the values	**0.9994**	**1**

The table 4-13 shows the power values for each user in the case of 12 users and 4 sub channels using NOMA-GA and NOMA-GWO.

Table 4-13 The power values of each user in the case of 12 users with external interference.

Users	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.0833	0.05
2	0.0125	0.15
3	0.25	0.125
4	0.125	0.025
5	0.0416	0.25
6	0.1006	0.075
7	0.05	0.045
8	0.0859	0.125
9	0.0527	0.05
10	0.0312	0.025
11	0.125	0.0552
12	0.0416	0.0248
Sum of the values	**0.9994**	**1**

4) The case of 16 users:

Figure 4-4 shows the difference in the user achievable sum rate in different cases when applying the OMA, NOMA-GA and NOMA-GWO methods indicated by blue, red and green curves respectively. The figure below shows that the highest user sum rate was obtained in OMA technique is when the NOS was 7, where the sum rate became 40.2803 Mbps. While in the case of NOMA-GA, the highest rate was obtained when the NOS was 7, where the total rate became 106.2261 Mbps. In the case of NOMA-GWO, the highest total rate was obtained when the NOS was 7, so the total rate became 110.5116 Mbps. As such, NOMA-GWO achieved the highest sum-rate against all the used methods.

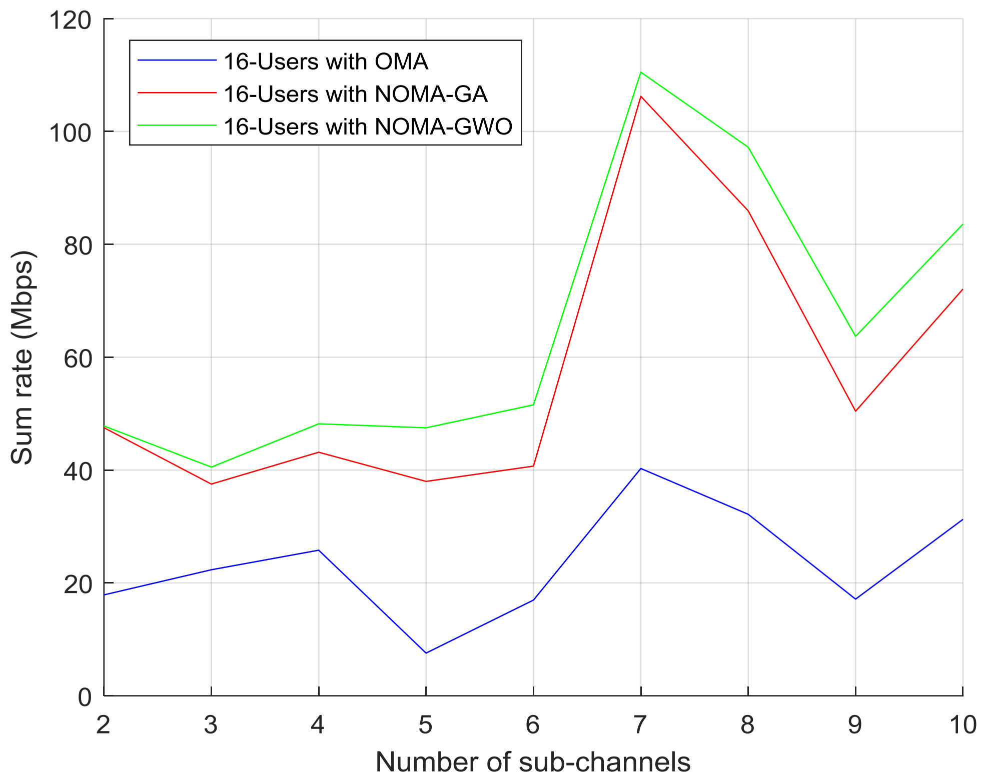

Figure 4-4 The sum rates in the case of 16 users with external interference.

For existing curves in Figure 4-4, The value of the sum rate of the user has begun to increase or leasing in each case as a result of the same reasons mentioned in figure 4-1.

The tables 4-14 and 4-15 show the sum rate values for each sub-channel and user, respectively, in the case of 16 users and 10 sub-channels using OMA, NOMA-GA and NOMA-GWO techniques.

Table 4-14 The sum rate values of each sub channel in the case of 16 users with external interference.

Sub channels	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	8.98	3.7092	0.0424
2	5.8204	11.5946	8.3275
3	2.5875	5.4594	15.3801
4	2.1281	11.7496	8.9777
5	3.6257	3.6766	7.2216
6	1.5851	10.0352	5.6218
7	0.8686	12.8139	13.498
8	0.9626	4.2656	11.4576
9	1.9027	4.9439	4.8669
10	2.8050	3.8170	8.1943
Sum of the values	**31.2657**	**72.065**	**83.5879**

Table 4-15 The sum rate values of each user in the case of 16 users with external interference.

User	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	1.4962	0.4085	2.1196
2	5.1146	0.1925	2.3068
3	0.3252	14.4496	4.4283
4	1.2843	1.0488	2.6010
5	1.5391	2.3720	1.3923
6	0.0066	0.2052	13.1080
7	2.9688	7.1691	3.1055
8	4.9626	0.2754	2.9883
9	1.9027	0.2766	2.2185
10	2.1050	16.1375	3.1616
11	7.4838	11.6293	30.0703
12	0.0057	0.0010	0.2244
13	0.2623	4.9602	0.9010
14	0.1437	4.7886	10.0196
15	0.0866	6.6249	0.2262
16	1.5785	1.5258	4.7165
Sum of the values	**31.2657**	**72.065**	**83.5879**

The tables 4-16 and 4-17 show the power values for each sub-channel and user respectively, in the case of 16 users and 10 sub channels using NOMA-GA and NOMA-GWO techniques.

Table 4-16 The power values of each sub channel in the case of 16 users with external interference.

Sub channels	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.25	0.0933
2	0.02	0.16
3	0.0166	0.1225
4	0.02	0.10080
5	0.0111	0.1231
6	0.0105	0.03
7	0.02	0.081
8	0.3059	0.11
9	0.3142	0.085
10	0.025	0.09
Sum of the values	**0.9933**	**0.9957**

Table 4-17 The power values of each user in the case of 16 users with external interference.

Users	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.0833	0.07
2	0.0309	0.05
3	0.02	0.0825
4	0.1	0.0574
5	0.1	0.0633
6	0.1	0.02
7	0.0416	0.07
8	0.05	0.05
9	0.0111	0.05
10	0.0533	0.0926
11	0.0509	0.1
12	0.0327	0.0291
13	0.1	0.0558
14	0.1	0.03
15	0.07	0.04
16	0.05	0.135
Sum of the values	**0.9933**	**0.9957**

4.2.B. Scenario Two: Results in the absence of external interference

In this subsection, the total sum rate will be calculated without the interference caused by the BSs of the six neighboring cells on the users in the CC. Furthermore, the OMA, NOMA-GA, and NOMA-GWO methods were used with different numbers of users, as shown below :

1. The case of 4 users:

Figure 4-5 shows the difference in the total user achieved sum rate in different cases when applying the OMA, NOMA-GA and NOMA-GWO methods shown with blue, red and green curves respectively. The figure below shows that the highest sum rate obtained in the case of OMA is when the NOS was 8, whereby the sum rate became 240.8915 Mbps. Whereas in the case of NOMA-GA, the highest rate was obtained when the NOS was 8, whereby the sum rate became 254.8119 Mbps. In the third case, when NOMA-GWO was applied, the highest total rate was obtained when the NOS was 8, where the total rate became 258.0092 Mbps. As such, NOMA-GWO achieved the highest sum rate against all the used methods.

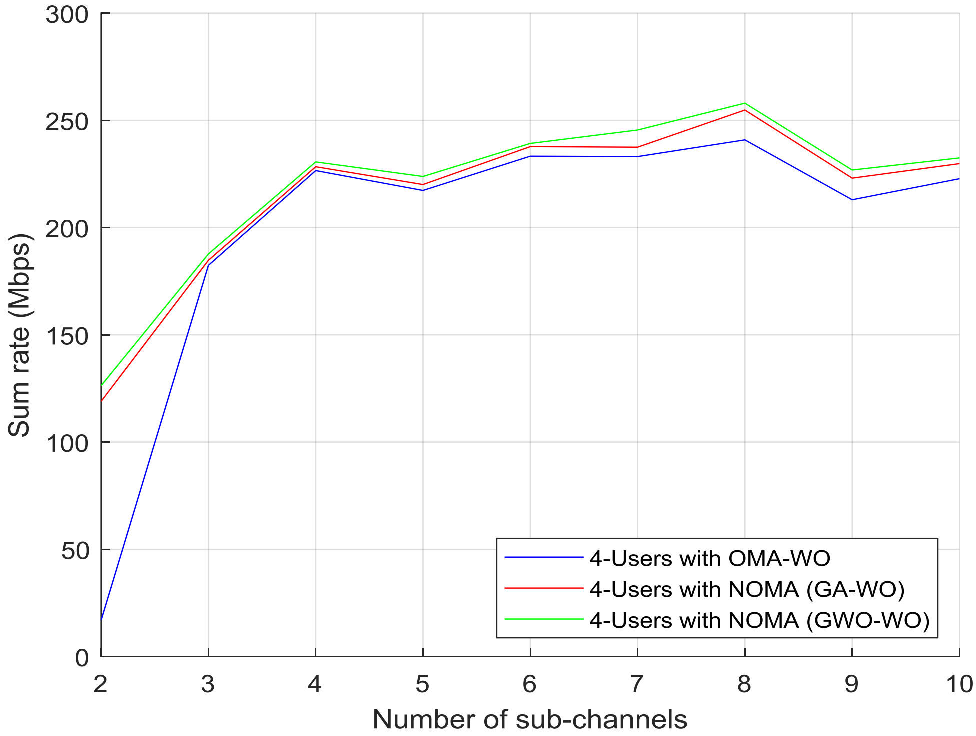

Figure 4-5 The sum rates in the case of 4 users without external interference.

Each curve in Figure 4-5 represents the user's sum-rate values in each of the above scenarios, and these values rise and fall in each case depending on the quality of the channel. Whereas, in the case of generating random fading channels that have high quality, the sum rate values increased. In the case of having a lower quality channel, this value decreases. Compared with values obtained in Figure 4-1, an apparent increase was visible in the value of the sum rate of the user due to the neglect of the interference value caused by BSs of neighboring cells.

The tables 4-18 and 4-19 show the sum rate values for each sub channel and user, respectively, in the case of 4 users and 10 sub-channels using OMA, NOMA-GA and NOMA-GWO techniques.

Table 4-18 The sum rate values of each sub channel in the case of 4 users without external interference.

Sub channels	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	3.8819	23.6819	19.8819
2	22.8478	24.7478	27.1777
3	21.9541	62.7529	30.2432
4	40.8510	0.3510	14.8510
5	62.8959	0.2170	21.8170
6	1.9338	24.1557	24.1557
7	1.3411	21.3856	31.2188
8	20.2268	23.8120	15.2120
9	45.5103	0.5103	47.5103
10	1.3411	48.0956	0.3411
Sum of the values	**222.7838**	**229.7098**	**232.4087**

Table 4-19 The sum rate values of each user in the case of 4 users without external interference.

Users	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	91.1781	121.1556	107.3997
2	96.1228	23.1478	61.3411
3	13.1142	22.4167	23.5169
4	22.3687	62.9897	40.1510
Sum of the values	**222.7838**	**229.7098**	**232.4087**

The table 4-20 shows the power values for each user in the case of 4 users and 10 sub channels using NOMA-GA and NOMA-GWO.

Table 4-20 The power values of each user in the case of 4 users without external interference.

Users	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.5	0.7
2	0.1	0.1
3	0.1	0.1
4	0.2991	0.0994
Sum of the values	**0.9991**	**0.9994**

2) The case of 8 users:

Figure 4-6 shows the difference in the user achievable sum rate in different cases when applying the OMA, NOMA-GA and NOMA-GWO methods indicated by blue, red and green curves, respectively. The figure below shows that the highest user sum rate was obtained in OMA technology is when the NOS 9, where the total rate was 201.0483 Mbps. While in NOMA-GA, the highest rate was obtained when the NOS was 9, where the total rate was 217.5398 Mbps. In the case of applying NOMA-GWO, the highest total rate was obtained when the NOS was 10, where the total rate was 234.5602 Mbps. NOMA-GWO achieved the highest sum rate against all the used methods.

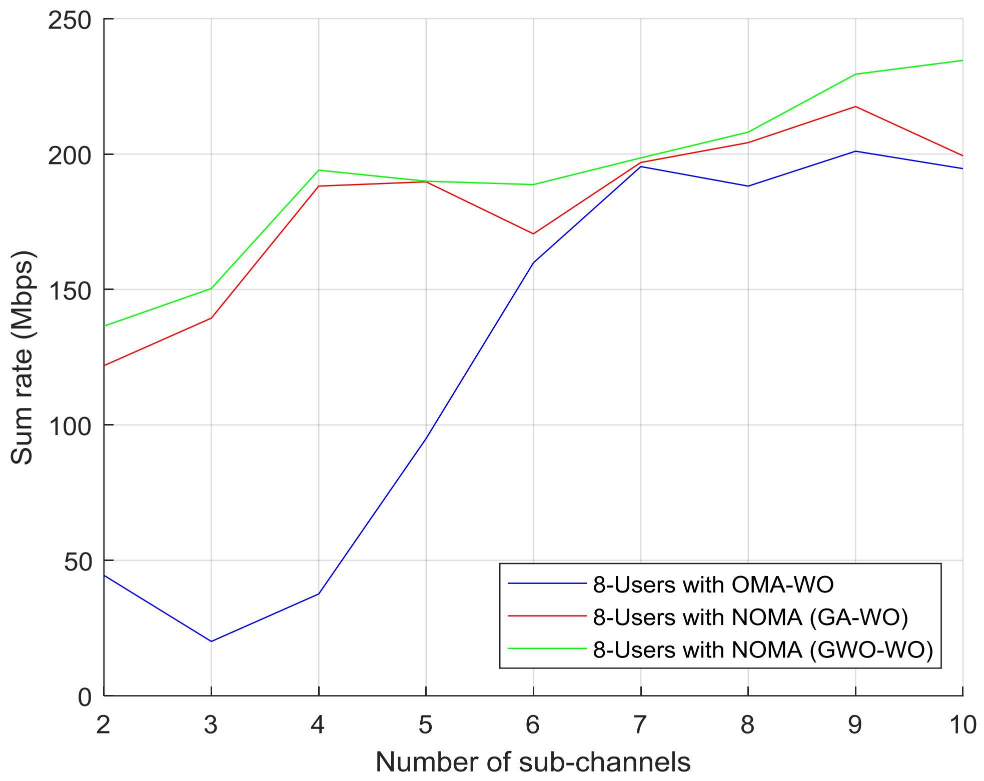

Figure 4-6 The sum rates in the case of 8 users without external interference.

For existing curves in Figure 4-6, The value of the sum rate of the user has begun to increase or leasing in each case as a result of the same reasons mentioned in figure 4-5.

The tables 4-21 and 4-22 show the sum rate values for each sub channel and user, respectively, in the case of 8 users and 4 sub channels using OMA, NOMA-GA and NOMA-GWO techniques.

Table 4-21 The sum rate values of each sub channel in the case of 8 users without external interference.

Sub channels	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	3.2523	82.2474	57.1768
2	6.1454	16.5102	64.1789
3	7.0342	35.8695	9.4513
4	21.058	52.7730	63.1324
Sum of the values	**37.4899**	**187.4001**	**193.9394**

Table 4-22 The sum rate values of each user in the case of 8 users without external interference.

Users	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	1.1563	10.2016	11.8786
2	6.1672	52.7730	47.7768
3	1.3209	1.4917	0.0049
4	16.491	65.7116	98.6437
5	1.1960	44.8695	0.0011
6	1.4786	7.0035	10.0456
7	8.1132	2.0952	5.8680
8	1.5667	3.2540	19.7207
Sum of the values	**37.4899**	**187.4001**	**193.9394**

The table 4-23 shows the power values for each user in the case of 8 users and 4 sub channels using NOMA-GA and NOMA-GWO.

Table 4-23 The power values of each user in the case of 8 users without external interference.

Users	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.25	0.25
2	0.0625	0.025
3	0.121	0.0833
4	0.05	0.075
5	0.0133	0.0416
6	0.07	0.025
7	0.125	0.25
8	0.25	0.25
Sum of the values	**0.9418**	**0.9999**

3) The case of 12 users:

Figure 4-7 shows the difference in the user achievable sum rate in different cases when applying the OMA, NOMA-GA and NOMAGWO methods indicated by blue, red and green curves, respectively. The figure below shows that the highest sum rate was obtained in the case of OMA when the NOS was 10, where the sum rate was 191.7636 Mbps. Whereas in the case of NOMA-GA, the highest rate was obtained is when the NOS was 10, with the total rate being 198.5792 Mbps. In the case of NOMA-GWO, the highest total rate was obtained when the NOS was 7, where the total rate was 214.1118 Mbps. As such, NOMA-GWO achieved the highest sum rate against all the used methods.

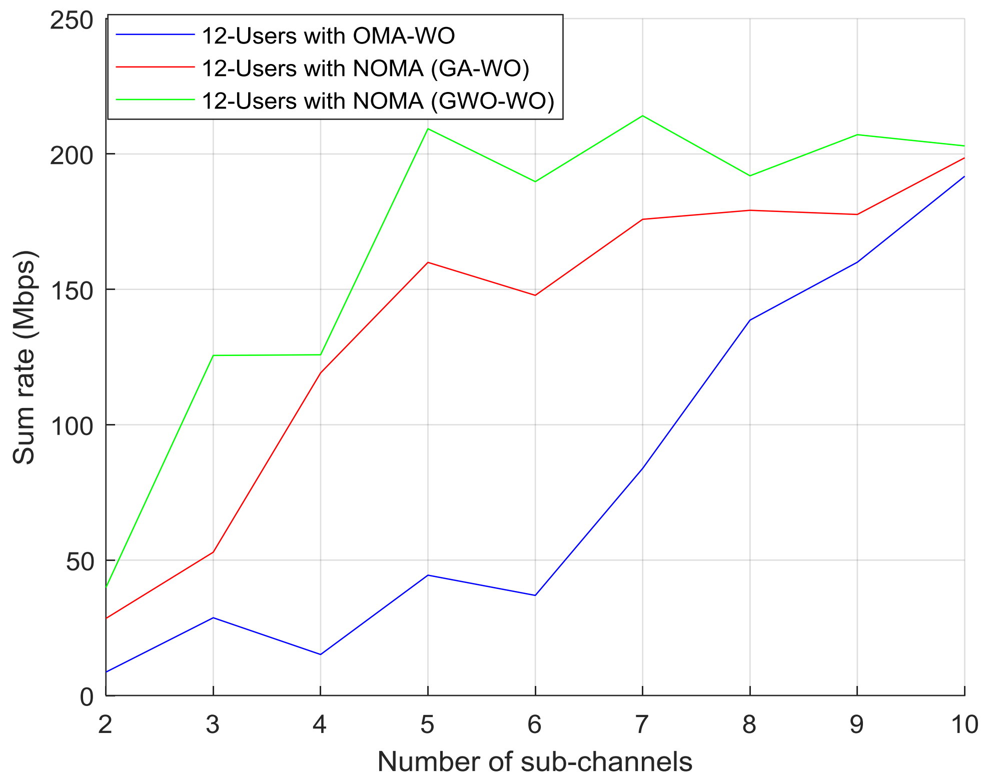

Figure 4-7 The sum rates in the case of 12 users without external interference.

For existing curves in Figure 4-7, The value of the sum rate of the user has begun to increase or leasing in each case as a result of the same reasons mentioned in figure 4-5.

The tables 4-24 and 4-25 show the sum rate values for each sub channel and user, respectively, in the case of 12 users and 4 sub channels using OMA, NOMA-GA and NOMA-GWO techniques.

Table 4-24 The sum rate values of each sub channel in the case of 12 users without external interference.

Sub channels	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	5.1154	50.1160	39.1399
2	8.1917	1.1160	16.3252
3	1.2218	6.2596	55.3540
4	0.5761	61.1562	14.6068
Sum of the values	**15.105**	**118.6478**	**125.4259**

Table 4-25 The sum rate values of each user in the case of 12 users without external interference.

Users	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	0.0448	0.0296	1.3410
2	1.0050	47.5121	2.1077
3	0.3280	0.1874	0.1582
4	0.2546	0.0610	10.0184
5	4.1520	0.2627	0.0115
6	6.0503	5.0245	56.193
7	0.1805	0.1318	0.0358
8	0.0172	0.0060	0.0279
9	0.3185	63.3504	41.1472
10	0.1363	1.3184	1.1662
11	1.4135	0.5150	2.0899
12	1.2043	0.2489	11.1291
Sum of the values	**15.105**	**118.6478**	**125.4259**

The tables 4-26 and 4-27 show the power values for each sub channel and user respectively, in the case of 12 users and 4 sub channels using NOMA-GA and NOMA-GWO.

Table 4-26 The power values of each sub channel in the case of 12 users without external interference.

Sub channels	**NOMA-GA power (watt)**	**NOMA-GWO power (watt)**
1	0.035	0.025
2	0.3405	0.4812
3	0.5093	0.025
4	0.085	0.4687
Sum of the values	**0.9698**	**0.9999**

Table 4-27 The power values of each user in the case of 12 users without external interference.

Users	**NOMA-GA power (watt)**	**NOMA-GWO power (watt)**
1	0.0312	0.0312
2	0.0607	0.1875
3	0.1166	0.025
4	0.0625	0.025
5	0.1468	0.0312
6	0.3	0.075
7	0.0833	0.025
8	0.0416	0.025
9	0.05	0.05
10	0.0317	0.025
11	0.0277	0.25
12	0.0177	0.25
Sum of the values	**0.9698**	**0.9999**

4) The case of 16 users:

Figure 4-8 shows the user achievable sum rate difference in different cases when applying the OMA, NOMA-GA and NOMA-GWO methods shown with blue, red and green curves, respectively. The figure below shows that the highest sum rate was obtained in the case of OMA when the NOS was 10, with a total rate of 118.4300 Mbps. Whereas in the case of NOMA-GA, the highest rate was obtained is when the NOS was 7, with the total rate being 186.6260 Mbps. In the case of the NOMA-GWO application, the highest sum rate was obtained when the NOS was 8, with a total rate of 215.4091 Mbps. NOMA-GWO had the highest sum rate against all the used methods.

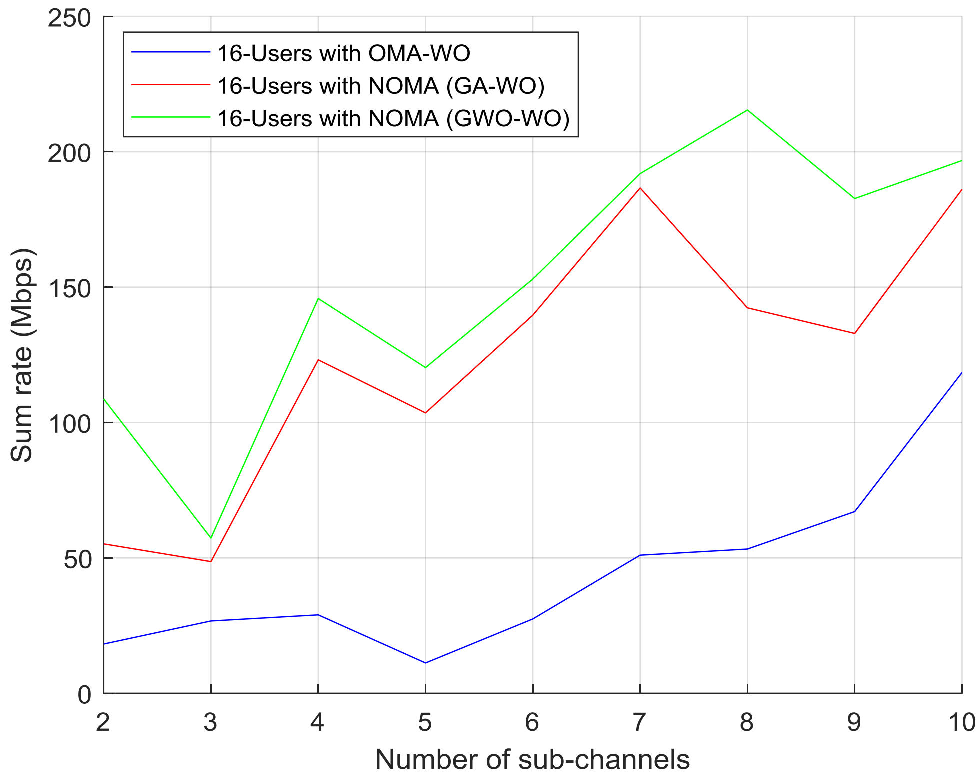

Figure 4-8 The sum rates in the case of 16 users without external interference.

For existing curves in Figure 4-8, The value of the sum rate of the user has begun to increase or leasing in each case as a result of the same reasons mentioned in figure 4-5.

The tables 4-28 and 4-29 show the sum rate values for each sub channel and user, respectively, in the case of 16 users and 10 sub channels using OMA, NOMA-GA and NOMA-GWO techniques.

Table 4-28 The sum rate values of each sub channel in the case of 16 users without external interference.

Sub channels	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	14.4452	16.3833	27.4659
2	0.8676	0.1187	28.4330
3	4.9355	29.647	27.9673
4	37.2972	21.656	8.9874
5	0.1266	18.4654	9.9191
6	0.2812	22.320	28.6667
7	0.7305	19.362	10.6399
8	23.6089	35.5232	24.0955
9	22.3196	0.921	7.2256
10	13.8170	21.678	23.2724
Sum of the values	**118.4293**	**186.0746**	**196.6728**

Table 4-29 The sum rate values of each user in the case of 16 users without external interference.

Users	OMA rate (Mbps)	NOMA-GA rate (Mbps)	NOMA-GWO rate (Mbps)
1	2.1669	15.345	0.04430
2	4.8333	4.1991	24.0955
3	2.5730	2.1206	2.35313
4	2.0979	22.320	4.55855
5	1.9065	21.656	0.78783
6	0.0167	0.2093	20.52181
7	23.730	3.0805	1.31165
8	23.608	21.921	1.51754
9	22.319	21.659	23.0724
10	23.817	2.0047	1.64180
11	7.2783	9.1007	83.281
12	0.0343	6.9963	0.81536
13	0.3624	21.678	29.11118
14	0.1992	10.1150	0.46937
15	1.2223	19.669	1.14198
16	2.2645	4.0004	1.94940
Sum of the values	**118.4293**	**186.0746**	**196.6728**

The tables 4-30 and 4-31 show the power values for each sub channel and user respectively, in the case of 16 users and 10 sub channels using NOMA-GA and NOMA-GWO.

Table 4-30 The power values of each sub channel in the case of 16 users without external interference.

Sub channels	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.235	0.04
2	0.26	0.01
3	0.01	0.01
4	0.01	0.218
5	0.1267	0.22
6	0.01	0.01
7	0.01	0.23
8	0.3113	0.01
9	0.01	0.24
10	0.01	0.01
Sum of the values	**0.993**	**0.998**

Table 4-31 The power values of each user in the case of 16 users without external interference.

Users	NOMA-GA power (watt)	NOMA-GWO power (watt)
1	0.0125	0.01
2	0.01	0.01
3	0.15	0.05
4	0.01	0.15
5	0.01	0.05
6	0.025	0.1
7	0.15	0.1
8	0.01	0.1
9	0.04	0.01
10	0.15	0.05
11	0.03	0.04
12	0.1	0.1
13	0.1105	0.048
14	0.05	0.05
15	0.035	0.03
16	0.1	0.1
Sum of the values	**0.993**	**0.998**

The results shown in the figures above represent the user's sum-rate values in various methods. NOMA using GA and GWO algorithms outperformed the first method (i.e., OMA) due to good bandwidth management and allocating different power levels. At the same time, the reason for the superiority of the GWO algorithm over the GA is that the first has better managed wireless resources in terms of allocating the appropriate power level to each user to achieve the best sum rate.

The values of the sum rate in the presence of interference (figures 4-1 to 4-4) increases or decreases in each case depending on the quality of the user's channel, taking into account the interference caused by the base stations of neighboring cells. In comparison, in the absence of interference (figures 4-5 to 4-8), the increase in the sum rate was seen as a result of neglecting the interference of the base stations of neighboring cells with the presence of variations in these values depending on the quality of the channel as mentioned previously.

Chapter Five

Chapter Five: The Conclusions and future works

5.1 Conclusions

NOMA is one of the most important 5G wireless communication technologies to overcome the major problems faced by OMA techniques. One of the main problems of OMA is its inability to provide massive connectivity due to poor management of wireless resources. In this thesis, the NOMA technique was studied, and its use led to a good increase in system throughput compared to OMA. This is because NOMA uses the same sub channel for multiple users with allocating different powers for the users, so NOMA's performance relied mainly on efficiency in distributing these resources among users. On this basis, this thesis has adopted various Algorithms for resource allocation (power) to get the highest sum rate for users..

A wireless system model has been proposed consisting of a central cell CC and six adjacent cells surrounding it in a circular shape. It was considered that each neighboring cell contains one BS while calculating the effect of interference caused by these stations on the total sum rate of the users in the CC. The total sum rate was considered a performance measure for each scenario used in this system.

OMA technique has been applied to the system model proposed in the first scenario. The results were not encouraging due to the inability to allocate the sub-channel at the same time to more than one user and the inefficiency in power distribution among users. In the second scenario, the NOMA technique was implemented using GA. A clear improvement was observed in the results compared to the first scenario. The reason is the ability to use the sub-channel for more than one user with a good allocation of resources. The NOMA technique was applied using the GWO algorithm to the proposed system in the third scenario. The results were much better than the previous two approaches in terms of overall system throughput and fairness in the distribution of resources among users. This scenario is superior to the OMA-based scenario due to its ability to allocate the same sub-channel for more than one user at the same time, allocating the appropriate power to each user and equitable distribution of these resources. The reason why the GA-based scenario is not superior is that the GWO algorithm allocates power to each user better compared to GA. The results also clearly showed the effect of interference caused by base stations to neighboring cells in all scenarios.

Finally, from all of the above, it was found that the best scenario used in this thesis was the scenario based on the use of the NOMA technique with the GWO Algorithm (NOMA-GWO). The reason for this scenario to outperform and achieve a higher sum rate is due to the optimal power allocation of power with due consideration of fairness in this distribution.

5.2 Future works

Regarding future works and ideas that can be applied to the wireless system that is proposed in this thesis, the following works have been included:

1. Enhancement of the wireless system performance by using multiple input multiple output technique (MIMO) to create small sub-cells within the single cell and apply NOMA on each sub-cell.

2. Enhance the spectral efficiency of the proposed system by using the Multiple input multiple output- Generalized frequency division multiplexing (MIMO-GFDM) technique.

3. Optimizing bandwidth management for proposed wireless system by using Artificial Intelligence AI techniques.

References

[1] Zeng, J., Li, B., Su, X., Rong, L., & Xing, R. (2015, October). Pattern division multiple access (PDMA) for cellular future radio access. In *2015 international conference on wireless communications & signal processing (WCSP)* (pp. 1-5). IEEE.

[2] Sacchi, C., Rahman, T. F., Bartolomei, N., Morosi, S., Mazzinghi, A., & Ciabini, F. (2016, December). Design and assessment of a CE-OFDM-based mm-wave 5G communication system. In *2016 IEEE Globecom Workshops (GC Wkshps)* (pp. 1-7). IEEE.

[3] Prajapati, S., Sindal, R., & Saxena, A. (2020). *NOMA: Emerging Radio Access Technique for Next Generation Wireless Networks* (No. 3617). EasyChair.

[4] Nonaka, N., Kishiyama, Y., & Higuchi, K. (2015). Non-orthogonal multiple access using intra-beam superposition coding and SIC in base station cooperative MIMO cellular downlink. *IEICE Transactions on Communications*, *98*(8), 1651-1659.

[5] Cecchini, G., Bazzi, A., Masini, B. M., & Zanella, A. (2017, June). LTEV2Vsim: An LTE-V2V simulator for the investigation of resource allocation for cooperative awareness. In *2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)* (pp. 80-85). IEEE.

[6] Saito, Y., Kishiyama, Y., Benjebbour, A., Nakamura, T., Li, A., & Higuchi, K. (2013, June). Non-orthogonal multiple access (NOMA) for cellular future radio access. In *2013 IEEE 77th vehicular technology conference (VTC Spring)* (pp. 1-5). IEEE.

[7] Islam, S. R., Avazov, N., Dobre, O. A., & Kwak, K. S. (2016). Power-domain non-orthogonal multiple access (NOMA) in 5G systems: Potentials and challenges. *IEEE Communications Surveys & Tutorials*, *19*(2), 721-742.

[8] Masaracchia, A., Nguyen, L. D., Duong, T. Q., Costa, D. B. D., & Le-Tien, T. (2019, August). User-pairing scheme in noma systems: A pso-based approach. In *International Conference on Industrial Networks and Intelligent Systems* (pp. 18-25). Springer, Cham.

[9] Di, B., Bayat, S., Song, L., & Li, Y. (2015, December). Radio resource allocation for downlink non-orthogonal multiple access (NOMA) networks using matching theory. In *2015 IEEE global communications conference (GLOBECOM)* (pp. 1-6). IEEE.

[10] Zhu, J., Wang, J., Huang, Y., He, S., & You, X. (2017, December). Multichannel resource allocation for downlink non-orthogonal multiple access systems. In *GLOBECOM 2017-2017 IEEE Global Communications Conference* (pp. 1-6). IEEE.

[11] Islam, S. R., Zeng, M., Dobre, O. A., & Kwak, K. S. (2018). Resource allocation for downlink NOMA systems: Key techniques and open issues. *IEEE Wireless Communications*, *25*(2), 40-47.

[12] Wang, C. L., Chen, T. Y., Chen, Y. F., & Wu, D. S. (2018, September). Low-complexity resource allocation for downlink multicarrier NOMA systems. In *2018 IEEE 29th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)* (pp. 1-6). IEEE.

[13] Long, K., Wang, P., Li, W., & Chen, D. (2019). Spectrum resource and power allocation with adaptive proportional fair user pairing for NOMA systems. *IEEE Access*, *7*, 80043-80057.

[14] Cejudo, E. C., Zhu, H., Wang, J., & Alluhaibi, O. (2019, April). A fast algorithm for resource allocation in downlink multicarrier NOMA. In *2019 IEEE Wireless Communications and Networking Conference (WCNC)* (pp. 1-5). IEEE.

[15] Lamba, A. K., Kumar, R., & Sharma, S. (2020). Power allocation for downlink multiuser hybrid NOMA- OMA systems: An auction game approach. *International Journal of Communication Systems*, *33*(7), e4306.

[16] Hojeij, M. R., Farah, J., Nour, C. A., & Douillard, C. (2016). New optimal and suboptimal resource allocation techniques for downlink non-orthogonal multiple access. *Wireless Personal Communications*, *87*(3), 837-867.

[17] Baidas, M. W., AbdelGhaffar, A. M., & Alsusa, E. (2021, October). Joint power allocation and antenna selection for network sum-rate maximization in clustered downlink NOMA networks. In *2021 International Symposium on Networks, Computers and Communications (ISNCC)* (pp. 1-7). IEEE.

[18] Kim, D. Y., Jafarkhani, H., & Lee, J. W. (2021, April). Low-complexity joint user and power scheduling for downlink NOMA over fading channels. In *2021 IEEE 93rd Vehicular Technology Conference (VTC2021-Spring)* (pp. 1-5). IEEE.

[19] Arachchillage, U. S. S. S., Jayakody, D. N. K., Biswash, S. K., & Dinis, R. (2018, June). Recent advances and future research challenges in non-orthogonal multiple access for 5G networks. In *2018 IEEE 87th Vehicular Technology Conference (VTC Spring)* (pp. 1-6). IEEE.

[20] Tsiropoulos, G. I., Yadav, A., Zeng, M., & Dobre, O. A. (2017). Cooperation in 5G HetNets: Advanced spectrum access and D2D assisted communications. *IEEE Wireless Communications*, *24*(5), 110-117.

[21] Faruque, S. (2019). Frequency division multiple access (FDMA). In *Radio Frequency Multiple Access Techniques Made Easy* (pp. 21-33). Springer, Cham.

[22] Ahmadi, S. (2013). *LTE-Advanced: a practical systems approach to understanding 3GPP LTE releases 10 and 11 radio access technologies*. Academic Press.

[23] Yang, Y., Zhang, S., & Zhang, R. (2020). IRS-enhanced OFDMA: Joint resource allocation and passive beamforming optimization. *IEEE Wireless Communications Letters*, *9*(6), 760-764.

[24] Singh, R. (2013). Multiple access techniques for 4G mobile wireless networks. *International Journal of Engineering Research and*

Development, *5*(11), 86-94.

[25] Boccuzzi, J. (2019). Introduction to cellular mobile communications. In *Multiple Access Techniques for 5G Wireless Networks and Beyond* (pp. 3-37). Springer, Cham.

[26] Sharma, S., Sharma, E. B., & Kanwar, V. (2016). Review Paper on Performance of OFDM in 4g Wireless Communication. *International Journal*, *6*(9), 1-20.

[27] Wei, Z., Yuan, J., Ng, D. W. K., Elkashlan, M., & Ding, Z. (2016). A survey of downlink non-orthogonal multiple access for 5G wireless communication networks. *arXiv preprint arXiv:1609.01856*.

[28] Aldababsa, M., Toka, M., Gökçeli, S., Kurt, G. K., & Kucur, O. (2018). A tutorial on nonorthogonal multiple access for 5G and beyond. *wireless communications and mobile computing, 2018*.

[29] Dai, L., Wang, B., Yuan, Y., Han, S., Chih-Lin, I., & Wang, Z. (2015). Non-orthogonal multiple access for 5G: solutions, challenges, opportunities, and future research trends. *IEEE Communications Magazine*, *53*(9), 74-81.

[30] Li, A., Lan, Y., Chen, X., & Jiang, H. (2015). Non-orthogonal multiple access (NOMA) for future downlink radio access of 5G. *China Communications*, *12*(Supplement), 28-37.

[31] Iswarya, N., & Jayashree, L. S. (2021). A survey on successive interference cancellation schemes in non-orthogonal multiple access for future radio access. *Wireless Personal Communications*, *120*(2), 1057-1078.

[32] Andrews, J. G., Buzzi, S., Choi, W., Hanly, S. V., Lozano, A., Soong, A. C., & Zhang, J. C. (2014). What will 5G be?. *IEEE Journal on selected areas in communications*, *32*(6), 1065-1082.

[33] Bao, W., Chen, H., Li, Y., & Vucetic, B. (2017). Joint rate control and power allocation for non-orthogonal multiple access systems. *IEEE Journal on Selected Areas in Communications*, *35*(12), 2798-2811.

[34] Ding, Z., Schober, R., Fan, P., & Poor, H. V. (2019). OTFS-NOMA: An efficient approach for exploiting heterogenous user mobility profiles. *IEEE Transactions on Communications*, *67*(11), 7950-7965.

[35] Ding, Z., Lei, X., Karagiannidis, G. K., Schober, R., Yuan, J., & Bhargava, V. K. (2017). A survey on non-orthogonal multiple access for 5G networks: Research challenges and future trends. *IEEE Journal on Selected Areas in Communications*, *35*(10), 2181-2195.

[36] Lee, S. (2018). Cooperative non-orthogonal multiple access for future wireless communications. *EAI Endorsed Transactions on Industrial Networks and Intelligent Systems*, *5*(17).

[37] Kayama, H., & Jiang, H. (2014, November). Evolution of LTE and new radio access technologies for FRA (future radio access). In *2014 48th Asilomar Conference on Signals, Systems and Computers* (pp. 1944-1948). IEEE.

[38] Ding, Z., Fan, P., & Poor, H. V. (2015). Impact of user pairing on 5G

nonorthogonal multiple-access downlink transmissions. *IEEE Transactions on Vehicular Technology*, *65*(8), 6010-6023.

[39] Dai, L., Wang, B., Ding, Z., Wang, Z., Chen, S., & Hanzo, L. (2018). A survey of non-orthogonal multiple access for 5G. *IEEE communications surveys & tutorials*, *20*(3), 2294-2323.

[40] Ding, Z., Liu, Y., Choi, J., Sun, Q., Elkashlan, M., Chih-Lin, I., & Poor, H. V. (2017). Application of non-orthogonal multiple access in LTE and 5G networks. *IEEE Communications Magazine*, *55*(2), 185-191.

[41] Mohammadi, M., Shi, X., Chalise, B. K., Ding, Z., Suraweera, H. A., Zhong, C., & Thompson, J. S. (2019). Full-duplex non-orthogonal multiple access for next generation wireless systems. *IEEE Communications Magazine*, *57*(5), 110-116.

[42] Khan, W. U., Jameel, F., Ristaniemi, T., Elhalawany, B. M., & Liu, J. (2019, April). Efficient power allocation for multi-cell uplink NOMA network. In *2019 IEEE 89th Vehicular Technology Conference (VTC2019-Spring)* (pp. 1-5). IEEE.

[43] Liu, Y., Ding, Z., Elkashlan, M., & Yuan, J. (2016). Nonorthogonal multiple access in large-scale underlay cognitive radio networks. *IEEE Transactions on Vehicular Technology*, *65*(12), 10152-10157.

[44] Liu, Y., Qin, Z., Elkashlan, M., Ding, Z., Nallanathan, A., & Hanzo, L. (2017). Nonorthogonal multiple access for 5G and beyond. *Proceedings of the IEEE*.

[45] Sharma, P., Kumar, A., & Bansal, M. (2020). Performance analysis of PN-NOMA over generalized fading channel. *IEEE Access*, *8*, 105962-105971.

[46] Islam, S. M., Zeng, M., Dobre, O. A., & Kwak, K. S. (2019). Non-orthogonal multiple access (NOMA): How it meets 5G and beyond. *arXiv preprint arXiv:1907.10001*.

[47] Chih-Lin, I., Han, S., Xu, Z., Sun, Q., & Pan, Z. (2016). 5G: rethink mobile communications for 2020+. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *374*(2062), 20140432.

[48] Wang, B., Dai, L., Mir, T., & Wang, Z. (2016). Joint user activity and data detection based on structured compressive sensing for NOMA. *IEEE Communications Letters*, *20*(7), 1473-1476.

[49] Saito, K., Benjebbour, A., Kishiyama, Y., Okumura, Y., & Nakamura, T. (2015, June). Performance and design of SIC receiver for downlink NOMA with open-loop SU-MIMO. In *2015 IEEE International Conference on Communication Workshop (ICCW)* (pp. 1161-1165). IEEE.

[50] Yang, Z., Xu, W., Pan, C., Pan, Y., & Chen, M. (2017). On the optimality of power allocation for NOMA downlinks with individual QoS constraints. *IEEE Communications Letters*, *21*(7), 1649-1652.

[51] Kara, F., & Kaya, H. (2018). BER performances of downlink and uplink NOMA in the presence of SIC errors over fading channels. *IET Communications*, *12*(15), 1834-1844.

[52] Ali, M. S., Tabassum, H., & Hossain, E. (2016). Dynamic user clustering and power allocation for uplink and downlink non-orthogonal multiple access (NOMA) systems. *IEEE access*, *4*, 6325-6343.

[53] Ding, Z., Yang, Z., Fan, P., & Poor, H. V. (2014). On the performance of non-orthogonal multiple access in 5G systems with randomly deployed users. *IEEE signal processing letters*, *21*(12), 1501-1505.

[54] Higuchi, K., & Benjebbour, A. (2015). Non-orthogonal multiple access (NOMA) with successive interference cancellation for future radio access. *IEICE Transactions on Communications*, *98*(3), 403-414.

[55] Mirjalili, S., Song Dong, J., Sadiq, A. S., & Faris, H. (2020). Genetic algorithm: Theory, literature review, and application in image reconstruction. *Nature-inspired optimizers*, 69-85.

[56] Chen, W., Tsangaratos, P., Ilia, I., Duan, Z., & Chen, X. (2019). Groundwater spring potential mapping using population-based evolutionary algorithms and data mining methods. *Science of The Total Environment*, *684*, 31-49.

[57] Salih, S. Q., Sharafati, A., Ebtehaj, I., Sanikhani, H., Siddique, R., Deo, R. C., ... & Yaseen, Z. M. (2020). Integrative stochastic model standardization with genetic algorithm for rainfall pattern forecasting in tropical and semi-arid environments. *Hydrological Sciences Journal*, *65*(7), 1145-1157.

[58] Gebreel, A. Y. (2018). An overview of genetic algorithm, bacterial foraging algorithm, and harmony search algorithm. *GSJ*, *6*(9).

[59] Immanuel, S. D., & Chakraborty, U. K. (2019, July). Genetic algorithm: an approach on optimization. In *2019 International Conference on Communication and Electronics Systems (ICCES)* (pp. 701-708). IEEE.

[60] Bhattacharjee, P. S., Fujail, A. K. M., & Begum, S. A. (2017). Intrusion detection system for NSL-KDD data set using vectorised fitness function in genetic algorithm. *Adv. Comput. Sci. Technol*, *10*(2), 235-246.

[61] Lamini, C., Benhlima, S., & Elbekri, A. (2018). Genetic algorithm based approach for autonomous mobile robot path planning. *Procedia Computer Science*, *127*, 180-189.

[62] Mirjalili, S., Mirjalili, S. M., & Lewis, A. (2014). Grey wolf optimizer. *Advances in engineering software*, *69*, 46-61.

[63] Mohammad Aghdam, S., Soleimanian Gharehchopogh, F., & Masdari, M. (2021). Opinion Leader's Selection with Grey Wolf Optimizer Algorithm on Social Networks. *International Journal of Industrial Mathematics*, *13*(2), 163-174.

[64] Sankhwar, S., Gupta, D., Ramya, K. C., Sheeba Rani, S., Shankar, K., & Lakshmanaprabu, S. K. (2020). Improved grey wolf optimization-based feature subset selection with fuzzy neural classifier for financial crisis prediction. *Soft Computing*, *24*(1), 101-110.

[65] Riaz, M., Hanif, A., Hussain, S. J., Memon, M. I., Ali, M. U., & Zafar, A. (2021). An optimization-based strategy for solving optimal power flow problems in a power system integrated with stochastic solar and wind power

energy. *Applied Sciences*, *11*(15), 6883.

[66] Rezaei, H., Bozorg-Haddad, O., & Chu, X. (2018). Grey wolf optimization (GWO) algorithm. In *Advanced Optimization by Nature-Inspired Algorithms* (pp. 81-91). Springer, Singapore.

List of publications

1. Performance Analysis Based on Relaying Techniques for Cooperative Non-Orthogonal Multiple Access (C-NOMA).

"Accepted in AIP Conference Proceedings (2021). "

2. An analysis based on technologies for (cooperative non-orthogonal multiple access), also known as relay-technologies, is used for improving performance (C-NOMA).

"Accepted in AIP Conference Proceedings (2021). "

3. Resource Allocation Optimization of NOMA Network via Metaheuristic Algorithms**.**

“Accepted in 5th International Iraqi Conference on Engineering Technology and its Applications (5th IICETA 2022)”.

الخلاصة

واحدة من أكثر تقنيات الوصول اللاسلكي المرشحة للاستخدام في الجيل التالي من الاتصالات اللاسلكية هي الوصول المتعدد غير المتعامد (NOMA). عند إجراء مقارنة بين إحدى تقنيات الوصول المتعدد المتعامد (OMA) ، على سبيل المثال ، تقنية الوصول المتعدد بتقسيم التردد المتعامد (OFDMA) ، نلاحظ أن NOMA تقدم مجموعة من الخصائص الجيدة مثل الاتصال الهائل والموثوقية العالية مع تقليل زمن الوصول وإدارة موارد الطيف بكفاءة. مبدأ العمل الرئيسي لـ NOMA هو خدمة أكثر من مستخدم باستخدام نفس الموارد اللاسلكية من حيث الوقت والتردد. يعد تخصيص الموارد (RA) لنظام NOMA (تخصيص الطاقة ، وتخصيص القنوات الفرعية) ، والإنصاف بين المستخدمين ، وإدارة التداخل وتحسين إنتاجية النظام من التحديات المهمة لأنه يعمل في ظل مجموعة كبيرة من القيود التي تمنع الضرر عن المستخدم الذي يعاني من حالة قناة سيئة.

من بين التحديات والمشاكل التي تواجه (NOMA) زيادة معدل المجموع والحفاظ على مستوى مناسب من العدالة في تخصيص الطاقة والقنوات الفرعية بين المستخدمين. نتيجة لذلك ، في هذه الرسالة تم اقتراح نموذج نظام لاسلكي لتعظيم معدل مجموع المستخدمين من خلال تخصيص الطاقة المناسبة والقنوات الفرعية. يتكون هذا النموذج من خلية مركزية ومجموعة من ست خلايا مجاورة في نظام خلوي مع تداخل متعدد المستويات وخوارزميتين لتحسين معدل المجموع الكلي.

استخدمت هذه الأطروحة ثلاثة سيناريوهات ؛ في السيناريو الأول ، تم تطبيق تقنية OMA. السيناريو الثاني يطبق تقنية NOMA باستخدام الخوارزمية الجينية GA .في المقابل ، يتضمن السيناريو الثالث تطبيق تقنية NOMAباستخدام خوارزمية تحسين الذئب الرمادي Grey Wolf Optimization GWO على النظام المقترح. تم استخدام معدلات مجموع المستخدمين كمقياس لتقييم أداء الخوارزميات في سيناريوهات المحاكاة. بالإضافة إلى ذلك ، تمت مقارنة أداء الخوارزميات في وجود وغياب التداخل من الخلايا المجاورة. من خلال مقارنة OMA و NOMA-GA ، كانت الطريقة المقترحة أفضل من كلا النهجين. أظهرت النتائج أن الطريقة المقترحة (NOMA) باستخدام (GWO) أفضل من OMA و NOMA باستخدام GA من حيث معدل مجموع المستخدم والإنصاف. أعلى معدل إجمالي تم الحصول عليه من النظام هو (258.0092 ميجابت في الثانية). تمت محاكاة النتائج باستخدام Matlab 2021a .

تحسين أداء الوصول المتعدد غير المتعامد (NOMA) بناءاً على تقنيات التحسين

الرسالة

مقدمة الى قسم هندسة تقنيات الاتصالات كجزء من متطلبات نيل درجة

الماجستير

تقدم بها

أحمد جاسم محمديونس عبدالعزيز

إشراف

الأستاذ الدكتور أحمد غانم وداي

شباط 2022

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة الفرات الاوسط التقنية
الكلية التقنية الهندسية- نجف

تحسين أداء الوصول المتعدد غير المتعامد (NOMA) بناءاً على تقنيات التحسين

أحمد جاسم محمديونس عبدالعزيز

ماجستير هندسة تقنيات الاتصالات

2022