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ERBIL POLYTECHNIC UNIVERSITY

Performance Enhancement of 5G and 6G Mobile Communication Networks with Cooperative Non-Orthogonal Multiple Access and Caching

A Dissertation
Submitted to the Council of Erbil Technical Engineering College, at Erbil Polytechnic University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Information Systems Engineering

by

Salar Ismael Ahmed

B.Sc. in Electronic and Control, Kirkuk Technical College, Kirkuk (2006)

M.Sc. in Electrical and Electronic Engineering, Eastern Mediterranean University, Cyprus, (2014)

Supervised by

Prof. Dr. Siddeeq Y. Ameen

Erbil, Kurdistan Region, Iraq

2024

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I declare that the PhD Dissertation entitled: "**Performance Enhancement of 5G and 6G Mobile Communication Networks with Cooperative Non-Orthogonal Multiple Access and Caching"** is my own original work, and hereby I certify that unless stated, all work contained within this dissertation is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgment is made in the text.

Signature:

Student Name: Salar Ismael Ahmed

Date: / / 2024

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I confirmed that I have reviewed the Ph.D. dissertation entitled:

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from the English linguistic point of view, and I can confirm that it is free of grammatical and spelling errors.

Signature:

Name of Reviewer: Asst. Prof. Dr. Ismail Abdulrahman Abdulla

Lecturer at Erbil Polytechnic University

Phone No.: +964(0)7504065435

Email address: esmael.abdulla@epu.edu.iq

Date: 18 / 8 / 2024

SUPERVISOR CERTIFICATE

This dissertation entitled ***"Performance Enhancement of 5G and 6G Mobile Communication Networks with Cooperative Non-Orthogonal Multiple Access and Caching"*** and has been written under my supervision and has been submitted for the award of the Doctor of Philosophy in Information Systems Engineering with my approval as supervisor.

Signature:

Name: Prof. Dr. Siddeeq Yousif Ameen
(Supervisor)

Date: / /2024

I confirm that all requirements have been fulfilled.

Signature:

Name: Dr. Media Ali Ibrahim

Head of the Department of Information Systems Engineering

Date: / / 2024

I confirm that all requirements have been fulfilled.

Postgraduate Office

Signature:

Name: Byad Abdullqader Ahmed

Date: / / 2024

EXAMINING COMMITTEE CERTIFICATION

We certify that we have read this dissertation entitled: “***Performance Enhancement of 5G and 6G Mobile Communication Networks with Cooperative Non-Orthogonal Multiple Access and Caching”*** and as an examining committee examined the student: ***Salar Ismael Ahmed*** in its content and what related to it. We approve that it meets the standards of a dissertation for the degree of Doctor of Philosophy (PhD) in Information System Engineering.

Signature:
Name: Asst. Prof. Dr. Sarkar Hasan Ahmed
Member
Date: / / 2024

Signature:
Name: Asst. Prof. Dr. Reben Kurda
Member
Date: / / 2024

Signature:
Name: Asst. Prof. Dr. Halgurd Sarhang Maghdid
Member
Date: / /2024

Signature:
Name: Asst. Prof. Dr. Jalal Jamal Hamadameen
Member
Date: / /2024

Signature:
Name: Prof. Dr. Siddeeq Yousif Ameen
Supervisor and Member
Date: / /2024

Signature:
Name: Prof. Dr. Shavan Kamal Asker
Chairman
Date: / /2024

Signature
Name: Prof. Dr. Ayad Zaki Saber Agha
Dean of the College of Erbil Technical Engineering
Date: / / 2024

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ABSTRACT

The fifth generation (5G) mobile communication technology intends to address the massively increasing data rate requirements as well as the massive growth in traffic volume. The 5G technologies achieve higher performance, reduced latency, higher density, and higher mobility minus of sacrificing reliability. However, as the mobile core networks are facing exponential growth in traffic and computing demand as smart devices and mobile applications become more popular. One of the most promising solutions to the challenges is caching. Non-Orthogonal Multiple Access (NOMA) is one of the promising radio access techniques for performance enhancement in next-generation cellular communications. Especially the 5G networks are expected to provide a massively increased number of users at a thousand times higher data rates at lower power consumption because NOMA provides a higher spectral efficiency and higher system throughput. For more improvement, power domain (PD-NOMA), code domain (CD-NOMA) and cooperative (C- NOMA) techniques are proposed and implemented in the 5G to overcome the future network demands. The PD-NOMA, employs Successive Interference Cancellation (SIC) at the receiver and Superposition Coding (SC) at the transmitter.

The proposed systems implemented with the help of MATLAB and NYUSIM simulations. The results of simulation show that the proposed techniques meet the various needs of improved user fairness, quality-of-service (QoS), high reliability, high spectral efficiency, extensive connectivity, raising data rates, high flexibility, low transmission latency, massive connectivity, low delay, higher cell-edge throughput, and superior performance.

For more improvement, caching techniques, as a storing popular reusable information at intermediate nodes to reduce backhauling load in wireless

networks, have been integrated with C-NOMA to reduce the delay of storing planned content needs, relieve backhaul traffic and to alleviate the delay caused by handovers. The results of simulation of caching integrated with C-NOMA technique have shown promise in maximizing throughput, minimizing latency, and optimizing resource efficiency. In C-NOMA, dynamic resource allocation refers to the process of dynamically modifying the power required to transmit rates and resource blocks allocated to users under their QoS requirements and channel conditions.

Finally, a novel approach is proposed by integrating C-NOMA, massive multiple-input multiple-output (m-MIMO) with caching as a strategic technique to overcome the exponential growth in data demand, spectrum scarcity, mitigation of interference, energy efficiency and sustainability. The simulation and evaluation results proved that the proposed system provides significantly a higher performance in terms of data rate, bit error rate (BER), and outage probability and reduces the power consumption to 52.6% and 54.7% compared to NOMA without cooperative and without NOMA, respectively, which is higher than the related works. The results of simulation verify the achievement of low-latency required by the sixth generation (6G) mobile communication networks cause to operate bandwidth-intensive applications such as high-definition video streaming, augmented reality, virtual reality, and Internet of Things (IoT) devices.

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List of Abbreviations

Abbreviation	Definition
3GPPP	Third Generation Partnership Project
5G	Fifth Generation
6G	Sixth Generation
AF	Amplifier and forwarding
AI	Artificial Intelligence
AR	Augmented Reality
AWGN	Additive White Gaussian Noise
B5G	Beyond Fifth Generation
BDM	Bit Division Multiplexing
BER	Bit Error Rate
BS	Base Station
BSBS	Buffered Small Base Station
CAP-CF	Cluster Average Popularity Based Collaborative Filtering
CCRN	Cooperative Cognitive Radio Network
CCU	Cell-Center User
CDMA	Code Division Multiple Access
CD-NOMA	Code-domain Non-Orthogonal Multiple Access
CDSA	Control Data Split Architecture
CEU	Cell-Edge User
CHR	Cache Hit Ratio
C-NOMA	Cooperative Non-Orthogonal Multiple Access
CP	Cyclic Prefix
CRAN	Cloud Radio Access Network
CSI	Channel State Information

D2D	Device-to-Device
DF	Decode and forwarding
DL	Downlink
DSRC	Dedicated Short Range Communications
ECNs	Edge Computing Nodes
e-MBB	enhance Mobile Broadband
FBMC	Filter Bank Multicarrier Modulation
FD	Full-duplex
FDMA	Frequency Division Multiple Access
GHz	Gigahertz
GSM	Global System for Mobile
HD	Half-duplex
HDVS	High-Definition Video Streaming
ICI	Inter-Channel Interference
ICN	Information-centric Networking
IDMA	Interleave Division Multiple Access
IMT-A	International Mobile Telecommunications-Advanced
IoT	Internet of Things
ISP	Internet Service Provider
ITCTC	Intra-tier and Cross-tier Cooperation
JSPA	Joint Scheduling and Power Allocation Algorithm
KKT	Karush Kuhn Tucher's Technique
KPI	Key Performance Indicator
LDS-CDMA	Low density Spreading Code Division Multiple Access
LDS-OFDM	Low Density Signature-Orthogonal Frequency Division Multiplexing

LFU	Least Frequently Used
LRU	Least Recently Used
MA	Multiple Access
MC	Macro-cell
μC	Micro-cell
MC-CDMA	Multi-carrier CDMA
MEC	Multi-access Edge Computing
MENs	Mobile Edge Networks
MHz	Megahertz
MIMO	Multiple Input Multiple Output
m-MIMO	Massive-Multiple Input Multiple Output
m-MTC	Massive Machine Type Communication
mm-Wave	Millimeter Wave
MUSA	Multi-User Shared Access
NB-IoT	Narrow Band Internet of Things
NOMA	Non-Orthogonal Multiple Access
NP	Noise Power
NR	New Radio
OBU	On-board Processing Unit
OFDMA	Orthogonal Frequency Division Multiple Access
OMA	Orthogonal Multiple Access
PAC	Power Allocation Coefficient
PA-NOMA	Power Allocation Non-Orthogonal Multiple Access
PDMA	Polarization-Division Multiple Access
PD-NOMA	Power-domain Non-Orthogonal Multiple Access
PHY layer	Physical Layer

POP	Pure Popularity-based Caching
QoE	Quality of Experience
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RAN	Radio Access Network
RATs	Radio Access Technologies
RB	Resource Block
RFC	Rayleigh fading coefficient
RLU	Relative Light Units
RICH	RoadsIde CacHe
RSU	Road-Side Unit
SAMA	Spread ALOHA Multiple Access
SBS	Small Base Station
SC	Superposition Coding
SCMA	Sparse Code Multiple Access
SDMA	Space Division Multiple Access
SDN	Software Defined Networking
SE	Spectral Efficiency
SIC	Successive Interference Cancellation
SIE	Signal Efficiency
SINR	Signal-to-interference-plus-noise Ratio
SISO-MIMO	Single-input and Single-output MIMO
SNR	Signal-to-Noise Ratio
SS	Superimposed Signal
SVM	Support Vector Machines
TDMA	Time Division Multiple Access

THz	Tera Hertz
TTP	Total Transmit Power
UAV	Unmanned Aerial Vehicle
UDCN	Ultra-dense Cellular Networks
UE	User Equipment
UL	Uplink
u-RLLC	ultra-Reliability and Low Latency Communication
USR	User Satisfaction Ratio
UWB	Ultra-wideband
V2V	Vehicle-to-vehicle Connectivity
VANET	Vehicular ad-hoc Networks
VCNs	Vehicular Content Networks
VLC	Visible Light Communication
VR	Virtual Reality

List of Symbols

Symbol	Definition
α	Portion of the Power Resource Allocation
α_i	Power allocation factor for the (i_{th}) user
$\alpha_{m,n}$	The SINR achieved by user (*n*) when requesting content (*m*).
α_1	Power allocation coefficients for far user
α_2	Power allocation coefficients for near user
α_f	Power allocation coefficient for far user
α_n	Power allocation coefficient for near user
β	Portion of the Total Bandwidth
ε	The target SINR for the far user that has target rate (R^*)
σ^2	Noise power
A	The antennas number at the BSs
B	Bandwidth Waveform
C_i	The content cached at BS_i
$\|C_i\|$	Caching capacity constraints
C_m	The cache capacity for content (*m*)
$\mathbb{E}[R_{i,j}]$	The expected data rate for user *j* at BS_i
$h_{A,n}$	The channel gain between user (*n*) and the (A_{th}) antenna of the BS
h_f	Rayleigh fading coefficient for far user
$h_{i,j}$	The channel gain between BS_i and user *j*
h_i	Channel Gain for user *i*

h_{ii}	The channel gain of the direct link between the (i_{th}) user and the base station
h_{ij}	The channel gain on the subcarrier *j* for user *i*
$hit_{m,n}$	An indicator variable denoting whether user (*n*) requests content (*m*) from the cache
h_{ji}	The channel gain of the interference from the (j_{th}) user to the (i_{th}) user
h_k	Channel gain for user *K*
h_n	Rayleigh fading coefficient for near user
I_i	The interference for the (i_{th}) user
i	User
j	User
K	Number of users
L_i	The latency experienced by users at BS_i
$\log_2$	Logarithm Base 2
M	The cache capacity
Mcf	The number of cached files
N	The total number of users
N_0	Noise power
n_A	The AWGN at the (A_{th}) antenna of the BS
n_{Av}	The AWGN vector at the (A_{th}) antenna of the BS
$n_{i,j}$	The additive white Gaussian noise (AWGN) at user *j*
n_i	The AWGN at the receiver side for the user *i*
n_{ij}	The AWGN on the subcarrier *j* for user *i*.
n_k	The AWGN from user *K*
P	Total transmit power

P_{hit}	Cache Hit Probability
$P_{i,j}$	The power allocated to user *j* at BS_i for NOMA transmission
P_i	Power Allocated to User *i*
P_i	The transmit power of the (i_{th}) user
P_{ij}	Power Allocation on the subcarrier *j* for user *i*
P_k	Power allocation to user *K*
P_{max}	The maximum transmit power
P_{miss}	Cache Miss Probability
P_n	The transmit power allocated to user (*n*)
R	Data Rates
R^*	The target rate of far user
R_i	The achievable rate of the (i_{th}) user
R_n	The target rate of near user
R-NOMA	Data Rate for Non-Orthogonal Multiple Access
T_i	The throughput at BS_i
U_i	The set of users associated with BS_i
W_A	The beamforming vector for the (A_{th}) antenna of the BS
$x_{i,j}$	The transmitted signal from BS_i to user *j*
x_i	Transmitted Signal by the user *i*
x_{ij}	Transmitted signal by user *i* on the subcarrier *j*
x_k	Transmitted signal from user *K*
$x_{m,n}$	The caching content requested by user (*n*) for file (*m*)
x_n	The information symbol transmitted by user (*n*)
Y_{Av}	The received signal vector at the (A_{th}) antenna of the BS

$y_{A,n}$	The received signal at the (A_{th}) antenna of the BS from the (n_{th}) user
$y_{i,j}$	The received signal at user *j* from BS_i
y_i	Received Signal by the user *i*
y_{ij}	Received signal for the subcarrier *j* for user *i*

CHAPTER ONE

1 INTRODUCTION

1.1 Overview

The exponential growth of wireless networks increased the traffic burden on cellular operators. This development requires a lot of communication with applications that consume a lot of data. In particular, cellular operators will increase the density of their networks by supporting Buffered Small Base Station (BSBS); the use of active caching of common material at the network's edge, as well as multicasting to meet common needs. This obviously improves spatial frequency reuse, reduces backhaul congestion, and makes better use of radio frequencies (Wu et al., 2021).

The 5G mobile communication promises to deliver faster download speeds, lower latency, and higher capacity (Jijo et al., 2021a). New numbers and types of users will arise as wireless telecommunication becomes more widely used in a range of areas, including transportation, healthcare, intelligent buildings, and industrial automation. Despite the fact that the 5G has several benefits over traditional generations, deploying the 5G is not a simple or straightforward undertaking. The implementation of the 5G is fraught with difficulties for operators. These customers will have varying needs, such as greater bandwidth and reliability, lower latency, and greater energy economy (Zikria et al., 2018).

The 5G Wireless networks technology systems use higher frequencies, basically equivalent to 300GHz, and these bands have even more capacity, allowing them to deliver ultra-fast speeds 20 times faster than current fourth generation (4G) cellular network systems (Chen, 2020). Nonetheless, spectrum band availability and pricing remain a concern for operators. As they continue to create and operate the 5G wireless networks, they will need to compete for these higher spectrum bands. New services like as Mixed Reality, Virtual Reality, and the online presentation of strong 3D movies, on the other hand, are becoming increasingly significant. Ultra-high-definition video streaming, and autonomous vehicles require novel approaches to be explored in order to improve performance and efficiency as we proceed closer to the era of the 6G mobile communication networks (Nauman et al., 2024a).

The 5G is not just progressive for offering better bandwidth and reduced latency than current generation mobile technology wireless system, but it is also revolutionary in that it is predicted to enable fundamentally new applications with significantly higher latency and capacity requirements (Agiwal et al., 2021). Because of its utilization of new spectrum and improvements in spectral efficiency, the 5G might help solve the final (mile/km) issue and deliver broadband connectivity to the next billion users across the globe at a significantly cheaper cost (Elsayed and Erol-Kantarci, 2019). Though the 5G technology has the processing ability to handle massive amounts of data from a variety of sources, it requires more infrastructures to support it (Khelifi et al., 2021).

Whether a user has a strong or weak channel state, a specific frequency resource is allocated to them in Orthogonal Frequency Division Multiple Access (OFDMA) and Orthogonal Multiple Access (OMA), which results in low throughput and spectral efficiency for the system. Meanwhile, several mobile users with various channel conditions are concurrently assigned the same frequency resource in Non-Orthogonal Multiple access NOMA. Consequently, the dominant user utilizes the resources assigned to the less powerful user and SIC processes at the users' receivers can mitigate interference. Thus, there will undoubtedly be a considerable boost in the probability of achieving higher throughput and better spectral efficiency (Msayer et al., 2023b).

Cooperative communication NOMA networks, often called C-NOMA networks, use the wireless channel's broadcast characteristics by incorporating relays that serve as an alternate link in cases of weak transmission. The cooperation process is performed using relaying nodes. Employing relays in NOMA networks enhanced diversity gain and throughput in network performance once cooperative communication is successfully implemented in the 5G. Relaying networks might be source nodes facilitating user interaction or specialized relay nodes (Li et al., 2018). Cooperative communication is one of the main physical layer technologies that aim to maximize spectral efficiency. The idea is to enhance the transmission and reception processes by utilizing the users' standard information and resources (Ren et al., 2021).

C-NOMA with caching has shown promise in this regard as methods to optimize resource usage, minimize delay, and increase throughput in the 6G networks (Bepari et al., 2022). Caching makes use of the idea of keeping frequently requested content closer to users in order to minimize network congestion and access delay. Utilizing the diversity gains and increasing spectral efficiency, C-NOMA allows simultaneous transmission to numerous users on the same resource (Akhtar et al., 2020).

The combination of C-NOMA with caching appears to be an effective combination that has the potential to completely change the wireless communication scenario as the 6G mobile communication networks are navigated (Liang et al., 2020a). Using the cooperative diversity and spectral efficiency advantages made possible by NOMA, the 6G mobile communication networks will be able to achieve previously unreachable levels of performance and efficiency by utilizing caching to reduce network congestion and reduce latency (Bepari et al., 2023). C-NOMA with caching technique helps in fast content placement and delivery maintaining fairness in the 6G mobile communication networks. Therefore, due to the dynamic behaviors of the wireless channel and movement of the user content placement and delivery, that becomes challenges in wireless caching networks (Habibi et al., 2023). While there are many benefits of C-NOMA with caching, their effectiveness needs to be further investigated and evaluated in conjunction with other state-of-the-art techniques in order to fully solve the complex issues that the 6G networks confront (Banafaa et al., 2023). In the 6G mobile communication networks, integrating C-NOMA-m-MIMO with caching provides a comprehensive technique to address challenges with latency, spectrum scarcity, mitigation of interference, energy efficiency and increasing data demands. Through simultaneous transmissions and spatial multiplexing, this integration maximizes spectrum efficiency, reduces interference, and improves user experience by increasing data speeds and decreasing latency (Nauman et al., 2024b).

For spectral efficiency enhancement, C-NOMA exploiting the power domain for multiple access, enhancing simultaneous transmission to numerous users within the same frequency spectrum. When combined with spatial multiplexing-based Massive MIMO, this integration greatly improves spectral efficiency by supporting numerous users and data streams simultaneously. Through the optimization of the use of available spectrum resources, caching further enhances spectral efficiency by minimizing the need to retrieve content from distant servers (Hassan et al., 2023a). Caching further lowers latency and improves content delivery by prefetching and storing frequently accessed content closer to users. All things considered, this integrated strategy guarantees effective spectrum use, low latency communication, and a seamless user experience, establishing the stage for a robust and durable the 6G mobile communication ecosystem (Hassan et al., 2023b).

In order to improve throughput and reduce latency in content delivery, caching enhances this by prefetching and storing frequently visited content closer to the users (Saleh et al., 2023). For reducing the average latency, C-NOMA and m-MIMO collaborate to provide effective resource allocation and interference management, resulting in reduced transmission delays and lower latency. Caching contributes to latency reduction by enabling faster access to content through localized storage, minimizing the need for fetching data from remote servers. This is especially helpful for latency-sensitive applications like gaming, real-time communication, and (IoT) apps that need quick response times. The network infrastructure can save energy through the more effective use of resources made possible by C-NOMA and m-MIMO techniques. These methods support energy-efficient communication by maximizing power allocation and providing numerous users with minimal transmission resources. Caching further reduces the need for frequent long-distance data transmissions, which further saves energy usage in data delivery (Ogundokun et al., 2023a).

The integrated approach of C-NOMA m-MIMO with caching is inherently scalable and adaptable to varying network conditions and user demands. The flexibility to dynamically adjust resource allocation, power levels, and caching strategies ensures efficient utilization of network resources while accommodating fluctuations in user traffic and content popularity (Alsabah et al., 2021). The integration of these technologies leads to an overall improvement in the user experience. Faster data rates, reduced latency, and seamless content delivery result in smoother multimedia streaming, faster web browsing, and enhanced interactive applications. Users experience less waiting time for content retrieval, leading to higher satisfaction and engagement with the network services (Qadir et al., 2023). This integrated approach of C-NOMA m-MIMO with caching is inherently scalable and adaptable to varying network conditions and user demands. The flexibility to dynamically adjust resource allocation, power levels, and caching strategies ensures efficient utilization of network resources while accommodating fluctuations in user traffic and content popularity (Khan et al., 2023).

The integrating C-NOMA m-MIMO with caching in the 6G mobile communication networks is essential for addressing the challenges posed by the exponential growth in data demand, spectrum scarcity, and the need for low-latency communication. This integrated solution optimizes spectrum utilization, mitigates interference, improves user experience, and enhances energy efficiency, thereby laying the foundation for a more robust and sustainable wireless communication infrastructure (Ahmad et al., 2019).

1.2 Research Motivation

Wireless communications especially mobile communication systems, are rapidly expanding. Telecommunication and information systems must accommodate an expanding number of users as well as the demand for new applications, traffic types, and data services. Moreover, wireless communications have to support concepts such as smart grid, smart homes and cities, and e-health, and these applications have very different communication requirements, necessitating the use of a unified wireless technology. Thus, the key motivations are as follows:

i. Increased user demand and data traffic: Users in the modern world need reliable, fast, and speed internet access. The amount of data traveling across mobile networks is rising at an exponential rate due to the increasing number of IoT devices, Augmented Reality, Virtual Reality, and high-definition video streaming.

ii. There is a need to improve spectral efficiency by enabling several users to share the same time, same frequency spectrum in different power levels.

iii. Massive-MIMO technique can improve connection by beamforming energy into smaller, more accurate beams which aids in efficiently covering more people and overcoming physical challenges is required.

iv. Cooperative communications, which are crucial for applications like automation industrial, and autonomous driving, can lower latency and improve reliability by enabling devices to relay information between themselves. By keeping frequently requested content closer to the user, edge caching minimizes latency by reducing the need to fetch data from faraway servers.

v. Energy efficiency and cost reduction: By maximizing resource utilization and lowering data transmission power requirements, C-NOMA and m-MIMO can help create more energy-efficient networks.

vi. Support for services and diverse applications: the 5G and 6G mobile communication networks need to accommodate a wide variety of applications with different specifications. Cooperative NOMA, Massive MIMO, with caching work together to give the flexibility that need to effectively handle these various demands. Caching, specifically helps to promote edge computing paradigms by facilitating faster data access and lowering backhaul traffic—both of which are necessary for low-latency for IoT applications.

In the 5G and 6G mobile communication networks, the integration of massive MIMO cooperative NOMA with caching satisfies the needs for increased data rates, better spectral efficiency, better coverage, lower latency, higher throughput, and energy-efficient functionality. All together, these technologies contribute to build robust, expandable, and secure wireless communication networks that can accommodate a variety of services and applications in the ever-changing digital environment.

1.3 Research Problem Statement

The research problem statement in this dissertation is with the mobile core networks are facing exponential growth in traffic and computing demand as smart devices and mobile applications have become more popular. Due to the quick development of several new services and mobile applications, there is an anticipated consumption of frequency and bandwidth resources in the upcoming cell phone networks. Therefore, networks suffer from low speed and high latency.

Non-Orthogonal Multiple Access (NOMA) is one of the promising radio access techniques for performance enhancement in next-generation cellular communications. Especially the fifth-generation 5G networks expected to provide a massively increased number of users at hundreds or thousand times higher data rates at lower power consumption. NOMA provides a higher spectrum efficiency and higher system throughput, considered a promising technique for the 5G mobile communication networks. Power allocation is very significant system in NOMA. PA-NOMA supports multiple users on the same time-frequency resources, assigns different transmission powers to different users, and differentiates users by user channel gains. Therefore, the power allocation has a considerable impact on the NOMA system performance. C-NOMA is an approach method to meet the various needs of improved user fairness, high reliability, high

Spectral Efficiency (SE), extensive connectivity, raising data rates, high flexibility, low transmission latency, massive connectivity, low delay, higher cell-edge throughput, and superior performance. Cooperative communications attracted more attention in wireless networks because it might provide spatial location variety to reduce fading and overcome the challenges of installing several directional on compact communications terminals. As cooperative communications might reduce fading and solve the challenge of installing multiple antennas on small wireless connections, such as physical variety, it has been highly recommended for implementation during the deployment of the 5G. Cooperative communications, when implemented with NOMA, can enhance and increase the coverage capacity and reliability of the system. The NOMA systems technique, along with earlier information, is utilized by the C-NOMA technique. As a result, these users serve as relays to increase the dependability of users' reception for users with weaker connections to the BS. The C-NOMA technique in the 5G is considered to maximize the potential of NOMA in multiuser environments where one of the users acts as the relay role for another user.

The abilities of C-NOMA, PD-NOMA need to be improved to meet the requirements of new application and the growth in demands. Thus, this can be a major problem to be investigate in this research and to look for ways to improve C-NOMA in order to meet the 6G demands and requirements.

1.4 Research Objectives

This dissertation aims to enhance the performance of the 5G and 6G mobile communication networks by using power-domain (PD-NOMA), which employs successive interference cancellation (SIC) at the receiver and superposition coding (SC) at the transmitter. The dissertation also aims to investigate C-NOMA, NOMA, and OMA for different types of environmental fading. The combination of C-NOMA with caching as an effective combination that has the potential to completely change the wireless communication scenario as the 6G mobile communication networks are navigated. Using the cooperative diversity and spectral efficiency advantages made possible by NOMA, the 6G mobile communication networks will be able to achieve previously unreachable levels of performance and efficiency by utilizing caching to reduce network congestion and reduce latency. Moreover, the main objective of this dissertation is to enhance the performance of the 5G and 6G mobile communication networks by using C-NOMA, M-MIMO with caching. The above-mentioned aim identifies the following objectives:

i. Investigating the advantages of the cooperative NOMA compared to OMA and NOMA performance in the 5G mobile communication network systems. The power allocation NOMA technique in fixed and fair and improved dynamic method for fixed and fair method according to transmit power for different user distances for the 5G mobile communication networks system will be investigating and assessing. Investigate the performance of the 5G mobile communication networks systems for UL and DL C-NOMA channel systems for outage probability according to SNR in different channel fading, different signal spectrum, different noise power, and for different user distances in the 5G mobile communication networks system.
ii. Investigating the impacts of caching technique in the enhancement of the performance of the 5G and 6G mobile communication networks systems. To investigate and develop the sum-rate, average latency reduction, and throughput according to SNR for C-NOMA with and without caching for different file size, different networks traffic, different user numbers, different

station numbers, and different power allocation level in the 6G mobile communication networks system.

iii. Studying the proposed integration technique C-NOMA with caching, and M-MIMO for sum-rate, average latency reduction, and throughput according to time iteration in the 6G mobile communication networks system.

iv. Proposing integration technique of C-NOMA with caching and m-MIMO for sum-rate, average latency reduction, and throughput according to SNR for different file size, different networks traffic, different user numbers, different station numbers, and different power allocation levels in the 6G mobile communication networks system. Comparing the proposed integration the average m-MIMO C-NOMA with and without caching technique for sum-rate, average latency reduction, and throughput according to SNR for 6G mobile communication networks system.

1.5 Research Contributions

This research studied different techniques to enhance the performance of the 5G and 6G mobile communication networks system. Caching, C-NOMA, and m-MIMO techniques are studied, evaluated, improved and integrated with four different proposed algorithms. The process of a high-level overview of the C-NOMA SIC algorithm in the 5G, PA-NOMA algorithm for the 5G, the C-NOMA with caching proposed algorithm in the 6G and the C-NOMA Massive MIMO with caching algorithm for the 6G are proposed in this research. The research presents five primary contributions:

i. Caching technology: Caching refers to the process of storing data in a cache. Caching as a temporary holding storage location from which we can access files instead of traveling to the original server, saving time and networks traffic leads to increase the sum-rare, increase average latency reduction, and increase the throughput for the system exactly when combined with other technique such as D2D, NOMA or m-MIMO for the 5G mobile communication networks system.

ii. PA-NOMA: The power allocation has a considerable impact on the NOMA system performance. PA-NOMA supports multiple users on the same time-frequency resources, assigns different transmission powers to different users, and differentiates users by user channel gains. For this technique a new algorithm PA-NOMA is proposed to improve the SIC for the PA-NOMA in dynamic method for the 5G mobile communication networks system.

iii. C-NOMA: This technique includes diversity-exploiting techniques to cancel out interfering signals linked to each user. C-NOMA considers that the lower-power users are expected to retransmit the symbols their higher-power users' SIC have identified (usually by decoding and forwarding). The performance is enhanced by combining these signals. The proposed algorithm process of a high-level overview of the C-NOMA SIC combines the ideas of simultaneous usage of time-frequency resources, in which numerous users share them, with simultaneous decoding and subtraction of interference from received signals SIC.

iv. C-NOMA with Caching: For this technique, C-NOMA with caching algorithm proposed by combining C-NOMA with caching and dynamic resource allocation techniques to improve the performance and efficiency in the 6G mobile communication networks system.

v. C-NOMA m-MIMO with Caching: A novel system algorithm proposed for integrating C-NOMA m-MIMO with caching in the 6G mobile communication networks system. In this proposed algorithm various factors considered includes, resource allocation, interference management, and caching strategies.

The simulation and evaluation results proved that the proposed system provides significantly higher performance in terms of data rate, BER, outage probability and reduces the power consumption to 52.6% and 54.7% compared to NOMA without cooperative and without NOMA, respectively, which is higher than the related works.

1.6 Dissertation Layout

This dissertation is divided into six chapters and organized as follows:

The first chapter gives a background overview of the dissertation topic, research motivation, research problem statement, research objectives, and research contributions.

The second chapter presents a comprehensive theoretical background of techniques used to enhance the performance of the 5G and 6G mobile communication networks system. A literature review presented in this chapter regarding the related works to this research according to algorithms, methods, challenges and results they found.

The third chapter presents the research methodologies, algorithms and models to enhance the performance of the 5G and 6G.

Chapter four presents the simulation results and performance analysis of two modeled techniques C-NOMA and PA-NOMA in the 5G mobile communication networks systems.

Chapter five presents the integrated C-NOMA with m-MIMO and caching simulation performance analysis in the 6G.

Chapter six presents the conclusions and suggestions for future works related to this dissertation.

CHAPTER TWO

2 BACKGROUND THEORIES AND RELATED WORKS

2.1 Introduction

The exponential growth of wireless networks increased the traffic burden on cellular operators. This development requires a lot of communication with applications that consume a lot of data. In particular, cellular operators will increase the density of their networks by supporting Buffered Small Base Stations (SBS); Using active caching of common material at the network's edge, and multicasting to meet common needs. This obviously improves spatial frequency reuse, reduces backhaul congestion, and better uses radio frequencies (Wu et al., 2021).

In wireless networks, the most effective method for boosting bandwidth, data rate, and network capacity is Multiple Access (MA) transmission. Since users and network nodes (cells) can exchange data across the shared medium channel simultaneously and with the least amount of interference, multiple access techniques have been used by mobile communications in later generations to facilitate data transmission between a BS and users (Chen, 2020). Moreover, every generation of mobile communication requires innovative spectrum reuse techniques to enable users to share the available bandwidth (or channel) across several users in order to maximize capacity (Nauman et al., 2024a).

2.2 Fifth Generation 5G Communication Technology

The fifth generation 5G mobile communication technology intends to address the massively increasing data rate requirements as well as the massive growth in traffic volume. The 5G technologies are predicted to achieve good performance, reduced latency, greater density, and higher mobility minus of sacrificing reliability (Khelifi et al., 2021). Wireless mobile communication will undergo a paradigmatic leap with the 5G. The 5G provides lower latency and higher bandwidth than the present generation technology. It also enables qualitatively new applications with significantly higher latency and bandwidth requirements. Manufacturing operations will benefit from the 5G not just because it will allow firms to be speedier, but it will also allow them to be more proactive to customer requirements (Kalem et al., 2021). The 5G is being driven by various causes, some of which are solely linked to communications, such as providing high-speed mobile access to densely populated places, and others that are less related to communication channels, like the battery life of over 10 years. The growing demand for enhanced mobile broadband (e-MBB), ultra-reliable and low latency, so-called critical communication scenarios (u-RLLC), and the envisioned massive machine-type communication (m-MTC) are among the traffic-related motivations (Qureshi et al., 2020). The 5G promises to deliver faster download speeds, lower latency, and higher capacity. As wireless telecommunications expand in various sectors such as transportation, healthcare, intelligent buildings, and industrial automation, it will attract new numbers and types of subscribers. Despite the fact that the 5G has several benefits over traditional generations, deploying the 5G is not a simple or straightforward undertaking. The implementation of the 5G is fraught with difficulties for operators. These customers will have varying needs, such as greater bandwidth and reliability, lower latency, and greater energy economy. The 5G wireless networks technology systems use more significant frequencies, basically equivalent to 3 GHz to 300 GHz, and these bands have even greater capacity, allowing it to deliver ultra-fast speeds 20 times faster than current 4G cellular network systems (Lal et al., 2021). Figure 2.1 depicts why a the 5G network is needed, which has some important properties that distinguish it from previous generations, such as lower latency, higher speed, more devices that can connect than 4G, reduced price than 4G, and better performance (Ghous et al., 2022). Table 2.1 illustrates the performances, generation, and issues comparison for the 4G, 5G, and 6G.

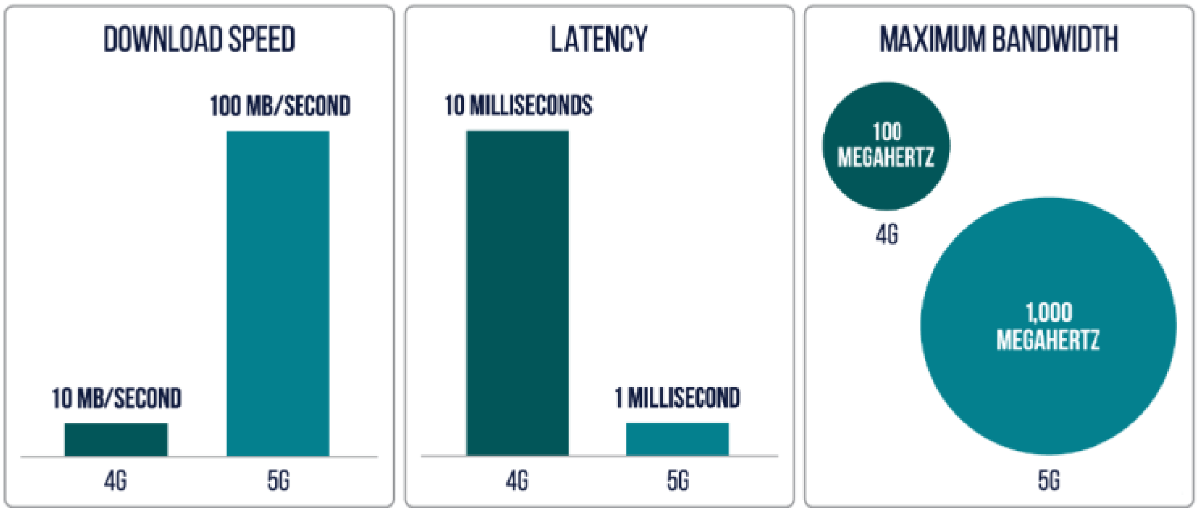

Figure2.1: The Need for 5G Technology (Lal et al., 2021)

Table 2.1: The Illustrated aim of the 5G and 6G Achievement as well as the Presently Offered with 4G (Jijo et al., 2021b)

Performances/Generation/Issues	4G	5G	6G
Mean of Data Rate	100 Mbps	1 Gbps	10 Gbps
Mean of Latency	50 ms	1 ms	0.1 ms
Mean of Spectral Efficiency	3.5 bits/Hz	4.5 bits/Hz	6.5 bits/Hz
Mean Maximum Device Connectivity	1,000 devices/km²	100,000 devices/km²	1,000,000 devices/km²
Integration of Satellite	None	None	Completely
AI	None	In part	Completely
Vehicle Autonomous	None	In part	Completely
Extended Reality	None	In part	Completely
Haptic Communication	None	In part	Completely
THz Frequency Communication	None	Very Limited	Broadly
Level of Service	Video	AR, VR	Tactile
Architecture	MIMO	m-MIMO	Intelligent Surface
Maximum Range Frequency	6 GHz	300 GHz	10 THz

Nonetheless, operators continue to need help with the availability and cost of spectrum bands. They will have to compete for these higher spectrum bands as they develop and run the 5G wireless networks. New services like as Mixed Reality, Virtual Reality, and the online presentation of strong 3D movies, from the other hand, are becoming increasingly significant (Nauman et al., 2024a). As for this, telecommunications services fulfill the standards of the three categories of High Data Rate Enhanced Mobile Broadband (e-MBB) Services, High Reliability (HRLC) Services, and Very Low Delay Ultra-reliable and Low-latency Communication (u-RLLC) Services, and are classified by very high connection capacity Massive Machine Type Communication (m-MTC). The 5G is not just progressive for offering reduced latency and better waveform signal bandwidth than current-generation mobile technology wireless system, but it is also revolutionary in that it is predicted to enable fundamentally new applications with significantly higher latency and capacity requirements (O'Connell et al., 2020, Borges et al., 2021b).

2.3 MIMO-OFDM Technique

Wireless communications, especially mobile communication systems, are rapidly expanding. Telecommunication and information systems must accommodate an expanding number of users and the demand for new applications, data services, and traffic types. The 5G mobile networks are being carried out to deal with the massive increase in bulk demand, the number of networks, and the expanding use of linked technology. MIMO plays an essential role in satisfying these demands (Siddavaatam et al., 2019). Among the various antenna configurations, MIMO (at both the transmitter and receiving ends, multiple antennas) has dominated the wireless sector because of its three remarkable qualities: diversity, better throughput, and support for numerous users. It will be a crucial enabler of the next generation of pervasive super-fast internet infrastructure and the future digital world, allowing processes to migrate across all sectors of the economy. The ability to achieve great performance via low latency during a short time will make the 5G network optimization and acceleration even more crucial for networks (Borges et al., 2021a).

m-MIMO is a development of MIMO technology that improves spectral efficiency and throughput by using hundreds or thousands of active communication antennas. m-MIMO is an improved modified version of SDMA that pushes spatial multiplexing to greater levels. The m-MIMO technology boosts wireless throughput without increasing the number of cells or consuming more bandwidth. Consequently, the transmitted power can be considerably lowered, allowing massive antenna arrays to achieve high energy efficiency. The higher number of antennas a BS provides, the more degrees of freedom it offers, and thus the more users who can communicate at the same time-frequency resource at the same time. Massive MIMO is significantly assisted by using Millimeter Wave (mm-Wave) channels because the shorter wavelength allows huge antenna arrays to be packed at both the transmitter and receiver (Chataut and Akl, 2020a).

Orthogonal Frequency Division Multiplexing (OFDM) uses many subcarriers to enable high-speed data transmission. Due to mm-wave communication, the 5G wireless networking equipment can operate in the frequency range of 3 GHz to 300 GHz. Using these techniques, system capability can be considerably boosted, enabling greater mobile traffic to be accommodated. Due to newly developed techniques, traditional Channel State Information (CSI) estimation algorithms encounter a few obstacles in calculating CSI in the 5G wireless communication systems. Because the 5G wireless communication networks use massive MIMO, OFDM, and mm-wave communications, they have considerably more channels than existing cellular communication systems, complicating channel estimation. Communication networks use massive MIMO, OFDM, and mm-wave communications; they have considerably more channels than existing cellular communication systems, complicating channel estimation (Khudhair and Singh, 2020).

Wireless connectivity demand has become the most important factor to consider in any new wireless network, such as the 5G. This necessitates a 1000-time increase in the 5G network bandwidth over current (4G) cellular systems. This can be accomplished using a variety of Physical (PHY) layer enhancement techniques, as shown in Figure 2.2 (Chataut and Akl, 2020b).

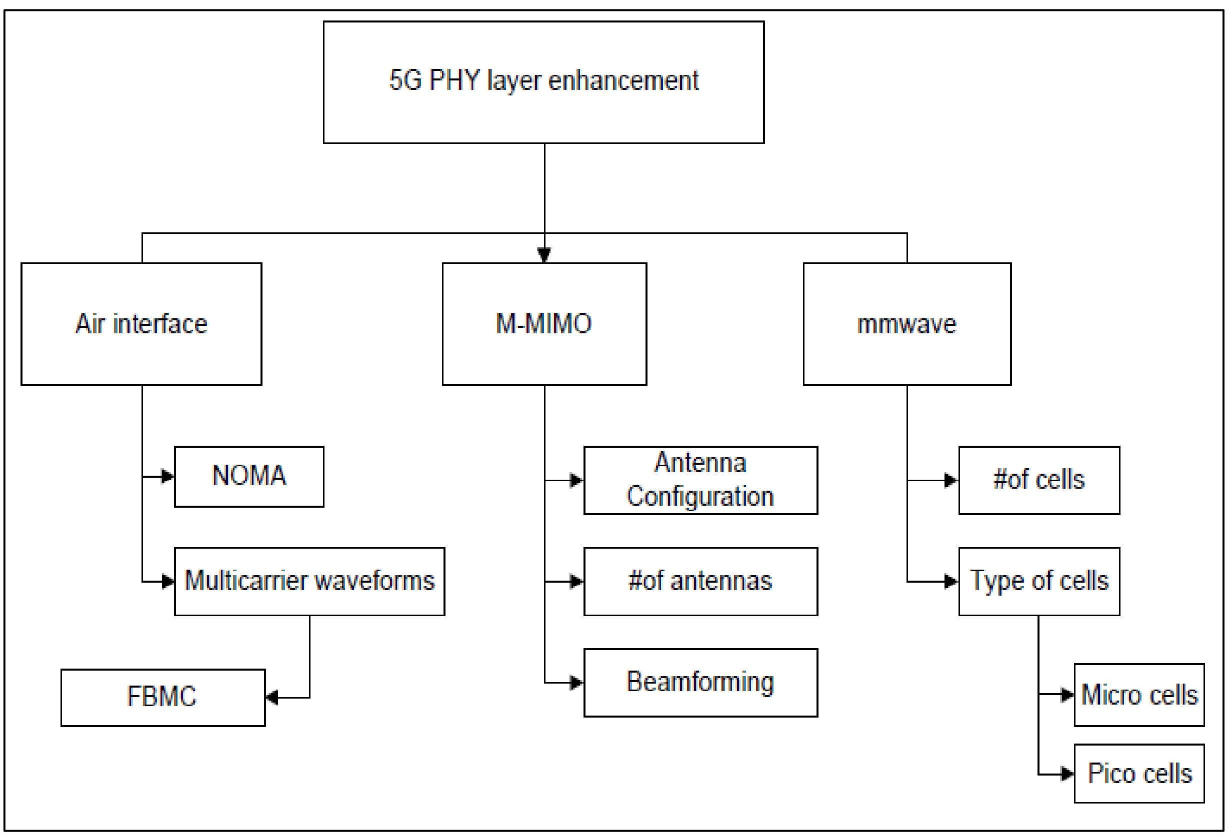

Figure 2.2: The 5G PHY Layer Enhancement Techniques Taxonomy (Chen et al., 2019)

These include modern air interface architecture used in fourth generation (4G) to address the disadvantages of Inter-Channel Interference (ICI), which is particularly problematic in high density and mobility networks. Filtered-OFDM and NOMA are the latest air interfaces used in the 5G to resolve the effect of Cyclic Prefix (CP) in OFDMA NOMA. The Filter Bank Multicarrier (FBMC) is a Filtered-OFDM type that is designed to eliminate the CP effect and is compatible with other techniques used to improve the 5G performance in the PHY layer, such as m-MIMO configuration and mm-Wave (Chen et al., 2019).

2.4 Multiple Access Techniques

The most common Orthogonal Multiple Access (OMA) is represented by three facilities: CDMA Division Multiple Access with Coding Domain, TDMA Division Multiple Access with Time Domain, and FDMA Division Multiple Access with Frequency Domain. Conventional OMA technique methods provide radio resources to numerous users; they are orthogonal to other users concerning time, frequency, or code domain. Ideally, OMA's orthogonal resource allocation would not cause any interference between users. In conventional OMA technique methods, the total number of orthogonal resources and their allocation complexity determine the maximum number of supported users (Krishnamoorthy et al., 2020).

Moreover, the demanding requirements of incoming cellular systems, such as spectrum with higher efficiency, massive connections with a higher range of quality of service (QoS), lower latency, and fairness of users, have not been achieved by OMA. Considering all of these needs, it is not unexpected that promising communication systems and new technologies are considered a problem. Whether a user has a strong or weak channel state, a specific frequency resource is allocated to them in Orthogonal Frequency Division Multiple access

OFDMA and OMA, which results in low throughput and spectral efficiency for the system (Msayer et al., 2023b, Al Khansa et al., 2023).

Meanwhile, several mobile users with various channel conditions are concurrently assigned the same frequency resource in NOMA. Consequently, the dominant user utilizes the resources assigned to the less powerful user and SIC processes at the users' receivers can mitigate interference. Thus, there will undoubtedly be a considerable boost in the probability of achieving higher throughput and better spectral efficiency (Omarov et al., 2021).

Multiple access techniques can be categorized into two main types OMA and NOMA as shown in Figure 2.3.

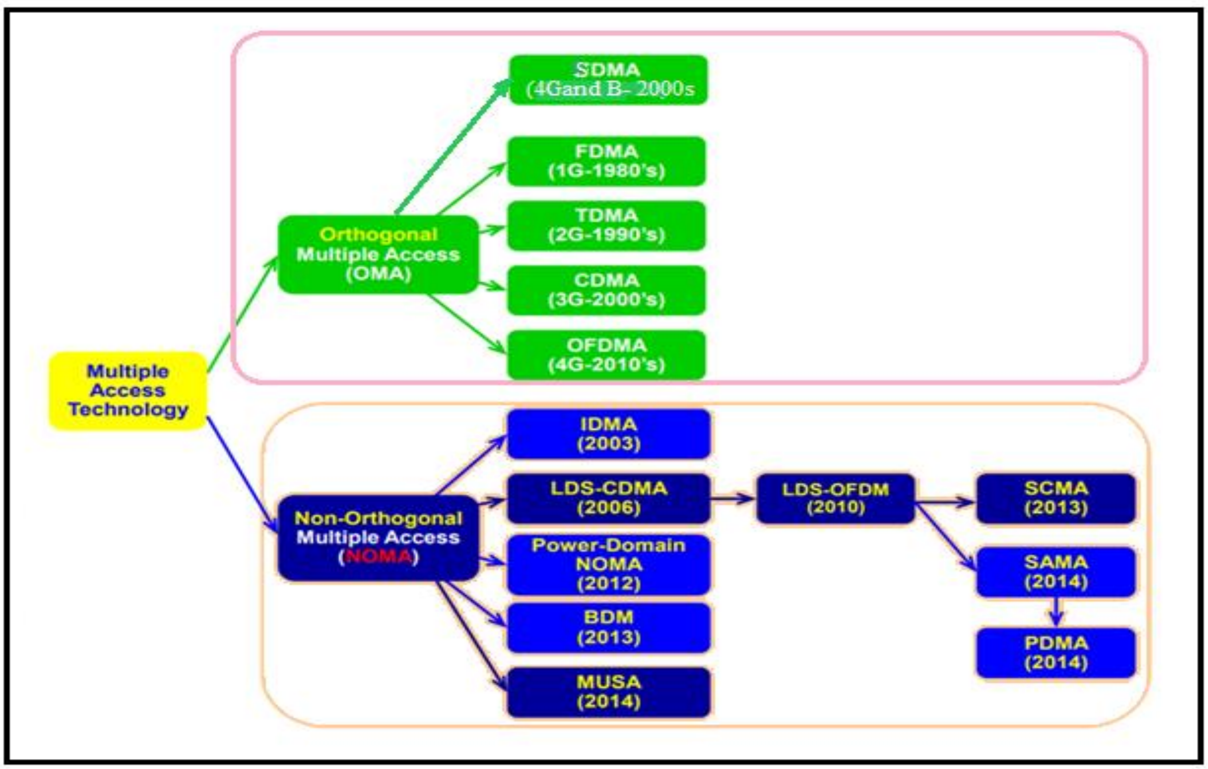

Figure 2.3: The Milestones Developments of Multiple Access (Dai et al., 2018)

Traditional OMA methods provide radio resources to many users that are orthogonal to each other in terms of time, frequency, or code domain. In an ideal scenario, the orthogonal resource allocation in OMA results in no interference between several users. Consequently, distinct user signals can be distinguished using straightforward single-user detection. It is known that OMA does not always reach the sum-rate capacity of multiuser wireless systems. Furthermore, in traditional OMA methods, the total amount and scheduling granularity of orthogonal resources set a maximum number of supported users (Dai et al., 2018).

The strict requirements of future communication systems, such as high spectrum efficiency, massive connections with a range of QoS, low latency, and user fairness, have not been met by OMA. It is not unexpected that new and promising communication systems view them as a challenge given all of these needs. Consequently, NOMA is introduced as a possible technology that might be applied to satisfy the new requirements. Regarding wireless communications networks, NOMA is a workable method for constructing New Radio (NR) access for the 5G and 6G networks. Figure 2.4 demonstrates how the power allocated to each user in the OMA and NOMA approaches differs (Adam and Science, 2023).

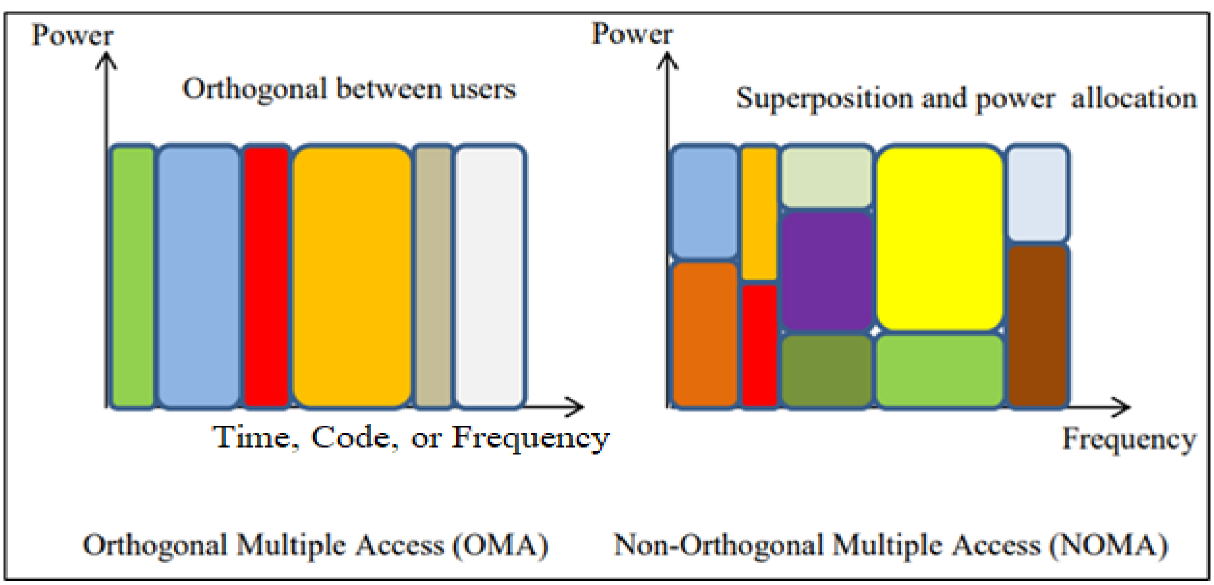

Figure 2.4: Resources Allocation of Multiple Access Approaches for OMA and NOMA (Adam and Science, 2023)

The NOMA technique is proposed for various communication mechanisms and applications within the area of communications. In this regard, it is recommended that NOMA participate in cooperative communications through relays using the buffering technique and that relays be chosen to achieve the best possible connectivity. Furthermore, the decode-and-forward relay is used to model and analyze the NOMA for a two-way, half-duplex (HD) relaying network. Furthermore, NOMA with m-MIMO relaying is proposed, demonstrating a notable throughput gain over traditional MIMO-OMA (Ghosh et al., 2022).

The NOMA technique has been suggested as an achievable method to increase wireless communication systems' radio coverage and reliability. For the 5G and 6G wireless networks to satisfy the diverse demands on low latency, high dependability, huge connection, enhanced fairness, and high throughput, NOMA is a crucial enabling technology. Serving numerous users in the same Resource Block (RB) as a time slot, subcarrier, or spreading code is the fundamental principle of NOMA. Several newly proposed the 5G multiple access techniques can be seen as specific examples within the broad framework of the NOMA principle. One of the fundamental enabling technologies for upcoming wireless communications generations is thought to be the innovative concept of NOMA (Ghosh et al., 2023).

NOMA is an upcoming technique for the 5G and beyond networks. NOMA technique has been recognized as one of the most promising the 5G techniques, due to its capability of massive connectivity and providing high Spectral Efficiency (SE). NOMA technique has the ability to serve larger number of users when compared to OMA. Table 2.2 shows a comparison for advantages and disadvantages between OMA and NOMA.

Table 2.2: A comparison for advantages and disadvantages between OMA and NOMA (YOUNIS, 2022a).

Technique	Advantages	Disadvantages
OMA	• In the receiver low complexity.	• It has a low spectral efficiency. • Supports fewer number of users (limited). • Not achieving justice.
NOMA	• Spectral efficiency is higher. • Provides a high connection density. • Achieve user fairness. • Latency transmission lower. • Higher QoS.	• In the receiver High complexity. • To channel uncertainty high sensitivity.

The two primary types of NOMA technique schemes are Code-Domain CD-NOMA and Power-Domain PD-NOMA. In PD-NOMA, several users share the same time-frequency-code resources, but are assigned varying power levels based on their channel quality. In order to differentiate amongst users based on SIC, power domain NOMA takes advantage of the users' power-difference at the receiver end. With the exception of favoring low-density or non-orthogonal sequences with low cross-correlation, CD-NOMA is comparable to CDMA or MC-CDMA (Alkhawatrah, 2023). Figure 2.5 shows the graphical representation of PD-NOMA, CD-NOMA, and traditional OMA-OFDM.

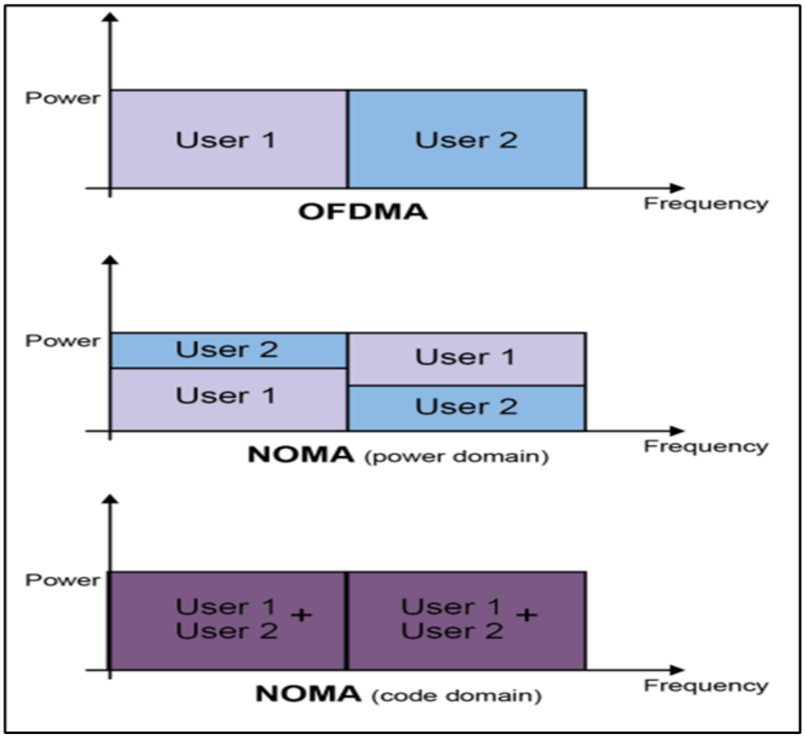

Figure 2.5: The Graphical Representation of Power-Domain NOMA, Code -Domain NOMA and Traditional OMA-OFDMA (Erpina and Gopireddy, 2021)

The power domain multiplexing technique and the code domain multiplexing technique are two of NOMA's primary standards. This separation domain often belongs to one of two techniques: power-based or code-based, which results in NOMA processes specific to the power domain or code domain, accordingly (Balasubramanya et al., 2018). Depending on their Channel Status Information (CSI), different users in the power domain NOMA are assigned varying power levels. successive interference cancellation SIC at the decoder is achievable by the difference in power levels and channel gains. NOMA utilizes SC to utilize the advantages of the power domain and SIC for multiuser identification. As a result, SIC is required on the destination receiver side. Different codes are assigned to various users within the source code domain, multiplexing NOMA to facilitate multiuser communications (Kumar et al., 2019).

Compared with traditional OMA, NOMA may provide more significant sum rates, reduced outage probabilities, and improved customer fairness (Aldababsa et al., 2018). Several reasons show the domination of NOMA over conventional OMA; these include:

i. NOMA achieves superior spectral efficiency.
ii. NOMA can support massive connectivity.
iii. The user experiences less latency because they do not have to wait for a scheduled time to transmit their information;
iv. NOMA can preserve the diverse quality of service (QoS) and user fairness.

To utilize all the benefits of NOMA, several restrictions and implementation concerns must be resolved, such as:

i. Every user with lower channel gains must decode the data of every other user.
ii. The subsequent decoding of all other users' information will likely be done incorrectly when a user's SIC error happens.
iii. In order to reap the purported advantages of power-domain multiplexing, a significant differential in channel gain between strong and weak users is necessary.
iv. Every user must provide the BS with information about their channel gain.

2.5 NOMA and C-NOMA in Fifth Generation the 5G Mobile Communication

NOMA is a practical approach in network wireless communication for creating New Radio (NR) access for the 5G mobile cell networks. NOMA can achieve excellent spectrum efficiency by combining the concept of SC, which is used on the transmitting side, with the SIC principle, which can be utilized on the receiving side. The NOMA system, an upcoming physical layer communication technique, has attracted much attention as a new method for boosting the vast number of users that can be serviced concurrently by arranging many users carrying on the same spectrum resource allocation but at various power allocation levels. The primary justification for implementing NOMA in the 5G is its capacity to accommodate numerous users concurrently while utilizing similar frequency and time resources (Hassan et al., 2023b).

The NOMA technique utilizes SIC, wherein the first nearby user decrypts another user's signal from a received signal that has been superposed coded before decoding his message from the signal. In particular, during SIC, the nearby user decrypts the information signal from the far user. However, the data of the weak user needs to be decoded by the nearby user (Kara and Kaya, 2018). To provide the weak user, the strong user may as well provide him with the information that the far user possesses. The nearby user will give the far user variance in retransmitting data since the far user's channel with the transmitting BS is weak. In other words, the same message will be sent to the far-away user two times. One message is from the BS, while the other is from a nearby user serving as a relay. As a result, we can anticipate a drop in the far user's outage probability (Wei, 2019). Furthermore, NOMA can be implemented using m-MIMO relaying, which significantly enhances throughput when compared to traditional MIMO-OMA. The two main types of NOMA technique schemes are the power and coded NOMA techniques. Several users share the same time-frequency code resources in the power domain NOMA but are assigned varying power levels based on their channel quality. The PD-NOMA technique uses SIC at the receiver side to identify different users using the power difference between users. Except for its inclination to use low-density or non-orthogonal sequences with limited coding, the coded

NOMA technique is comparable to Code Division Multiple Access (CDMA) or Multi-carrier (MC-CDMA). NOMA's fundamental idea is that numerous signals of different power allocation levels are connected on the transmitter side to create a superimposed signal (SS). The SIC, as seen in Figure 2.6, is employed on the receiving end to retrieve each user's signal from the SS to guarantee a weak user's QoS. By considering other signals as interference, the far-right user can specifically decrypt the strongest signal. SIC terminates if the decrypt signal is its data. If not, the next strongest signal will be deciphered by the receiver, subtracting the decrypted signal from SS (Ahmed et al., 2020).

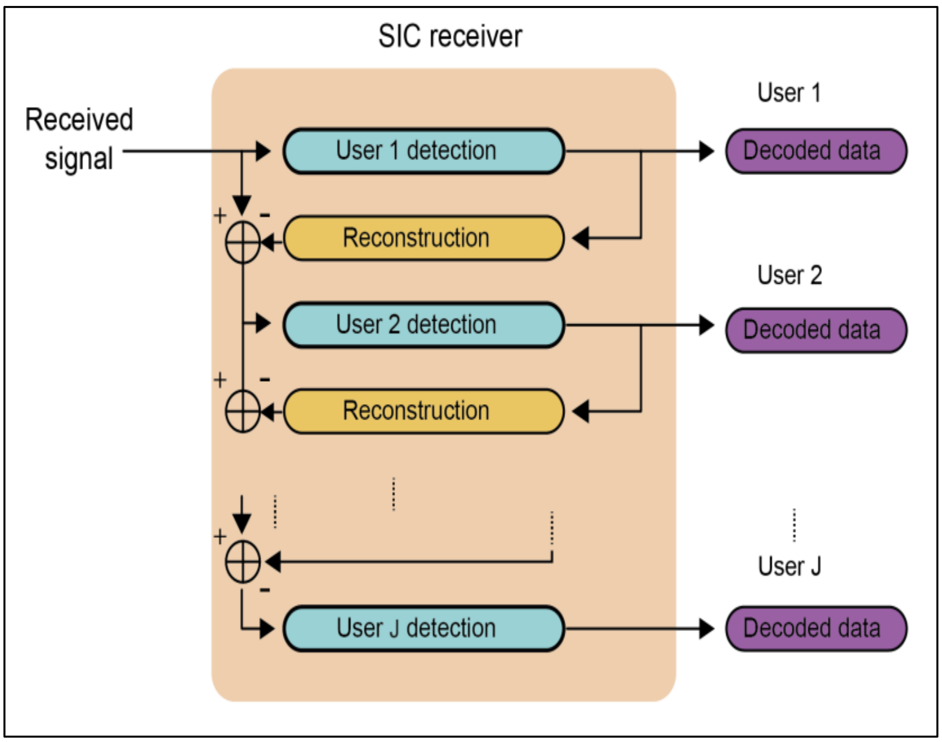

Figure 2.6: The Process Steps of The SIC Technique (Wei, 2019)

In the NOMA technique system, SIC is a crucial tool used at the receiver, enabling the detection and decoding of many users. In transmitter/receiver (Up link UL/ Down link DL detection), the SIC processor first decodes a prominent interference and subtracts it from the SS to retrieve each user-desired signal. The superposition of many signals with varying power levels is crucial to diversifying each user signal. Moreover, the SIC is performing at a specific UE end. Because in the DL, each UE gets the other user's signal (the required interference signal) across its channel. The following formula relation (2.1) will be used to determine the possible data rates (R) for each UE paired with NOMA (Sravya, 2021):

$$R_{NOMA} = B * \beta * \log_2\big(1 + (\alpha * SINR)\big) \quad (2.1)$$

where the portion of the total bandwidth waveform B occupied by the UE is represented by β, and the portion of the power resource allocated is represented by α. The data rates (R) for OMA in formula (2.2) in comparison to NOMA are calculated as follows (Sravya, 2021):

$$R_{OMA} = B * \beta * \log_2(1 + SINR) \quad (2.2)$$

Cooperative communications attracted more attention in wireless networks because it might provide spatial location variety to reduce fading and overcome the challenges of installing several directional on compact communications terminals. Multiple relay nodes are designated in a communications cooperative system to aid a source in forwarding information to the appropriate recipients. In wireless networks, a cooperative communication system is an efficient way of expanding coverage and offering location diversity. Reducing cell edge users' outage probability and raising their overall quality of service is the primary objective of implementing C-NOMA. As cooperative communications might reduce fading and solve the challenge of installing multiple antennas on small wireless connections, such as physical variety, it has been highly recommended for implementation during the deployment of the 5G and 6G (Khan, 2020).

Cooperative communications, when implemented with NOMA, can enhance and increase the coverage capacity and reliability of the system. The NOMA systems technique, along with earlier information, is utilized by the C-NOMA technique. By using the NOMA technique, users with greater network characteristics enable other users to decode the information messages. As a result, these users serve as relays to increase the dependability of users' reception for users with weaker connections to the BS (Msayer et al., 2023a).

The C-NOMA technique in the fifth generation is considered to maximize the potential of NOMA in multiuser environments where one of the users acts as the relay role for another user. The purpose of C-NOMA is to reduce this restriction by enabling weaker power users to transmit stronger power users' signals over wireless communication without any interference. The capacity to improve system performance, particularly efficiency and reliability are two major issues in wireless communication, is another important benefit of utilizing cooperative communications in NOMA (Ligwa et al., 2022).

With the introduction of the 6G mobile communication networks, wireless communication anticipates going through a paradigm shift that will require innovative solutions to meet the increasing demands for high throughput, low latency, and ubiquitous connection. C-NOMA is a cutting-edge technology in the 6G mobile communication networks that has the power to fundamentally alter how users share and utilize wireless resources. The purpose of this study is to understand C-NOMA's role in enhancing network performance and efficiency by examining its principles, opportunities, and limitations. C-NOMA utilizes the concept of users collaborating to share the same time-frequency resources, which leads to enhanced spectral efficiency and reliability over traditional orthogonal multiple access systems. C-NOMA enables cooperative resource optimization and aids users in mitigating the impact of fading channels and interference by dynamically adjusting transmit power levels and utilizing diversity improvements offered by cooperative transmission. For C-NOMA deployment in the 6G mobile networks, resource management, algorithmic optimization, infrastructure enhancement, and user-centered design are all necessary components of a diverse approach. The following are the main functions that are involved in implementing C-NOMA (Lam et al., 2023):

a) Base stations have been upgraded with cutting-edge antenna arrays and signal processing capabilities to enable cooperative communication between users, especially in places where propagation circumstances are difficult.

b) Backhaul optimization refers to improving to enable increased data interchange between base stations and relay nodes.

c) Effective power allocation algorithms for dynamic change in the transmit power levels with scheduling algorithms to control user and relay node transmission and reception operations to achieve cooperative diversity gains.

d) Channel condition prediction is needed to provide cooperative beamforming and precoding.

e) Dynamically allocated spectrum to accomplish interference reduction and spectral efficiency for resource management.

f) User satisfaction should take precedence over QoS measures like latency, throughput, and dependability in C-NOMA arrangements.

g) Coordinated NOMA transmission and reception will be possible with improved UE, making integration with both present and future devices easier.

h) Secure key exchange techniques to guard against surveillance and illegal access.

i) Privacy-preserving approaches to preserve user privacy in C-NOMA settings and guarantee regulatory compliance.

2.6 Caching Techniques

Caching technique is the process of storing data in a cache. A cache is a temporary storage place from which we can retrieve files rather than the original server, thus saving time and reducing network traffic. With the ever-increasing strain on the Internet and Web servers, caching has become increasingly important. The most suitable caching files are chosen based on user demand and mobility. The network's latency was used as efficiency metric. Thus, for caching schemes, optimization problems are formulated to mitigate cache prominence for non-cooperative and cooperative schemes. The greedy algorithm was able to solve the problem for each of the schemes. Vehicles have a variety of features that make them caching nodes, including a suitable power source, memory, versatility, and an On-board Processing Unit (OBU). Vehicle -to- Vehicle (V2V) is being pushed to explore the advantages of caching in vehicles. When the vehicles are still moving, they will relay information to each other (Zhang et al., 2021).

The caching hit ratio of Vehicular Content Networks (VCNs), which Vehicular ad-hoc Networks (VANET) used for streaming live video content, was also improved by caching in parked vehicles. Between two layers, cache-based versatility is also used. The vehicle demand profile and velocity in the highway network traffic model have been used to assess vehicle and RSU caching. Leading to packet delay and the increased likelihood of transmission collision, the output of Dedicated Short-Range Communications (DSRC) will be degraded as the number of vehicles attempting to transmit on the same channel at the same time grows. Visible Light Communication (VLC) equipment has recently seen a spike in low-cost hardware and installation (Ismail et al., 2021).

In the 5G and beyond, caching near users in a Radio Access Network (RAN) has been established as a successful solution to decrease backhaul traffic load and decrease latency (Nauman et al., 2024b). With mobile traffic increase, causes congestion in backhaul networks, resulting in higher operating and maintenance costs, reduced quality of service (QoS), and data transmission delays. Small-cell networks, which can achieve much higher throughput and energy consumption, will be widely deployed to meet the growing data demands.

Mobile Edge Networks (MENs), as (Kakar, 2021) maintains, is a solution to increasing demand for bandwidth, congestion of backhaul networks, higher operating and maintenance costs, lower QoS, demand for higher Quality of Experience (QoE), and performance problems, that illustrated in Figure 2.7.

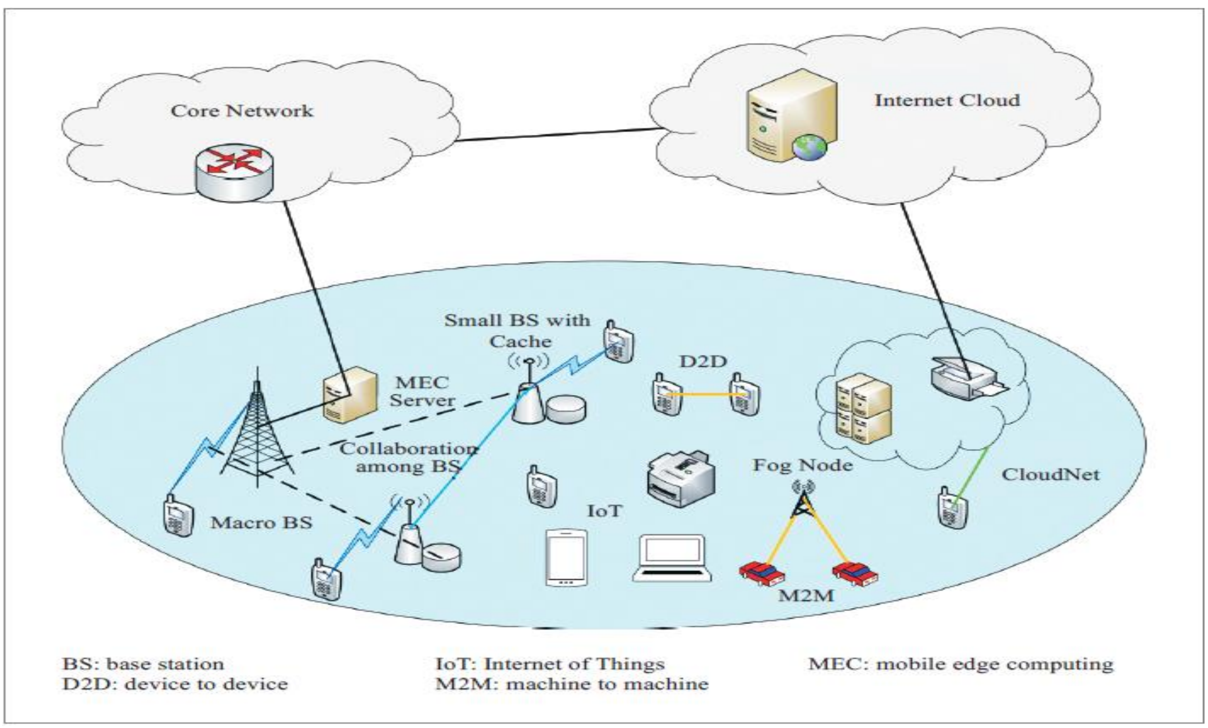

Figure 2.7: Mobile Edge Network Architecture (Kakar, 2021)

The demand for information sharing, entertainment, and multimedia rises in a vehicular communications climate, causing backhaul networks to become congested. Latency and resource constraints are the network's biggest problems. Local caches may provide proactive caching rather than remote servers, avoiding long delays caused by restricted backhaul capacity and resources (Anokye and SEID, 2019).

In the last decade, cellular networks have increased rapidly. The exponentially demands of end users for a high data rate are driving this development. To achieve a high data rate and spectral quality, a variety of techniques have been used. Through effectively controlling cellular spectrum, spectral efficiency can be achieved. Control Data Split Architecture (CDSA), Cloud Radio Access Network (CRAN), Ultra-dense Cellular Networks (UDCN), and Device-to-Device (D2D) networking are all examples of these techniques. Almost all of these innovations are thought to be enablers for the 5G cellular networks (Krishnamoorthy et al., 2020). Multi-tier architecture and D2D communication have been identified as key enablers for providing access to a large number of users as well as high data rate connectivity. An overlaid Macro-cell (MC) with multiple Micro-cells (μCs) operating in its coverage area is used in multi-tier architecture. Although MCs can provide local area services and high data rate access, μCs can provide overall coverage and mobility management. Caching in cellular networks, on the other hand, was implemented to take advantage of the storage space of a variety of network devices. These devices vary from the user to the network side User Equipment (UE), edge devices: μCs, MC and extended packet core (Saif, 2020).

The Millimeter Wave (mm-Wave) BSs that are cached do not always cover the entire area. Mobile users dynamically enter and depart the area covered by mm-Wave signals, as seen in Figure 2.8. When high-speed connection is available, a user will cache popular content that it may be interested in as much as feasible. At the mm-Wave wavelength, the 5G wireless networks have a greater bandwidth advantage. The user's requests may be partially served by the local cache after leaving the mm-Wave covered area. Without dense deployment of mm-Wave BSs, the cache-enabled hierarchical Radio Access Network RAN enhances the user's QoS. Caching allows mm-Wave BSs to sleep (Kumar, 2021).

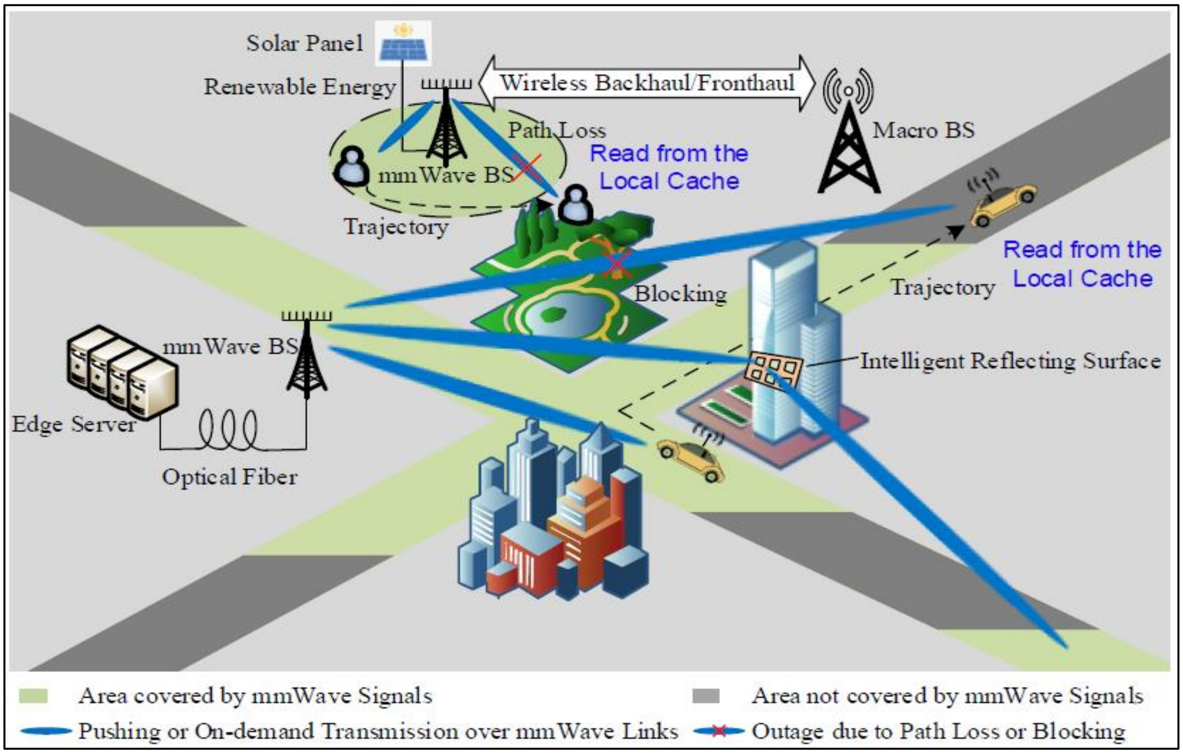

Figure 2.8: A Hierarchical RAN with Partial mm-Wave Coverage that Uses Caching to Lower the Density and Deployment Costs of mm-Wave BSs (Chen and Poor, 2021)

Caching reduces access latency and network congestion by taking use of the idea of keeping frequently requested content closer to users. Topology, popularity model, catalog, and cache size are four factors that have been retrieved and compared between caching strategies in various simulation scenarios of the most well-known caching strategies (Mehamel, 2020).

i. Topology: When evaluating caching techniques, there are different topologies to consider. These topologies range from simple k-ary trees to complicated ISP-level topologies, or a combination of these two.
ii. Popularity model: User demand and priority are indicated by popularity. As time passes, the priority shifts. The content popularity model is a function that determines how popular a piece of material is, or how frequently it will be requested. A probability distribution function, such as a distribution law (Zipf) or Mandelbrot (MZipf), is commonly used to model content popularity. Real traces have been used in other works.
iii. The catalog: is a representation of the complete network's content collection. As a result, the popularity model has a direct impact on the number of requests for a certain piece of material. For the catalog size, wide ranges of numbers were chosen.
iv. Cache size: The cache size controls how much space each Multi-access Edge Computing (MEC) server has to store web material temporarily. In relation to the catalog size, this size is commonly stated as an absolute value or as a ratio. The study looked at the impact of different item sizes on online caching performance and overhead, and found that being aware of the size and could be critical for cache efficiency.

As the result of studies;

i. Caching makes use of the idea of keeping frequently requested content closer to users in order to minimize network congestion and reduce access delay.

ii. Caching can significantly improve throughput and low latency in the 5G mobile communications.

iii. Caching improves backhauling load in wireless networks by caching popular repeatable information at intermediate nodes. The backhaul traffic load is reduced, and customer satisfaction is increased.

2.7 Related Works

In this dissertation, numerous studies have been utilized based on the works. To enhance the performance of the 5G and 6G mobile network communication over traditional communications, three combination techniques Non-Orthogonal Multiple Access (NOMA), Device-to-Device (D2D) communications, and wireless caching have been investigated in the related works. Thus, caching, Cooperative (C-NOMA), and massive-Multiple Input Multiple Output (m-MIMO) are the main techniques studied and compared with other related research studies.

2.7.1 OMA, NOMA, and D2D Techniques Related Works

Two novel approaches to improve the signal efficiency SIE of the DL PD-NOMA integrated with a Cooperative Cognitive Radio Network (CCRN) in a the 5G network were studied in (Hassan et al., 2023b). The approaches made use of Single-input and Single-output (SISO-MIMO) and massive (m-MIMO) in the same network and a single cell. According to their findings, increasing the number of users and utilizing m-MIMO, along with effective bandwidth shaping techniques, efficient channel coding techniques, and substantial multiple access techniques, are the key strategies for enhancing Spectral Efficiency (SE).

The paper (Sravya, 2021) proposed the performance of a communication system for two users in three phases: NOMA with cooperation, NOMA without cooperation, and OMA techniques. The project was analyzed and compared concerning various parameters over a channel. The author evaluated the improvements in communication concerning parameters like outage probability, achievable channel capacity, bit error rate, and sum rate. The author investigated that for an effective communication system, the outage probability should be less, the achievable capacity should be more, the bit error rate should be less, and the sum rate should be more.

In (YOUNIS, 2022b), the author used three scenarios: OMA technology, NOMA technology by using Genetic Algorithms GA, and NOMA technology by using Gray Wolf Optimization GWO. The author performed comparisons with and without neighboring cell interference. The author findings demonstrated that the proposed method—NOMA by employing GWO—is superior to the other two situations in terms of user fairness and sum rate.

The researcher in (Mehamel, 2020), suggested a method for choosing a relay to assist users experiencing poor service quality based on angle and coverage. Researcher implemented NOMA in a single-cell setting, using cooperative relays to transmit signals to users with weak connections. The researcher findings indicate that their proposed approach successfully addressed the issue of inadequate service quality, particularly when a relay is allocated reduced power and adaptive sectorization leads to subpar performance.

A two-phase cooperative communication system is proposed in (Lam et al., 2023). The authors used the NOMA technique to allocate radio resources and power for the relays. To derive the performance metrics of the Cell-Center User (CCU), Cell-Edge User (CEU), and the typical user, the mm-Wave properties, which are modelled by Nakagami-m, and the stretch path loss were used. Authors result demonstrated that this approach offers a substantially higher coverage probability and data rate performance compared to non-cooperative communication systems, while also reducing power consumption by as much as 16.7%.

The performance of Massive-MIMO and NOMA for both conventional and C-NOMA is explored in (Adam and Science, 2023). The authors explored the efficacy of DL and UL PD-NOMA in the 5G network. A QPSK model on selected frequency channels with diverse user characteristics has been used in the evaluation. The results show that MIMO-NOMA remarkably improve performance in term of BER and power required in transmission in the download transmission. Moreover, the average capacity rate has been increased with UL transmission. The results of performance enhancement have been carried out with and MIMO technology.

The authors in the paper (Karim et al., 2023) analyzed the outage probability and sum rate in the case of the DL dynamically ordered NOMA system. Their study maximized the sum rate by using Karush Kuhn Tucher's Technique (KKT). Researchers studied and simulated to confirm the expression obtained for outage probability and sum rate over Rayleigh channel fading. Also, they implemented a comparison between dynamic NOMA and fixed NOMA for sum rate. Their results showed that the sum rate was maximized using the KKT technique.

The idea of splitting power into two portions, intra-sub bands and inter-sub bands, is proposed in (Basheri et al., 2022b) as a useful algorithm. Authors solved such optimization problems; they used proportional fair scheduling and water-filling algorithms and they modeled error propagation and analyzed for the residual interference. They proposed technique effectively increased the system throughput and performance under various operating settings according to simulation findings.

For the sum-rate maximization problem in DL multi-cell non-orthogonal multiple access NOMA systems, a globally optimal combined SIC ordering and JSPA algorithm was proposed in (Rezvani et al., 2021). Researchers addressed the problem of optimal joint SIC ordering and power allocation in multi-cell NOMA systems to achieve the maximum users sum-rate. For the given total power consumption of BSs, we obtained the optimal powers in closed form.

In (Sim et al., 2020b), the power-domain NOMA system's ability to disperse signals through power allocation in accordance with Channel State Information (CSI) is examined. The authors looked into a SIC scheme for NOMA communication systems that was based on deep learning.

For NOMA systems to provide green communication and improve system performance overall, power allocation and efficient user clustering are critical. Based on the examination of DL NOMA system features, researchers in (Chen et al., 2021) developed a rapid user clustering technique by presenting the energy efficiency maximization problem of DL NOMA systems as an optimization problem with numerous restrictions.

A framework based on the idea of power allocation between users by using NOMA technology, as well as depending on the idea of cooperation and boosting energy using one of the green energy methods, was proposed in (Msayer et al., 2023a) to increase the area of the spectrum while increasing energy efficiency. They used the outage probability and the possible data rates to analyze the system performance.

In the paper (Elhattab, 2022), NOMA is considered by authors to be one of the essential enabling multiple access techniques for the next six-generation 6G networks because of its capacity to accommodate a large number of connected devices and improve network spectral efficiency. The fundamental difficult issues of integrating NOMA with other B5G/6G enabling technologies in upcoming wireless networks were tackled to maximize the number of linked devices and achieve high spectrum efficiency and energy-efficient communications.

Various aspects of the 6G wireless networks with different perspectives covered in (Seetharaman et al., 2021). In order to set the standard for the upcoming generation of communication systems, they presented a vision for B5G/6G communications, the 6G network design, Key Performance Indicator (KPI) criteria, important enabling technologies, their use-cases, and network dimensions. The authors discussed how these possible technologies could fulfill the systems' KPI needs. Next, they discussed the prospects and research obstacles related to next-generation communication network commercialization, including hardware complexity, variable radio resource allocation, preemptive scheduling, power efficiency, coexistence of multiple Radio Access Technologies (RATs), and issues with security, privacy, and trust issues for these technologies.

Researchers in (Liang et al., 2020b) offered a thorough analysis of current developments and emerging patterns. They clarified that the 6G, which has more technological needs than the 5G, will allow for faster and more connectivity, to the point where it will be impossible to distinguish between the real world and the virtual world.

The paper (Jain et al., 2022) investigated the performance of NOMA and OMA techniques in a unique cell environment, where the cellular users are dispersed randomly, and cooperative relays are taken into consideration for improved system reliability. The researchers deliberated over a realistic situation in which the battery power levels of each relay device are not constant throughout. Based on the three KPIs of sum rate, fairness, and energy efficiency, the authors compared the effectiveness of OMA and NOMA plans. After investigating the fairness aspect and evaluating how well the two schemes performed in three different deployment scenarios urban, suburban, and rural, they evaluated how equitable the distribution of resources is to all users of the system. The dominance of the NOMA scheme over the OMA scheme was demonstrated through numerical data.

In (Hassan et al., 2023a), researcher presented new issues for the 6G networks. Researcher said that NOMA is one of the most efficient ways to boost the SE of a 6G network. they improved that the most promising contemporary technologies, such as multiple access, can be used to improve SE of the DL PD-NOMA.

Authers in (Saleh et al., 2023) proposed Backhaul and access links with sub-6 GHz and mm-Wave bands, respectively. The researcher considered two radio links with different frequency bands for BS serving users via DF cooperative relays. Authers evaluated achievable throughput, error and outage probabilities in their system. They utilized outage probability, achievable throughput, and bit error rate performance metrics to evaluate the system's performance. This will Significantly assist in selecting the required number of receiving antennas for a particular transmit power rating they found.

In the paper (Jain et al., 2023), authors proposed a novel efficient clustering technique and Massive MIMO NOMA double mode model scheme to increase the average sum rate, average energy efficiency the cell edge user's energy efficiency and reduce battery expenditure. The researchers showed that m-MIMO NOMA m-MIMO NOMA double mode model optimizes the system's energy and paves the way for a green wireless communication network. They also showed a comprehensive numerical improvement result in their proposed system for average sum rate and average energy efficiency as compared with conventional system. Table 2.3 shows the summary of related works regarding NOMA, D2D communications for proposed model, technique studied, algorithm and method adopted, challenges and problems, and the results obtained.

Table 2.3: Summary of related works regarding OMA, NOMA, and D2D communications.

Ref.	Problem	Proposal	Techniques Studied	Method Adopted	Finding
(YOUNIS , 2022b)	OMA inability to provide massive connectivity Power allocation fairness.	The centre cell and six other cells that are encircled in a circle	(PD-NOMA) technique	GA and Grey Wolf optimization algorithm.	High total rate. Better user sum rate and fairness.
(Msayer et al., 2023b)	5G higher energy consumption, higher operational costs, and an effort to prolong smart device battery life.	At the transmitter, NOMA SC is used, while at the receiver (SIC) is used.	Evaluate the data rates for the three users who are separated by a barrier.	Data is deciphered using an iterative algorithm with a decreasing power with cooperative concept to increase energy.	Allow all users to function without interruption, boosting the proposed system's throughput, spectrum efficiency, and overall reliability for all users.
(Basheri et al., 2022b)	Power allocation problem in NOMA DL systems	Error free and error propagation models	Iterative water-filling technique	Splitting power, Intra sub-bands & inter-sub-bands	Error-free propagation model performs approximately 3.3%, 5.4%, 9.2%, and 10.8% better. Error propagation model performance is enhanced by

					around 0.3%, 0.5%, 2.1%, and 3.2%.
(Rezvani et al., 2021)	Ideal cooperative SIC arrangement and power distribution in multiple-cell NOMA networks	Globally optimal joint SIC ordering and power allocation (JSPA)	Power usage of base stations (BSs) and the closed-form representation of the ideal powers attained for each cell	Analysis of base station (BS) power consumption to determine the globally optimal joint SIC ordering and JSPA.	Maximum users sum-rate obtained in closed form. Fixed-rate-region power allocation (FRPA) leads to a very high outage when the number of multiplexed users increases. Fully distributed framework has a poor performance.
(Chen et al., 2021)	Multiple transmission simultaneously consumes more energy.	Inter-cluster dynamic programming model	Efficient user clustering strategy and power allocation design of DL NOMA systems.	Inter-cluster dynamic programming algorithm	Improvement in energy efficiency. PA-NOMA systems have a significantly higher energy efficiency.
(Sim et al., 2020a)	The inaccuracies that arise from repeating the signal cancellation by the SIC system.	SIC scheme-based convolutional neural network (CNN)	a CNN-based SIC method as a possible NOMA detection scheme technique.	CNN-based SIC method.	The CNN-based SIC approach can effectively improve detection performance and relieve the limitations of the conventional SIC.

2.7.2 Caching Technique Related Works

The other related works studied are those related to caching and how can be integrated with NOMA and m-MIMO in the 5G and 6G mobile communication system networks.

NOMA schemes, in contrast to OMA, can serve a pool of users without utilizing the limited frequency or time domain resources, thereby meeting the 6G network requirements, which include low latency, massive connectivity, users' fairness, and high spectral efficiency. However, content caching limits the transmission of duplicate data by pre-archiving popular contents at the network edge, hence decreasing the 6G data traffic (Bepari et al., 2022). Authors concentrated on cache-assisted NOMA-based wireless networks, which can benefit from both cache and NOMA; by moving from OMA to NOMA, cache-assisted networks can push more files to content servers concurrently and increase the likelihood of a cache hit. The basic ideas, guiding principles, and main difficulties related to the caching and NOMA approaches were described by researchers. The purposes and objectives of cache-assisted NOMA-based wireless networks and flexibly combined cache with NOMA have been well demonstrated.

In (Shen, 2023), the author created and assessed four novel system models that combine NOMA, D2D communications, and wireless caching. The total delivery time, according to academics, is a useful metric for assessing the level of expertise and the deductions made in order to solve the optimization problem. In order to illustrate key performance metrics such as delivery times and sum rate, scientist devoted resources to model optimization, which was subsequently tested using numerical simulations. The author claimed that the total delivery time is shortened when all files are delivered simultaneously.

A novel approach for context-aware caching at the edge in the 5G networks is proposed by the authors in (Islam, 2019). The suggested innovation is a context-aware caching technique for the 5G networks that is based on collaborative filtering. The fundamental concept involves calculating a popularity matrix that includes ratings for users, items, and context. The author suggested that the caching decisions can then be made with the help of the computed popularity matrix.

In (Mahmood, 2018), authors investigates that one crucial component of the cellular networks of the future will be content caching. Furthermore, users can get content with a lower latency on a network that has caching capabilities, which lowers the amount of traffic traveling over the network backhaul. Authers compared their method against two popular edge approaches: pure popularity-based caching (POP), which is popularity-based, and net Predict, which is mobility-aware caching. Researchers assessed their method using real-world mobility datasets. Authers compared to net Predict and POP, respectively, they obtained that RoadsIde CacHe (RICH) edge caching technique offers improvements in content availability of up to 33% and 190%. Simultaneously, there is a ratio of 57% to 70% reduction in the backhaul penalty bandwidth.

According to research in (Liu et al., 2016), caching at the wireless edge is a viable strategy for increasing spectral efficiency and lowering energy usage in wireless networks and When compared to caching at the wired edge, caching at the wireless edge can significantly improve the Spectral Efficiency (SE) and Energy Efficiency (EE) of wireless networks connection. The two features of caching systems—content delivery and placement—were covered by researchers. The main distinctions between wired and wireless caching are explained by researchers, along with the system variations that result from caching occurring at base stations or on the wireless devices themselves.

Information-centric networking ICN was put up by researcher in (Zhang, 2019) as one of the emerging next-generation Internet paradigms to address the issues given by the Internet of Things' exceptional growth and the wireless networks' rapid development. This study focuses on developing in-network caching strategies from both a theoretical and practical standpoint for various networks, such as pure ICN networks, ICN-5G networks, and ICN-IoT networks. This study discusses caching strategies that are both proactive and reactive. Furthermore, network caching efficiency can be greatly increased by utilizing the ideas of software defined networking (SDN).

In the paper (Ahmad et al., 2020), the authors explored how to maximize Cache Hit Ratio (CHR) and User Satisfaction Ratio (USR) in a multi-tiered cellular network. For multi-tier cellular networks, researchers create a CHR and USR problem while placing significant restrictions on the cache space of the BSs in each tier. For the purpose of grouping related BSs in each tier and measuring the popularity of the content, unsupervised learning methods like K- mean clustering and collaborative filtering have been employed in this research. Authers maximize the CHR in each tier, a unique approach called the Cluster Average Popularity Based Collaborative Filtering (CAP-CF) algorithm is utilized to cache popular material. Furthermore, they have used two cutting-edge techniques to maximize the USR: Intra-tier and Cross-tier Cooperation (ITCTC) and modified ITCTC algorithms. The simulation results in the research attest that in comparison to other traditional methods, the proposed approaches produce significant enhancements in average CHR and USR.

A comprehensive overview of the function of mm-Wave and Unmanned Aerial Vehicle (UAVs) using cooperative caching in vehicular networks in the 5G with a focus on current advancements and difficulties can be found in (Khan et al., 2021). Researchers concentrating on UAV relay topologies identify relevant problems and constraints in the simultaneous deployment of UAVs employing mm-Wave in both access and backhaul networks. The study focused on privacy and security concerns in UAV-based cellular networks. The research findings hold great significance for scholars, application engineers, and decision-makers involved in the development and implementation of the 5G networks backed by UAV.

Authers In the paper (Shahraki et al., 2021) studied the 6G as the next communication paradigm for IoT. Researchers first discussed the need for the 6G networks and introduced the potential the 6G requirements and trends, as well as the latest research activities related to the 6G like Tactile Internet and Terahertz THz. Furthermore, the key performance indicators, applications, new services, and the potential key enabling technologies for the 6G networks they have presented. Finally, the paper presented several potential unresolved challenges for future the 6G networks.

A summary of caching type, algorithms and techniques used to improve the performance of the 5G and 6G mobile communication network system with the help of caching and how can be integrated with NOMA and m-MIMO is as shown in Table 2.4.

Table 2.4: Summary algorithms and techniques used to improve the performance of the 5G and 6G with the help of caching.

Ref.	Caching Type	Algorithms/Techniques	Finding
(Bepari et al., 2022)	Cooperative Caching	QoI-based decision algorithm	Decreased transmission costs with improved precision.
(Shen, 2023)	Wireless edge caching	Wireless caching; D2D communications; and NOMA.	Improve throughput and sum rate, and shorten delivery timeframes.
(Islam, 2019)	Edge Caching	Cache frequently accessed contents at the edge of the network. (C-RAN), CLNC, CBS offloading and users' (QoS)-guarantee trade-off for fog-RAN system.	Prevent the load on the backhaul network optimize different metrics, such as throughput, CBS offloading, and completion time.
(Mahmood, 2018)	Content caching. smart proactive caching strategies.	RICH (RoadsIde CacHe). Named Data Networking (NDN). (RICH prefetching algorithm).	An enhancement of up to 33% and 190% when compared with net Predict and POP respectively. The backhaul penalty bandwidth is reduced.
(Liu et al., 2016)	Caching at the wireless edge	User preferences and popularity distributions.	The gain comes from saving bandwidth and energy.
(Zhang, 2019)	Reactive and proactive caching approaches	NMF technique. SDN technique. ALS technique.	Network caching efficiency can be greatly increased by utilizing the ideas of software defined networking (SDN).
(Ahmad et al., 2020)	Proactive Caching	K-mean clustering and collaborative filtering. CAP-CF algorithm with sub-optimal caching policy. CC-GA and B,N,P-Caching.	Maximizing the cache hit ratio (CHR) and user satisfaction ratio. Enhance the network capability to improve the (QoE) Significant performance gain when compared to the baseline reactive. More efficient than the noncooperative scheme. Significant reduction in backhaul traffic load and

			increase the user satisfaction rate.
(Khan et al., 2021)	C-Caching	Cooperative Caching in Vehicular Networks. QoI-based decision algorithm	Reduce transmission costs while improving accuracy.
(Shahraki et al., 2021)	Content caching closer to the end user.	Employing semantic inference by mobile edge computing,	Significantly reduce the end-to-end latency in 5G networks, intelligently anticipate future user requests and prefetch the items that are needed.

2.8 Critical Review Analysis

It is clear from the previous studies, related to OMA, NOMA, D2D communications, that OMA suffers from poor data rates and signal quality. Moreover, NOMA can fix this problem by employing suitable power allocation. Thus, NOMA is worth investigating and will be an excellent candidate for achieving the researches objectives. Using the same band of frequency simultaneously for numerous users in the cell and some form of corporative communication, such as D2D NOMA, can be extremely helpful in achieving massive connections. Moreover, using a power allocation approach in transmissions between the BS and the MS in the UL and DL phases, user fairness, secure connectivity, and spectral efficiency can all be satisfied by NOMA.

It is clear from the previous studies that C-NOMA with caching has shown promise in resource sharing, minimize latency, and increase throughput in the 6G networks. While there are many benefits of C-NOMA with caching, their effectiveness needs to be further investigated and evaluated in conjunction with other state-of-the-art techniques in order to fully solve the complex issues that the 6G networks confront. Dynamic resource allocation among users and relay nodes have not been investigated to see the its impact sum rate, latency reduction, and throughput increase in the 6G mobile communication networks. Furthermore, the impact of file size, number of users, number of stations, traffic levels and PA on the sum rate, throughput and average latency reduction needs also to be investigated.

2.9 Summary

In this chapter, two main topics have been represented and explained, a background theorem and a brief related works. Firstly, a detailed background theorem has been represented for techniques MA, OMA, OFDMA, NOMA, C-NOMA, MIMO, m-MIMO, caching, and the 5G and 6G mobile network communications. Secondly, a literature review has been represented for related works for techniques above for proposed model, techniques, algorithms, methods, caching types, and results are researchers fined for the 5G and 6G mobile communication networks systems.

CHAPTER THREE

3 METHODOLOGIES

3.1 Introduction

This chapter represents all the methodologies about how to enhance the performance of the 5G and 6G mobile communication networks systems. The methodologies firstly include Cooperative non-Orthogonal Multiple Access (C-NOMA) with caching, Power Allocation Non-Orthogonal Multiple access (PA-NOMA) with caching techniques for enhance the performance of the 5G mobile communication network systems. Secondly, Cooperative non-Orthogonal Multiple Access (C-NOMA) with caching techniques for enhance the performance and efficiency of the 6G mobile communication network systems. Novelty algorithm proposed for the process of a High-level overview of the C-NOMA SIC algorithm for the 5G. The block diagram for proposed PA-NOMA algorithm for basic steps of PA-NOMA are presented for the 5G. The C-NOMA with caching algorithm is proposed for 6G. The C-NOMA Massive MIMO with caching algorithm is proposed for 6G.

3.2 Cooperative Non-Orthogonal Multiple Access (C-NOMA) Technique

A Cooperative non-Orthogonal Multiple Access (C-NOMA) transmission technique is proposed to utilize previous information that is accessible in NOMA systems. Users collaborate to enhance and improve the systems through performance and Power Domain (PD) multiplexing, similar to NOMA, but with user cooperation. If the power allocated to user *i* is represented by P_i and channel gain for user *i* is represented by h_i, the received signal y_i can be stated as in the formula (3.1) (Himeur et al., 2023):

$$y_{i=}\sqrt{P_i \cdot h_i} \cdot x_i + n_i \tag{3.1}$$

where x_i is the transmitted signal by the user i and n_i is represents the Additive White Gaussian Noise (AWGN) at the receiver side for the user i. The optimization involves power allocation based on channel conditions. If P_{ij} is denoted the power allocation on the subcarrier j for user i, and h_{ij} is the channel gain on the subcarrier j for user i, the received signal for the user y_{ij} for traditional OMA can be expressed as in the formula (3.2):

$$y_{ij=}\sqrt{P_{ij} \cdot h_{ij}} \cdot x_{ij} + n_{ij} \tag{3.2}$$

where x_{ij} is the transmitted signal by user i on the subcarrier j, and n_{ij} is AWGN on the subcarrier j for user i. The power allocation in this system is done across subcarriers to optimize system performance.

User collaboration in Cooperative (C-NOMA) is active among users, such as relaying signals or sharing decoding information to improve reliability. While in traditional NOMA and OMA, users do not typically collaborate, each user is treated independently based on their channel conditions. Furthermore, in C-NOMA, users collaborate to mitigate interference, particularly for users with poorer channel conditions. While in traditional NOMA, interference is managed through power-domain multiplexing; users do not actively collaborate to reduce interference. With the above C-NOMA collaboration, the spectral efficiency and reliability aim to improve and provide higher system throughput. The capacity of users in C-NOMA will be enhanced through non-orthogonal resource allocation and user collaboration. Users with superior communication conditions, in particular, need to decrypt the messages of other users due to the usage of Successive Interference Cancelation (SIC) techniques at the receivers typically ranges from tens of microseconds to a few milliseconds per decoding layer. As a result, users with strong signals are employed as relays to increase reception reliability for users with weak signal base station connections. This C-NOMA can maximize diversity gain for all users by achieving the desired outage probability and signal diversity sequence. The system complexity required to coordinate collaboration among users might render it impractical to invite every user in the network to participate in Cooperative (C-NOMA).

One promising way to reduce system complications is by adopting user pairing. As illustrated in Figure 3.1, the proposed cooperative communication uses one or more relays to increase the signal strength between the source and destination. Relays use two separate frames, with direct phase transmission occurring in the first frame and relays using the second frame to forward information to the final destinations.

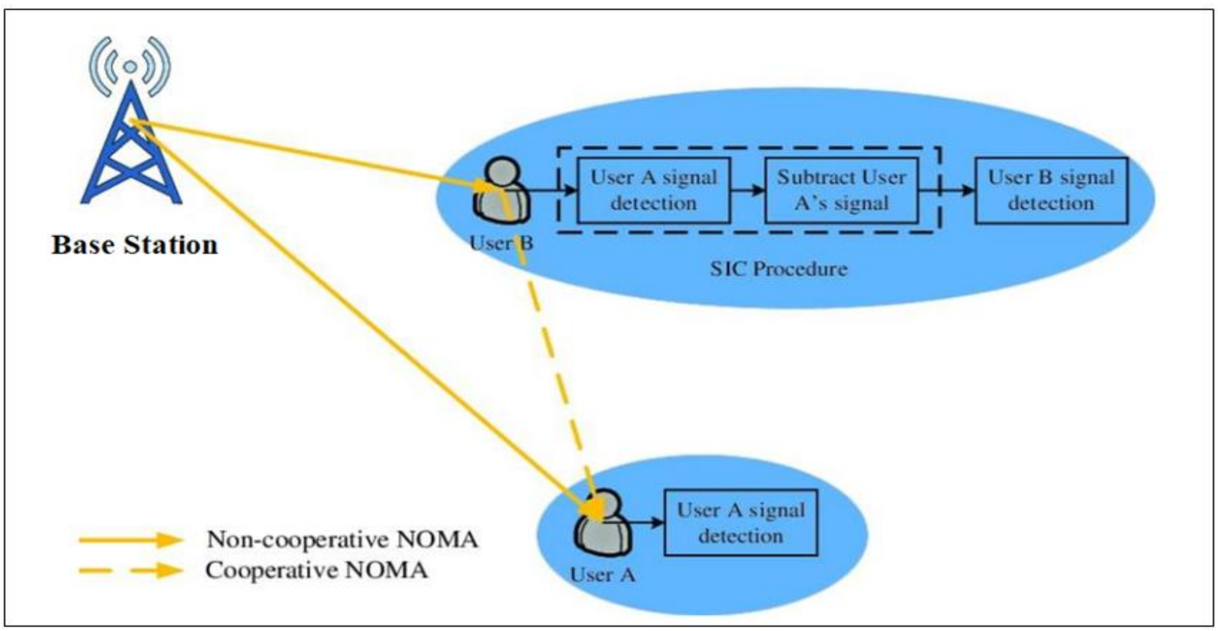

Figure 3.1: C-NOMA and Non-C-NOMA Communication

In the proposed cooperative communication systems, Amplifier and Forwarding (AF) and Decode and Forwarding (DF) are two forwarding protocols that relay use to send the received information signals to the appropriate destinations. Furthermore, based on the relaying operation, relays during the past ten years can be broadly divided into Half-duplex (HD) and Full-duplex (FD). In contrast to HD, an FD relay keeps data transmission and reception rates and frequency simultaneously. Therefore, the FD relay achieves a higher spectral efficiency relative to its HD counterpart. Figure 3.1 illustrates how with traditional NOMA, fewer power users indicate persistent interference. The SIC cannot cancel interference when the reference user exhibits higher power. Cooperative NOMA can be used to get around this restriction. By enabling lower-power users to relay higher-power users' signals over the air without interference, cooperative NOMA aims to mitigate this restriction. Higher-power users can mix the relayed signal with the base station's received signal, utilising any algorithm (Kumar, 2023).

As in traditional NOMA, user A uses the SIC to remove user B's signal from the total received signal before user A is identified. This supposes that user B is the reference (higher power level user) and that user A is an interfering user (lower power level user). According to C-NOMA, users that interfere (user A) transmit the signals that the SIC (user B) detects across the airspace. This enables user B, who has a higher received power level, to receive multiple copies of its signal. The signal relayed by the interfering participant, User A, may not be disrupted by interference from lower-power users. Meanwhile, the signal received directly from the source might still experience interference from lower-power users, which cannot be mitigated through SIC. According to the description above, user A's signal is presumed to be lower power. Once recognized, it can be regenerated and cancelled from user B's total signal before being relayed since adding an extra iteration is required. Afterwards, user B's (higher power user) signal can be transmitted across the air. At the data symbol level b^, the many copies of user B's signals can be joined using any combining technique.

The C-NOMA that is being proposed includes diversity-exploiting techniques to cancel out interfering signals linked to each user. Cooperative NOMA considers that the lower-power users are expected to retransmit the symbols their higher-power users' SIC have identified (usually by decoding and forwarding). Because lower power users transmit an interference-free replication of the identical signals that are also received directly from the base station (assuming that Down Link DL), higher power users exploit these extra signals to exploit diversity. The performance is enhanced by combining these signals. The proposed approach combines the ideas of simultaneous usage of time-frequency resources, in which numerous users share them, with simultaneous decoding and subtraction of interference from received signals SIC. The C-NOMA with the SIC algorithm's high-level overview process is depicted in Figure 3.2.

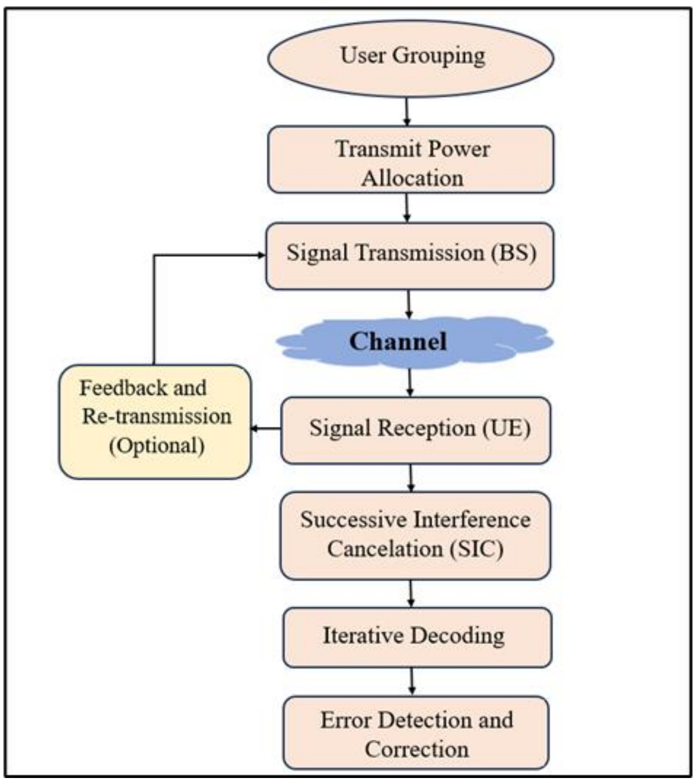

Figure 3.2: The Block Diagram for Proposed Process of a High-level Overview of the C-NOMA SIC Algorithm

The users in a group receive superposed signals from the base station. These signals are encoded in a way that enables simultaneous transmission. Each user in the group receives the superposed signal, which contains multiple users' information. Users performed SIC to decode the strongest signal in the received superposition. They first decode the waveform with the highest level of power (strongest) and subtract that from the received signal. If there are more signals in the superposition, users iterate through the SIC process to decode and subtract interference until all signals are decoded. After interference cancellation, each user performs error detection and correction to recover the original information. Users may send feedback to the base station indicating successful or unsuccessful decoding depending on the system design. The base station can then decide whether to retransmit the information. The Flow Chart for Process of a High-level Overview of the C-NOMA SIC Algorithm shows in Figure 3.3.

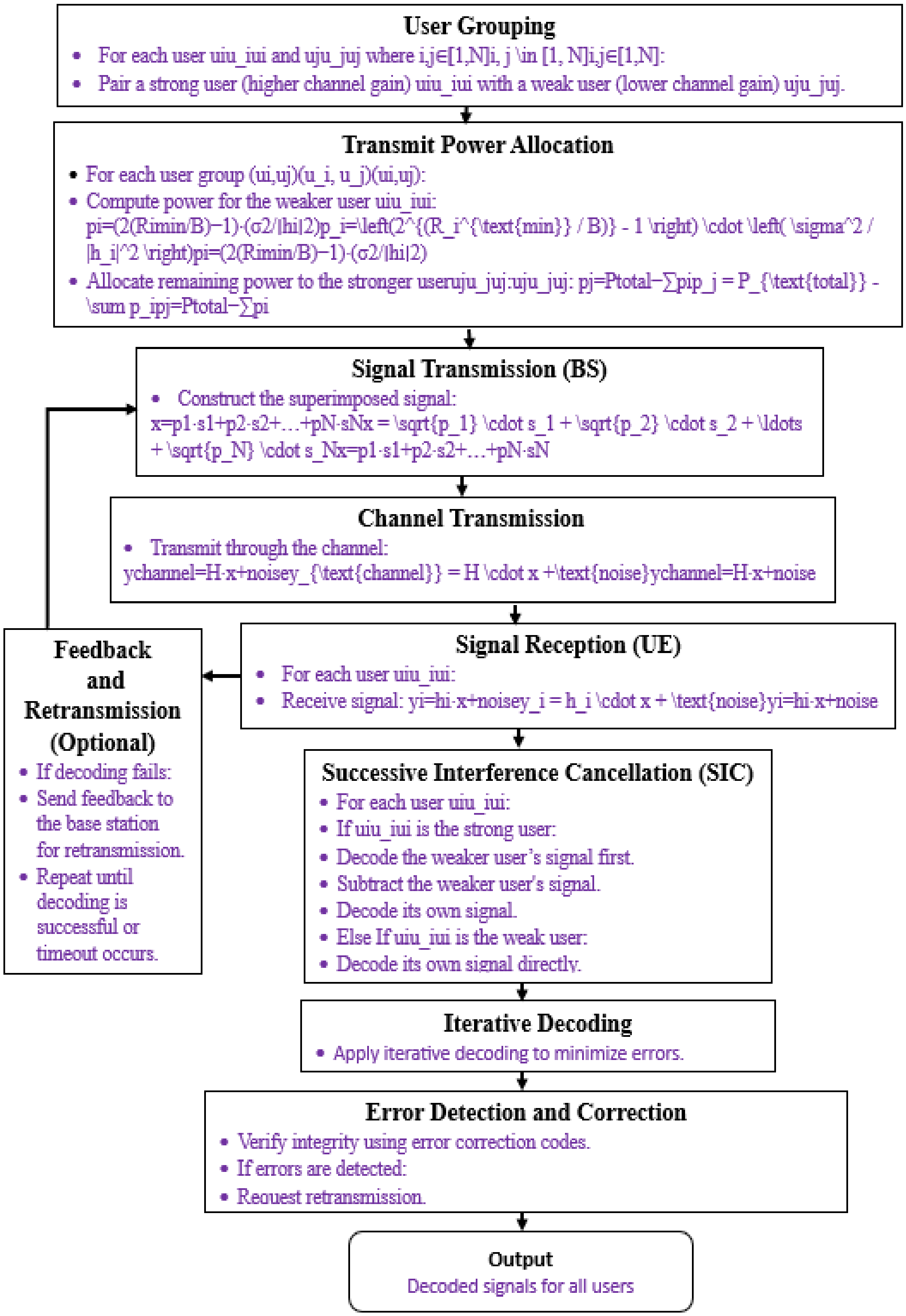

Figure 3.3: The Flow Chart for Process of a High-level Overview of the C-NOMA SIC Algorithm

Permitting several users to share a single resource can significantly improve the efficiency of the spectrum and increase the number of served users compared to traditional orthogonal multiple access schemes. However, advanced signal processing techniques and careful power allocation are required for optimal performance. Further, by using SIC techniques in NOMA, the strong user has already deciphered the message from the weak user; hence, it makes sense to consider using the DF protocol for weak signals. It is possible to explicitly re-modulate and retransmit the weak signal from a location closer to the intended recipient. A beneficial feature of C-NOMA is a notable improvement in weak user reliability. This leads to an improvement in the fairness of NOMA transmission, especially in the cases where the BS illustrates the weak user as being at the cell's border. NOMA is an efficient method of mitigating multipath fading because it can increase diversity gain for the poor NOMA user.

3.3 Power Allocation Non-Orthogonal Multiple Access (PA-NOMA) System Model

Power allocation is a key component of Non-Orthogonal Multiple Access (NOMA) for the 5G communication systems, which optimizes the performance of multiple users using the same time-frequency resources. In standard PA-NOMA scenario, that at the transmitter side both signals of the two users are superposed upon each other with different power allocation. Typically, a user with good channel gain will have their signal allocated at a lower power, whereas a user with weak channel gain will have their signal allocated at a higher power. The weak user's signal will then have a high Signal-to-noise Ratio (SNR) at the strong user's receiver since its power is greater than his own. This means that the strong user can successfully decode and subtract the weak user's signal before decoding his own signal, which is performing Successive Interference Cancellation (SIC). The weak user will be decoding his signal without using SIC as, at his receiver, the strong user's signal, which is weaker than his own, will be seen as noise.

In the case of the two-user Up Link (UL) PA-NOMA scenario, both users broadcast their signals to the BS simultaneously, albeit at varying transmit powers. Each user's power share is determined by their channel conditions in relation to the base station once more. Subsequently, the BS receives the superposed signal comprising the signals of both users after the transmission. It begins by decoding the strongest signal and deleting it from the superposed signal before decoding the other signal. In this research, the system model that shown in Figure 3.4, different objective functions formulated based on specific optimization purpose, such as Bit Error Rate (BER) with fixed power allocation, outage probability, and sum rate with transmit power of fixed and fair PA-NOMA.

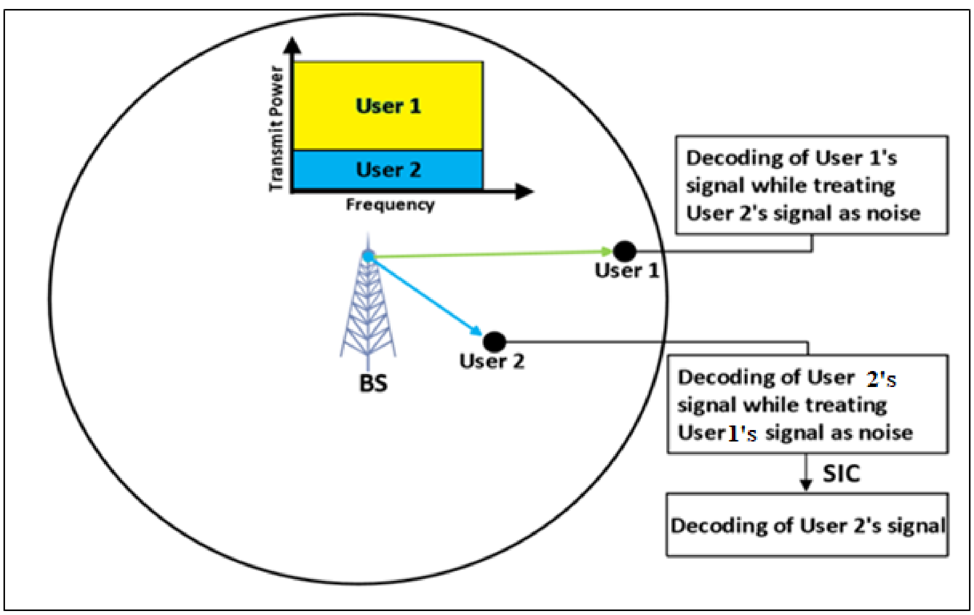

Figure 3.4: DL PA-NOMA System for two-users

There are two types to perform the power allocation: fixed power allocation and dynamic power allocation. Fixed power allocation method advantages are: first no computation is required and second no knowledge of CSI is required. In fixed power allocation the coefficients denoted with (α_1 and α_2) irrespective of the channel condition, the (α_1 = 0.75) for far user and (α_2 = 0.25) for near user. Figure 3.5 shows block diagram for the basic steps of power allocation algorithm:

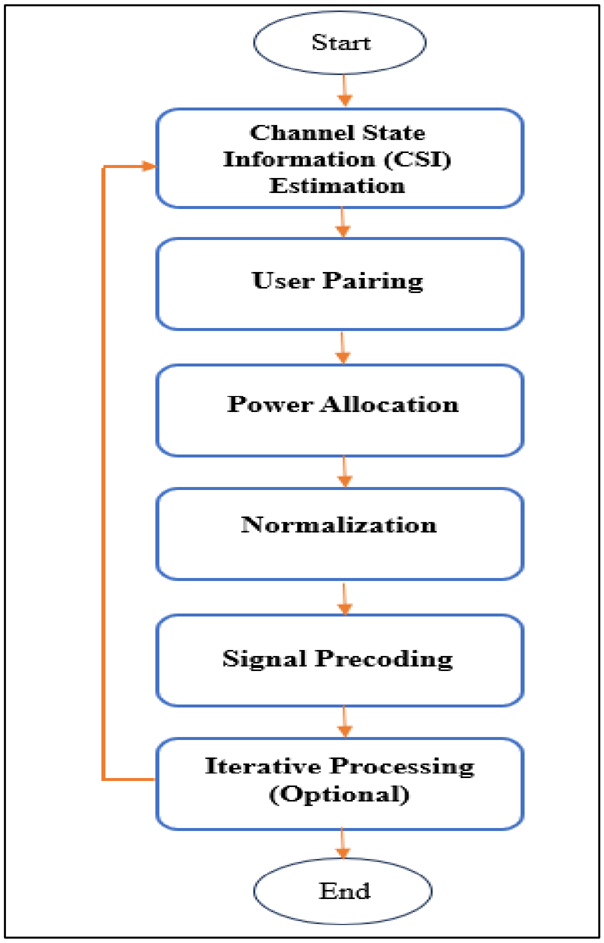

Figure 3.5: The Block Diagram for Proposed PA- NOMA Algorithm for Basic Steps

The power allocation algorithm in NOMA aims to assign different power levels to different users in order to maximize the overall system throughput. The proposed technique differs from traditional technique due to the new stages Normalization and an iterative processing to the first stage Channel State Information (CSI) Estimation as feedback to mitigate the interference and maintaining system stability. The basic outline of a power allocation PA-NOMA algorithm is:

i. CSI Estimation: Acquire accurate channel state information for all users. This information is essential for determining the channel conditions of each user.

ii. User Pairing: Pair users with distinct channel conditions. This pairing is crucial for effective power allocation in NOMA.

iii. PA: Allocate power levels to the paired users based on their channel conditions. The goal is to assign more power to users with better channel conditions and less power to users with poorer channel conditions. One simple power allocation algorithm is to use a proportional fair approach. The power allocated to each user (P_i) can be determined as a function of the channel gain (h_i) and a fairness parameter (α): $P_i = \frac{1}{h_i^{\alpha}}$

where ($0 \leq \alpha \leq 1$) his parameter controls the trade-off between fairness and throughput optimization. A smaller (α) values favor fairness, while larger values favor throughput maximization.

iv. Normalization: Normalize the power levels to ensure that the total power transmitted by the base station does not exceed a predefined maximum power limit. This step is essential for avoiding interference and maintaining system stability.

v. Signal Precoding: Apply signal precoding to the transmitted signals to ensure that users can decode their intended signals with minimal interference. Techniques like SIC can be used at the receiver to separate and decode signals from different users.

vi. Iterative Processing (Optional): Implement iterative processing if needed. Iterations may be performed between power allocation, precoding, and decoding steps to improve the overall system performance. The flow char for Proposed PA-NOMA Algorithm for Basic Steps is shows in Figures 3.6.

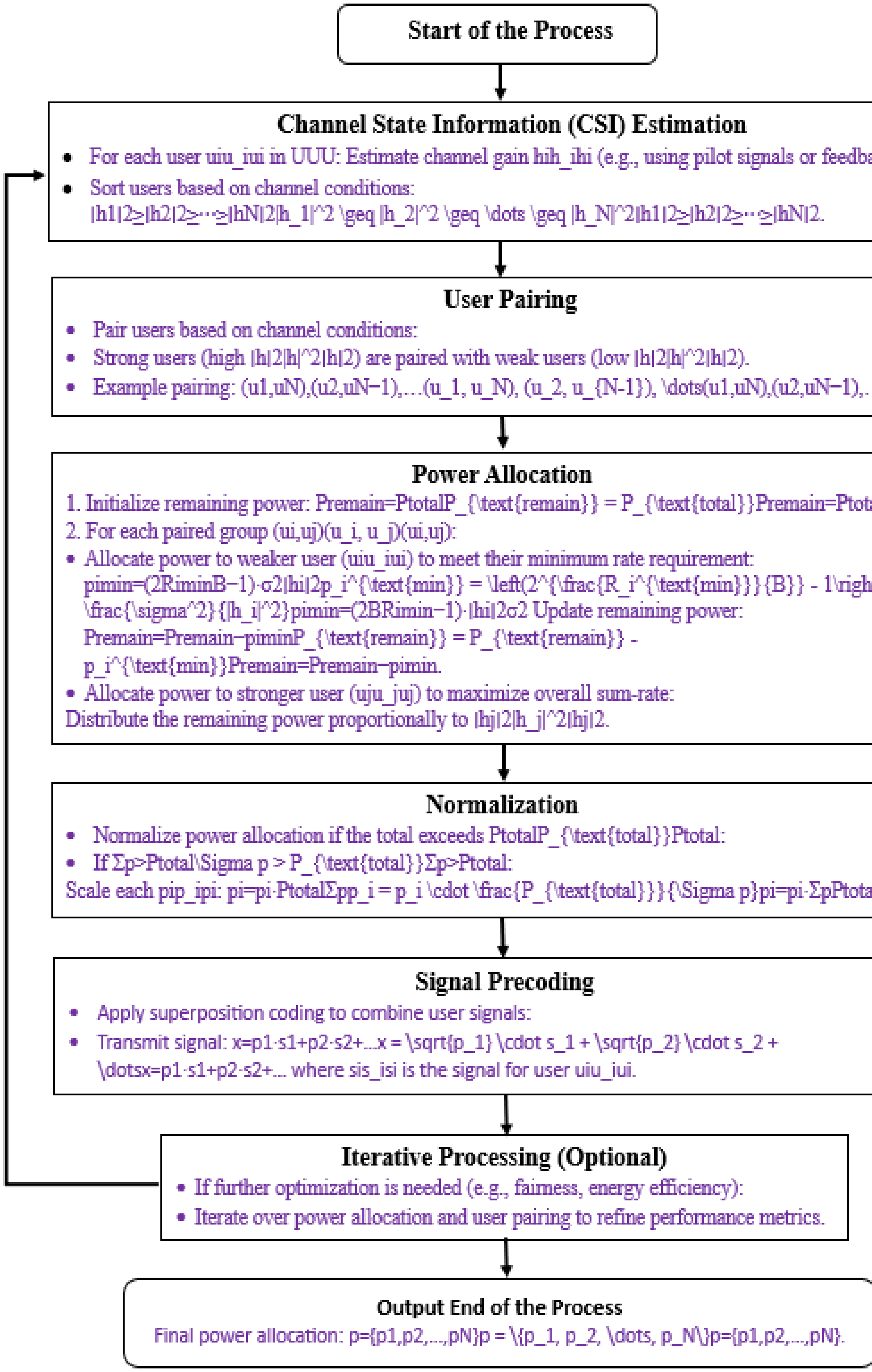

Figure 3.6: The Flow Chart for Process of Proposed PA- NOMA Algorithm for Basic Steps

The system model in this research consists of Kusers sharing the same time same frequency resources block. For CSI, h_k represent the channel gain for user K, indicate the quality of the channel between the user and the BS. The received signal at the BS from user K is given by (Shen, 2023):

$$y_k = \sqrt{P_k \cdot h_k} \cdot x_k + n_k \tag{3.3}$$

where P_k is the power allocation to user K, x_k is the transmitted signal from user K, and n_k is the Additive White Gaussian Noise (AWGN). The users transmitted signal x_k is normalized to unit power for simplicity, and introducing power allocation variable P_k for each user, represent the power allocated to user K.

$$\sum_{k=1}^{K} log_2(1 + \frac{P_k \cdot h_k}{N_0}) \tag{3.4}$$

where N_0 is the noise power.

To achieve the improvement for power allocation, firstly, the NOMA capacity equation for far user and near user can be written as in equation number (3.5) and (3.6):

$$(Far\ User\ Capacity)\ R_f = log_2\left(1 + \frac{|h_f|^2 P\alpha_f}{|h_f|^2 P\alpha_n + \sigma^2}\right) \tag{3.5}$$

$$(Near\ User\ Capacity)\ R_n = log_2\left(1 + \frac{|h_n|^2 P\alpha_n}{\sigma^2}\right) \tag{3.6}$$

where:

α_n: is the Power Allocation Coefficient (PAC) for near user

α_f: is the Power Allocation Coefficient (PAC) for far user

h_n: is the Rayleigh fading coefficient (RFC) for near user

h_f: is the Rayleigh fading coefficient (RFC) for far user

P: is the Total Transmit Power (TTP)

σ^2: is the Noise Power (NP)

$\alpha_n + \alpha_f = 1$

$\alpha_f > \alpha_n$

According to the proposed PA NOMA algorithm SIC process, (R_n) is obtained after removing the interference from far user transmission. Derivation the Power Allocation Coefficient (PAC) for (α_n) and(α_f):

where (R^*) denoted the target rate of far user and choosing (α_n) and(α_f) like $\left(R_f \geq R^*\right)$. Then, setting the $\left(R_f = R^*\right)$as: (Basheri et al., 2022a)

$$log_2\left(1 + \frac{\left|h_f\right|^2 P\alpha_f}{\left|h_f\right|^2 P\alpha_n + \sigma^2}\right) = R^* \qquad (3.7)$$

To remove the (log_2), taking (2^{x}) on both sides:

$$\left(1 + \frac{\left|h_f\right|^2 P\alpha_f}{\left|h_f\right|^2 P\alpha_n + \sigma^2}\right) = 2^{R^x} \qquad (3.8)$$

$$\left(\frac{\left|h_f\right|^2 P\alpha_f}{\left|h_f\right|^2 P\alpha_n + \sigma^2}\right) = 2^{R^x} - 1 \qquad (3.9)$$

By denoting ($\varepsilon = 2^{R^x} - 1$): where ($\varepsilon$) is the target Signal-to-interference-plus-noise Ratio (SINR) for the far user that has target rate (R^*).

$$\left(\frac{\left|h_f\right|^2 P\alpha_f}{\left|h_f\right|^2 P\alpha_n + \sigma^2}\right) = \varepsilon \qquad (3.10)$$

$$\left|h_f\right|^2 P\alpha_f = \varepsilon \ \left|h_f\right|^2 P\alpha_n + \varepsilon \ \sigma^2 \qquad (3.11)$$

Since, $(\alpha_{\mathrm{n}} + \alpha_f = 1)$, then $(\alpha_{\mathrm{n}} = 1 - \alpha_f)$:

$$\left|h_f\right|^2 P\alpha_f = \varepsilon \left|h_f\right|^2 P\left(1 - \alpha_f\right) + \varepsilon \sigma^2 \tag{3.12}$$

$$\left|h_f\right|^2 P\alpha_f = \varepsilon \left|h_f\right|^2 P - \varepsilon \left|h_f\right|^2 P\alpha_f + \varepsilon \sigma^2 \tag{3.13}$$

By collecting all the (α_f) terms to left-hand side (LHS):

$$\left|h_f\right|^2 P\alpha_f + \varepsilon \left|h_f\right|^2 P\alpha_f = \varepsilon \left|h_f\right|^2 P + \varepsilon \sigma^2 \tag{3.14}$$

$$\left|h_f\right|^2 P\alpha_f (1 - \varepsilon) = \varepsilon \left|h_f\right|^2 P + \varepsilon \sigma^2 \tag{3.15}$$

$$\alpha_f = \frac{\varepsilon \left|h_f\right|^2 P + \varepsilon \sigma^2}{\left|h_f\right|^2 P(1 - \varepsilon)} \tag{3.16}$$

$$\alpha_f = \frac{\varepsilon \left(\left|h_f\right|^2 P + \sigma^2\right)}{\left|h_f\right|^2 P(1 - \varepsilon)} \tag{3.17}$$

The Power Allocation Coefficient PAC for far user should not be $(\alpha_f > 1)$, then:

$$\alpha_f = minimum\left(1, \frac{\varepsilon\left(\left|h_f\right|^2 P + \sigma^2\right)}{\left|h_f\right|^2 P(1 + \varepsilon)}\right) \tag{3.18}$$

After computing the (α_f) by using the equation (3.16), then the PAC for far user is equal to:

$$\alpha_n = 1 - \alpha_f \tag{3.19}$$

3.4 Cooperative (C-NOMA) and Caching in the 6G Mobile Communication Networks

In this section, two wireless communication techniques, cooperative Non-orthogonal Multiple Access (C-NOMA) and caching, are explained, modeled, and mathematically expressed to enhance the performance and efficiency of the 6G mobile communication network systems as follows:

3.4.1 Cooperative (C-NOMA) in the 6G Mobile Communication Networks

With the introduction of the 6G mobile communication networks, wireless communication anticipates going through a paradigm shift that will require innovative solutions to meet the increasing demands for high throughput, low latency, and ubiquitous connection (Alsabah et al., 2021). C-NOMA is a cutting-edge technology in the 6G mobile communication networks that has the power to fundamentally alter how users share and utilize wireless resources. The purpose of this study is to understand C-NOMA's role in enhancing network performance and efficiency by examining its principles, opportunities, and limitations. C-NOMA utilizes the concept of users collaborating to share the same time-frequency resources, which leads to enhanced spectral efficiency and reliability over traditional orthogonal multiple access systems. C-NOMA enables cooperative resource optimization and aids users in mitigating the impact of fading channels and interference by dynamically adjusting transmit power levels and utilizing diversity improvements offered by cooperative transmission (Shan et al., 2021). For C-NOMA deployment in the 6G mobile networks, resource management, algorithmic optimization, infrastructure enhancement, and user-centered design are all necessary components of a diverse approach. The following are the main functions that are involved in implementing C-NOMA (Asghar et al., 2022):

a) BS have been upgraded with cutting-edge antenna arrays and signal processing capabilities to enable cooperative communication between users, especially in places where propagation circumstances are difficult.

b) Backhaul optimization refers to improving to enable increased data exchange between base stations and relay nodes.

c) Effective power allocation algorithms for dynamic change the transmit power levels with scheduling algorithms to control user and relay node transmission and reception operations to achieve cooperative diversity gains.

d) Channel condition prediction is needed to provide cooperative beamforming and precoding.

e) Dynamically allocated spectrum to accomplish interference reduction and spectral efficiency for resource management.

f) User satisfaction should take precedence over QoS measures like latency, throughput, and ad dependability in C-NOMA arrangements.

g) Coordinated NOMA transmission and reception will be possible with improved UE, making integration with both present and future devices easier.

h) Secure key exchange techniques to guard against surveillance and illegal access.

i) Privacy-preserving approaches to preserve user privacy in C-NOMA settings and guarantee regulatory compliance.

In C-NOMA, power allocation aims to distribute transmit power between users within a NOMA cluster to enhance and increase system throughput while satisfying power limits (Khan et al., 2020a):

The power allocation (PA) factor, denoted by (α_i) for the (i_{th}) user, the ratio of (PA) is:

$$\sum_{i=1}^{N} \alpha_i = 1 \tag{3.20}$$

To maximize the (PA):

$$\text{Maximize (PA)} \sum_{i=1}^{N} \alpha_i R_i \tag{3.21}$$

where (R_i) represents the achievable rate of the (i_{th}) user.

The achievable rate (R_i) of users in C-NOMA depends on the power allocation, channel conditions, and interference from other users. The achievable rate for the (i_{th}) user, is expressed as follows:

$$R_i = \log_2\left(1 + \frac{P_i|h_{ii}|^2}{\sum_{j=1,j\neq i}^{N} P_j\left|h_{ji}\right|^2 + \sigma^2}\right) \tag{3.22}$$

where (P_i) is the transmit power of the (i_{th}) user, (h_{ii}) represents the channel gain of the direct link between the (i_{th}) user and the base station, (h_{ji}) represents the channel gain of the interference from the (j_{th}) user to the (i_{th}) user, and (σ^2) is the noise power. The (R_i) of each user is impacted by the interference that other users in the NOMA cluster cause. The interference (I_i) for the (i_{th}) user expressed as in the formula (3.24):

$$I_i = \sum_{j=1, j \neq i}^{N} P_j \left| h_{ji} \right|^2 \tag{3.23}$$

To maximize the sum-rate of all users within the NOMA cluster, power and interference limits should be considered. The objective function for maximize sum rate formulated as (3.25):

$$\text{Maximize sum rate} \sum_{i=1}^{N} R_i \tag{3.24}$$

subject to power constraints (3.26):

$$\sum_{i=1}^{N} P_i \leq P_{\text{total}} \tag{3.25}$$

and interference limits as in (3.27):

$$I_i \leq I_{max} \text{ for all users } i \tag{3.26}$$

These formulas are used to assess and optimize C-NOMA in the 6G mobile communication networks, and used to create efficient resource allocation algorithms that ensure fairness and quality of service while improving network performance and efficiency.

3.4.2 Caching in the 6G Mobile Communication Networks

Due to the emergence of new technologies and a multitude of data-intensive applications, there is an increasing need for ultra-fast and dependable wireless connectivity as the 6G mobile communication networks approach. A key component of improving network performance and efficiency in the 6G environments is caching that strategically stores and distributes frequently visited content closer to end users. Caching is used by the 6G mobile communication networks to guarantee faultless user experiences in a range of applications, from ultra-high-quality video streaming to immersive virtual and augmented reality. These user experiences can be achieved by employing cutting-edge algorithms and edge computing infrastructure. To successfully implement caching in the 6G mobile networks, an integrated approach comprising infrastructure deployment, algorithmic optimization, and user-centered design is required. The key ideas behind caching in the 6G system networks are outlined below (Shen, 2023):

a) Careful positioning of nodes to be close to the network edge for lower latency and to enhance content delivery supported by backhaul networks ensure seamless content distribution and synchronization.

b) Optimization involves anticipating user demand and proactively storing content at edge nodes through the use of sophisticated predictive caching algorithms.

c) Effective content placement strategies can be created by accounting for factors such as popularity dynamics, user spatial dispersion, and content characteristics.

d) Optimizing cache replacement algorithms is necessary to cache the most relevant content and maximize hit rates while minimizing cache contamination.

e) QoE optimization and user-centric design are required to emphasize user experience by providing lower-latency access to popular information and personalized services.

f) Secure caching techniques and robust security measures should be used to guard against unwanted access, modification, and data breaches involving cached content.

g) Creating a caching infrastructure that can grow with the volume of data and users in the 6G mobile communication networks is the idea of scalable architecture.

A complete approach that considers user-centric design, algorithmic optimization, infrastructure deployment, security and privacy concerns, scalability, and interoperability is required for the successful implementation of caching in the 6G mobile communication networks (Ogundokun et al., 2023b). Caching is a key enabler for the 6G mobile communication networks, which can enhance performance, efficiency, and user experience. This will pave the way for the creation of services and applications for wireless communication of the next generation (You et al., 2021). In the context of the 6G mobile communication networks, mathematical expressions are widely utilized to mimic various aspects of caching technique, resource allocation, and optimization algorithms. The following mathematical formulas are used to study and examine caching in the 6G mobile communication networks. The probability that an item of content will be found in the cache when it is requested is known as the Cache Hit Probability (P_{hit}) (Mastrodicasa, 2022).

$$P_{\text{hit}} = \frac{\text{Quantity of demand provided by cache}}{\text{Total quantity of demand}} \tag{3.27}$$

For the (P_{miss}) Probability of Cache Miss, the probability that, should the requested information not be fetched in the cache, it will need to be fetched from the origin server:

$$P_{\text{miss}} = 1 - P_{\text{hit}} \tag{3.28}$$

For the Cache Hit Rate: The ratio of cache hits to total requests, often used as a performance metric for caching technique:

$$\text{Cache Hit Rate} = \frac{\text{Number of cache hits}}{\text{Total number of requests}} \tag{3.29}$$

3.4.3 Proposed Dynamic C-NOMA with Caching

This research offers a proposed system that combines C-NOMA with caching and dynamic resource allocation to improve efficiency and performance in the 6G mobile communication networks. An extensive overview of the algorithm that combines C-NOMA with caching in the 6G mobile networks is as shown in Figure 3.7.

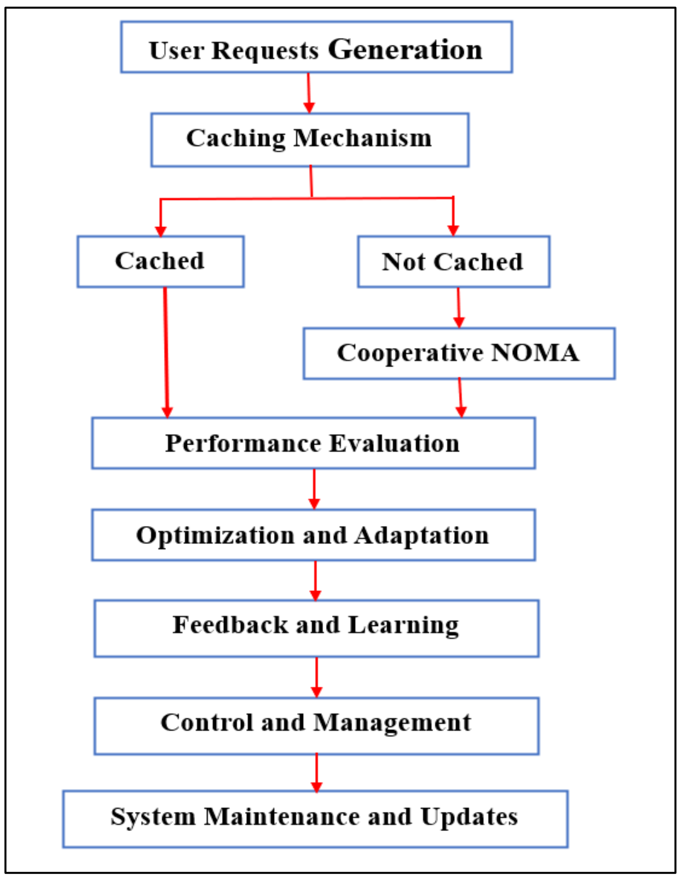

Figure 3.7: The Block Diagram of C-NOMA with Caching Proposed Algorithm

Each block represents a significant stage or process in the algorithm. Outlining the key components and procedures of the system is part of the algorithm that covers C-NOMA with caching in the 6G mobile communication networks. The following are the algorithm's primary steps:

a) Generate user requests to provide content requests from all users in the system.

b) Check the cache to see if the requested content is available. Serve content straight from the cache if it is cached. Proceed to C-NOMA if not cached.

c) Determine which users are taking part in NOMA transmission and setting power allocation for transmission in tandem with sending data by utilizing NOMA methods, and signal decoding at the receiving end.

d) Optimizing NOMA transmission power allocation techniques, and adjust system settings to reflect evolving network requirements.

e) To guarantee effective resource allocation, establish control systems in a desired place, and adapt system resources dynamically to network and demand conditions.

f) Updating the system and performing routine maintenance, such as cache updates and system upgrades, are important, and implement new standards and technology to maintain the system current.

Figure 3.8 shows the system model for the C-NOMA with caching to enhance the performance and efficiency in the 6G mobile network communication systems.

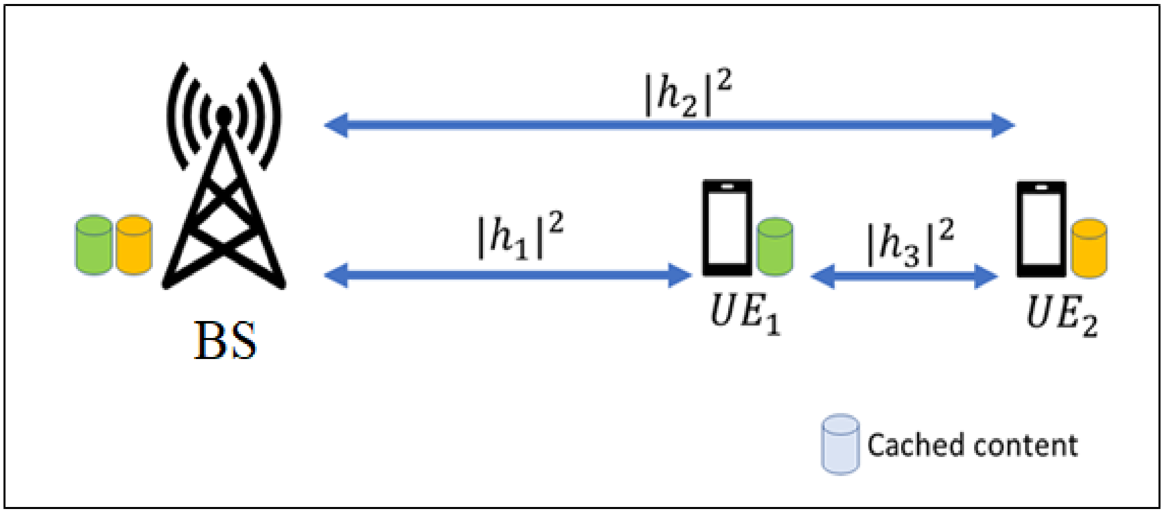

Figure 3.8: The System Model for C-NOMA with Caching

The system model for C-NOMA with caching in the 6G networks components and mathematical expressions involved can be break down as:

a) For network architecture, the network consists of Base Stations (BSs), Edge Computing Nodes (ECNs), and User Equipment (UEs). Base stations serve as access points for user communication. ECNs host caching functionalities and facilitate C-NOMA transmission. For Caching Infrastructure, each edge computing node is equipped with a cache to store popular content items. The cache employs predictive caching algorithms to proactively store content based on user behavior and content popularity. For caching mechanism, each BS caches popular content items. (C_i) denote the content cached at (BS_i). The cache capacity (M) represents the maximum number of content items that can be stored at each BS. Each (BS_i) caches a set of content items (C_i) with a cache capacity (M): $C_i = \{c_{i,1}, c_{i,2}, \dots, c_{i,M}\}$. The cache content (C_i) is determined based on popularity profiles, user demands, or other caching policies.

b) For the user request model, user requests arrive at ECNs, requesting specific content items from the cache. Requests follow a certain distribution, which may vary over time and geographical locations. For user association, each user is associated with a nearby BS based on signal strength or other association criteria. Each user (j) is associated with a nearby (BS_i) based on signal strength or other association criteria: $U_i = \{u_{i,1}, u_{i,2}, \ldots, u_{i,N}\}$. (N) is the total number of users, and (U_i) is the set of users associated with (BS_i).

c) In C-NOMA transmission, users requesting un-cached content items form NOMA clusters with nearby relay nodes. Then, relay nodes assist in cooperative transmission by relaying signals between users and base stations. Power allocation and resource allocation schemes are employed to optimize system throughput and mitigate interference. Beamforming and precoding techniques are utilized to enhance signal quality and minimize interference among users.

d) The channel between each user and base station, as well as between users and relay nodes, is modeled considering path loss, shadowing, and fading effects. Channels are assumed to be frequency-selective and time-varying, necessitating dynamic adaptation of transmission parameters.

C-NOMA enables multiple users to share the same resource block by exploiting power domain NOMA. ($P_{i,j}$) represent the power allocated to user *j* at (BS_i) for NOMA transmission, that is subject to power constraints and interference management. The received signal ($y_{i,j}$) at user (*j*) from (BS_i) can be expressed as:

$$y_{i,j} = \sqrt{P_{i,j}} h_{i,j} x_{i,j} + \sum_{k \neq j} \sqrt{P_{i,k}} h_{i,k} x_{i,j} + n_{i,j} \tag{3.30}$$

where:

- $(h_{i,j})$ is the channel gain between (BS i) and user (j).
- $(x_{i,j})$ is the transmitted signal from (BS i).
- $(n_{i,j})$ is the additive white Gaussian noise (AWGN) at user (j).

The throughput (T_i) at (BS_i) is determined by the caching hit rate, user association, and NOMA transmission.

$$T_i = \sum_{j \in U_i} \mathbb{E}\left[R_{i,j}\right] \tag{3.31}$$

where $\mathbb{E}\left[R_{i,j}\right]$ is the expected data rate for user (j) at (BS_i). The latency (L_i) experienced by users at (BS_i) depends on the content retrieval time and transmission delay. For the system optimization, the system aims to optimize caching policies, user association, power allocation, and resource scheduling to maximize throughput and minimize latency:

$$\text{Maximize/Minimize} \sum_{i} \text{Throughput/Latency} \tag{3.32}$$

This involves solving optimization problems subject to constraints such as cache capacity, power constraints, and QoS requirements. The system constrains are:

- Caching capacity constraints: $|C_i| \leq (M)$.
- Power constraints: $P_{i,j} \leq P_{max}$ for all (i, j).
- Quality-of-Service (QoS) requirements: $T_i \geq T_{min}$ or $L_i \leq L_{max}$.

Power allocation among users within NOMA clusters is optimized to maximize system throughput while satisfying power constraints and quality of service (QoS) requirements. Each user is allocated a certain portion of transmit power, determined based on channel conditions and cooperation strategies. For the resource allocation, spectrum resources, time slots, and transmission durations are allocated dynamically among users and relay nodes to maximize spectral efficiency and throughput. Resource allocation decisions consider channel conditions, interference levels, and traffic demands. The model for Cache Hit/Miss process, upon receiving a user request, the edge computing node checks the cache for the requested content item. The user receives the content with the least amount of latency possible if it is cache-hit. If the content cannot be located in the cache, a request for C-NOMA transmission (cache miss) is made. Performance metrics such as cache sum rate, average latency reduction, system throughput, and user satisfaction are evaluated to see how well C-NOMA with caching enhance network performance and efficiency. The flow chart for C-NOMA with Caching Proposed Algorithm in the 6G Mobile Communication Network System shows in Figure 3.9.

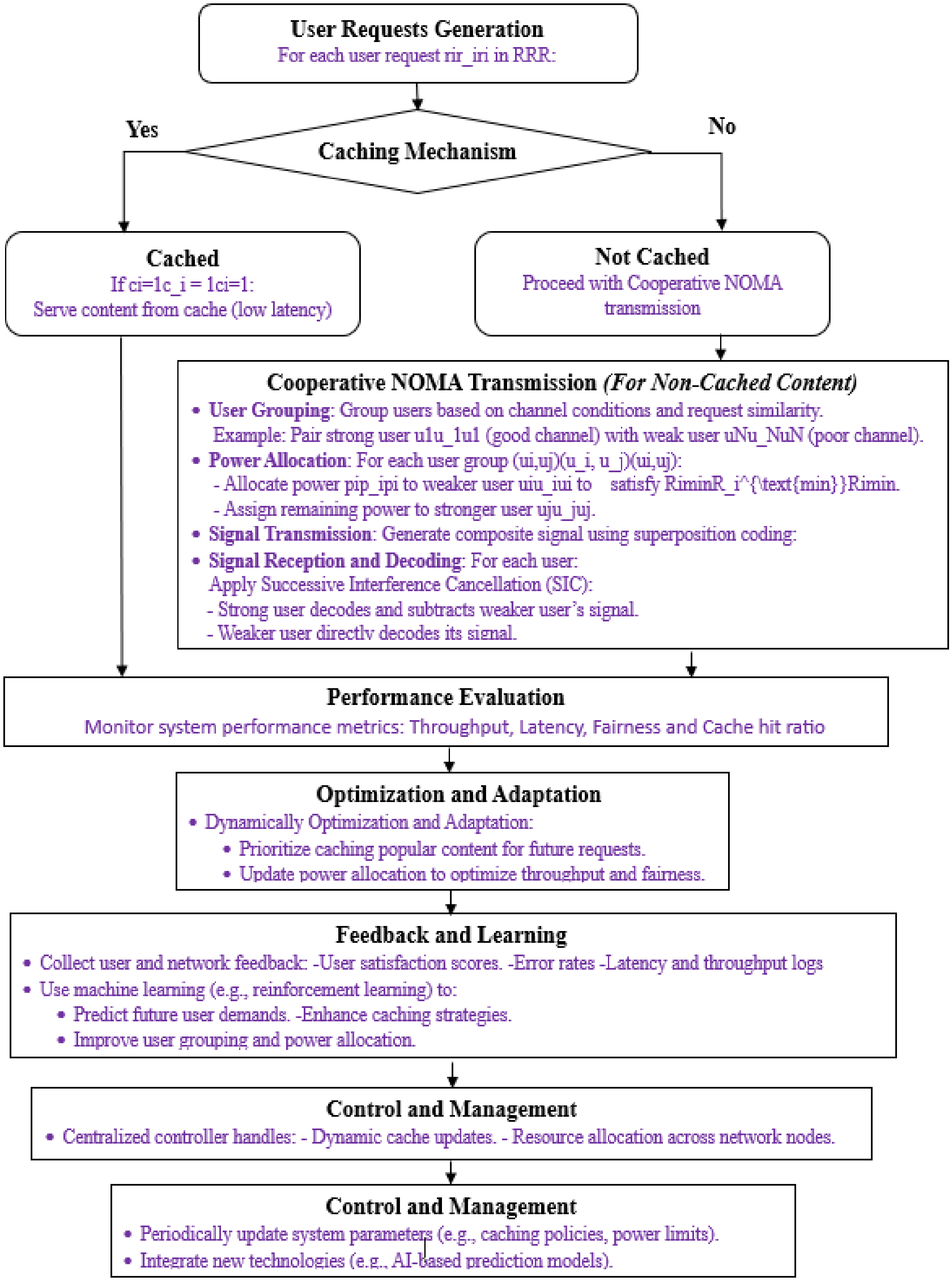

Figure 3.9: Flow Chart for C-NOMA with Caching Proposed Algorithm in the 6G Mobile Communication Network System

3.4.4 C-NOMA m-MIMO with Caching in the 6G Mobile Communication Networks

The two advanced techniques C-NOMA and m-MIMO are significantly enhancing the performance and efficiency in the 6G networks mobile communication. m-MIMO contributes to improved spectral efficiency, higher data rates, enhanced coverage, capacity, and energy efficiency. While, the NOMA contributes the system with allowing multi user diversity, better user fairness, lower latency, supporting for m-MTC and IoT. Combining these two advanced techniques, provides additional advantages such as enhanced capacity, higher improved spectral efficiency, lower latency and higher throughput, and higher robustness and flexibility (Liang et al., 2020b).

In C-NOMA m-MIMO in the 6G mobile communication networks can be expressed mathematically as follows:

When N denotes the users total served by the base station, and A is the antennas number at the BSs. The received signal at the (A_{th}) antenna of the base station (BS) from the (n_{th}) user can be expressed as: (Shen, 2023).

$$y_{A,n} = \sqrt{P_n} \cdot h_{A,n} \cdot x_n + \sum_{\substack{j=1 \\ j \neq n}}^{N} \sqrt{P_j} \cdot h_{A,j} \cdot x_j + n_A \tag{3.33}$$

where:

- (P_n) represents the transmit power allocated to user (n).
- $(h_{A,n})$ is the channel gain between user (n) and the (A_{th}) antenna of the BS.
- (x_n) represents the information symbol transmitted by user (n).
- (n_A) is the AWGN at the (A_{th}) antenna of the BS.

For NOMA, users are divided into multiple power domains. (P_{max}) denotes the maximum transmit power, and (P_n) denotes the power allocation to user (n).

The power allocation problem for NOMA can be formulated as (El-Gayar and Ajour, 2023):

$$\max_{P_n} \sum_{n=1}^{N} \log_2 \left(+ \frac{P_n \cdot \left|h_{k,n}\right|^2}{\sum_{\substack{j=1 \\ j \neq n}}^{N} P_j \cdot \left|h_{k,j}\right|^2 + \sigma^2} \right) \quad (3.34)$$

subject to:

$0 \leq P_n \leq P_{max}$, where (σ^2) denotes the noise power.

For m-MIMO, the BS employs beamforming to serve multiple users simultaneously. Where (W_A) represents the beamforming vector for the (A_{th}) antenna of the BS. The received signal vector at the base station can be expressed as (Khan et al., 2020b):

$$\mathrm{y}_{Av} = \sum_{n=1}^{N} \sqrt{P_n} \cdot h_{A,n} \cdot x_n + \mathrm{n}_{Av} \quad (3.35)$$

where:

- (Y_{Av}) represents the received signal vector at the (A_{th}) antenna of the BS.
- (n_{Av}) denotes the AWGN vector at the (A_{th}) antenna of the BS.

The beamforming vectors are optimized to maximize the SINR or capacity, subject to power constraints and possibly other constraints such as fairness or user-specific QoS requirements.

This mathematical formulation captures the essence of C-NOMA m-MIMO in the 6G mobile communication networks, where NOMA is used for power domain multiplexing and Massive MIMO employs beamforming for spatial multiplexing, collectively enhancing the system's performance and efficiency.

By integrating C-NOMA-m-MIMO with caching in the 6G mobile communication networks involves optimizing resource allocation for both transmission and caching to enhance performance and efficiency. With incorporating caching, where the (*Mcf*) represents the number of cached files, ($x_{m,n}$) denotes the caching content requested by user (*n*) for file (*m*). As the caching strategy aims to optimize the content placement at the base station or users' devices to minimize latency and improve throughput. The optimization problem for caching can be formulated as (Bepari et al., 2022):

$$\max_{x_{m,n}} \sum_{m=1}^{Mcf} \sum_{n=1}^{N} \mathrm{hit}_{m,n} \cdot \log_2\left(1 + \alpha_{m,n}\right) \tag{3.36}$$

subject to:

$$\sum_{n=1}^{N} x_{m,n} \leq C_m \tag{3.37}$$

where:

- ($hit_{m,n}$) is an indicator variable denoting whether user (*n*) requests content (*m*) from the cache.
- ($\alpha_{m,n}$) is the SINR achieved by user (*n*) when requesting content (*m*).
- (C_m) is the cache capacity for content (*m*).

This integration mathematically optimized problem, seeks to maximize the overall utility considering both transmission and caching, subject to power and caching constraints. Solving this integrated optimization problem provides an optimal resource allocation strategy that leverages C-NOMA m-MIMO with caching to enhance the performance and efficiency of the 6G mobile communication networks.

3.4.5 Proposed Dynamic C-NOMA m-MIMO with Caching Algorithm

This proposed system combines C-NOMA m-MIMO with caching and dynamic resource allocation to improve efficiency and performance in the 6G mobile communication networks. The system algorithm for integrating C-NOMA m-MIMO with caching in the 6G mobile communication networks requires consideration of various factors, including resource allocation, interference management, and caching strategies. An extensive overview of the algorithm that combines C-NOMA m-MIMO with caching in the 6G mobile communication networks is as shown in Figure 3.10.

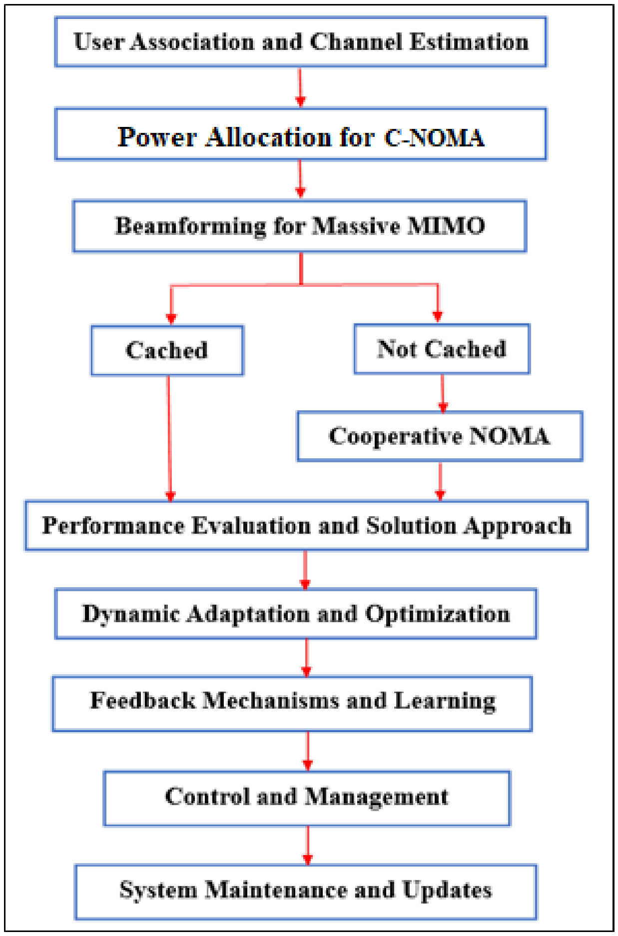

Figure 3.10: The Block Diagram of C-NOMA m-MIMO with Caching Proposed Algorithm in 6G Mobile Communication Networks

Each block represents a process or significant stage in the algorithm system. Outlining the key components and procedures of the system is part of the algorithm that covers C-NOMA m-MIMO with caching in the 6G mobile communication networks. The following are the main algorithm's steps:

a) Based on channel conditions and proximity, associating users with the BS. Then, employing channel estimation techniques to estimate the CSI for each user.

b) For C-NOMA transmission, transmitting power allocate to users. Then optimizing power allocation to maximize the sum rate or fairness among users while satisfying power constraints.
c) To serve multiple users simultaneously, establishing beamforming vectors for each antenna. Then utilizing techniques to mitigate inter-user interference and maximize the received signal power at each user.
d) For caching at the BS or users' devices, determining the optimal content placement strategy. Then considering factors such as content popularity, user preferences, and available cache capacity and employ Least Recently Used (LRU), Least Frequently Used (LFU), or probabilistic caching to optimize content placement and eviction policies.
e) Formulate an optimization problem that jointly considers power allocation, beamforming, and caching strategies. Then, defining the objective function to maximize system utility, and incorporate constraints on transmit power, beamforming vectors, cache capacity, and user-specific Quality of Service (QoS) requirements.
f) Utilizing optimization techniques to solve the joint resource allocation problem. Then, applying iterative algorithms or heuristic methods to iteratively refine the resource allocation decisions. And considering distributed optimization techniques for scalability and real-time implementation.
g) Implementing mechanisms for dynamic adaptation based on changing network conditions and user demands. And incorporate feedback mechanisms to continuously update channel estimates, power allocations, and caching decisions.
h) Conducting simulations or real-world experiments to evaluate the performance of the integrated system algorithm. And assess metrics such as

throughput, average latency reduction, throughput, and user satisfaction under various scenarios and traffic conditions.

i) Updating the system and performing routine maintenance, such as cache updates and system upgrades, are important, and implement new standards and technology to maintain the system current.

By following this systematic algorithm approach, the integration of C-NOMA m-MIMO with caching in the 6G mobile communication networks enable to enhance performance and efficiency while addressing the challenges of resource allocation and content delivery optimization.

3.4.6 Proposed C-NOMA m-MIMO with Caching System Modeling

Figure 3.11 shows the system model for the C-NOMA m-MIMO with caching to enhance the performance and efficiency in the 6G network communication.

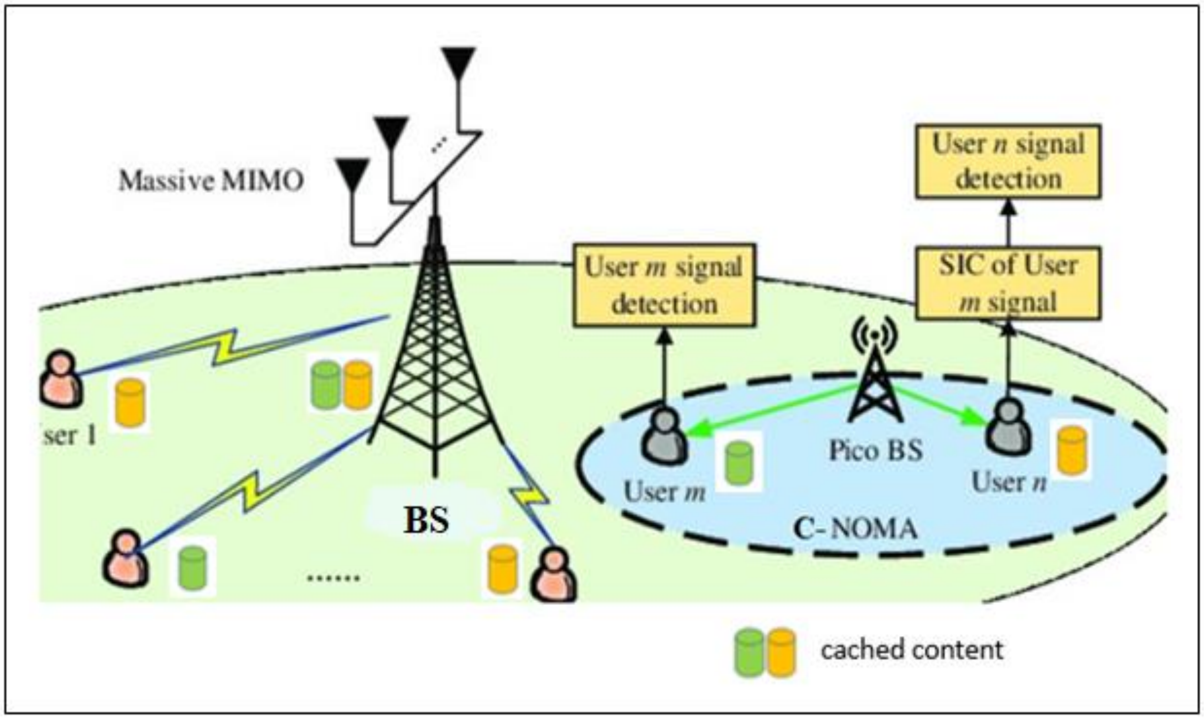

Figure 3.11: The System Model for C-NOMA Massive MIMO with Caching

To integrate C-NOMA Massive MIMO, with caching in the 6G mobile communication networks, in this research, a system model is developed. This model considers the joint optimization of resource allocation, beamforming, and caching strategies to enhance system performance and efficiency.

The system model for C-NOMA Massive MIMO with caching in the 6G networks components involved can be broken down into the following:

a) For network architecture, the network consists of BSs equipped with (A) antennas for m-MIMO transmissions, ECNs, and (N) is denoted the numbers of UEs served by the BS, each user has a unique identifier (n), where $n = 1, 2, 3, \dots, N$).

b) The channel gain between user (n) and the (A_{th}) antenna of the BS is denoted with ($h_{A,n}$) and the channels fading model are Rayleigh fading with small-scale fading effect.

c) The transmit NOMA power allocation to user (n) is denoted by (P_h) and power allocation is performed considering the channel conditions and fairness constrains.

d) M-MIMO is employed to serve multiple users simultaneously using beamforming techniques. The beamforming vector for the (A_{th}) antenna of the BS is denoted with (W_{kA}). The content caching is performed at the BS or user devices. The total number of files available for caching is denoted with (Mcf). The cached content availability is represented by a binary indicator ($x_{m,h}$), if user (n) has file (m) cached, then ($x_{m,h} = 1$), and otherwise ($x_{m,h} = 0$).

e) Base stations serve as access points for user communication. ECNs host caching functionalities and facilitate C-NOMA transmission. For caching infrastructure, each edge computing node is equipped with a cache to store popular content items. The cache employs predictive caching algorithms to proactively store content based on user behavior and content popularity. For caching mechanism, each BS caches popular content items. (C_i) denote the content cached at (BS_i). The cache capacity (M) represents the maximum number of content items that can be stored at each (BS). Each (BS_i) caches a set of content items (C_i) with a cache capacity (M): $C_i = \{c_{i,1}, c_{i,2}, \dots, c_{i,M}\}$. The cache content (C_i) is determined based on popularity profiles, user demands, or other caching policies.

f) The channel between each user and BS, as well as between users and relay nodes, is modeled considering path loss, shadowing, and fading effects. Channels are assumed to be frequency-selective and time-varying, necessitating dynamic adaptation of transmission parameters.

The flow chart for the C-NOMA m-MIMO with Caching Proposed Algorithm in the 6G Mobile Communication Network System shows in figure 3.12.

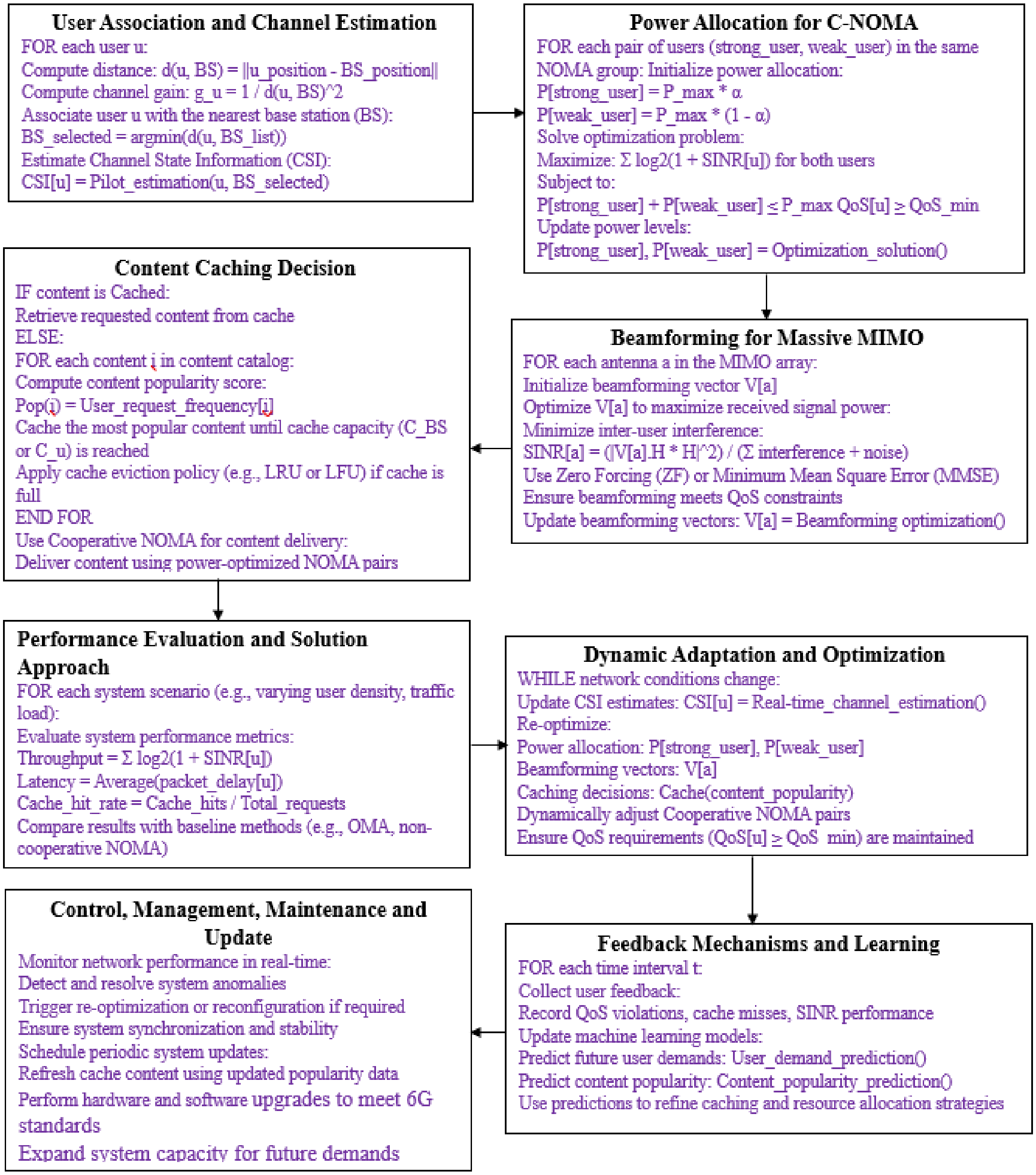

Figure 3.12: The Flow Chart for C-NOMA m-MIMO with Caching Proposed Algorithm in the 6G Mobile Communication Network System

3.5 Summary of Chapter Three

Chapter three in this dissertation presented four techniques studied and modeled with four proposed algorithms. Firstly, the technique C-NOMA modeled with proposed algorithm to enhance the performance of the 5G mobile communication networks systems. Secondly, PA-NOMA System modeled and a new algorithm proposed to enhance the performance of the 5G mobile communication networks systems. Thirdly, C-NOMA with caching studied and modeled with an algorithm to enhance the performance and efficiency of the 6G mobile communication networks systems. The fourth study in this chapter was integration of techniques C-NOMA m-MIMO with caching studied and modeled by proposed algorithm to enhance the performance and efficiency for the 6G mobile communication networks systems. In the next two chapters, all these techniques with proposed algorithms will be simulated and evaluated. The software used for all simulation results in this dissertation are MATLAB (V 2022a) and NYUSIM (V 3.1).

CHAPTER FOUR

4 THE FIFTH GENERATION 5G SIMULATION AND PERFORMANCE ANALYSIS

4.1 Introduction

This chapter presents the results and performance assessments of two modeled techniques Cooperative-Orthogonal Multiple Access (C-NOMA) and Power Allocation (PA-NOMA) in the 5G mobile communication networks systems. The performance improvement with two proposed algorithm methodologies which presented in chapter three are presented. Initially, C-NOMA simulated and evaluated with comparison between traditional Orthogonal Multiple Access OMA- Orthogonal Frequency-Division Multiple Access OFDMA, and NOMA for strong and weak user rates. The Bit Error Rate (BER) and outage probability versus Signal -to-Noise Ratio (SNR) for Down Link (DL) C-NOMA channel systems studied for both two users and three users without NOMA, with NOMA without cooperative, and NOMA with cooperative. Moreover, the BER and outage probability versus SNR for Up Link (UL) C-NOMA channel system are studied for far and near users. In these tests, different channel fading Rayleigh and Rician, different signal spectrum bandwidth, different noise power, and different user distances have been considered. Secondly, PA-NOMA is simulated and evaluated for BER, outage probability, and sum rate versus power allocation, target rates of far users, and transmitted power respectively for fixed and dynamic power allocation with different user distances. All these studies are implemented and simulated with MATLAB (V 2022a) and NYUSIM (V 3.1) software.

4.2 Cooperative Non-Orthogonal Multiple Access (C-NOMA) Simulation and Evaluation in the 5G

This section demonstrates that NOMA fulfils the requirements for the 5G better than OMA techniques. Furthermore, the UL NOMA and DL NOMA in this section are evaluated and studied. The software used for all simulation results in this research are MATLAB (V 2022a) and NYUSIM (V 3.1). Table 4.1 shows the simulation parameters used to compare NOMA with OMA-OFDM.

Table 4.1: Simulation parameters used to compare NOMA with OMA-OFDM

Parameters	Data
Number of Base Stations	1
Number of Users Equipment	2 (weak and strong)
Number of Antennas at the BS	64×8
Power (P), P_1 = P*alpha, P_2 = P - P_1	P=1
Transmit Power (splitting factor)	alpha = 0:0.01:1
Channel Gain: G_1, G_2	G_1=G_2 for symmetric G_1>G_2 for un-symmetric
Bandwidth in Hz	20 MHz
Rate R_1	$\log_2(1 + P_1*G_1)$
Rate R_2	$\log_2(1 + P_2*G_2/(P_1*G_2 + 1))$
Channel Gain Type	[Rayleigh fading]

Different implementations were compared between the NOMA technique and the OMA-OFDMA as shown in Figure 4.1.

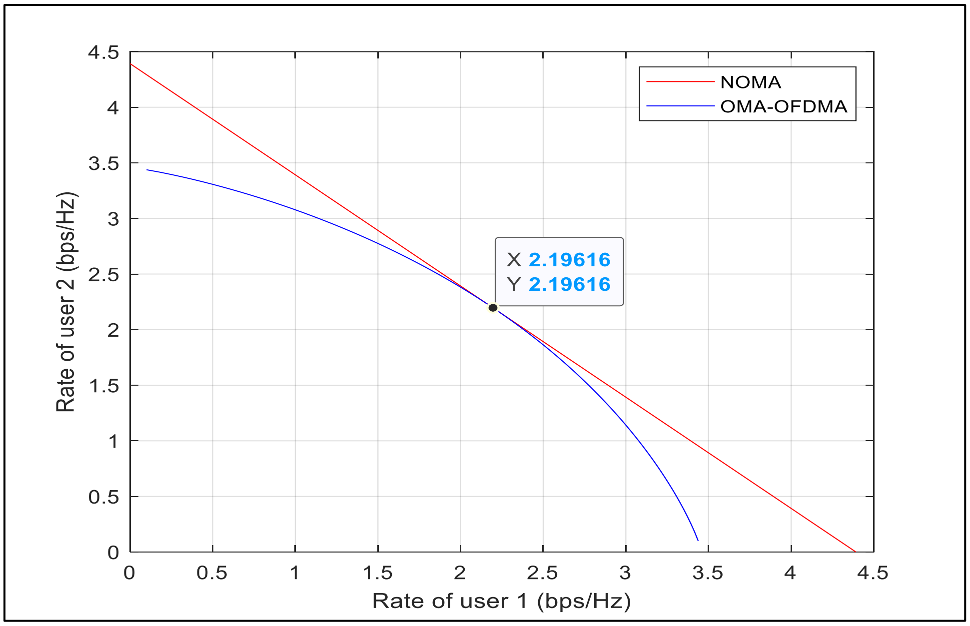

Figure 4.1: NOMA versus OMA-OFDM for symmetric rate pairs

It has been assumed that there is a pair of users in the system network, a symmetric DL medium, and the users are at the same distance from the base station. Moreover, the SNR for user one and user two are equal (20 dB) and symmetric rate pairs. Figure 4.1 shows that NOMA outperforms OFDMA in rate pairings, except in corner cases, where rates are equivalent to single-user capacities. This is because of simultaneous transmission, NOMA users suffer from interference, but OMA users do not encounter this kind of interruption. Both users receive (2.19616 bps/Hz) throughputs for both OFDMA; further NOMA at the fairness level is high. However, compared to OMA-OFDMA, NOMA produces significantly greater rate pairings. Sum capacity and specific system throughputs are larger with NOMA when the fairness is lower. When the channel fading is unsymmetric rate pairs for user one and user two, SNR user one (20 dB) and SNR user two (2 dB), the performance will be shown in Figure 4.2.

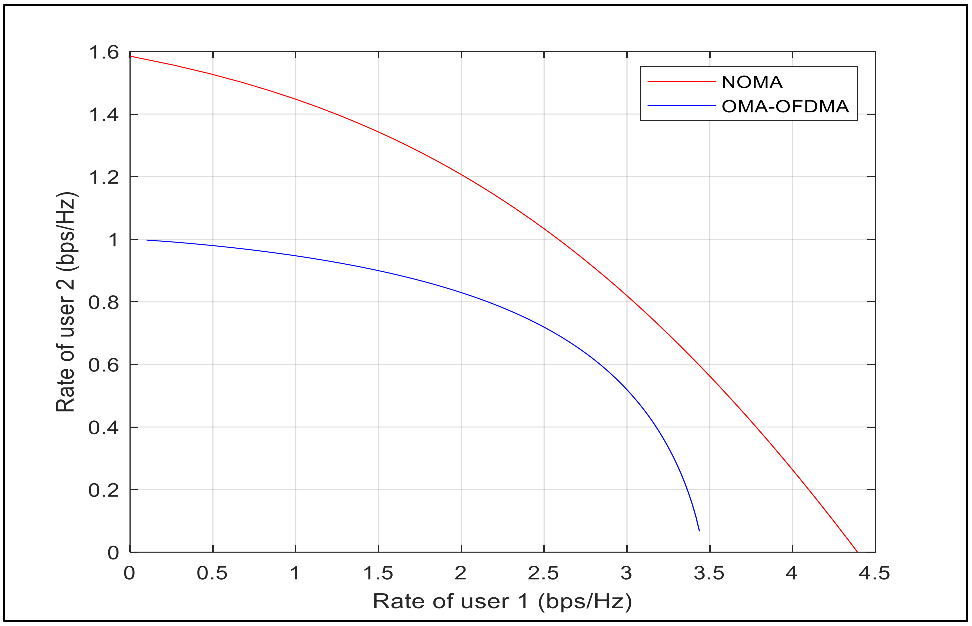

Figure 4.2: NOMA versus OMA-OFDM for un-symmetric rate pairs

It is clear that with un-symmetric rate pairs, compared to OMA OFDMA, NOMA achieves significantly higher rate pairings, particularly for the far user. Pairing two users with more distinctive channel settings to perform NOMA can result in a stronger performance gain. Table 2.4 summarizes the simulation results evaluation of symmetric and un-symmetric user one and user two rate for NOMA compared to OFDMA-OMA.

Table 4.2: Simulation Result Evaluation of Symmetric and Un-symmetric Users Rate (bps/Hz) for NOMA Compared to OFDMA-OMA

Users Rate	Symmetrical Rate		Unsymmetrical Rate	
	NOMA	OMA-OFDM	NOMA	OMA-OFDM
Rate of User 1(bps/Hz)	4.4	3.4	4.3	3.4
Rate of User 2(bps/Hz)	4.4	3.4	1.6	1

4.2.1 Downlink C-NOMA Channel System Evaluation

Here, the BS transmitter uses SC for non-orthogonal user multiplexing, which is the primary goal of Down Link (DL) NOMA. Subsequently, every user's data is subsequently channel-coded, modulated, and combined with signals from other users. The user terminal performs SIC (the order of increasing gain should be followed when decoding SIC in the DL). Any other user can block the user whose channel state is worse than their own. Table 4.3 summarizes the main simulation parameters used to compare the DL NOMA and OMA for two weak and strong users and three weak, medium, and strong users.

Table 4.3: Simulation Parameters Used to Compare DL NOMA with OMA-OFDM for Two and Three Users in the System

Parameters	Data
Number of Base Stations	1
Number of Users Equipment	2 (weak and strong) 3 (weak, medium, and strong)
User Distances	2 Users: [60, 20] m 3 Users: [80, 40, 20] m
Number Symbols	32
Number Subcarriers	128
Cyclic Prefix length	16
Channel length	16
SNR dB Range	-10:10:80 -10:10:90
Number of blocks	1024
Mean square value	1
Signal Power	1
Path Loss Exponent	2
Channel Gain Type	[Rayleigh fading]

Tests have been conducted to show the comparison between NOMA for users weaker near and stronger far and OMA for users weaker near user and stronger far user for BER regarding SNR (dB). The results of such simulation are as shown in Figure 4.3.

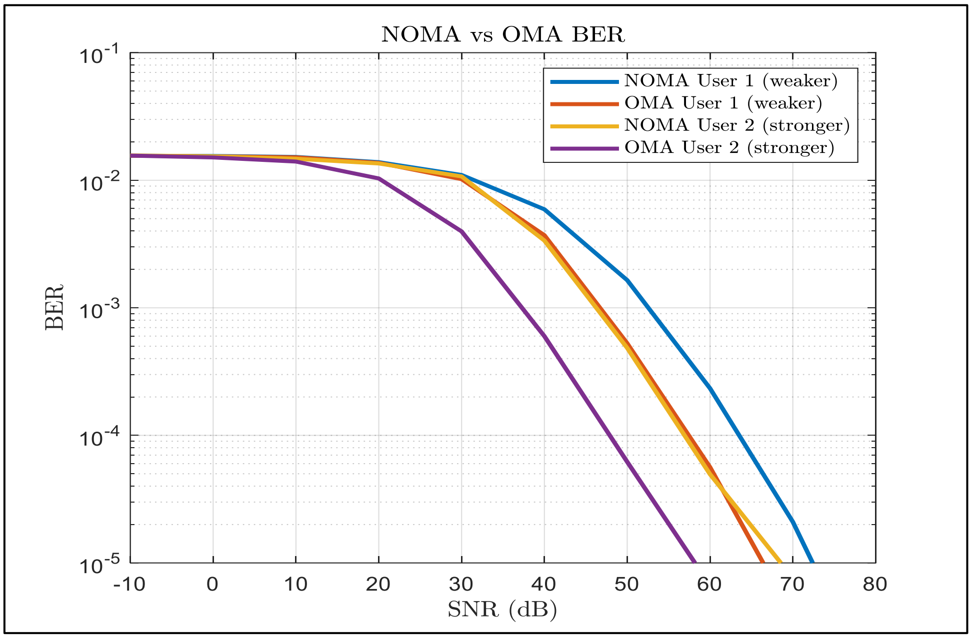

Figure 4.3: NOMA and OMA Comparison for Weaker (near) User and Stronger (far) User

Two users' simulation findings showed that at low SNR, OMA performs slightly better than NOMA. This result shows NOMA performs better than OMA because it offers higher capacity. The simulation results at BER with ($\mathbf{10^{-5}}$) shows that NOMA for weaker near users has SNR (73 dB) and NOMA for stronger (far) users with SNR (68 dB) as pair users have higher values than OMA weaker near users with SNR (66 dB) and OMA stronger far user with SNR (58 dB).

Similarly, for the two users, for the three users, BER versus SNR for NOMA and OMA, OMA outperforms NOMA slightly at low SNR, as shown in Figure 4.4.

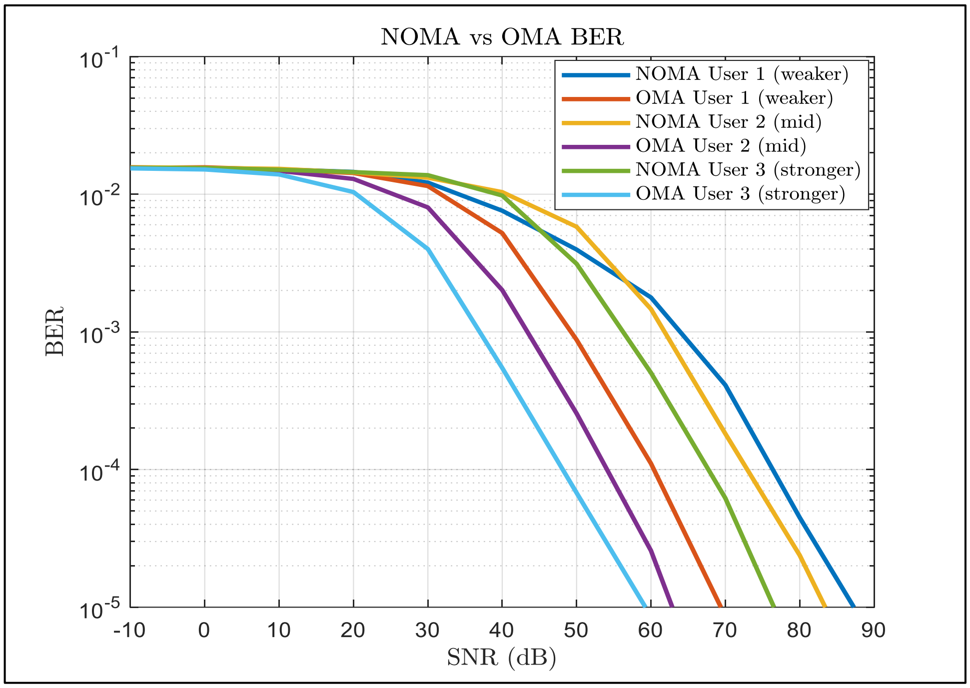

Figure 4.4: NOMA and OMA Comparison for Three users: Near (weaker) User, Middle User, and Far (stronger) User

Due to simultaneous transmission, NOMA users suffer from interference, but OMA users do not encounter this kind of interruption. On the other hand, NOMA beats OMA at high SNR by providing a higher capacity spectral. The simulation results at BER with ($\mathbf{10^{-5}}$) shows that NOMA for weaker near user has SNR (of 88 dB), NOMA mid user has SNR (of 84 dB), and NOMA stronger far user has SNR (77 dB) as three pair users has higher value than OMA weaker near user with SNR (69 dB), OMA mid user SNR (63 dB), and OMA stronger far user with SNR (59 dB).The increase in the number of users in DL C-NOMA has several impacts. With the increase in the number of users, the potential for cooperation increases, leading to enhanced throughput for all users involved. With more users, the spectral efficiency increased since the resources were utilized more efficiently. As the number of users increases, interference among users also increases. However, with proper power allocation, interference can be mitigated effectively. Increasing the number of users increases the complexity of the cooperative NOMA system, especially regarding resource allocation, power control, and signal processing at the BS and UE. With more users, ensuring fairness becomes crucial. Resource allocation algorithms must be designed to maintain fairness among users while maximizing system throughput. C-NOMA can potentially improve energy efficiency by exploiting the gain of multi-user diversity. With more users, the energy efficiency gains may become more pronounced, especially if users have varying channel conditions.

A comparison of outage probability versus SNR (dB) for OMA, C-NOMA, and Non-C-NOMA is conducted and the results are as shown in Figure 4.5.

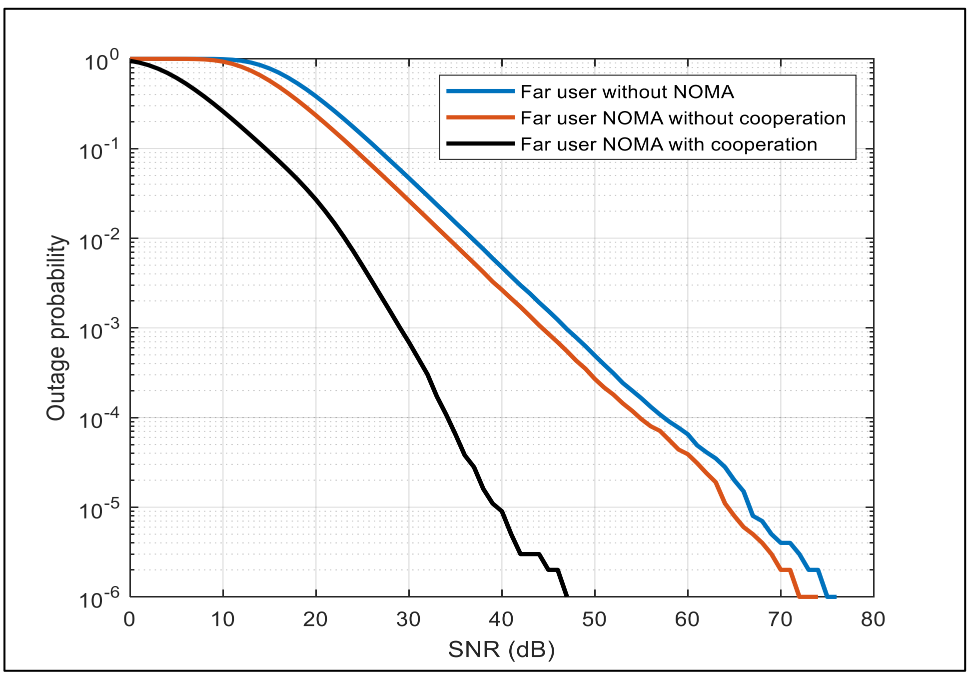

Figure 4.5: A Comparison of (OMA), (C-NOMA), and (Non-C-NOMA) for the outage probability versus SNR (dB)

It is clear from Figure 4.5 that the outage probability (at $\mathbf{10^{-6}}$) in cooperative NOMA has a lower value of SNR (47 dB) than the other two systems, non-cooperative NOMA SNR (73 dB) and OMA with SNR (76 dB). As illustrated in the Figure 4.5, cooperative communication is more beneficial.

4.2.2 Uplink C-NOMA Channel System Evaluation

The same parameters are used in the UL C-NOMA simulation results, except in the channel fading scenario, where Rayleigh and Rician channel fading are used. Rayleigh fading is commonly used to model wireless channels in urban and suburban environments with many obstructions and scattering objects, resulting in many reflected signals arriving at the receiver with random phases and amplitudes. While Rician fading is suitable for modelling wireless channels in environments with a dominant line-of-sight (LOS) path and scattered paths, this often occurs in rural or suburban areas with fewer obstructions. No power control has been established in the UL NOMA model system simulation.

In order to facilitate power domain multiplexing, the intrinsic variations in the channel gains are utilized. Tests for such utilization are as shown in Figures 4.6 and 4.7 for far and near users with Rayleigh and Rician channel fading.

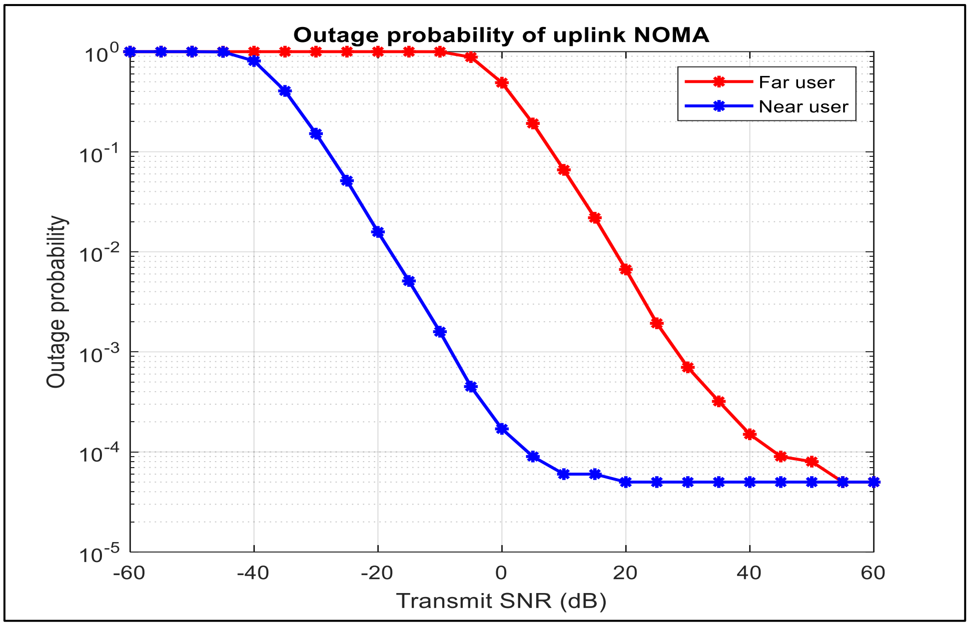

Figure 4.6: The Probability of Outage Versus Transmit SNR Comparison for Far and Near users with Rayleigh channel fading

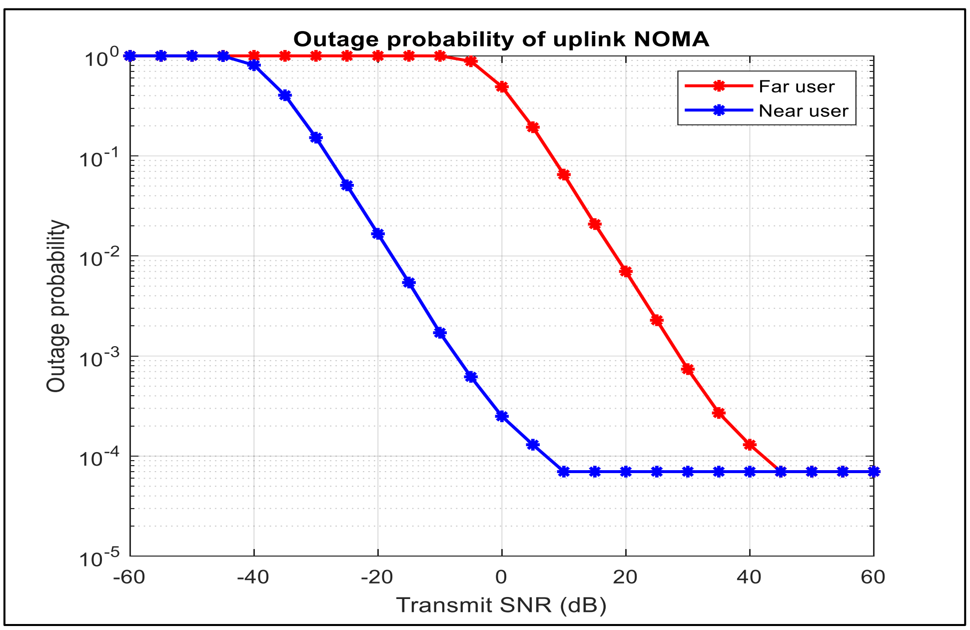

Figure 4.7: The Probability of Outage Versus Transmit SNR Comparison for Far and Near Users with Rician Channel Fading

Figures 4.6 and 4.7 show that the outage probability related to SNR transmission varied for various channels fading. The simulation results for cases of fading channels showed that the types of fading channels affect outage probability. The Rayleigh channel fading model (as a more realistic model) has a value of 5×10^{-5}, and channel fading Rician has a lower value of outage probability 7×10^{-5} in transmit SNR 60 dB. Table 4.4 shows the outage probability versus SNR for Rayleigh and Rician channel fading for UL C-NOMA.

Table 4.4: A Comparison Between Rayleigh and Rician channel fading for Outage Probability versus SNR at (60dB) for UL C-NOMA

	Rayleigh Channel Fading	Rician Channel Fading
Outage Probability vs. SNR (60dB)	5×10^{-5}	7×10^{-5}

Tests with UL NOMA outage probability versus transmit SNR (60 dB) have used signal spectrum bandwidth for near and far users. Different bandwidth frequencies are allocated to the model. Figures 4.8, 4.9, and 4.10 show the numerical simulation for model bandwidth with $10^5, 10^6$, and 10^7 Hz respectively.

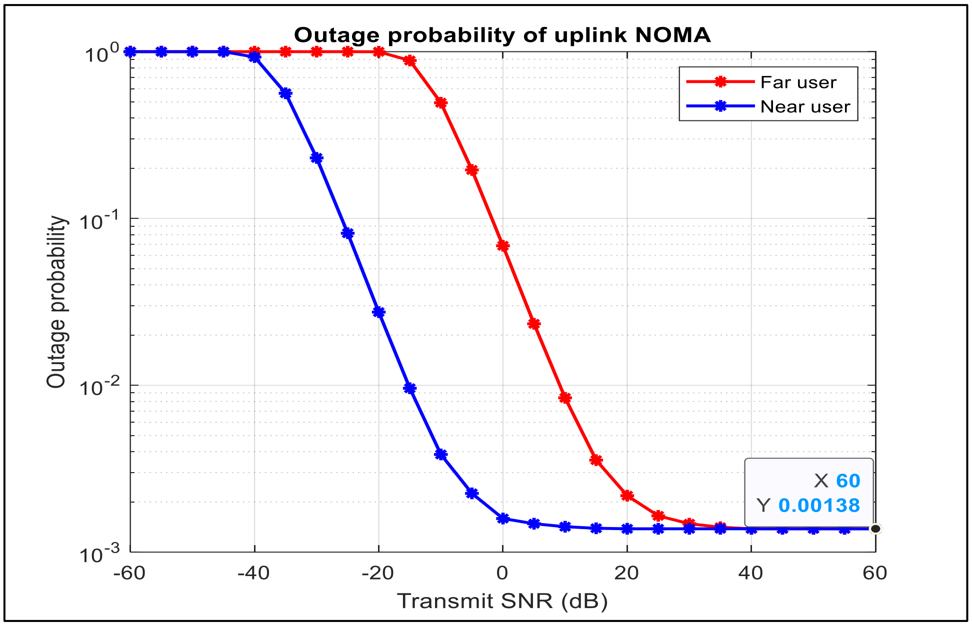

Figure 4.8: Uplink NOMA Signal Spectrum Bandwidth with value (10^5 Hz) for Strong Near and Weak Far Users

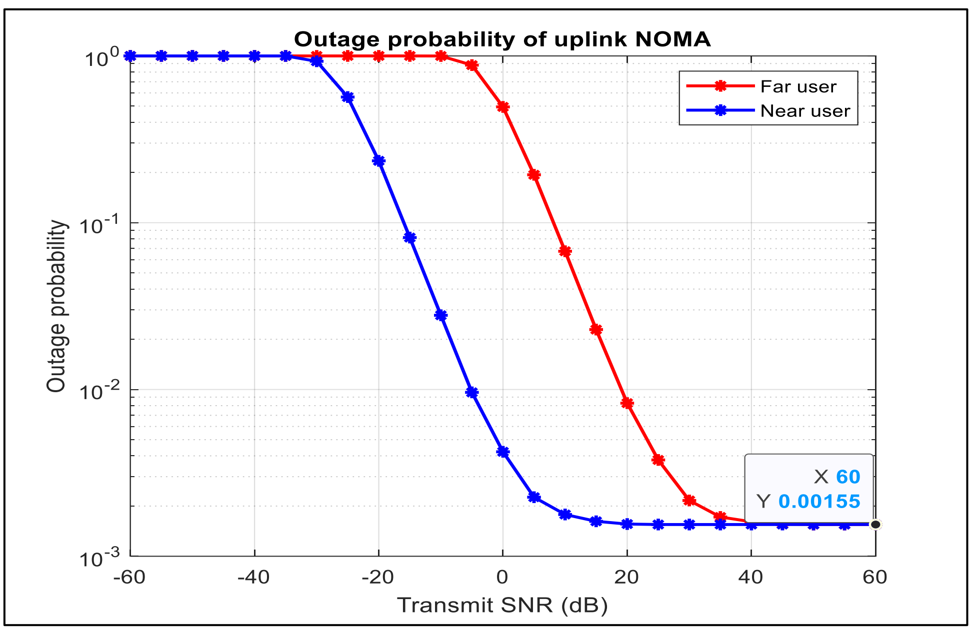

Figure 4.9: Uplink NOMA Signal Spectrum Bandwidth with value (10^6 Hz.) for Strong Near and Weak Far Users

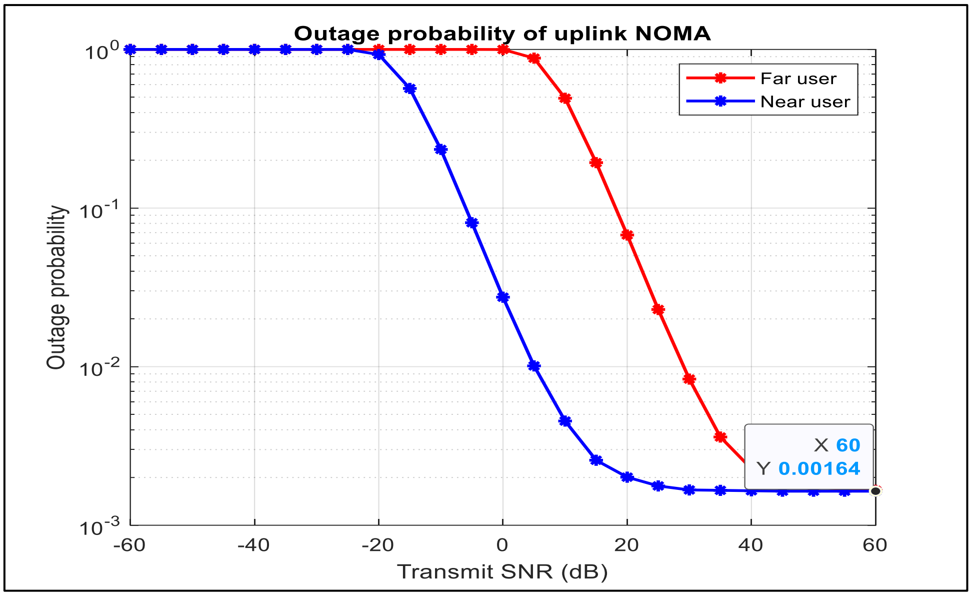

Figure 4.10: Uplink NOMA Signal Spectrum Bandwidth with value (10^7 Hz.) for strong near and weak for users

The analytical results indicate that the outage probability increases when the bandwidth frequency signal spectrum increases for both near and far users. Table 4.5 shows the outage probability versus SNR for different signal spectrum bandwidth for UL C-NOMA.

Table 4.5: The Outage Probability versus SNR at (60dB) different Signal Spectrum Bandwidth ($10^5, 10^6$, and 10^7 Hz) for UL C-NOMA

	Signal Spectrum Bandwidth (10^5 Hz)	Signal Spectrum Bandwidth (10^6 Hz)	Signal Spectrum Bandwidth (10^7 Hz)
Outage Probability vs. SNR (60 dB)	0.00138	0.00155	0.00164

Noise power in the UL NOMA technique is evaluated in this research. Test for probability of outage versus transmits SNR (60 dB) for the case noise power values (-164, -174, and -184 dB) are conducted and the results are as shown in

Figures 4.11, 4.12, and 4.13 these figures with an increase in noise power (-164, -174, and -184 dB), the outage probability of UL NOMA decreases (18×10^{-5}, 11×10^{-5}, and 6×10^{-5}), respectively, with the noise power.

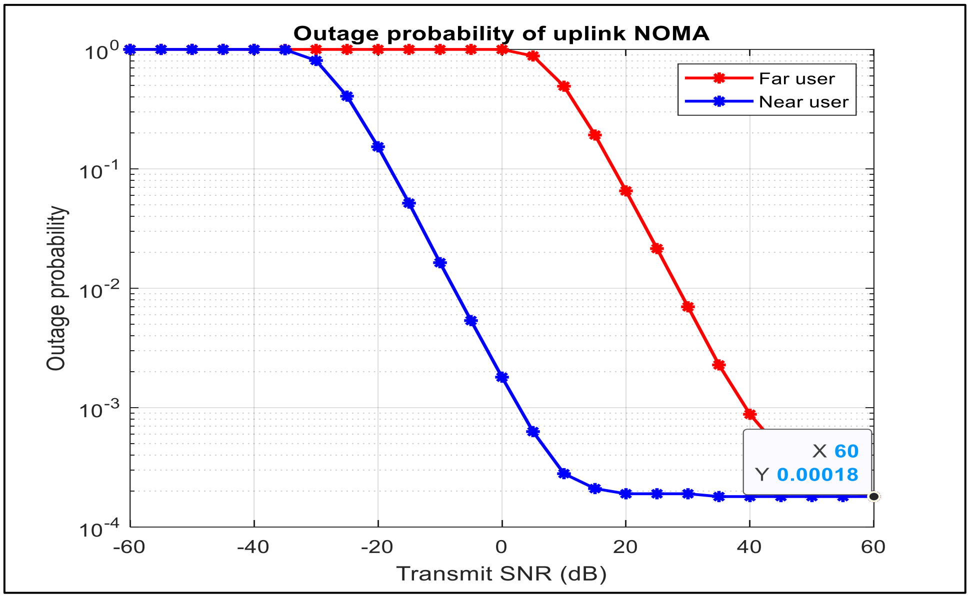

Figure 4.11: The Probability of Outage versus Transmits SNR (60 dB) for the case Noise Power value (-164 dB)

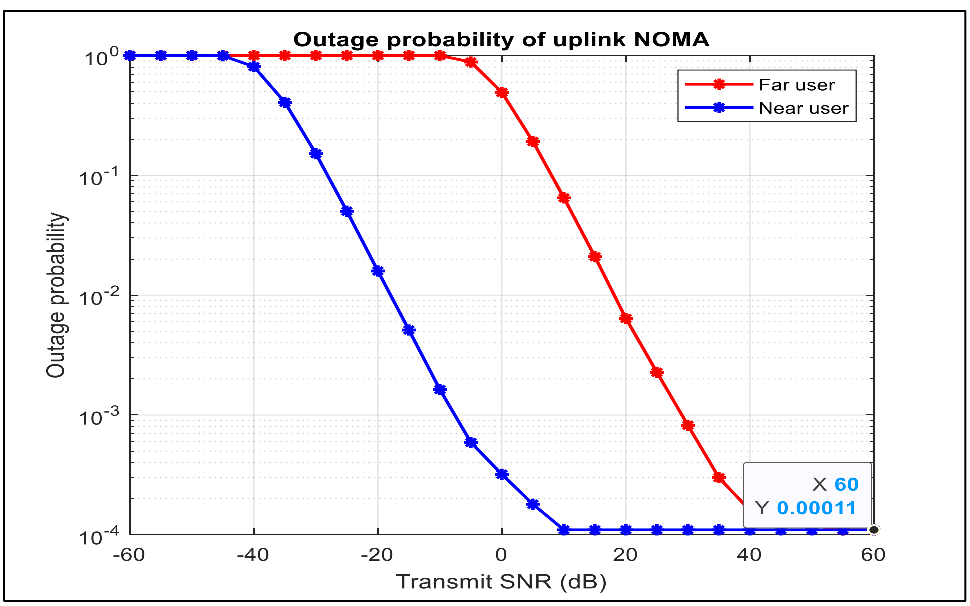

Figure 4.12: The Probability of Outage versus (60 dB) Transmit SNR for the case Noise Power value (-174 dB)

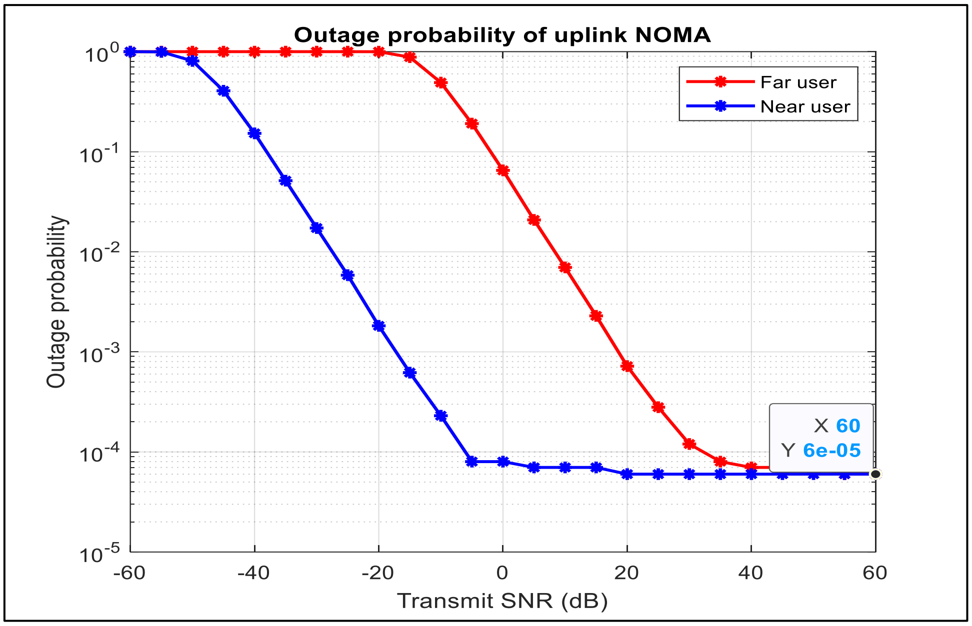

Figure 4.13: The Probability of Outage versus (60 dB) Transmit SNR for the case Noise Power value (-184 dB)

The numerical results show increased noise power decreases outage probability according transmit SNR. Table 4.6 shows the outage probability versus SNR for different noise power for UL C-NOMA.

Table 4.6: The Outage Probability versus SNR at (60dB) for Different Noise Power (-164, -174, -184 dB) for UL C-NOMA

	Noise Power (-164 dB)	Noise Power (-174 dB)	Noise Power (-184 dB)
Outage Probability vs. SNR (60 dB)	18×10^{-5}	11×10^{-5}	6×10^{-5}

With the varying near and far user distances, an improvement in the performance of the model was obtained in the simulation result as shown in Figures 4.14 and 4.15.

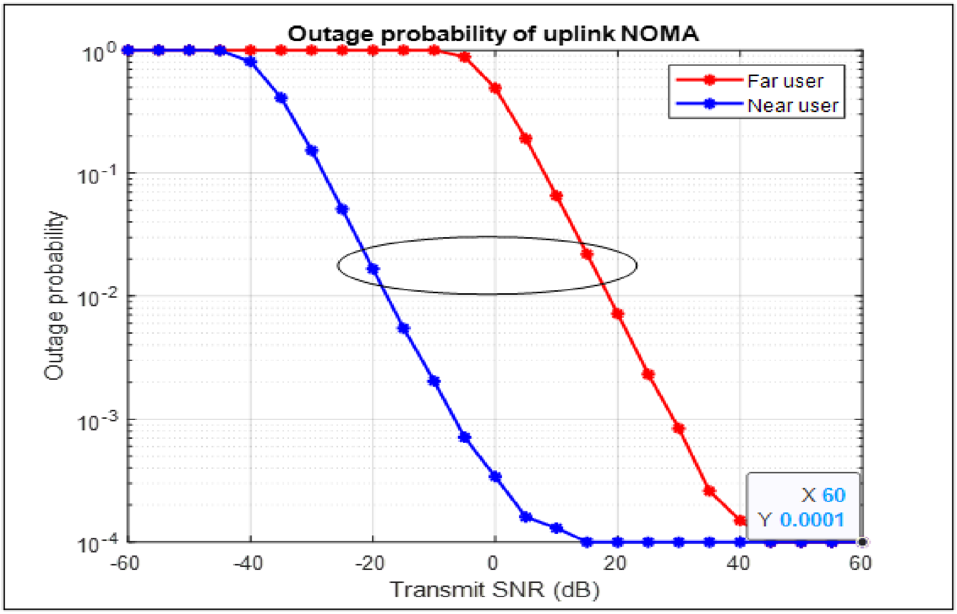

Figure 4.14: The Probability of outage with respect transmit SNR for user distance pair (800-100 m)

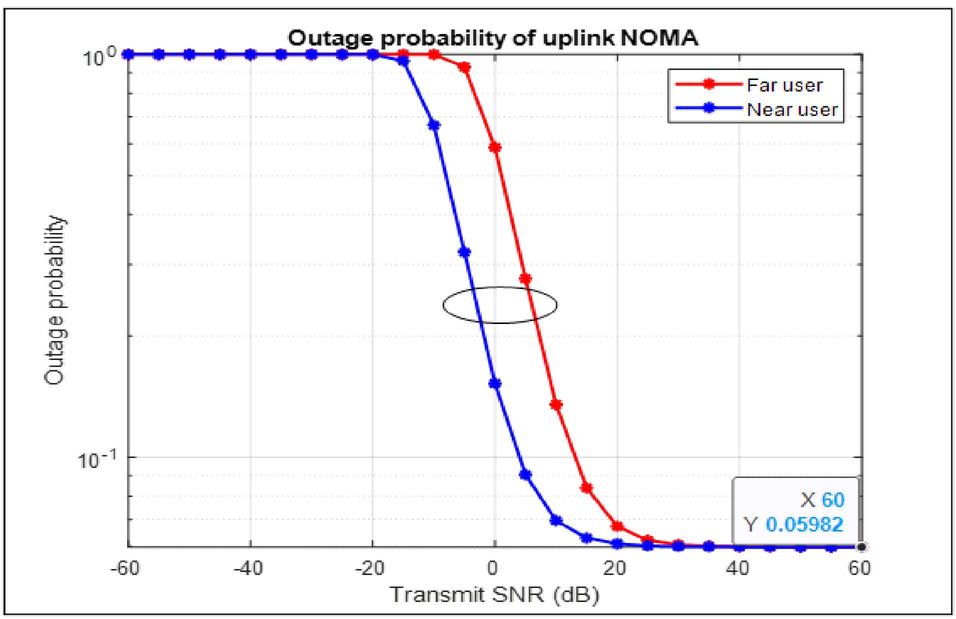

Figure 4.15: The Probability of outage with respect transmit SNR for user distance pair (800-500 m)

From the results shown in Figures 4.14 and 4.15, it is clear for the user distance pair (800-100m), the probability of outage is lesser for either the two users experience, or for the distance pair 800-500 m, the probability of outage is higher for either the two users experience. Table 4.7 shows the outage probability versus SNR at (60 dB) for different users distance pair for UL C-NOMA.

Table 4.7: The Outage Probability versus SNR for Different users distance pair (800-100 m) and (800-500 m) for UL C-NOMA

	Users distance Pair (800-100 m)	Users distance Pair (800-500 m)
Outage Probability vs. SNR (60 dB)	0.0001	0.05982

This finding result validates that when the channel circumstances between the users become significantly distinct, the C-NOMA technique performs better than other techniques.

4.3 Power Allocation (PA-NOMA) Technique Evaluation

In this section, the performance of proposed PA-NOMA algorithm using MATLAB (2022a) software program is evaluated. Firstly, the Bit Error Rate BER results with respect to the power allocation in fixed method is evaluated as shown in Figure 4.16.

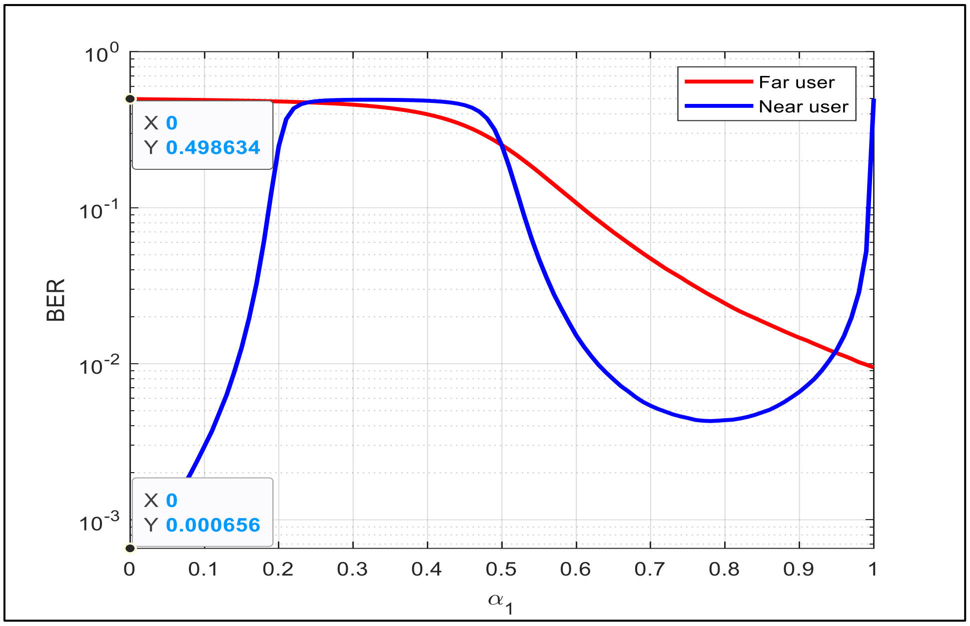

Figure 4.16: The Performance Simulation of BER versus Power Allocation Coefficient According to Far User for Far User and Near user with Fixed Power Allocation (20 dBm)

Figure 4.16. shows the performance simulation for BER versus power allocation coefficient for far user with power allocation for total transmit power (20 dBm) for near (500 m) and far (1000 m) users. The simulation result obtained with ($\alpha_1 = 0.75$ *and* $\alpha_2 = 0.25$). The simulation result for BER can be interpreted in terms of (α_2) by applying the transformation ($\alpha_2 = 1 - \alpha_1$) since the ($\alpha_1 > \alpha_2$) and ($\alpha_1 + \alpha_2 = 1$). The performance simulation for BER versus power allocation coefficient for far user with power allocation for total transmit power (40 dBm) for near (500 m) and far (1000 m) users illustrated in Figure 4.17.

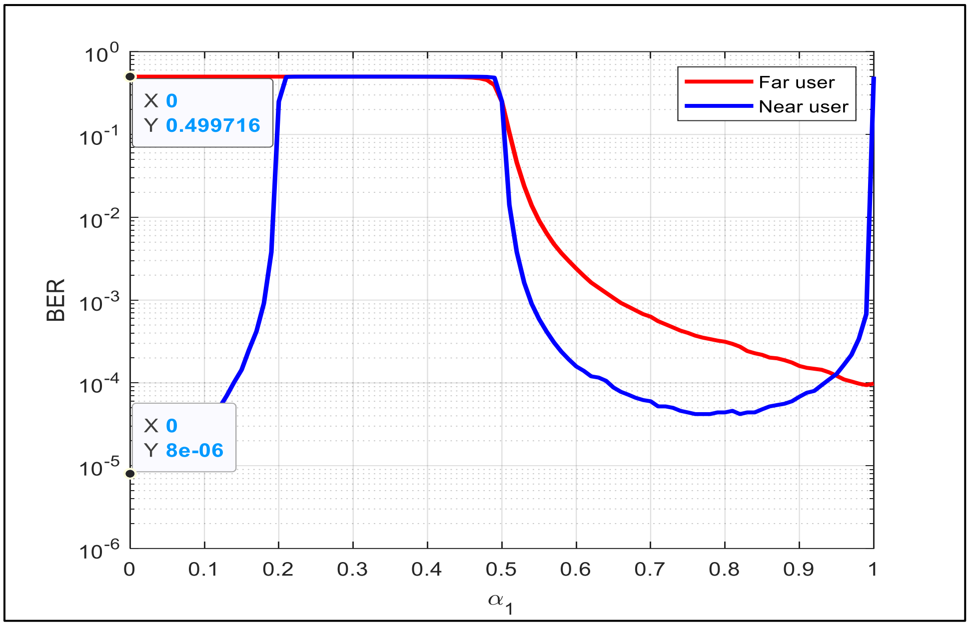

Figure 4.17: The Performance Simulation of BER versus Power Allocation Coefficient According to Far User for Far User and Near user with Fixed Power Allocation (40 dBm)

It is clear from the results presented in Figures 4.16 and 4.17 that the BER decrease with increase the power allocation for near (500m) and far (1000m) users. Table 4.8 shows the BER versus power allocation coefficient of far user and near user for different fixed power allocation.

Table 4.8: The BER versus Power Allocation Coefficient According to Far User of Far user and Near user Comparison for Different Fixed Power Allocation (20 and 40 dB)

	Fixed Power Allocation (20 dB)		Fixed Power Allocation (40 dB)	
BER vs. Power Allocation Coefficient for far and near user According to Far user	Far user	Near User	Far user	Near User
	0.498	0.000656	0.499	0.000008

To evaluate the second function parameter (outage probability), a dynamic power allocation is performed to optimize (α_1 *and* α_2) based on the value of Channel State Information (CSI). Fair power allocation provides priority to the near (weak) user and far (strong) user. The Power Allocation Coefficient (PAC) are calculated are for the far user position rate. All the remaining available power is allocated to the near user after meeting the target rate of far (strong) user. A comparison in performances of dynamic fair power allocation and fixed power allocation for outage probability versus target rate for both near and far users have been obtained as shown in Figure 4.18. Here the outage probabilities are the function of far users target rate (R^*) and total transmit power fixed as (30dBm).

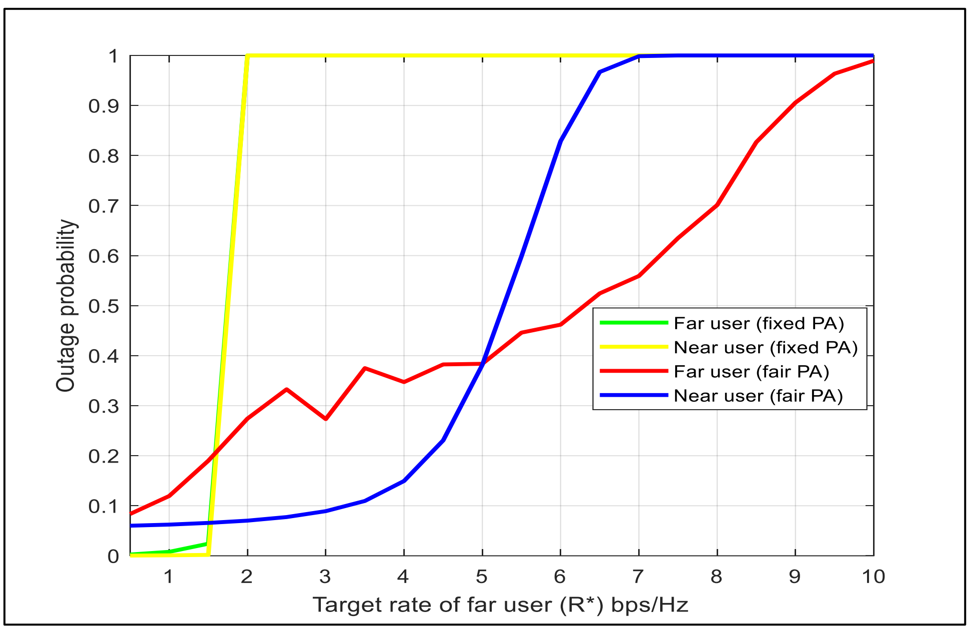

Figure 4.18: Outage Probability versus Target Rate for Fixed and Fair PA with Power Transmit Equal to 30 dBm

The simulation result in Figure 4.18 shows that fixed PA is performing very poorly and its probability of outage saturates to (1) when $(R^*) > 1.5$ bps/Hz. This means that the receiver is in outage if used fixed PA with $(R^*) > 1.5$ bps/Hz because fixed PA takes into account the target rate requirements neither exploits the instantaneous CSI. The output probability for fair power allocation in lower level than fixed power allocation because (α_1 $and \alpha_2$) dynamically adjusted based on target requirement and CSI.

Since the likelihood of a far user reaching the target rate decreases as the target rate rises, the far user outage steadily increases as the target rate requirement rises for fair power allocation. As a result, the likelihood of an outage probability increases. The outage probability of near user shows quite a sharp transition around (R^*) values of 4 to 7 bps/Hz). Beyond that value, the near user is always in outage probability of the dynamic PA is better than fixed PA. This study observed that in case of increasing the power transmit (P_t) to higher level (higher than 30dBm), the outage probability stays in low level (under 0.1) of target rate of far user R^* from 0-6 and 0-8 for power transmit $P_t = 40$ dBm and $P_t = 50$ dBm respectively as illustrated in Figures 4.19 and 4.20. Therefore, the near user obtains higher power level because ($\alpha_n = 1 - \alpha_f$).

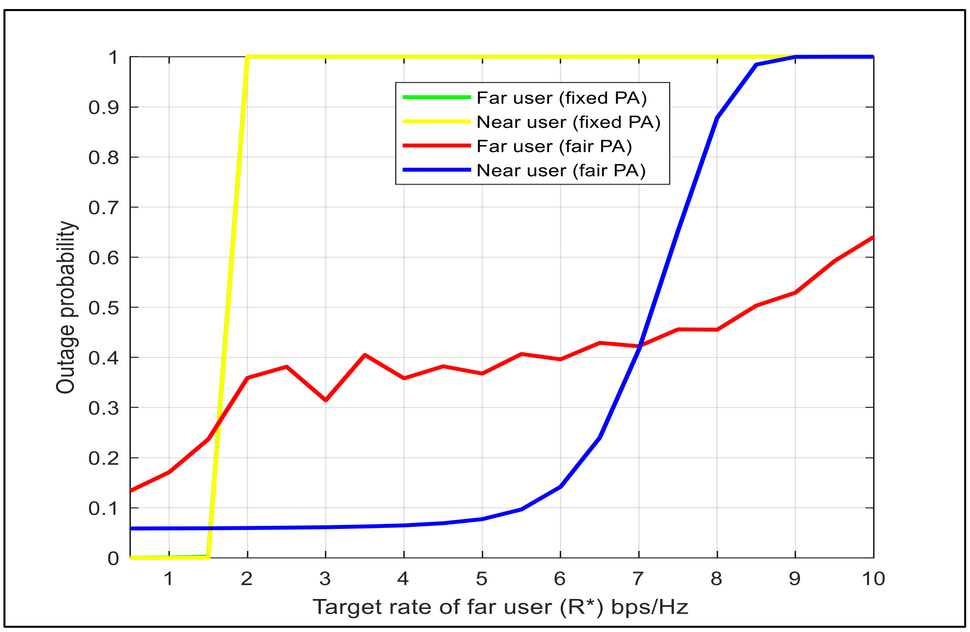

Figure 4.19: Outage probability versus Target Rate for Fixed and Fair PA with Power Transmit Equal to 40 dBm

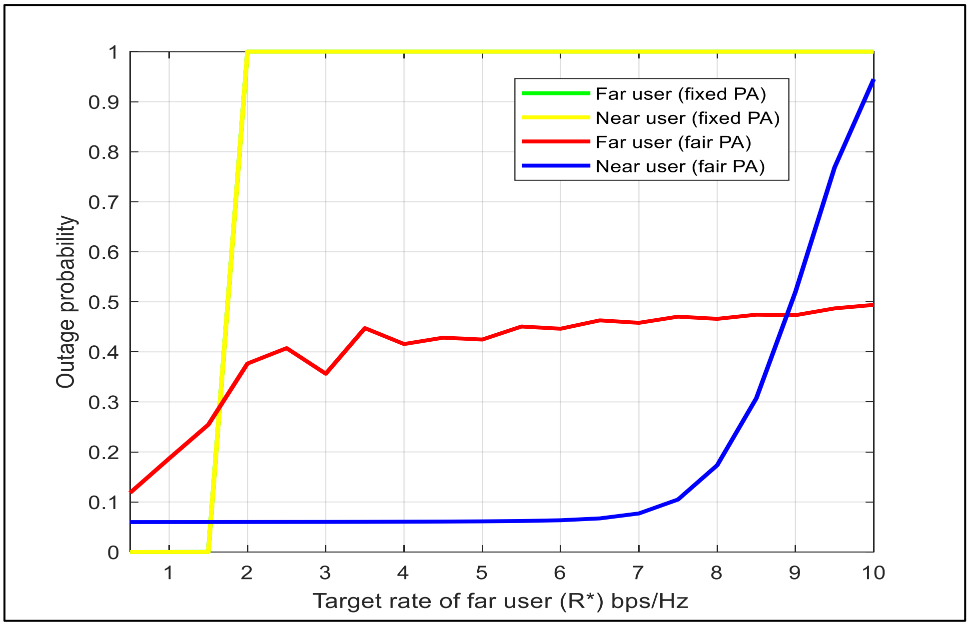

Figure 4.20: Outage probability versus Target Rate for Fixed and Fair PA with Power Transmit Equal to 50 dBm.

Table 4.9 describes the outage probability versus target rate for fixed and fair PA with power transmit is (30, 40, and 50 dBm).

Table 4.9: The Outage Probability versus Target Rate for Fixed and Fair PA with Power Transmit is (30, 40, and 50 dBm)

	Power Allocation (30 dB)			Power Allocation (40 dB)		Power Allocation (50 dB)	
Outage Probability versus Target rate for fixed and fair PA	User	Fixed	Fair	Fixed	Fair	Fixed	Fair
	Far	1.5-2⇒1	0-10⇒0.6	1.5-2⇒1	0-10⇒0.5	1.5-2⇒1	0-10⇒1
	Near	1.5-2⇒1	6-7⇒1	1.5-2⇒1	7-10⇒1	1.5-2⇒1	6-10⇒0.2

The result of optimization shows improvement for the outage probability versus target rate for fixed and fair PA as shown in Figure 4.21.

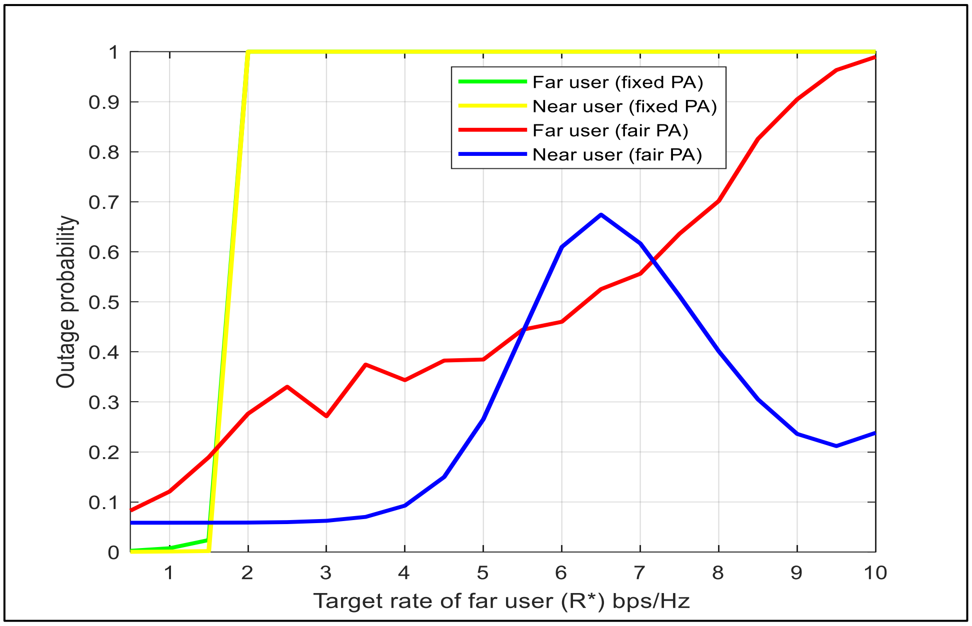

Figure 4.21: Outage probability versus Target Rate for Fixed and Improved Fair Power Allocation PA

It is clear from Figures 4.20 and 4.21, that the outage probability of far user is the same for the as the fair PA and optimized improved fair PA. This indicates that the optimization improved by setting $\alpha_f = 0$. This means that α_f *is* not affecting the outage of far user at all. While for near user outage, the outage probability increases, tops and then starts to decrease. When R^* lies in the range of (0 to 6.5 bps/Hz), it looks like favoring the far user by allocating more and more power to him, at the cost of sacrificing the performance of near user. However, beyond 6.5 bps/Hz, any value of α_f may not fully satisfy R^*. When this happens, the near user favored, instead of wasting all power on the far user. This leads to a decrease in the outage of near user, for $R^* > 6.5$ bps/Hz, without affecting the outage of far user, which is a positive point.

Different dynamic power allocation method has been implemented for maximizing the sum rate and maximizing the energy efficiency. To compare the improved sum rate (Rn+Rf) as a function of transmit power of fair PA with the fixed PA. The fair PA outperforms fixed PA in terms of achievable capacity. The result of such improvement is as shown in Figure 4.22.

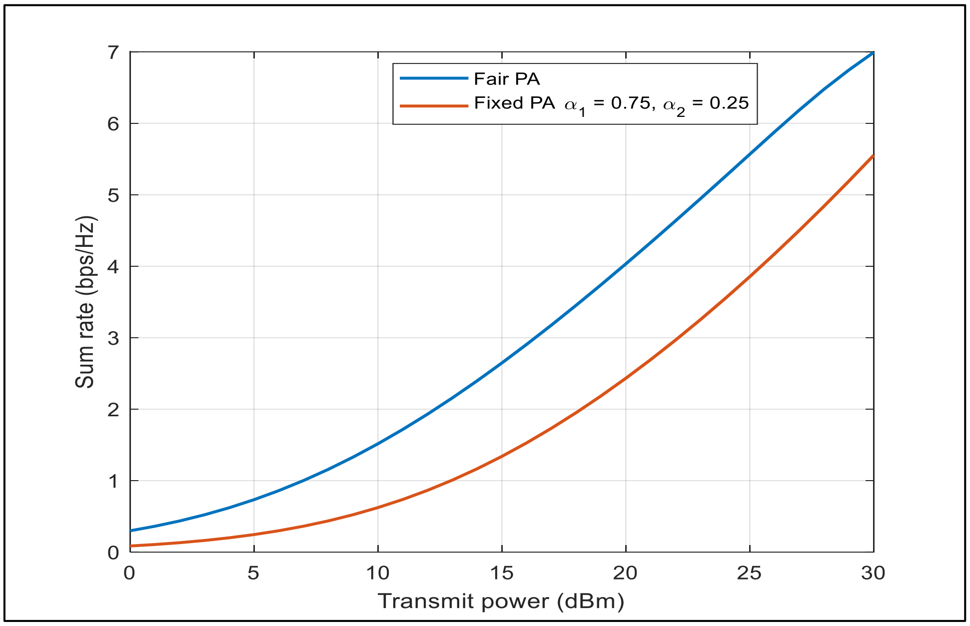

Figure 4.22: Sum Rate vs Transmit Power of Fixed and Fair PA improved with Far User (500 m) and Near User (100 m)

Figure 4.22 shows the impact of distance on the sum rate. Since the figure show that the improvement difference in the sum rate as a function of transmit power for far user (500 m) and near user (100 m). Higher sum rate can be achieved with use of fair PA as shown in Figure 4.23. Table 4.10 describes the sum rate versus transmit power of fixed and fair PA improved for far user.

Table 4.10: Sum Rate vs Transmit Power of Fixed and Fair PA Improved with Far User (500 m) and Near User (100 m)

	Transmit Power (dB)	
	Fair PA	Fixed PA
Sum rate (bps/Hz)	7	5.5

Figure 4.23 shows the improved fair PA outperforms fixed PA in terms of achievable capacity. The figure shows the sum rate versus transmit power for fixed PA and dynamic fair PA improved system for far user (600 m) and near user (200 m).

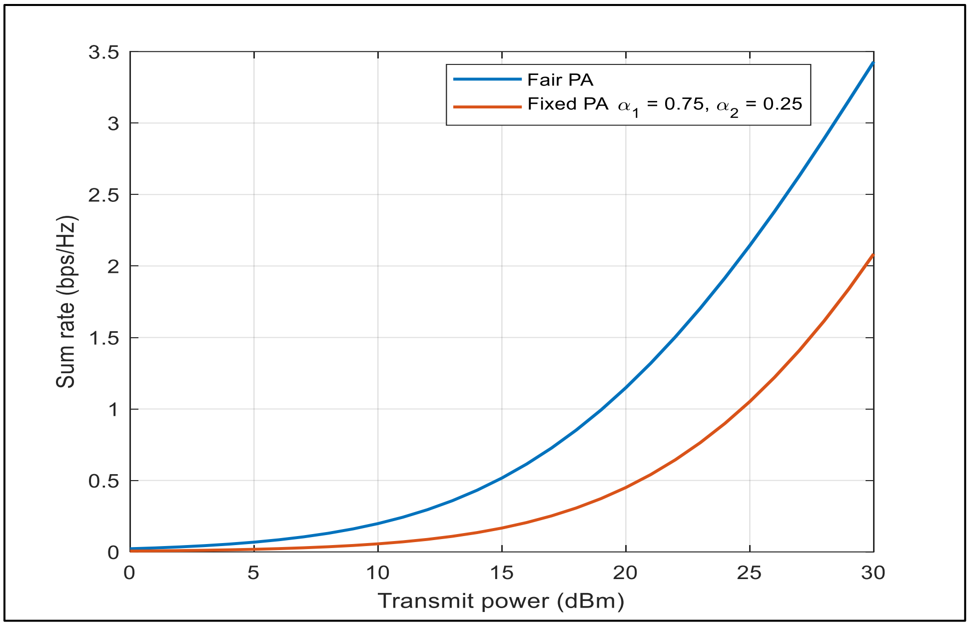

Figure 4.23: Sum Rate vs Transmit Power of Fixed and Fair PA improved with Far User (600 m) and Near User (200 m)

The simulation results in Figures (4.22 and 4.23) show that the improved dynamic fair PA system achieve higher sum rate especially compared for two users near and far for longer distance location. Table 4.11 shows the sum rate versus transmit power of fixed and fair PA improved for far user.

Table 4.11: Sum Rate vs Transmit Power of Fixed and Fair PA Improved with Far User (600 m) and Near User (200 m)

	Transmit Power (dB)	
	Fair PA	Fixed PA
Sum rate (bps/Hz)	3.4	2.1

4.4 Chapter Summary

The simulation results in this chapter have aimed to improve and enhance the 5G performance through the use of PA-NOMA, which employs SIC at the receiver and SC at the transmitter. The research also aims to investigate C-NOMA, NOMA, and OMA for different types of environmental fading. On this aspect, the research proposes a study of C-NOMA system communication for UL NOMA and DL NOMA as a new technique system used to enhance the performance of the 5G mobile cellular networks to mitigate the three features as e-MBB enhances mobile broadband, m-MTC massive machine-type communication, and u-RLLC ultra-reliable and low-latency communication. As a contribution, the research shows how NOMA performance can be improved when combined with numerous confirmed wireless communication network strategies, including C-NOMA system communications, with the help of optimization. The simulation and evaluation results proved that the proposed system provides significantly higher performance in terms of data rate, BER, and outage probability and reduces the power consumption to 52.6% and 54.7% compared to NOMA without cooperative and without NOMA, respectively, which is higher than when compared with the related works.

CHAPTER FIVE

5 INTEGATED C-MOMA with m-MIMO AND CACHING PERFORMANCE EVALUATION IN THE SIXTH GENERATION 6G

5.1Introduction

This chapter presents the results and performance assessments of two modeled techniques C-NOMA with caching and C-NOMA m-MIMO with caching in the sixth generation the 6G mobile communication networks. The chapter shows the performance and efficiency improvement with two proposed algorithm methodologies which presented in chapter three. In this chapter the sum-rate, average latency reduction, and throughput according to SNR simulated and evaluated. C-NOMA with and without caching as a dynamic resource allocation among users and relay nodes compared for different file size, different networks traffic, different number of users, different number of stations, and different power allocations. Next the integration of C-NOMA with caching with and without m-MIMO compared for different file size, different networks traffic, different number of users, different number of stations, and different power allocations. Finally, integration C-NOMA m-MIMO with and without caching is simulated and evaluated for sum-rate, average latency reduction, and throughput.

5.2 Performance of C-NOMA with Caching in the 6G Mobile communication Networks

In this section, performance metrics sum rate, average latency reduction, and throughput are used to analyze caching techniques, power allocation, user association. All metrics are taken into account when simulating and analyzing the system that uses C-NOMA with caching in the 6G mobile communication networks. The main parameters used to simulate comparison the C-NOMA with caching of the proposed dynamic system is shown in Table 5.1.

Table 5.1: Main parameters used in the simulation of proposed dynamic system

Parameters	Data
SNR in dB	SNR dB = -20:5:20
SNR in Linear Scale	$10^{(SNR\_dB/5)}$ $10^{(SNR\_dB/10)}$ $10^{(SNR\_dB/20)}$
Number of SNR Points	N = length (SNR)
Number of Users comparison	[2, 5, and 10]
Number of Monte Carlo Simulations	M = 10000
Number of Stations comparison	[5, 10, 15, and 20]
File size comparison	[1, 10, and 100 MB]
Cache hit ratio for 10 MB File Size	1 - exp (-file size)
Different numbers of Stations	[5, 10, 15, and 20]
Traffic Levels comparison	[high, medium, and low]
Channel Gain Type	[Rayleigh fading]

The simulation results are achieved via the implementation of systems using MATLAB (V 2022a). The system performance is measured by the values of sum rate, average latency reduction and throughput. The sum rate refers to the total data rate or capacity achieved by the system over a given time interval or bandwidth. It is calculated as the sum of the individual data rates of all users or channels in the system. Given N is the number of users, and (Data Rate_i) represents the data rate of the (i_{th}) user, then the sum rate expressed as: (Alnakhli and Networking, 2024)

$$Sum\ Rate = \sum_{i=1}^{N} \text{Data Rate}_i \tag{5.1}$$

While, throughput, on the other hand, specifically measures the rate at which data is successfully transmitted from source to destination. It considers the actual amount of useful data delivered per unit of time, accounting for factors like retransmissions, errors, and system overhead, and resource allocation strategies. For these reasons the sum rate is higher than the throughput. The mathematical expressions for the sum rate and throughput in the context of a communication system for C-NOMA with caching in the 6G networks is as follows: (Jain et al., 2022)

$$\text{Throughput} = \frac{\text{Useful Data Transmitted}}{\text{Time Interval}} \tag{5.2}$$

Due to the system overhead (protocol headers, control signaling, and error correction codes):

$$\text{Throughput} = \text{Sum Rate} - \text{Overhead} \tag{5.3}$$

as well as, due to the packet loss and channel conditions (packet loss, interference, noise, and channel conditions):

$$\text{Throughput} = \text{Sum Rate} \times \text{Channel Efficiency} \tag{5.4}$$

In this research, the proposed system simulation performance evaluation compares the values of sum rate, average latency reduction and throughput of C-NOMA and C-NOMA with caching technique in a wireless communication to investigate enhancement in the performance and efficiency in 6G mobile communication networks under different scenarios.

5.2.1 Sum Rate Evaluation

To evaluate the sum rate for the proposed dynamic system C-NOMA with caching versus traditional C-NOMA, Figure 5.1 shows the simulation result comparison for C-NOMA versus C-NOMA with caching for sum rate with different environment aspects.

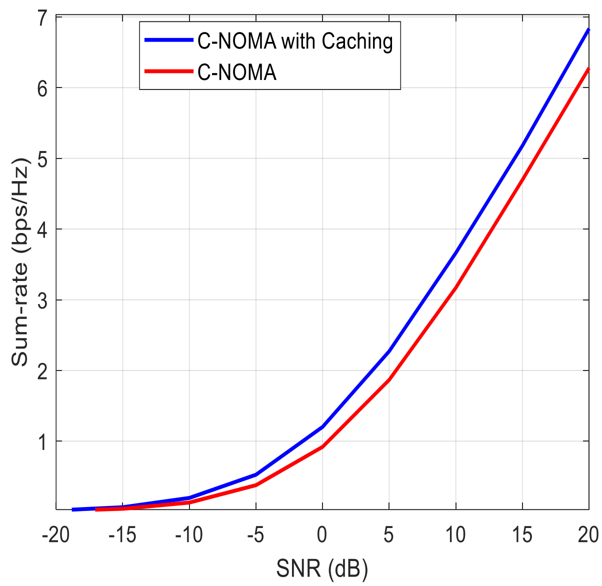

Figure 5.1a

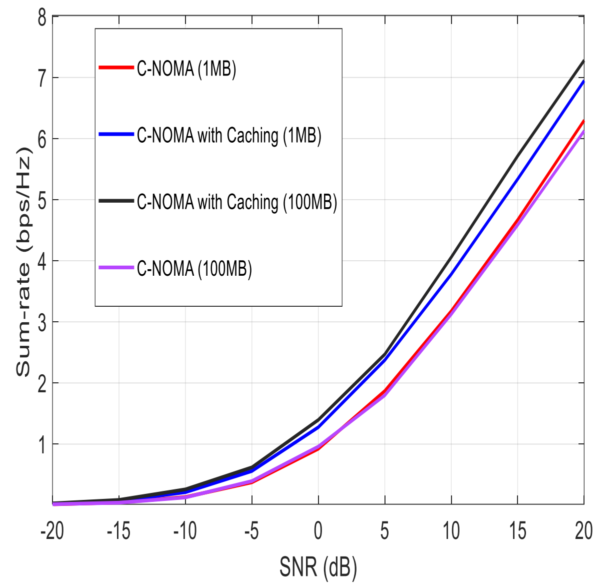

Figure 5.1b

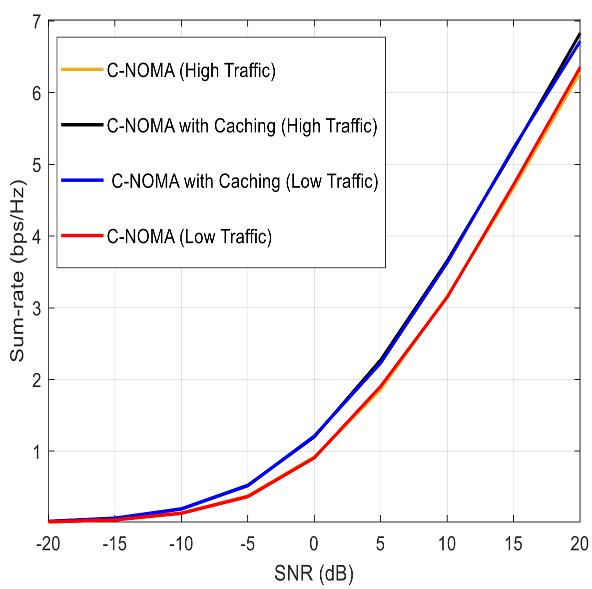

Figure 5.1c

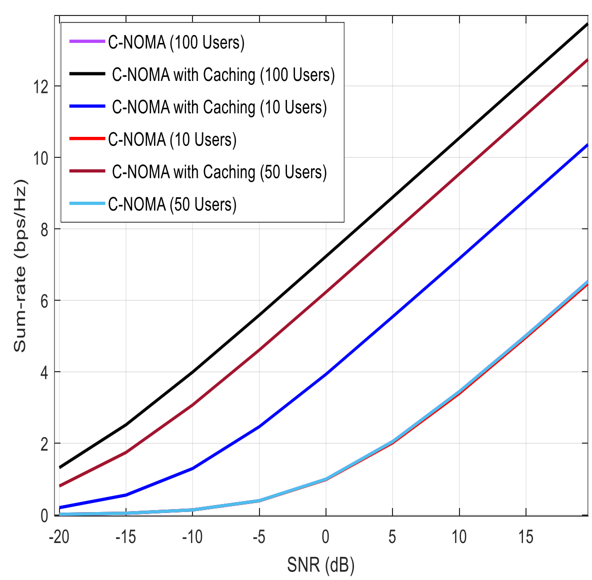

Figure 5.1d

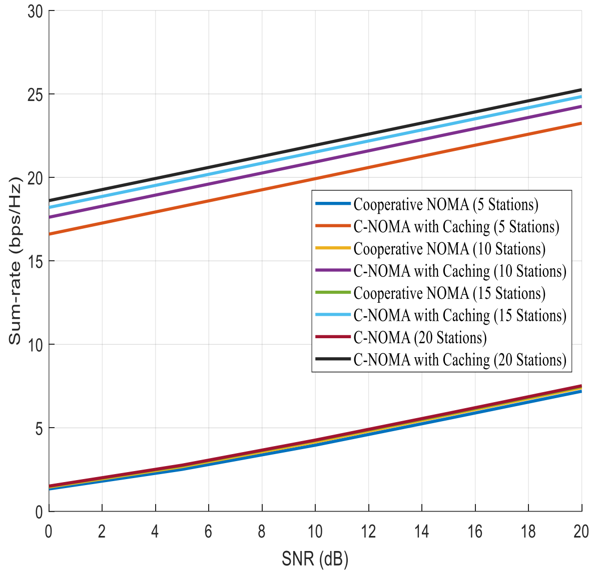

Figure 5.1e

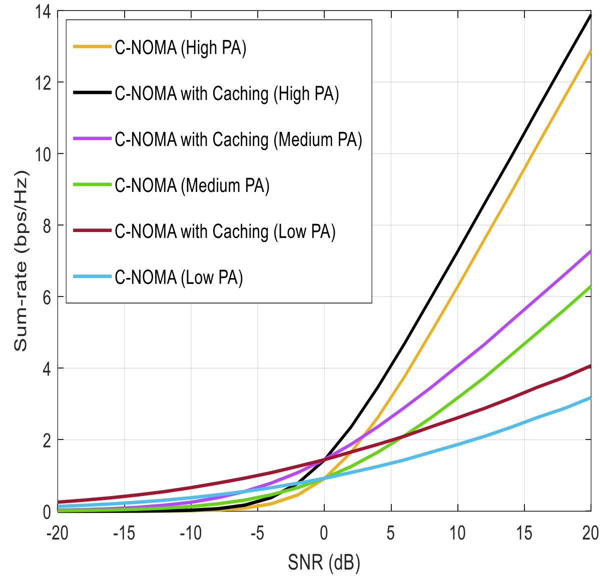

Figure 5.1f

Figure 5.1: Sum Rate Comparison Between the C-NOMA with Caching versus Traditional C-NOMA for Different Cases

Figure 5.1a illustrates the sum-rate performance of two different multiple access techniques C-NOMA with caching and C-NOMA, over a range of SNR values. The figure highlights the conditions under which one technique outperforms the other. In C-NOMA, users cooperate with each other to transmit simultaneously over the same resources. The sum-rate increases with SNR, due to the improved signal quality. In caching NOMA incorporates caching at the users' end, allowing them to retrieve frequently requested data locally. This can potentially enhance the system's throughput. At lower Power Allocation (PA) value, C-NOMA tends to outperform C-NOMA with caching. This is likely because, at lower PA, the benefits of cooperation outweigh the gains from caching. Table 5.2 describes the simulation evaluation of sum rate versus SNR comparison for C-NOMA with caching and traditional C-NOMA.

Table 5.2: The Sum Rate (bps/Hz) versus SNR (dB) Comparison between C-NOMA with caching and traditional C-NOMA

	C-NOMA with Caching	Traditional C-NOMA
Sum rate (bps/Hz) vs. SNR (dB)	6.8	6.2

The file size impact on the sum rate performance of the proposed system is shown in Figure 5.1b for different file size for both cases system C-NOMA and C-NOMA with caching. From Figure 5.1b for traditional C-NOMA, it is clear that when the file size increase from (1MB) to (100MB), the sum rate decreases (6.298 bps/Hz) to (6.125 bps/Hz). While, for C-NOMA with caching when the file size increase from (1Mb) to (100MB) the sum rate increase (6.947 bps/Hz) to (7.279 bps/Hz). From these results, one can observe the advantage roll of the proposed system when caching is combined with C-NOMA.

The network traffics impact on the sum rate of the system results is as shown in Figure 5.1c. For C-NOMA with caching technique, when the system at low network traffic scenario, the sum rate value is (6.715bps/Hz). While, for the high network traffic scenario, the sum rate value increase to (6.827 bps/Hz) due to the advantages use of caching the sum rate increases in the system. For the traditional C-NOMA in low network traffic scenario, the sum rate is (6.352bps/Hz), while the sum rate decreases to (6.250bps/Hz) for high network traffic scenario. This result confirms the role of caching when combined with C-NOMA technique.

Figure 5.1d shows the simulation results for sum rate with (10, 50, and 100) users for C-NOMA and C-NOMA with caching technique. In the case of 10 users, the sum rate is (10.478bps/Hz) for C-NOMA with caching whereas the sum rate for C-NOMA is (6.584bps/Hz). When the number of users increases to 50 users, the sum rate rises to (12.859bps/Hz) for cooperative with caching and sum rate for C-NOMA is (6.641bps/Hz). While, when the number of users increases to 100 users, the sum rate rises more to (13.861bps/Hz) for cooperative with caching and sum rate for C-NOMA is (6.652 bps/Hz). The results show that the proposed system C-NOMA with caching has significant advantages leads to achieve higher sum rate than the C-NOMA when the number of users increases in the 6G network systems.

The simulation results in Figure 5.1e show the impacts of station numbers (5, 10, 15, and 20) on sum rate in the proposed system. The sum rate for C-NOMA with caching increases as the station numbers increase. The sum rate (25.256 bps/Hz) for 20 stations, sum rate (24.844bps/Hz) for 15 stations, sum rate (24.252bps/Hz) for 10 stations, and sum rate (23.248bps/Hz) for 5 stations. While, the sum rate for C-NOMA is (7.523bps/Hz) for 20 stations, (7.7 bps/Hz) for 15 stations, (7.403bps/Hz) for 10 stations, and (7.198bps/Hz) for 5 stations as seen in Figure 5.1e. These results, shows the advantage of C-NOMA with caching in improving the performance and efficiency in the 6G network mobile communication.

Figure 5.1f shows the Power Allocation PA with different level rate (high, medium, and low) impacts on sum rate. The sum rate with high level PA is (13.887bps/Hz) for C-NOMA with caching, while for C-NOMA is (12.887bps/Hz). For medium level of PA, the sum rate is (7.279bps/Hz) for C-NOMA with caching and sum rate is (6.293bps/Hz) for C-NOMA. For the low level of PA, the sum rate is (4.071bps/Hz) for C-NOMA with caching, while, for C-NOMA, the sum rate is (3.178bps/Hz). From these results with all three PA levels, C-NOMA combined with caching has higher value than the sum rates for C-NOMA due to the advantage rolls of caching in the system. Table 5.3 describes the sum rate evaluation of C-NOMA with caching versus traditional C-NOMA for difference file size, network traffic, user numbers, station numbers, and power allocation levels.

Table 5.3: Evaluation of Sum Rate (bps/Hz) of C-NOMA with Caching versus Traditional C-NOMA for difference File, size (1 and 100 MB), Network Traffic (High and Low), User Numbers (10, 50, 100), Station Numbers (5, 10, 15, 20) and Power Allocation PA Levels (High, Medium, and Low)

System Technique	File Size		Network Traffics		User Numbers			Station Numbers				Power Allocation Level		
	1MB	100MB	High	Low	10	50	100	5	10	15	20	High	Medium	Low
C-NOMA with Caching	6.947	7.279	6.82	6.71	10.4	12.8	13.8	23.2	24.2	24.8	25.2	13.8	7.2	4
Traditional C-NOMA	6.298	6.125	6.25	6.35	6.58	6.64	6.65	7.19	7.4	7.49	7.52	12.8	6.2	3.1

5.2.2 Average Latency Reduction Evaluation

The other measure of performance is the average latency reduction for the proposed dynamic system C-NOMA with caching versus traditional C-NOMA as shown in Figures 5.2.

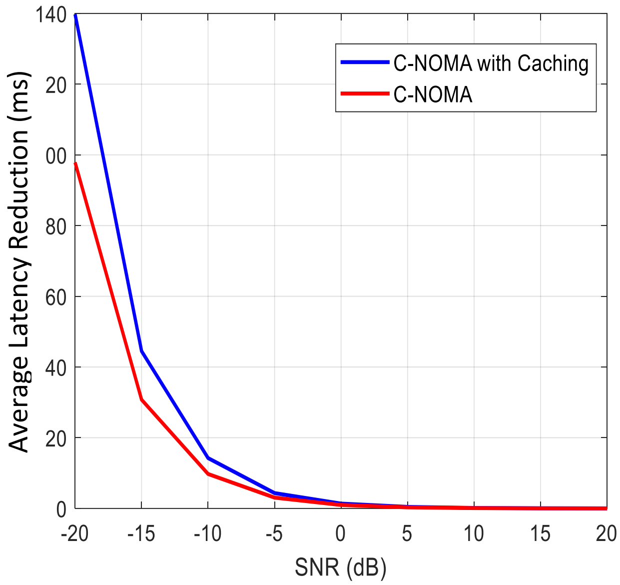

Figure 5.2a

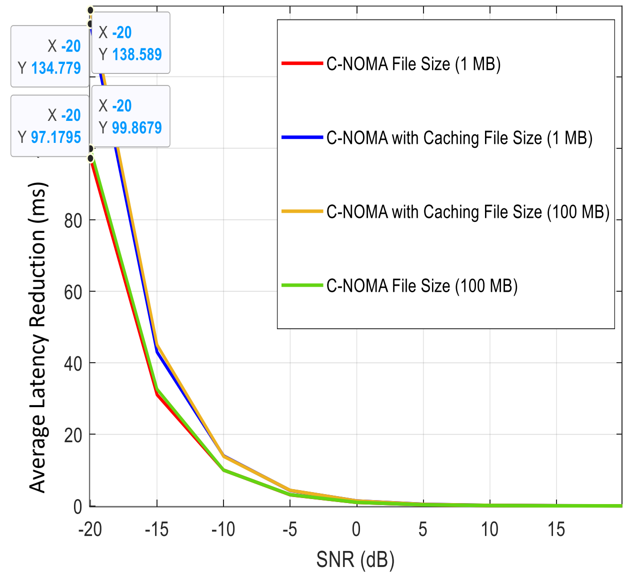

Figure 5.2b

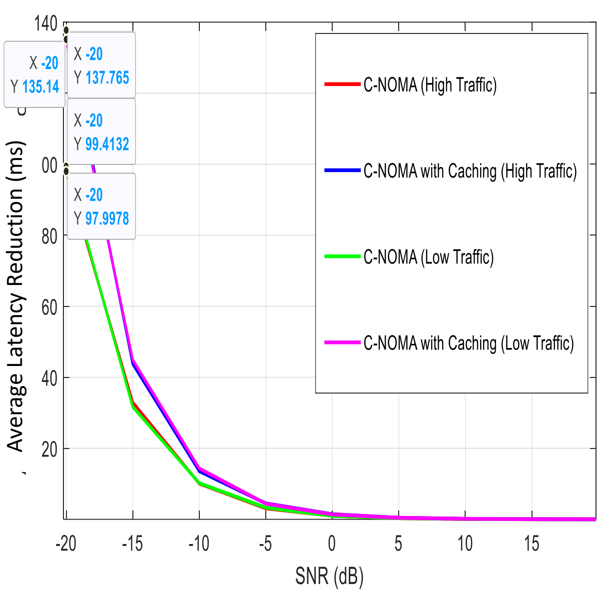

Figure 5.2c

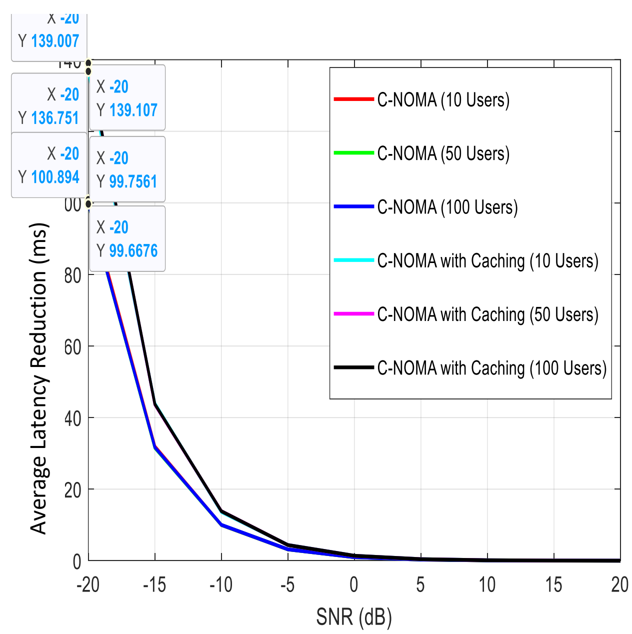

Figure 5.2d

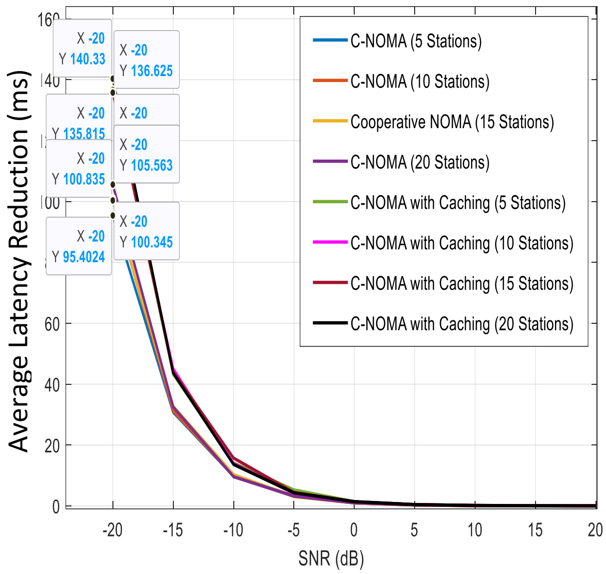

Figure 5.2e

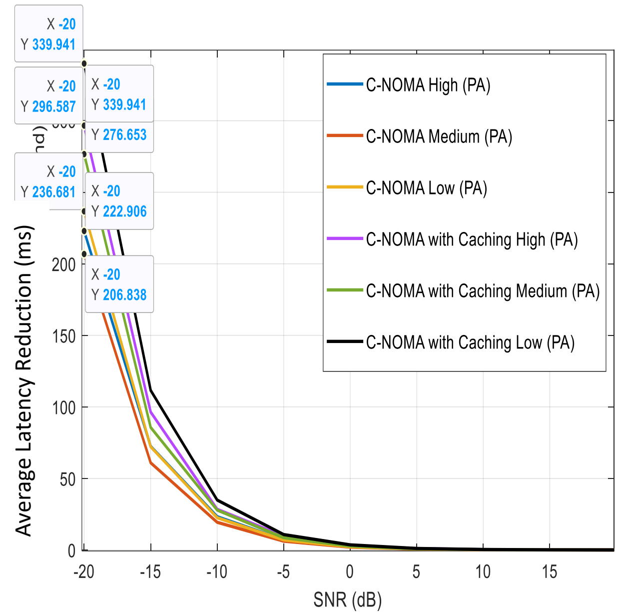

Figure 5.2f

Figure 5.2: Average Latency Reduction (ms) Comparison Between the C-NOMA with Caching versus Traditional C-NOMA for Different Cases.

As seen in the Figure 5.2a, the average latency reduction for proposed dynamic C-NOMA with caching has a higher value (136.163 ms) than the traditional C-NOMA (101.26 ms) at different environment aspects. Table 5.4 describes the Average latency reduction evaluation versus SNR comparison for C-NOMA with caching and traditional C-NOMA.

Table 5.4: The Average Latency reduction (ms) versus SNR (dB) for C-NOMA with caching and traditional C-NOMA Comparison.

	C-NOMA with Caching	Traditional C-NOMA
Average Latency Reduction (ms) vs. SNR (dB)	140	98

The file size impacts on the performance of the system have been investigated as shown in Figure 5.2b, for both files size (1 MB and 100 MB). For the proposed C-NOMA with caching the average latency reduction is (134.779 ms) and (138.589 ms) respectively for 1 and 100MB file size, while for traditional C-NOMA, the average latency reduction is (97.179 ms) and (99.867 ms) respectively for 1 and 100 MB file size.

The impact of caching and network traffic on the average latency reduction is shown in Figure 5.2c. For proposed dynamic system C-NOMA with caching at the high network traffic, it has been found the average latency reduction is (135.14 ms) is higher than the traditional C-NOMA (97.997 ms). Furthermore, the average latency reduction at low traffic for proposed dynamic system C-NOMA with caching is (137.765 ms) and for traditional C-NOMA is (99.413 ms). This due to the advantages of caching technique in the system.

User numbers impact the performance of proposed dynamic system C-NOMA with caching is shown in Figure 5.2d. The simulation results for average latency reduction with (10, 50, and 100) users for C-NOMA and C-NOMA with caching technique in the case of (10 users), the average latency reduction is (136.751ms) for C-NOMA with caching and average latency reduction for C-NOMA is (100.894 ms). When the number of users increases to (50 users), the average latency reduction for cooperative with caching rises to (139.007 ms) and average latency reduction for C-NOMA is (99.756 ms). While, when the number of users increases to (100 users), the average latency reduction rises more to (139.107 ms) for cooperative with caching and for C-NOMA is (99.667 ms). The simulation results shows that the proposed dynamic system C-NOMA with caching has significant advantages leads to achieve higher average latency reduction than the C-NOMA.

The simulation results in Figure 5.2e, shows the impacts of station numbers (5, 10, 15, and 20) on average latency reduction in the proposed dynamic system. The average latency reduction for C-NOMA with caching increase with increase of station numbers directly. Average latency reduction (140.33 ms) for (20) stations, (136.625 ms) for (15) stations, (135.815 ms) for (10) stations, and (135.753 ms) for (5) stations. While, the average latency reduction for traditional C-NOMA has increase with increase of station numbers. The average latency reduction (105.563 ms) for (20) stations, (100.835 ms) for (15) stations, (100.345 ms) for (10) stations, and (95.402 ms) for (5) stations. These results show the advantage of caching when combined with C-NOMA to improve the performance.

Figure 5.2f shows the power allocation (PA) with different level rate (high, medium, and low) impacts on the average latency reduction. The average latency reduction with low level (PA) is (339.941 ms) for C-NOMA with caching, while for C-NOMA is (236.681 ms). For medium level of (PA), the average latency reduction is (296.587 ms) for C-NOMA with caching and (222.906 ms) for C-NOMA. For the high level of (PA), the average latency reduction is (276.653 ms) for C-NOMA with caching, while, for C-NOMA is (206.838 ms). The simulation results confirms that when the (PA) with a low level, resulting in higher average latency reduction. Table 5.5 describes the average latency reduction evaluation of C-NOMA with caching versus traditional C-NOMA for difference file size, network traffic, user numbers, station numbers, and power allocation levels.

Table 5.5: The Average Latency Reduction (ms) Evaluation of C-NOMA with caching versus traditional C-NOMA for difference file size (1 and 100 MB), network traffic (High and Low), user numbers (10, 50, and 100), station numbers (5, 10, 15, 20), and power allocation levels (High, Medium, and Low)

System Technique	File Size		Network Traffics		User Numbers			Station Numbers				Power Allocation Level		
	1MB	100MB	High	Low	10	50	100	5	10	15	20	High	Medium	Low
C-NOMA with Caching	134.7	1385	135.14	137.7	136.7	139.1	139.1	135.7	135.8	136.6	140.3	276.6	296.5	339.9
Traditional C-NOMA	97.1	99.8	97.9	99.4	100.8	99.7	99.6	95.4	100.3	100.8	105.5	206.8	222.9	236.6

5.2.3 Throughput Evaluation

Simulation results showing throughput for the proposed dynamic system C-NOMA with caching versus traditional C-NOMA are shown in Figures 5.3 for different cases.

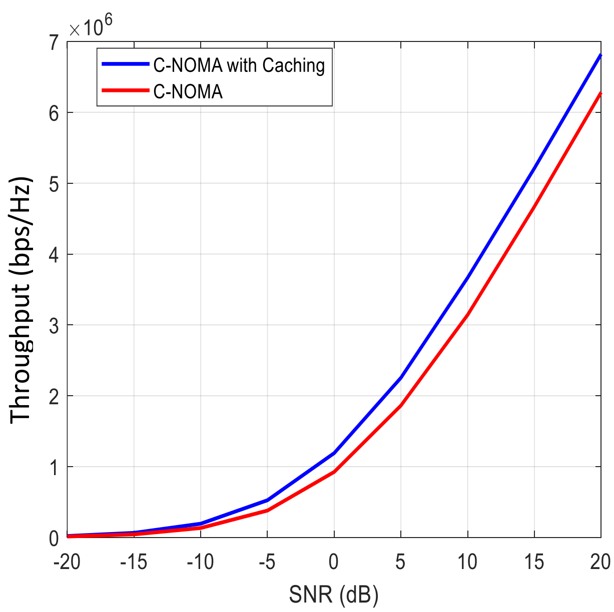

Figure 5.3a

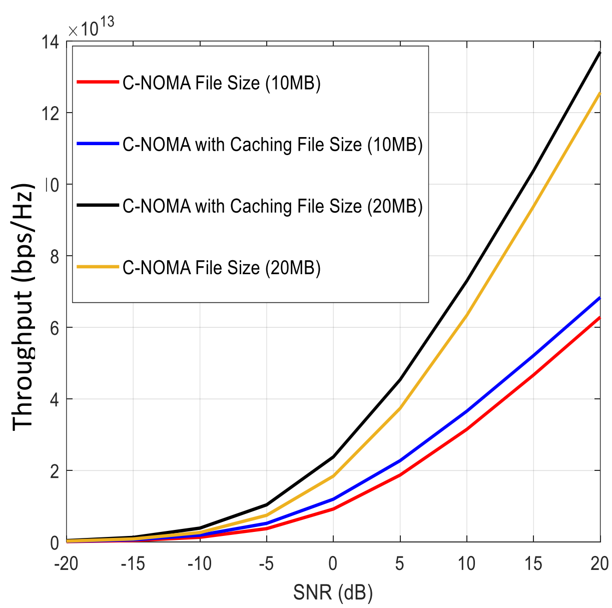

Figure 5.3b

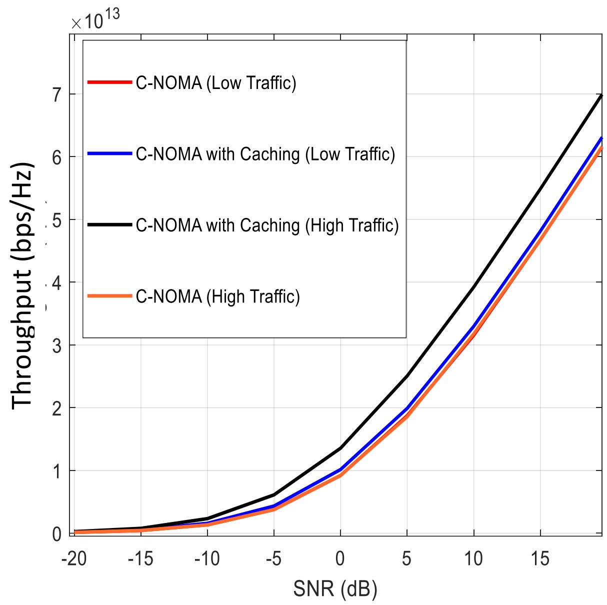

Figure 5.3c

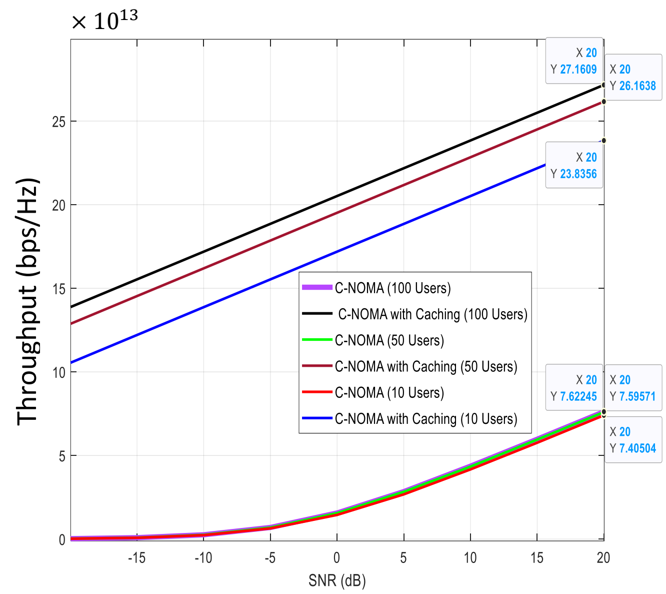

Figure 5.3d

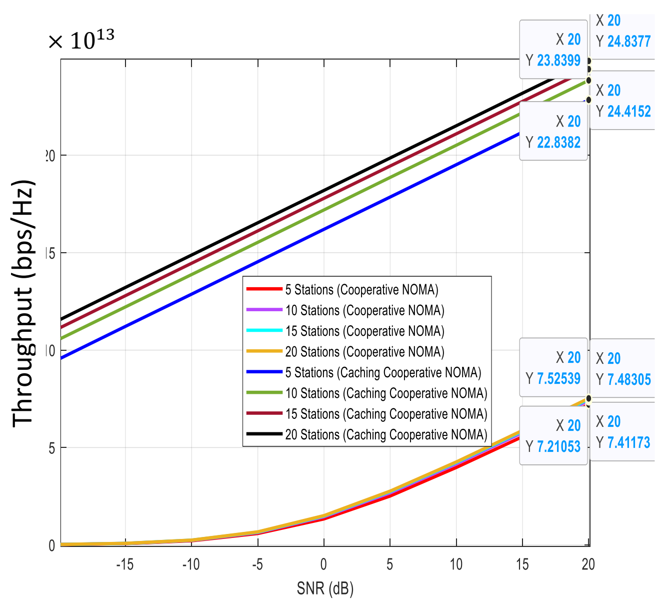

Figure 5.3e

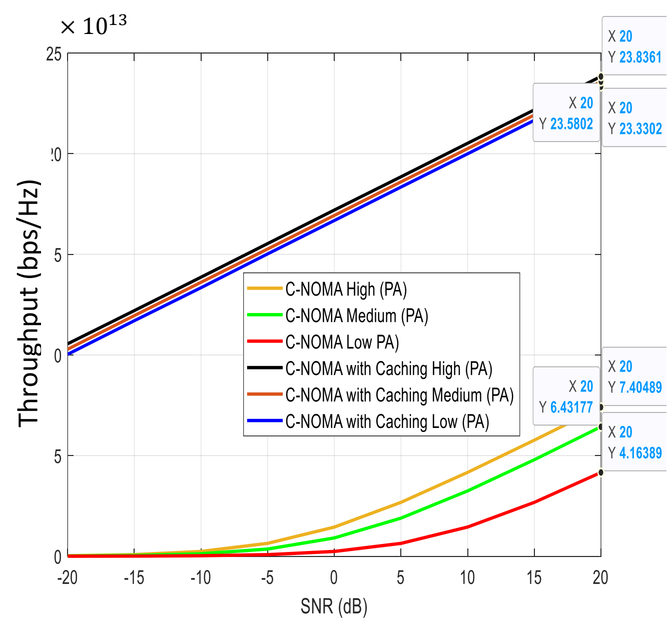

Figure 5.3f

Figure 5.3: Throughout Comparison Between the C-NOMA with Caching versus Traditional C-NOMA for Different Cases

As seen in the Figure 5.3a, the throughput for proposed dynamic C-NOMA with caching has a higher value (6.8 $\times 10^{6}$ bps/Hz) than the traditional C-NOMA (6.2 $\times 10^{6}$ bps/Hz) at different environment aspects. Table 5.6 describes the throughput evaluation versus SNR comparison for C-NOMA with caching and traditional C-NOMA.

Table 5.6: The Throughput (bps/Hz) versus SNR (dB) for C-NOMA with Caching and Traditional C-NOMA Comparison.

	C-NOMA with Caching	Traditional C-NOMA
Throughput (bps/Hz) vs. SNR (dB)	6.8 $\times 10^{6}$	6.2 $\times 10^{6}$

The file size impacts on the throughput have been measured for both C-NOMA and C-NOMA with caching as shown in Figure 5.3b. For traditional C-NIOMA the results show that when the file size increases from (10 MB) to (20 MB), the throughput increases (6.28693 $\times 10^{13}$ bps/Hz) to (12.562 $\times 10^{13}$ bps/Hz). While, for C-NOMA with caching when the file size increases from (10 Mb) to (20 MB), the throughput increases (6.83923 $\times 10^{13}$ bps/Hz) to (13.7001 $\times 10^{13}$ bps/Hz). These results confirm the advantage of caching when combined with C-NOMA.

As seen in the Figure 5.3c, the simulation results for throughput versus SNR (20 dB), has a higher value (7.27 $\times 10^{13}$ bps/Hz) for the proposed dynamic system C-NOMA with caching at the high network traffic, is higher than the traditional C-NOMA (6.42 $\times 10^{13}$ bps/Hz). furthermore, the throughput for traditional C-NOMA (7.1 $\times 10^{13}$ bps/Hz) at the high network traffic is less than at the low network traffic (6.26 $\times 10^{13}$ bps/Hz). All the results are due to the caching advantageous role when combining with C-NOMA. These results confirm the advantageous roles of caching when combined with C-NOMA.

User numbers impact the throughput of the proposed dynamic system C-NOMA with caching is investigated as shown in Figure 5.3d. The figure shows the throughput for (10, 50, and 100) users in case of C-NOMA and C-NOMA with caching technique. When the number of users is (10 users), the throughput is (23.835$\times 10^{13}$ bps/Hz) for C-NOMA with caching while the throughput for C-NOMA is (7.622$\times 10^{13}$ bps/Hz). When the number of users increases to (50 users), the throughput for C-NOMA with caching rises to (26.163$\times 10^{13}$ bps/Hz) and throughput for C-NOMA is (7.595 bps/Hz). Finally, when the number of users increases to (100 users), the throughput rises to (27.16$\times 10^{13}$ bps/Hz) for C-NOMA with caching while the throughput for C-NOMA is (7.405$\times 10^{13}$ bps/Hz). The simulation results show the that proposed dynamic system C-NOMA with caching has significant advantageous leads to throughput increase with the user numbers increase, compared to C-NOMA.

The simulation results in Figure 5.3e show the impacts of station numbers (5, 10, 15, and 20) on throughput of the proposed C-NOMA with caching. The throughput for C-NOMA with caching increases with the increase of station numbers proportionally such that the throughput (24.837$\times 10^{13}$ bps/Hz) for (20) stations, (23.839$\times 10^{13}$ bps/Hz) for (15) stations, (23.415$\times 10^{13}$ bps/Hz) for (10) stations, and (22.838$\times 10^{13}$ bps/Hz) for (5) stations. While, the throughput for traditional C-NOMA is less increased with increase of station numbers such that, the throughput (7.525$\times 10^{13}$ bps/Hz) for (20) stations, (7.483$\times 10^{13}$ bps/Hz) for (15) stations, (7.411$\times 10^{13}$ bps/Hz) for (10) stations, and (7.21$\times 10^{13}$ bps/Hz) for (5) stations. These results, shows the advantageous roles of caching when combined with C-NOMA to improve the throughput performance and efficiency in the 6G network mobile communication.

Figure 5.3f shows the PA with different level allocation (high, medium, and low) impacts on throughput. The throughput with high level (PA) is (23.836×10^{13} bps/Hz) for C-NOMA with caching, while for C-NOMA is (7.404×10^{13} bps/Hz). For medium level of PA, the throughput is (23.58×10^{13} bps/Hz) for C-NOMA with caching and (6.431×10^{13} bps/Hz) for C-NOMA. For the low level of (PA), the throughput is (23.33×10^{13} bps/Hz) for C-NOMA with caching, while, for C-NOMA is (4.163×10^{13} bps/Hz). The simulation results confirms that when the PA with a high level, resulting in higher throughput and the throughput for proposed dynamic system C-NOMA with caching has higher value than the throughput for C-NOMA. Table 5.7 describes the throughput evaluation of C-NOMA with caching versus traditional C-NOMA for difference file size, network traffic, user numbers, station numbers, and power allocation levels.

Table 5.7: The Throughput (bps/Hz) Evaluation of C-NOMA with Caching versus Traditional C-NOMA for Difference File size (1 and 20 MB), network traffic (High and Low), user numbers (10, 50, and 100), station numbers (5, 10, 15, 20), and power allocation levels (High, Medium, and Low)

System Technique	File Size		Network Traffics		User Numbers			Station Numbers				Power Allocation Level		
	1MB	20MB	High	Low	10	50	100	5	10	15	20	High	Medium	Low
C-NOMA with Caching	6.8392	13.7001	7.27	7.1	23.83	26.16	27.16	22.8	23.41	23.83	24.83	23.836	23.58	23.33
Traditional C-NOMA	6.2869	12.562	6.42	6.26	7.62	7.59	7.405	7.21	7.411	7.483	7.525	7.404	6.431	4.163

5.3 Evaluation of Integrated C-NOMA with Caching and Massive MIMO Technique

By integrating C-NOMA with caching and m-MIMO technique, can improve the overall performance and efficiency of the 6G mobile communication networks, catering to diverse user requirements and user demands. By combining these three techniques, the system can obtain higher level for sum rate, average latency reduction, and throughput. Figures (5.4a, 5.4b, and 5.4c) show the simulation results for C-NOMA with caching technique integrated with m-MIMO techniques.

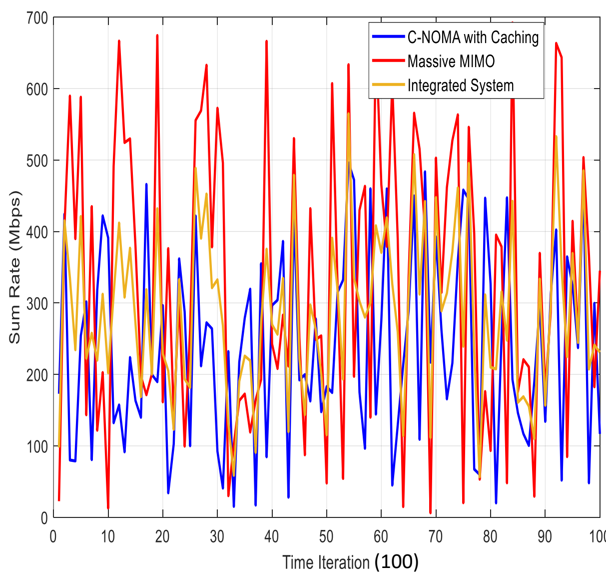

Figure 5.4a

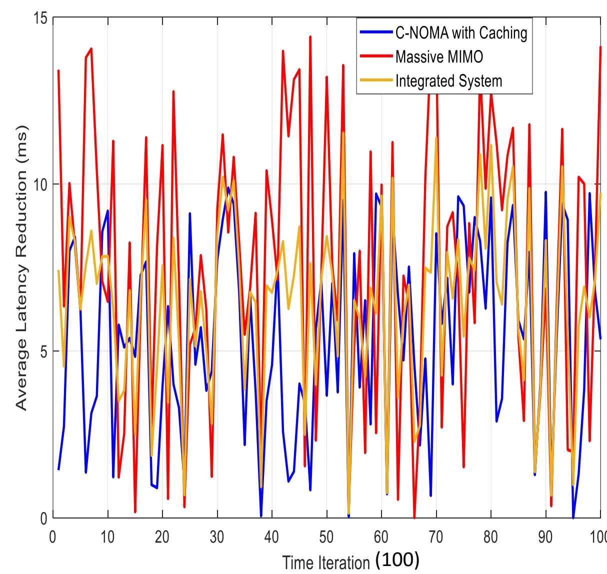

Figure 5.4b

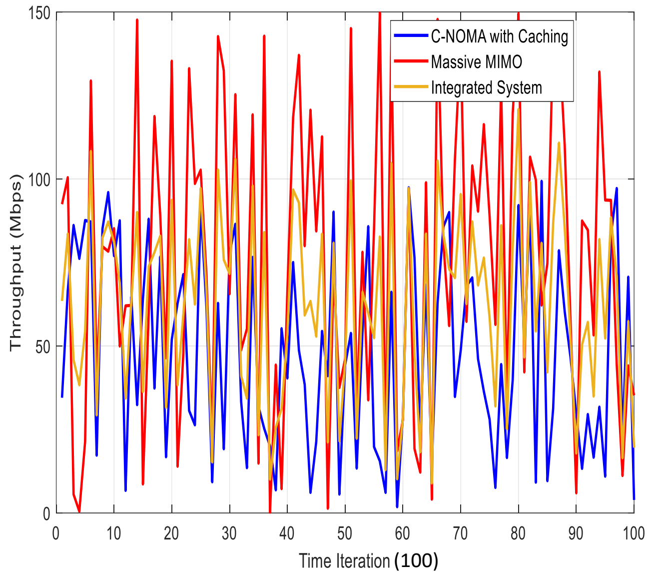

Figure 5.4c

Figure 5.4: Integration of Proposed Dynamic System C-NOMA with Caching and Massive MIMO techniques in the 6G Networks Mobile Communication: 5.4a: The Sum Rate (Mbps) Over time Iteration (100). 5.4b: Average Latency reduction (ms) Over time Iteration (100). 5.4c: Throughput (Mbps) Over time Iteration (100).

As seen in three Figures 5.4a, 5.4b, and 5.4c, by integrating three system techniques, C-NOMA, with caching and m-MIMO technique, the achievement for sum rate, average latency reduction, and throughput improved to a higher-level performance, leads to improve the 6G system networks. To summarize the simulation result, Table 5.8 describes the numerical data for the sum rate, average latency reduction, and throughput for proposed C-NOMA with caching and m-MIMO techniques to enhance the performance and efficiency in the 6G networks mobile communication.

Table 5.8: A comparison for Sum Rate, average latency reduction, and Throughput between proposed C-NOMA with caching and m-MIMO techniques over time iteration (100)

System Technique	C-NOMA with Caching Technique	Massive MIMO Technique	Integration of Two Techniques
Sum Rate (Mbps)	480	680	580
Average Latency Reduction (ms)	9.5	14.5	12
Throughput (Mbps)	100	150	125

To simulate different aspects, sum rate versus SNR for integration the Proposed System with m-MIMO technique, Figure 5.5a shows the effects of file size (10, 50, and 100 MB) on the performance of the system. As seen in the figure, the sum rare of (100 MB) file size has higher value (665.821 Mbps), the (50 MB) file size has sum rate (332.911 Mbps), while, file size (10 MB) has lower value than the other two file sizes (66.5821 Mbps). These results confirm that with increase of the file size, the sum rate increases due to the advantageous of integrating the proposed system C-NOMA with m-MIMO technique.

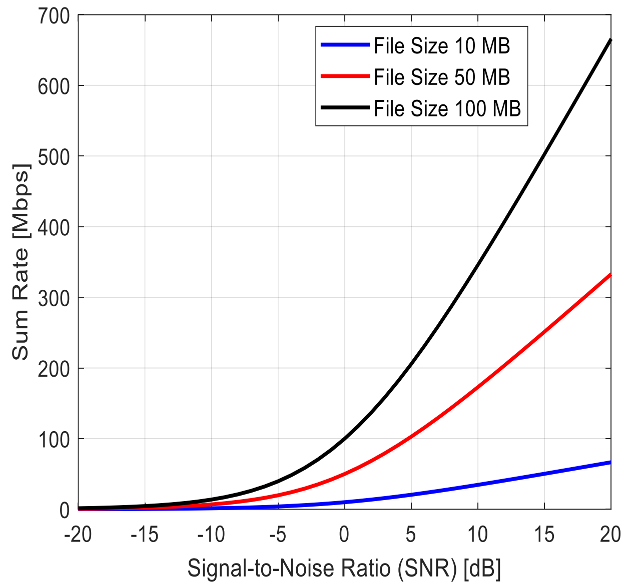

Figure 5.5a

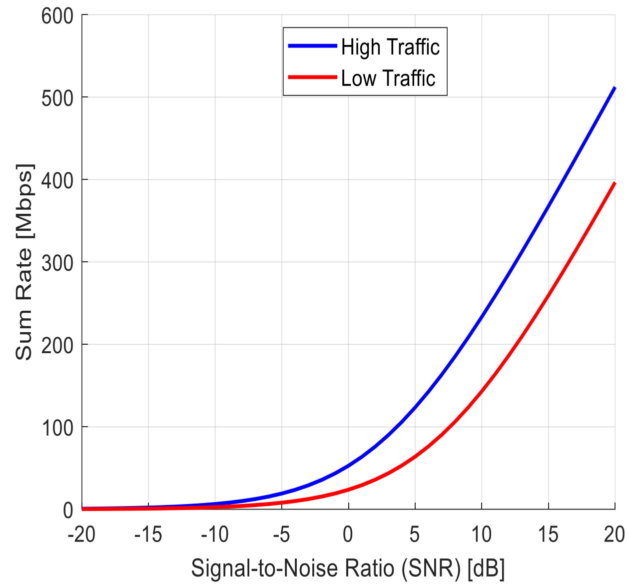

Figure 5.5b

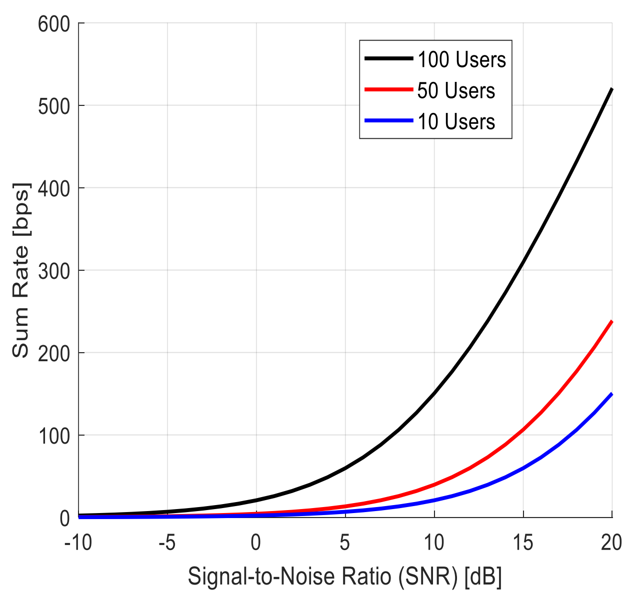

Figure 5.5c

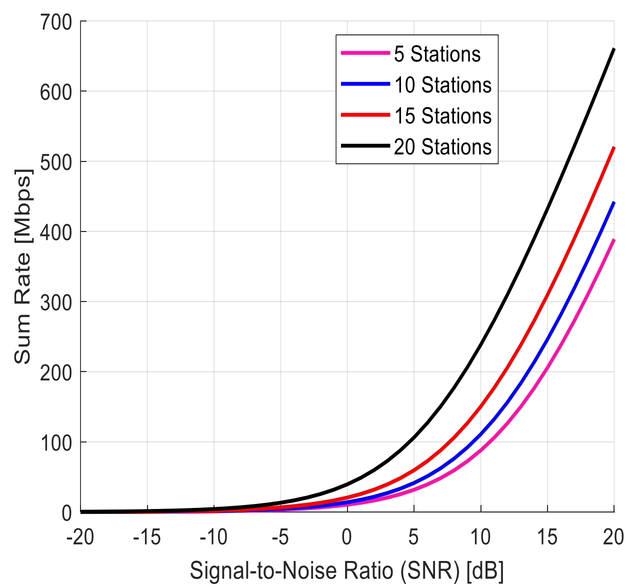

Figure 5.5d

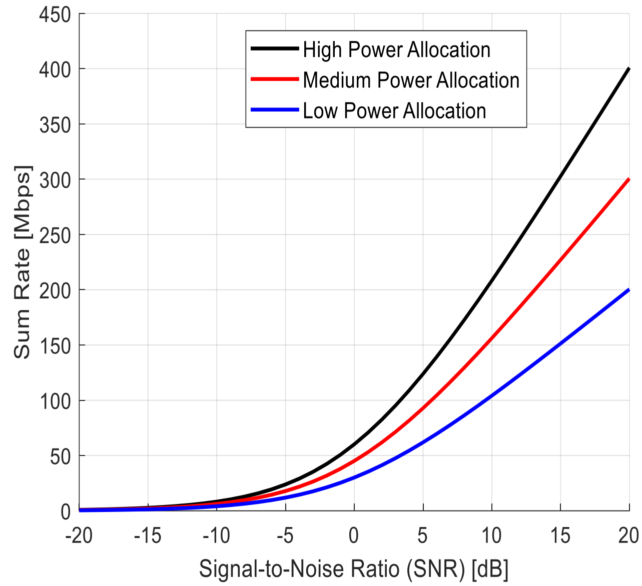

Figure 5.5e

Figure 5.5: The Sum Rate (Mbps) versus SNR (dB) for integration the Proposed System C-NOMA with Caching and Massive MIMO technique in the 6G Networks Mobile Communications: 5.5a: Sum Rate (Mbps) versus SNR (dB) for Different File Sizes (10, 50, and 100 MB). 5.5b: Sum Rate (Mbps) versus SNR (dB) for Different network Traffics (High, and Low). 5.5c: Sum Rate (Mbps) versus SNR (dB) for Different User Numbers (10, 50, and 100). 5.5d: Sum Rate (Mbps) versus SNR (dB) for Different Station Numbers (5, 10, 15, and 20). 5.5e: Sum Rate (Mbps) versus SNR (dB) for Different (PA) levels (High, Medium, and Low)

The file size impacts on sum rate have been measured for proposed system C-NOMA with caching and m-MIMO technique as shown in Figure 5.5a. The result show that when file size increase from (10, 50, to 100 MB), the sum rate increase (66.58, 332.9, to 665.8 Mbps) respectively according to file size. These results confirm the advantage of integrating the proposed system C-NOMA with caching and m-MIMO technique.

To simulate the integration of proposed system C-NOMA with caching and m-MIMO technique for different network traffic, Figure 5.5b shows the sum rate versus SNR for different network traffic (high and low). The simulation results show that sum rate is (512.271 Mbps) for high traffic and sum rate is (396.666 Mbps) for low traffic. This result confirms the advantageous role of integrating the proposed system with massive MIMO technique however, the network traffic increased the sum rate increase.

Figure 5.5c shows the simulation results for integrating the proposed system C-NOMA with caching and m-MIMO technique for sum rate (Mbps) versus SNR (dB). As seen in the graph, the sum rate increases with the increase of SNR. And the sum rate increases with the increase of the user numbers. At SNR is (25 dB), and number of users is 100, the sum rate has a higher value (358.235 Mbps), the sum rate is (220.074 Mbps) when the number of users is 50. While, the sum rate is (65.2622 Mbps) when the number of users is 10. These results show that however, the number of users increased the sum rate increase due to the advantageous of integrating the proposed system with m-MIMO techniques which enhance the performance in the 6G networks mobile communication.

Figure 5.5d shows the simulation results for integration proposed system C-NOMA with caching and m-MIMO technique for sum rate (Mbps) versus SNR (dB) for different number of stations. As seen in the graph, the sum rate increases with increase of (SNR). And the sum rate increases with the number of stations increase. At SNR is (20 dB): and number of stations is 20, the sum rate has higher value (661.11 Mbps), the sum rate is (520.696 Mbps) when the number of users is 15. The sum rate is (442.303 Mbps) when the number of users is (10). While, the sum rate has lower value (389.076 Mbps) with the number of stations is (5). These results show that with the number of stations increased the sum rate increase due to the advantageous of integrating the proposed system with m-MIMO techniques which enhance the performance in the 6G networks mobile communication.

To evaluate the power allocation (PA) for the integration proposed system with massive MIMO techniques, Figure 5.5e shows the simulation results of sum rate versus SNR to evaluate the system with different PA (high, medium, and low) levels. As seen in the graph, sum rate has a higher level (400.864 Mbps) when the PA is in high level. The sum rate is (300.648 Mbps) when PA is in medium level. While, the sum rate is (200.432 Mbps) when PA is in low level. Table 5.9 describes the sum rate evaluation versus SNR of integrated C-NOMA with caching and m-MIMO for different file size, network traffics, user numbers, station numbers, and power allocation levels.

Table 5.9: The Sum Rate (Mbps) Evaluation versus SNR (dB) of Integrated C-NOMA with Caching and m-MIMO for Different file size (10, 50, 100 MB), network traffics (High and Low), user numbers (10, 50, and 100), station numbers (5, 10, 15, 20), and power allocation levels (High, medium, and Low)

System Technique	File Size			Network Traffics		User Numbers			Station Numbers				Power Allocation Level		
	10MB	50MB	100MB	High	Low	10	50	100	5	10	15	20	High	Medium	Low
Sum rate (Mbps) vs. SNR (dB)	66.58	332.9	665.8	512.27	396.66	65.26	220.07	358.23	389.07	442.3	520.6	661.1	400.86	300.64	200.43

5.4 Evaluation of Integrated m-MIMO NOMA with Caching Technique

The exponential growth in data demand, spectrum scarcity, mitigation of interference, energy efficiency and sustainability and the need for low-latency in the 6G mobile communication networks caused by multiplication of bandwidth-intensive applications such as High-Definition Video Streaming (HDVS), Augmented Reality (AR), Virtual Reality (VR), and Internet of Things (IoT) devices. By integrating Massive-Multiple Input Multiple Output m-MIMO, Non-Orthogonal Multiple Access NOMA with caching as a strategic technique aimed to significantly enhancing the performance and efficiency of the network infrastructure in the 6G mobile communication networks. Integrating m-MIMO NOMA with caching provides higher data rates, reduced latency, improve the spectral efficiency, and overall enhancing the performance and efficiency in the 6G networks.

The two advanced techniques m-MIMO and NOMA are significantly enhancing the performance and efficiency in the 6G networks mobile communication. m-MIMO contributes to the improved spectral efficiency, higher data rates, enhanced coverage, capacity, and energy efficiency. While, the NOMA contributes the system with allowing multi user diversity, better user fairness, lower latency, supporting for massive-Machine Type Communication m-MTC and IoT. Combining these two advanced techniques provides additional advantageous such as enhanced capacity, higher improved spectral efficiency, lower latency and higher throughput, and higher robustness and flexibility. The main parameters used to implement in this section are illustrated in Table 5.10.

Table 5.10: The Main Parameters Used to Compare Sum Rate, Average Latency Reduction, and Throughput for Massive MIMO NOMA with and without Caching Techniques in the 6G Networks Mobile Communication

Parameters	Data
Number of Base Stations	5
Number of Users Equipment	100
Number of Antennas at the Base Station	64*64
Signal-to-Noise Ratio (SNR) in dB	-20 to 20
Bandwidth in Hz	20 MHz
Cache capacity (number of content items)	100
Total number of content items	1000
Caching Policy Replacement Strategy	Least Recently Used (LRU)
Content Popularity Zipf distribution with exponent	$\alpha = 0.8$
Simulation Duration	1000 s
Number of Simulation Runs	10
Performance Metrics Collection Interval	Every 10s
C-NOMA Transmission Gain	2
Average request rate (requests per user per second)	0.1
Number of simulation iterations	100
Channal Gain Type	[Rayleigh fading]

By integrating m-MIMO NOMA with caching, the system achieves higher sum rate, higher average reduction, and higher throughout, contributes to enhance the performance and efficiency in the 6G networks mobile communication. Figures 5.6a, 5.6b, and 5.6c shown comparisons for sum rate, average latency reduction, and throughput for m-MIMO NOMA with and without caching technique.

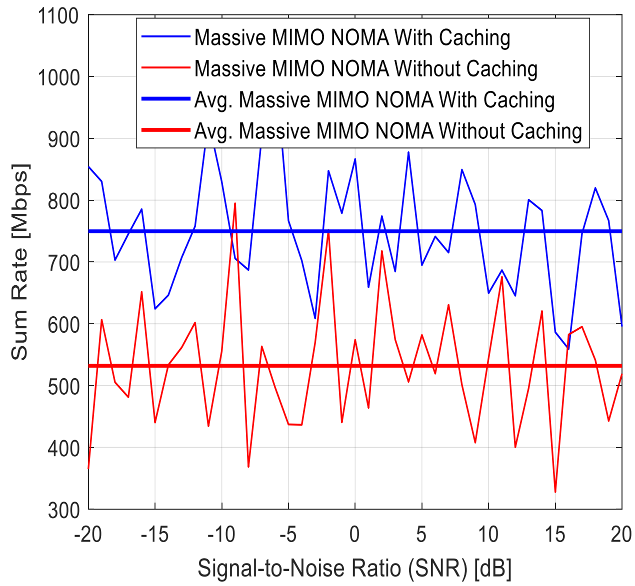

Figure 5.6a

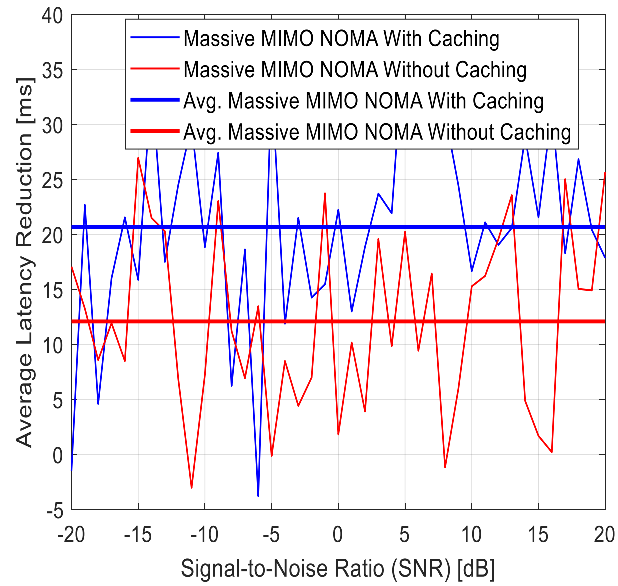

Figure 5.6b

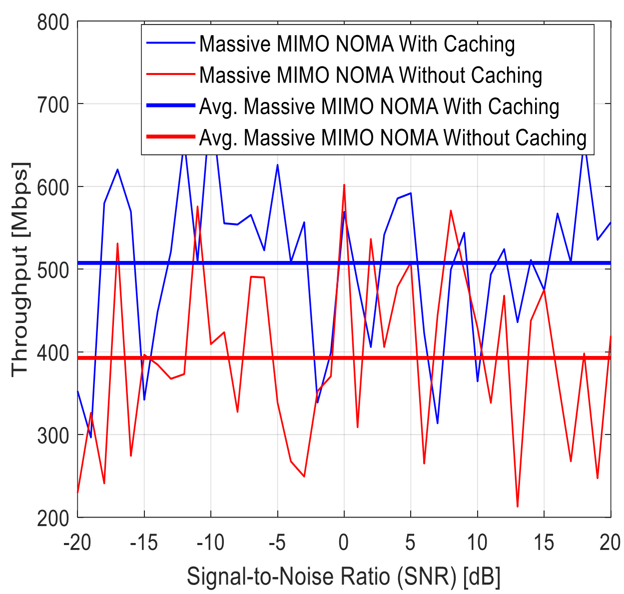

Figure 5.6c

Figure 5.6: Integration of m-MIMO NOMA for with and without Caching Techniques comparisons in the 6G Networks Mobile Communication: 5.6a: The Sum Rate (Mbps) versus SNR (dB). 5.6b: Average Latency reduction (ms) versus SNR (dB). 5.6c: Throughput (Mbps) versus SNR (dB)

As seen in simulation results, Figure 5a shows the sum rate for the m-MIMO NOMA with and without caching technique. The average sum rate without caching is 530 Mbps and with caching increases to (750 Mbps). For the average latency reduction, m-MIMO NOMA without caching that shown in Figure 5b is (12 ms) and with caching increases to (21 ms). Figure 5c shows the average throughput without caching is (390 Mbps) and with caching increases to (510 Mbps). The simulation results summary of sum rate (Mbps), average latency reduction (ms), and throughput (Mbps) for all techniques studied in this dissertation summarized in Table 5.11.

Table 5.11: Simulation results of sum rate (Mbps), average latency reduction (ms), and throughput (Mbps) for systems and techniques **C**-NOMA with Caching Technique, m-MIMO Technique, Integration of Two Techniques, MIMO-C-NOMA without Caching, and MIMO C-NOMA with Caching

System Technique	C-NOMA with Caching Technique	m-MIMO Technique	Integration of Two Techniques	m-MIMO-C-NOMA Without Caching	m-MIMO-C-NOMA With Caching
Sum Rate (Mbps)	480	680	580	530	750
Average Latency Reduction (ms)	9.5	14.5	12	12	21
Throughput (Mbps)	100	150	125	390	510

All these improvements of the system due to the advantageous of caching when integrated in the system.

5.5 Chapter Summary

The simulation results in this chapter proved that caching and C-NOMA technique have shown promise in maximizing throughput, minimizing latency, and optimizing resource efficiency. Caching reduces access latency and network congestion by taking use of the idea of keeping frequently requested content closer to users. The proposed technique in this research that combines C-NOMA with caching as a dynamic resource allocation among users and relay nodes is used to enhance and optimize performance and efficiency in the 6G mobile communication networks. The simulation results demonstrate the enhancements of the 6G mobile communication networks C-NOMA with caching compared to all systems through the improvement in latency, sum rate, and throughput compared to the case of NOMA without caching. By integrating C-NOMA m-MIMO with caching as a strategic technique aimed to significantly enhancing the performance and efficiency of the network infrastructure in the 6G mobile communication networks. In this research C-NOMA m-MIMO with caching integrated to enhance the performance and efficiency in the 6G mobile communication networks. In this chapter the proposed system has been evaluated through a comparison with cases of C-NOMA with caching and with and without m-MIMO with the help of MATLAB simulations. The simulation results demonstrate the enhancements of the 6G mobile communication networks C-NOMA massive MIMO with caching compared to all systems through the improvement in latency, sum rate, and throughput.

CHAPTER SIX

6 CONCLUSIONS AND FUTURE WORK

6.1 Conclusions

The dissertation investigates the performance in the fifth generation the 5G mobile communication networks systems of the technique systems for Orthogonal Multiple Access OMA, Cooperative C-NOMA, and non-Cooperative non-C-NOMA for Up Link UL and Down Link DL channel fading. Next, the dissertation proposes performance enhancement systems that enhance energy efficiency and spectrum based on dynamic power Allocation PA C-NOMA with caching over the the 5G specifications. Extra performance enhancement systems also proposed and investigated that use C-NOMA massive Multiple Input Multiple Output m-MIMO with caching over the sixth generation the 6G specifications. The simulation results for such investigated and proposed systems revel the following conclusions:

1. It was observed that the NOMA technique achieves much higher rate pairs than the OMA-OFDMA technique, especially in the case of unsymmetric rate pairs. For UL-NOMA channel fading, Bit Error Rate BER regarding Signal-to-Noise Ratio SNR dB was studied in cases of two users (near and far) and three users near, middle, and far.
2. Numerical simulation proved that NOMA outperforms OMA at high levels of SNR by offering high capacity. C-NOMA, non-C-NOMA, and OMA channels for outage probability versus SNR are studied in this dissertation. The probability of an outage in cooperative NOMA is lower than in the other two systems, non-cooperative NOMA and OMA. In contrast, non-

cooperative NOMA has a lower outage probability compared with OMA. The results show that the probability of an outage increases with the increase in bandwidth and frequency of the signal spectrum.

3. An improvement in the model's performance obtained in the simulation resulted from varying near and far user distances. This result confirms that NOMA gives superior performance when channeling among users in the communication systems becomes more efficient. One of the limitations of this study is investigating the impact of C-NOMA on latency, which is worth investigating in comparison to other studies.
4. As the wireless channel is extremely dynamic in nature, fixed PA does not satisfy the instantaneous channel conditions of users in particular for long distance users. Whatever be channel condition, $\alpha_n \, and \, \alpha_f$ are fixed. From the results, dynamic scheme fair PA is suitable for the wireless channel. In other words, the values of $\alpha_n \, and \, \alpha_f$ are adjusted to comply with the requirements whenever the channel changes. This demonstrates that compared to fixed PA, fair PA can achieve better total rates and lower outages probability.
5. The simulation and numerical results based on proposed PA-NOMA Algorithm showed that the improvement fair dynamic power allocation is more efficient and the fixed PA does not satisfy the instantaneous channel conditions of users in particular for long distance users.
6. The simulation results show the impact of file size, number of users, number of stations, traffic levels and PA on the sum rate, throughput and average latency reduction. The simulation result showed the significant approach of the proposed system offers improvement in sum rate, throughput, and average latency reduction in the 6G networks.

7. In this research, C-NOMA m-MIMO with caching have shown promising results in the enhancement the performance and efficiency of the 6G networks. The form of combination that showed promising results is dynamic resource allocation among users and relay nodes in the proposed system through the efficiency for higher sum rate, higher average latency reduction, and throughput increase in the 6G mobile communication networks. The simulation results showed the impact of proposed C-NOMA m-MIMO with caching technique compared with cases of C-NOMA m-MIMO without caching. The simulation result showed the significant approach of the proposed system offer improvement in sum rate, throughput and latency in the 6G networks except the case sum rate and throughput with of massive MIMO. Thus, the proposed system has been combined with m-MIMO to achieve further improvement as the simulation results approved.

6.2 Future Work

For future of the 5G mobile communication networks systems, the following can be recommended;

1. Integrating other technology with C-NOMA, such as mm-wave for UL and DL networks, to enhance the performance in the 5G mobile communication networks systems and contribute toward meeting the capacity demands expected in the future of the 5G mobile communication networks systems. It also, can implement the PA-NOMA in different channel models environment such as Additive White Gaussian Noise AWGN, Rayleigh, and Rician fading.
2. Integrating technologies, such as machine learning, artificial intelligence, optimizing resource allocation, addressing security and privacy concerns,

improving energy efficiency, and facilitating standardization and deployment. Combining different system techniques and C-NOMA with caching and applying algorithms for different resource allocations can obtain better results to improve the performance and efficiency in the 6G mobile communication networks systems.

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پوخته

(بەرزکردنەوەی ئەدای تۆڕەکانی پەیوەندی مۆبایل G5 و G6 لەگەڵ دەستڕاگەیشتنی فرەیی ناستونی هاوبەش و کاشکردن).

تەکنەلۆژیای پەیوەندی مۆبایل 5G توانای چارەسەری زیادبوونی بەرفراوانی پێداویستییەکانی ڕێژەی داتا و هەروەها گەشەسەندنی بەرفراوانی قەبارەی هاتوچۆ بکات. تەکنەلۆژیاکانی 5G کارایی بەرزتر، کەمکردنەوەی کاتە شاراوەکان، چڕی زیاتر، و جووڵەی بەرزتر بەدەست دەهێنێت بە کەمکردنەوەی قوربانیدانی متمانەپێکردن. بەڵام لەگەڵ ئەوەی تۆڕە ناوەکییەکانی مۆبایل ڕووبەڕووی گەشەیەکی بەرچاو دەبنەوە لە هاتوچۆ و خواست لەسەر کۆمپیوتەر وەک ئامێرە زیرەکەکان و بەرنامەکانی مۆبایل زیاتر بەناوبانگ دەبن. یەکێک لە چارەسەرە بەڵێندەرەکان بۆ تەحەددیاتەکان بریتییە لە کاشکردن. NOMA یەکێکە لە تەکنیکە بەڵێندەرەکانی دەستڕاگەیشتن بە ڕادیۆ بۆ بەرزکردنەوەی کارایی لە پەیوەندییە خانەییەکانی نەوەی داهاتوودا. بە تایبەتی تۆڕەکانی 5G کە چاوەڕوان دەکرا ژمارەیەکی زۆر زیادکراوی بەکارهێنەران بە ڕێژەی داتا هەزار هێندەی بەرزتر لە بەکارهێنانی کارەبای کەمتردا دابین بکەن چونکە NOMA کارایی سپێکترۆمی بەرزتر و توانای سیستەمێکی بەرزتر دابین دەکات. بۆ باشترکردنی زیاتر، تەکنیکەکانی Power Domain NOMA، Code Domain NOMA و Corporative NOMA پێشنیار دەکرێن و لە 5G جێبەجێ دەکرێن بۆ تێپەڕاندنی داواکارییەکانی تۆڕی داهاتوو. PD-NOMA، SIC لە وەرگر و SC لە گواستەرەوە بەکاردەهێنێت.

ئەو سیستەمە پێشنیار کراوانەی کە بە یارمەتی هاوشێوەکردنی MATLAB و NYUSIM جێبەجێ کراون. ئەنجامەکانی هاوشێوەکردن نیشان دەدەن کە تەکنیکە پێشنیار کراوەکان پێداویستییە جیاوازەکانی باشترکردنی دادپەروەری بەکارهێنەر، متمانەپێکراوی بەرز، کارایی سپێکترالی بەرز، پەیوەندییەکی بەرفراوان، بەرزکردنەوەی ڕێژەی داتا، نەرمییەکی بەرز، شاراوەیی گواستنەوەی کەم، پەیوەندییەکی گەورە، دواکەوتنی کەم، توانای بەرزتر لە لێواری خانەدا دابین دەکەن ، و ئەدای باڵا.

بۆ باشترکردنی زیاتر تەکنیکەکانی کاشکردن وەک هەڵگرتنی زانیارییە بەناوبانگەکانی دووبارە بەکارهێنەرەوە لە گرێکانی نێوان بۆ کەمکردنەوەی باری باکهاولکردن لە تۆڕە بێ وایەرەکاندا لەگەڵ C-NOMA یەکخراوە بۆ کەمکردنەوەی دواکەوتنی هەڵگرتنی پێداویستیەکانی ناوەڕۆکی پلان بۆ داڕێژراو، ڕزگاربوون لە ترافیکی باکهاول و بۆ کەمکردنەوەی دواکەوتن کە بەهۆی ڕادەستکردنەوەکانەوە دروست دەبێت. ئەنجامەکانی هاوشێوەکردنی کاشینگ کە لەگەڵ تەکنیکەکانی C-NOMA یەکخراوە، بەڵێنیان لە

زۆرترین توانای دەرچوون، کەمکردنەوەی کاتە شاراوەکان و باشکردنی کارایی سەرچاوەکان نیشانداوە. لە C-NOMA دا، تەرخانکردنی سەرچاوەی داینامیکی ئاماژەیە بۆ پرۆسەی دەستکاریکردنی داینامیکی هێزی پێویست بۆ گواستنەوەی ڕێژەکان و بلۆکی سەرچاوە کە بۆ بەکارهێنەران تەرخانکراوە لە ژێر پێداویستیەکانی QoS و بارودۆخی کەناڵەکانیان.

لە کۆتاییدا، ڕێبازێکی تازەگەری پێشنیار دەکرێت بە یەکخستنی C-NOMA، m-MIMO لەگەڵ کاشینگ وەک تەکنیکێکی ستراتیژی بۆ زاڵبوون بەسەر گەشەی ڕێژەیی لە داواکاری داتا، کەمی سپێکترۆم، کەمکردنەوەی دەستێوەردان، کارایی وزە و بەردەوامیی. ئەنجامەکانی هاوشێوەکردن و هەڵسەنگاندن سەلماندی کە سیستەمی پێشنیارکراوی کارایی بەرچاو بەرزتر لە ڕووی ڕێژەی داتا، BER، و ئەگەری پچڕان دابین دەکات و بەکارهێنانی کارەبا کەمدەکاتەوە بۆ 52.6% و 54.7% بە بەراورد بە NOMA بەبێ هاوکاری و بەبێ NOMA، بە ڕێککەوت، کە بەرزترە لە بەرهەمە پەیوەندیدارەکان. ئەنجامەکانی هاوشێوەکردن دەستکەوتی کەمی شاراوەیی پشتڕاست دەکەنەوە کە پێویستە لەلایەن تۆڕەکانی پەیوەندی مۆبایلی G6 دەبێتە هۆی کارپێکردنی بەرنامە چڕەکانی باندڤید وەکو ستریمینگی ڤیدیۆی ڕوونی بەرز، واقیعی زیادکراو، واقیعی مەجازی، و ئامێرەکانی IoT.

ملخص

(تحسين أداء شبكات الاتصالات المحمولة من 5G و6G باستخدام الوصول المتعدد غير المتعامد التعاوني والتخزين المؤقت)

تهدف تقنية الاتصالات المتنقلة لل 5G إلى تلبية متطلبات معدل البيانات المتزايدة بشكل كبير بالإضافة إلى النمو الهائل في حجم حركة المرور. تحقق تقنيات 5G أداءً أعلى، وزمن وصول أقل، وكثافة أعلى، وإمكانية تنقل أعلى دون التضحية بالموثوقية. ومع ذلك، نظرًا لأن شبكات الهاتف المحمول الأساسية تواجه نموًا هائلاً في حركة المرور والطلب على الحوسبة حيث أصبحت الأجهزة الذكية وتطبيقات الهاتف المحمول أكثر شيوعًا.أحد الحلول الواعدة للتحديات هو التخزين المؤقت Caching. يعد NOMA أحد تقنيات الوصول اللاسلكي الواعدة لتحسين الأداء في الاتصالات الخلوية من الجيل التالي. ومن المتوقع على وجه الخصوص أن توفر شبكات 5G عددًا متزايدًا بشكل كبير من المستخدمين بمعدلات بيانات أعلى بألف مرة واستهلاك أقل للطاقة لأن NOMA توفر كفاءة طيف أعلى وإنتاجية أعلى للنظام. لمزيد من التحسين، تم اقتراح وتنفيذ تقنيات Power Domain NOMA وCode Domain NOMA و Corporate NOMA في 5G للتغلب على متطلبات الشبكة المستقبلية. يستخدم PD-NOMA SIC عند جهاز الاستقبال وSC عند جهاز الإرسال.

تم تنفيذ الأنظمة المقترحة بمساعدة محاكاة MATLAB و NYUSIM. تظهر نتائج المحاكاة أن التقنيات المقترحة تلبي الاحتياجات المختلفة لتحسين عدالة المستخدم، والموثوقية العالية، والكفاءة الطيفية العالية، والاتصال الشامل، ورفع معدلات البيانات، والمرونة العالية، وزمن انتقال منخفض للإرسال، والاتصال الهائل، والتأخير المنخفض، وارتفاع حافة الخلية الإنتاجية، والأداء المتفوق.

لمزيد من التحسين، تم دمج تقنيات التخزين المؤقت باعتبارها وسيلة شائعة لتخزين المعلومات القابلة لإعادة الاستخدام في العقد الوسيطة لتقليل حمل التوصيل في الشبكات اللاسلكية مع C-NOMA لتقليل التأخير في تخزين احتياجات المحتوى المخطط لها، وتخفيف حركة مرور التوصيل وتخفيف التأخير الناجم عن عمليات التسليم . أظهرت نتائج محاكاة التخزين المؤقت المتكامل مع تقنية C-NOMA نتائج واعدة في زيادة الإنتاجية وتقليل زمن الوصول وتحسين كفاءة الموارد. في C-NOMA، يشير التخصيص الديناميكي للموارد إلى عملية التعديل الديناميكي للطاقة المطلوبة لإرسال معدلات الإرسال وكتل الموارد المخصصة للمستخدمين بموجب متطلبات جودة الخدمة الخاصة بهم وظروف القناة.

أخيرًا، تم اقتراح نهج جديد من خلال دمج C-NOMA وm-MIMO مع التخزين المؤقت كتقنية استراتيجية للتغلب على النمو الهائل في الطلب على البيانات، وندرة الطيف، وتخفيف التداخل، وكفاءة الطاقة، والاستدامة. أثبتت نتائج المحاكاة والتقييم أن النظام المقترح يوفر أداء أعلى بكثير من حيث معدل البيانات، BER، واحتمال الانقطاع ويقلل من استهلاك الطاقة إلى 52.6% و 54.7% مقارنة مع NOMA بدون تعاونية وبدون NOMA، على التوالي، وهو أعلى من الأعمال ذات الصلة. وتتحقق نتائج المحاكاة من تحقيق زمن الوصول المنخفض الذي تتطلبه شبكات الاتصالات المتنقلة من الجيل السادس لتشغيل التطبيقات ذات النطاق الترددي المكثف مثل بث الفيديو عالي الوضوح والواقع المعزز والواقع الافتراضي وأجهزة إنترنت الأشياء.

بەرزکردنەوەی ئەدای تۆڕەکانی پەیوەندی مۆبایل 5G و 6G لەگەڵ دەستڕاگەیشتنی فرەیی ناستونی هاوبەش و کاشکردن

پێشکەشی ئەنجومەنی کۆلێژی تەکنیکی ئەندازیاری کراوە لە زانکۆی پۆلیتەکنیکی هەولێر وەکو بەشێك لە پێداویستیەکانی بەدەست هێنانی دکتۆرای فەلسەفە

لە بەشی ئەندازیاری سیستەمی زانیاری

لەلایەن

سالار اسماعيل احمد

بەکالۆریۆس لە ئەندازیاری ئەلیکترۆنیك و کۆنتڕۆڵ ، کۆلێجی تەکنیکی کرکوك ، کەرکوك ، (2006)

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بەسەرپەرشتیاری

پ.د. صديق يوسف امين

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