



Design, Simulation and Analysis of Multi-Dimensional Multiple Access (MDMA) Schemes Using MATLAB for Quality of Service (QoS) Enhancement

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Abstract

To provide better Quality of Service (QoS), which is expected in contemporary 6G wireless networks. We project a MDMA scheme to fulfill UE-specific QoS needs with the aid of multi-dimensional radio resource cost. This method can be successfully called Multi-Dimensional Radio Resource Allocation (MDRA). Specifically, the planned scheme incorporates two novel aspects: for each UE, the choice of user-specific non-orthogonal multiple approach mode whose cost is determined by UE-specific non-orthogonal interference cancellation; and allocating multiple dimensional radio resources for co-existing UEs in dynamic network environment. To reduce the costs of using UE-specific resources, the BS mounts UEs with diverse multi-domain resources. Specific to each UE coalition by taking into consideration restrictions such as the availability of resources, the perceived quality of those resources, and the possibility for use. Every UE that is a part of the coalition has access to the radio resources that it needs, which helps to lower the costs of use while preventing resource-sharing disputes with the other nodes in the coalition. Furthermore, the allocation of multi-dimensional radio resources among co-existing user equipment makes it possible to solve the issue of maximizing the sum of cost-conscious utility. This is done to fulfil UE-specific quality of service needs as well as varied resource circumstances on the user equipment side. The gradient convexity with low complexity approximation and the Lagrange double decomposition approach are used in the development of the solution to this NP-hard issue. The efficacy of the system that we have presented is shown via the use of numerical simulations and a comparison of its performance with that of other methods.

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1. Introduction

For the development of 6G wireless networks, it was anticipated that the growing rate of data traffic would continue and that there would be a rapid expansion of a wide variety of services and application verticals. However, this endeavour would be met with several obstacles. On the one hand, it is anticipated that 6G networks will be able to accommodate much greater information rates in the future. The reason for this is that it is forecast that mobile data traffic will rise by seven times in 2022 compared to where it was in 2017 [1]. However, the rising tide of data traffic that is so closely integrated with the complex and highly dynamic landscape of numerous service types and applications has given us a new dimension to address unique challenges in wireless communications. This surge in data usage highlights the need for 6G networks that not only provide speeds much higher than those of current communication throughputs but also exceptional QoS to adequately address the diverse demands of users. As a

direct response to these predicaments, our research project becomes an innovative effort that aims at elaborate MDMA schemes. Taking advantage of the advanced functionalities offered by MATLAB, our investigation seeks to explore new frontiers in the telecommunication space where there has never been a greater need for increased data rates and QoS. The emphasis on MDMA projects is contrary to what has been considered a normal approach, indicating that there is a paradigm shift that aims at conducting multi-dimensional radio resources in an optimum manner to adapt to the demands of digital times.

The primary aim of this work is to raise the projected QoS expected in next generation 6G wireless networks, by introducing a holistic MDMA framework. The MDRA methodology has been finely crafted to address the UEs' specific QoS needs, all while minimizing the multiple-dimensional costs of radio resources. The following succinctly describes the study's main contributions:

- During this study, an MDMA scheme named MDRA is proposed. The goal of this scheme is to overcome the difficulties presented by the heterogeneous and dynamically changing resource constraints that future 6G wireless networks will face.
- The MDRA scheme presents an advanced Analog Multiple Access Mode Selection procedure. This step considers many factors including SNR, interference levels, and power consumption for the selection of an appropriate analogue access mode per UE. The intention is to mitigate non-orthogonal interference cancellation and maximize radio resource usage costs.
- The MDRA scheme concentrates on the effective management of multi-dimensional radio resources that serve coexisting UEs under a dynamic network environment. The goal of this action is to satisfy each UE's specific QoS requirements while minimizing the costs associated with resource utilization.
- Within the MDRA scheme, the study introduces a UE Coalition Formation strategic process. In this procedure, UEs are organized in coalitions under certain conditions involving perceived quality, resource availability and usage cost. The creation of such coalitions is intended to increase network efficiency by reducing the cost of energy consumption resources and thereby avoiding conflicts between them.
- To address the NP-hard problem of maximizing the sum of cost-aware utility in multi-dimensional resource allocation, this study uses advanced optimization methods. This involves gradient convexity, low-complexity approximation, and the Lagrange double decomposition method. Such techniques guarantee effective management of complicated resource allocation restrictions.

The part of the study is separated into the following sections: A thorough literature review is presented in Section 2. The suggested methodology is explained in detail in Section 3. The obtained results are presented in Section 4, which includes a thorough case study and the conclusions. A detailed analysis and discussion of the results are conferred in Section 5, and the studies' conclusions and a plan for future research projects are presented in Section 6.

2. Related Work

Because future networks and wireless devices will be diverse and need dynamic resource limits, the development of multiple-access technology that is both highly efficient and intelligent will become an essential component of 6G.

Instead of the scenario-specific solutions that are now being implemented in 5G, the provision of customized QoS and the efficient use of funds of UE operations are essential characteristics of 6G for it to perform its function. is a possibility. a platform that may serve several purposes and serve as the basis for a linked society [4]. The primary emphasis of the current attempts to achieve individualized quality of service provisioning in 6G is on combining recent technology advancements in operations and management. These advancements include network slicing and mobile edge computing, for example [5, 6]. However, it is possible that these advancements will not be feasible owing to the increasing complexity of the system. In the meanwhile, we think that bottom-up alternatives, which are the next-generation design of multi-access schemes that can make effective use of multi-dimensional radio resources and have the potential to provide situational awareness, might be pivotal in the supply of individual services for 6G [7], [8].

Numerous access protocols of the future generation provide a variety of QoS options to accomplish cost-effective customized QoS provisioning. It is anticipated that the use of multi-dimensional radio resources, which include power, time, location, frequency, and coding sphere, would provide improved servicing granularity for provisioning. This is accomplished by considering the resource circumstances and individual quality of service needs of each UE.

Several additional aspects, including the capabilities of the UE and the costs associated with the consumption of radio resources, need to be taken into consideration to enhance the efficiency of Intelligent Multiple Access for individual quality of service.

Recently, several new techniques for multiple access have been introduced. Two of these techniques, namely rate-splitting multiple access (RSMA) [10] and multiple-input multiple-output non-orthogonal multiple access (MIMO-NOMA) [9], have been introduced to improve the power domain system multiplexing capability and spectral efficiency. Both techniques allow for more spatial degrees of freedom.

On the other hand, these multiple access plans adhere to the scenario-specific approach that is now in place in 5G, and they continue to have a great deal of difficulty in meeting the demand of each person and the circumstance of each UE owing to failure.

A. Problem Statement

The estimated value of radio frequencies for individual users in different areas, based on the costs and performance advantages of resource utilisation as well as communication services. Because of the particular channel circumstances of each UE, each UE suffers unique resource restrictions, i.e., quality for multi-dimensional radio resources and varied degree of resource availability. Due to variations in radio resources while using the UE's abilities and induced cost: resources, the projected value of the allotted multidimensional will be UE-specific. To accomplish individualised and flexible multidimensional radio utilisation cohabitation among users, this review offers a novel intelligent multiple-access concept.

Addressing these issues is critically important in this environment, where personalized QoS and cost-effective UE operation are required. Although some new technologies like network slicing and mobile edge computing are already suggested for personalized QoS provisioning in 6G, they have not been practically feasible since the system's complexity growth. In addition, traditional multiplexing methods such as MIMO-Noma and RSMA have difficulties in addressing the heterogeneous and isolated nature of each user's equipment. The distinctive limitations imposed by radio resources, peculiar channel conditions and the capabilities of UEs lead to different perceived values of allocated radio resources in several domains. It is in consideration of this that a next-generation multi-access scheme is required to efficiently utilize multi-dimensional radio resources and accommodate personalized and opportunistic resource allocation required for each QoS provisioning. To solve these problems, this paper introduces the MDRA scheme under the umbrella of MDMA. The MDRA scheme incorporates novel elements, e.g., Analog Multi-Dimensional Radio Resource Allocation, Multiple Access Mode Selection, UE Coalition Formation, and cutting-edge optimization techniques to achieve optimal resource allocation at minimal cost usage. The aim will be to achieve a compromise between personalized QoS fulfilment and cost-efficient UE operations in the complex, dynamic landscape of 6G wireless networks.

3. Materials & Methods

The figure outlines a sequential process which is happening along the way of designing and simulating a two-tier MDMA system, taking the form of a Hierarchy. At the Design and Simulation point, the overall system architecture is presented. The process' subsequent phases are governed by the system architecture based on a hierarchical two-tier structure. The Analog Multiple Access Mode Selection is the first major element which contains cost optimization and interference cancellation. This step assures the effective distribution of radio resources as it chooses optimum analogue access modes depending on aspects such as signal-to-noise ratio, interference, and power. From this point onwards, the Multi-Dimensional Radio Resource Allocation phase concentrates on the maximization of the QoS for individual UEs within the dynamic environment of 6G wireless networks. The process takes into account the particular QoS needs for each UE that would lead to the least resource utilization costs. Second, UE coalition formation as a step towards coalition formation strategically creates coalitions of UEs depending on the resource availability, perceived QoS, and usage potential, respectively, to make the network more efficient. Following this, superior Optimization Techniques including Gradient Convexity, Low Complexity Approximation, and Lagrange Double Decomposition are utilized to deal with the NP-hard problem of maximizing utility within cost limitations. All these methods guarantee a rational use of resources due to the equilibrium of the

different needs of UEs living side by side. The process concludes with Optimized Allocation, denoting that the resource allocation objectives for the Hierarchical Two-Tier MDMA have been effectively achieved.

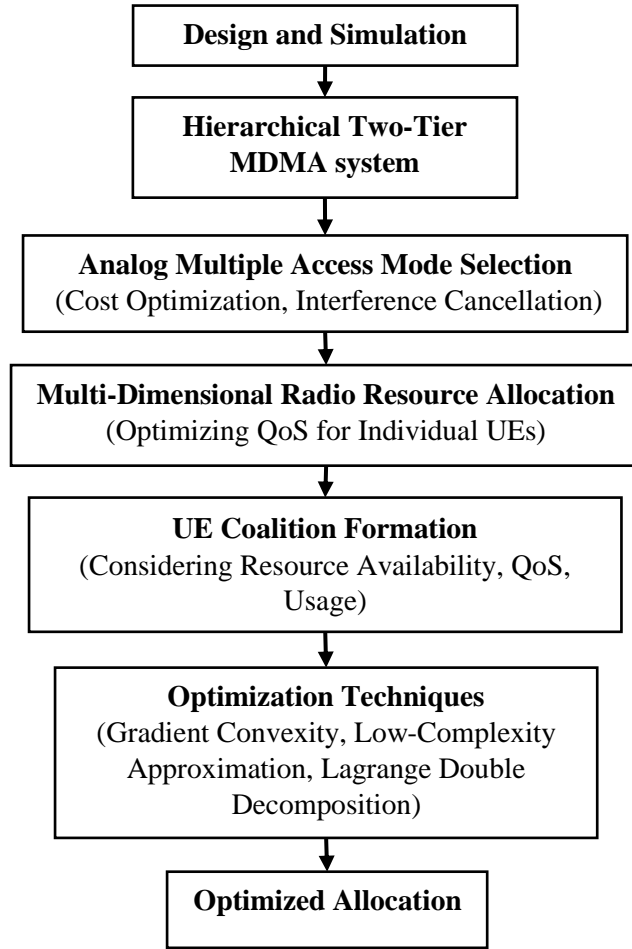


Figure 1: Overview of the Proposed Method

A. System Architecture

Future 6G wireless networks are likely to have a hierarchical two-tier MDMA system. This system addresses the specific QoS requirements of UEs. The first component of the Analogue Multiple Access Mode Selection Process gives non-orthogonal interference cancellation considerable attention. It is this process that determines the cost of radio resource consumption for each user's equipment. In this operation, UEs undergo a selection algorithm to establish adequate analogue multiple access modes. The goal is to reduce the level of interference and, thereby, consumption costs. The complicated algorithm based on non-orthogonal interference cancellation approaches is used to ensure that the consumption of radio resources by every UE is customized by the unique needs and limits of such UE. For dynamic radio resources management among coexisting UEs, an illustration of a technique is the Multidimensional Radio Resource Allocation Strategy, which is the second main element. To meet their crucial function, BS provide UEs with an extensive scope of resources that may be used across multiple domains. The strategy stipulates that the user entities should form coalitions due to various factors like perceived quality, availability of resources and usability.

For these coalitions, the basic radio resources are made available to UE. This not only decreases the costs of using them but also excludes the opportunity for conflicts by ensuring that every UE within a coalition has access to its portion of resources without interference from other users. The multidimensional feature of the resource distribution approach allows for flexibility and adaptability which is required because network situations are highly dynamic. One of the most important difficulties in the optimization of multidimensional radio resource allocation is to increase the sum of cost-conscious quality while ensuring UE-specific quality of service requirements. The NP-hardness of this optimization problem is intrinsic to the problem. This problem is managed through the use of

a system involving the application of the Lagrange double decomposition method along with gradient convexity low complexity approximation as recommended by this technique. This modern approach, when used, guarantees the best solution to the optimization difficulties that allow resource allocation depending on network condition changes.

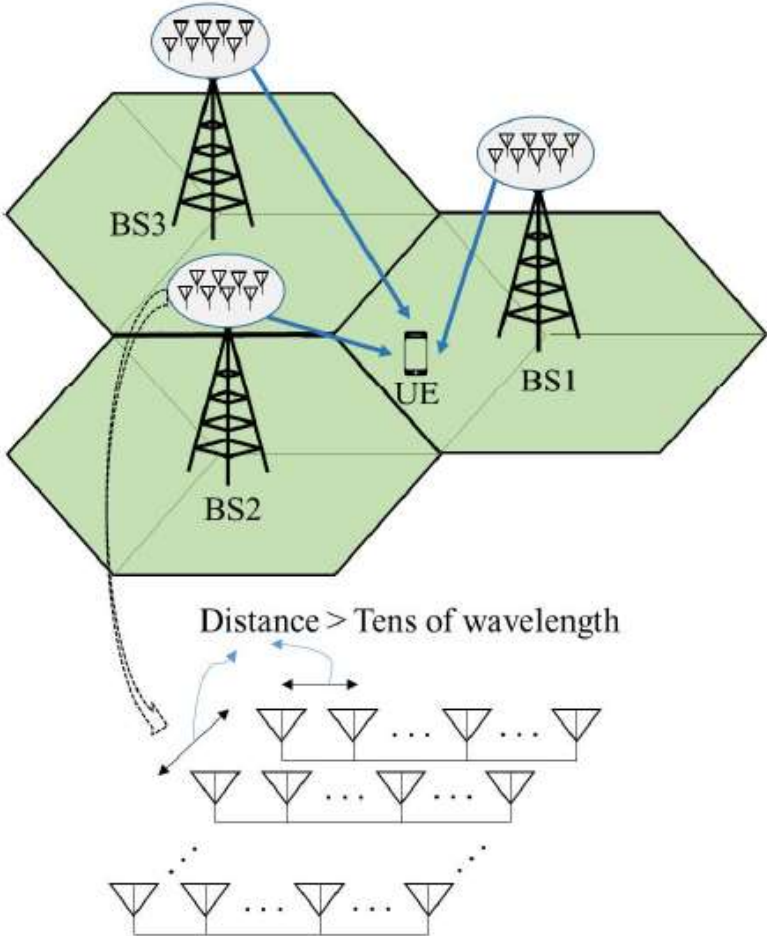


Figure 2: Two Tier MDMA system architecture

As shown in Figure 2, the MDMA system makes use of enormous antenna systems at base stations and anticipates a carrier frequency of 30 GHz. Furthermore, it is assumed that the distance among the base station antennas is several tens of wavelengths that are that the channel bandwidth is 200 MHz and that the total circumference of the cell is fifty meters. The method makes use of time division duplexing (TDD), and the UL channel state information (CSI) is attained at the base station (BS) via the process of channel estimation. This information is then used for DL precoding. To function properly, the system operates on the assumption that the power control is carried out in the uplink and that universal frequency reuse is used. Therefore, interference is restricted inside the MDMA system. The orthogonal frequency division modulation (OFDM) is the transmission method that the MDMA system uses. For the sake of simplicity, we will assume that the binary phase shift keying (BPSK) method is used in this study. However, the expansion to accommodate higher-order modulation is a trivial process. In the system, rake receivers and pre-rake transmitters are utilized in the uplink and downlink, respectively. These rake receivers and pre-rake transmitters can reduce the multiple access interference (MAI) that is caused by other devices operating in the identical cell, in addition to the adjacent cell interference (ACI) that is caused by base stations and users in other cells.

As seen in Figure 2, a frame in the MDMA system is comprised of 25 blocks. A total of four slots are included in each time block, with two slots designated for uplink (UL) and two slots designated for downlink (DL). Assuming that the length of a slot is ten seconds, we may deduce that the length of a frame is about one millisecond. We use the assumption that the maximum speed of cars is 108 kilometers per hour and that the carrier frequency is 30

gigahertz. As a result, the coherence time is around sixty seconds, which indicates that the channel impulse response is virtually completely time-invariant over several different time windows. With the use of this feature, the channel estimation for both DL and UL can be carried out at the BS. This enables the MDMA system to be capable of carrying out spatial focus point beamforming in both DL and UL. Regarding the initial frequency synchronization, we are operating under the assumption that the DL slot may also be used for the transmission of the principal control tone (PCT) in the frequency domain. It should be noted that to generate diversity for PCT, we would choose some antennas at random from among all of the antennas that are used for broadcasting PCT. Therefore, the use of such a spatial-hopping mechanism during the transmission of PCT may be of assistance in coping with hostile circumstances, such as settings that are characterized by extreme fading or interference.

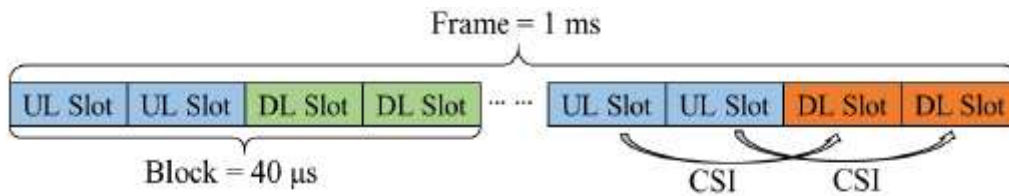


Figure 3: Frame Structure of the Two-Tier MDMA Architecture

The MDRA Algorithm illustrated in Algorithm 1 allocates resources optimally across a wireless network that has UEs in mind. After receiving a collection of UEs as input, the algorithm produces an optimized allocation of assets along several dimensions. At the beginning of the process, during startup, the initial lag-range multiplier values are generated together with the system parameters and network configuration. Step two of the algorithm's implementation is selecting an analogue multiple-access mode, after setup. For every UE in the given list, the algorithm utilizes the analog Mode Selection function conditioned on certain criteria described below. This step guarantees that each UE is assigned an appropriate analog access channel taking factors such as SNR, interference levels, and power consumption into account. Afterwards, the algorithm then moves to multi-dimensional radio resource allocation. Once again, the resource allocation function is applied on each UE in the listed QoS and cost factors. This step seeks to allocate multi-dimensional resources in a way that corresponds with the specific QoS demands of each UE while minimizing utilization costs. The third significant step is UE Coalition Formation, which for each UE again applies the coalition formation function. The formation of UE coalitions based on criteria such as quality perception and use cost is a process that involves. Strategic coalitions are formed to improve the network efficiency due to the specific needs of each UE and potential resource-sharing conflicts. The latter step entails Optimization Techniques in which the optimization process function is called. In this step, advanced methods such as gradient convexity, low-complexity approximation, and Lagrange double decomposition are used to solve the NP-hard problem of optimizing maximum cost-conscious utility. These are essential for the efficient management of complicated, multi-dimensional resource allocation constraints.

Algorithm 1: Multi-Dimensional Radio Resource Allocation (MDRA)
1. Input: List of User Equipments (UEs)
2. Output: Optimized multi-dimensional resource allocation
3. Initialization:
- Initialize system parameters and network conditions
- Set initial values for Lagrange multipliers
4. Analog Multiple Access Mode Selection:
for each UE in UEs:
selectedMode = analogModeSelection(UE)
Perform Analog Mode Selection based on criteria mentioned in the text
5. Multi-Dimensional Radio Resource Allocation:
for each UE in UEs:
allocatedResources = resourceAllocation(UE)
Perform Multi-Dimensional Resource Allocation based on QoS and cost considerations
6. UE Coalition Formation:

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for each UE in UEs:
    formedCoalition = coalitionFormation(UE)
    # Form coalitions based on perceived quality and usage cost
7. Optimization Techniques:
    optimizedAllocation is equal to optimizationProcess().
    # Use optimisation methods such as Lagrange's double decomposition, gradient convexity, and
    low-complexity approximation
8. Output:
    return optimizedAllocation
9. End Algorithm

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B. Analog Multiple Access Mode Selection

The suggested MDMA system necessitates that every UE undergoes a complex selection process called Analogue Multiple Access Mode Selection to maximize the expense of allocating radio resources while minimizing the quantity of non-orthogonal interference suppression. To get desirable results, this method takes several things into account. The choosing criterion's goal is to facilitate the efficient use of multiple access modes, tailoring their growth to the specific requirements of each user entity. What follows is a rundown of the factors regarded when settling on the analogue's technique:

Radio Resource Usage Cost Optimization

As part of the Analogue Multiple Access Mode Selection procedure, optimizing the cost of radio resource utilization is essential in implementing the MDRA system. By taking this approach, we can ensure that the method chosen maximizes signal quality while minimizing resource consumption costs. Consideration of Interference level, SNR, and energy usage are the three critical criteria in the optimization process. An essential metric that characterizes the signal's quality is the SNR for every UE. To maximize signal quality while minimizing consumption of resources, the analogue multiple mode selection method considers the SNR.

$$SNR = \frac{P_{signal}}{P_{noise}} \quad (1)$$

To measure the strength in relative terms of the signal and the noise, one uses the signal-to-noise ratio, shortened as SNR. It is the gold standard of signal quality measurement. The algorithm considers the interference generated by any UE. To reduce the costs of preventing interference, it is preferable to select an analogue multiple-access mode that reduces interference as much as possible.

$$Interference\ Level = \frac{P_{interference}}{P_{signal}} \quad (2)$$

Quantitative measure of disturbance affecting the signal is given as the interference's power to signal's power ratio. As such, decisions should incorporate the energy consumption per range of analogue multiple access alternatives. The objective is to built modes that simultaneously can reduce power consumption, improve signal quality and result to optimum power saving.

$$Power\ Consumption = P_{transmit} + P_{receive} \quad (3)$$

The power consumption is the total power induced throughout the reception and transmission. This measurement is paramount to establish the actual energy consumption of the system.

Mitigation of Non-Orthogonal Interference Cancellation

This step is fundamental for minimizing interference that might lead to occurrence when deciding the non-orthogonal analogue multiple access modes. This step also features several parameters that become involved concerning the assessment of various options of the pathway of success of distinct models while minimizing or mitigating the non-orthogonal interference. The selection of the analogue multiple access mode depends on the unique nature of the non-orthogonal irritation. Non-orthogonal interference impacts the selection process, and the modes may vary in their capacity to suppress such interference.

$$\text{Interference Characteristics} = f(\text{interferenc pattern}) \quad (4)$$

The interference quantification involves f as a function for the interference structure. It means that the measure is bounded by certain patterns, or type of interference presented in the channel of communication. The system may consist of adaptive techniques that possess the influence of altering the analogue multiple access mode with dynamic response to time-dependent interferences. Although changing interference conditions require the use of different modes, the adaptability that UE offers ensures the selection of optimal operating modes for effective cancellation.

$$\text{Adaptability} = f(\text{real time interference conditions}) \quad (5)$$

The measure employs a function called f to assess the adaptability due to current interference settings. It suggests that the system could evolve or change as a function of interference scenarios. The feedback loops comprising the system's architecture can be exploited in the process of decision-making. Given the performance of various modes in varying cases and the interference levels, each UE can select an analogue multiple-access mode.

$$\text{feedback} = f(\text{network feedback}) \quad (6)$$

In this measure, a function named f corrects for network feedback. Feedback information could include details on performance, network conditions or other important aspects.

UE-Specific Constraints

However, the abilities and flaws of any UE should be taken into consideration. To ensure effective implementation, the choice of an analogue multiple-access mode is required. This mode provides compatibility with the hardware and processing capabilities of the UE.

$$\text{Compatibility} = f(\text{UE hardware capabilities}) \quad (7)$$

The following indicator uses a f function to assess compatibility based on UE hardware capabilities. It implies that the compatibility measure depends on some features or constraints related to UE hardware. For an UE to be considered successful, the QoS requirements specific to this UE must be met. The selection approach considers the unique quality of service requirements of each unit of user equipment. This is, therefore, to ensure that the analogue multiple-access mode is commensurate with the required level of service.

$$\text{QoS Satisfaction} = f(\text{UE QoS requirements}) \quad (8)$$

In this measure, a function f is employed to assess the degree of QoS fulfilment on grounds of UE-specific QoS criteria. It suggests that the desired QoS levels for UE are considered as a reference when determining QoS satisfaction.

C. Multi-Dimensional Radio Resource Allocation

Improving the QoS estimates for impending 6G wireless networks is the purpose of the MDRA approach. The goal of the proposed MDMA protocol is to efficiently allocate radio resources across Individual UEs while meeting the unique QoS needs of each UE at a reasonable cost. This methodology introduces two novel features: multidimensional radio resource share among coexisting UEs nether dynamic network conditions; and the selection of an analogue binary access mode for each UE, regarding the radio resource particular to UE usage costs arising from non-orthogonal interference cancellation. The MDRA system lowers the costs related to UE-specific resource use by using a coalition strategy. BS are equipped with a range of multi-domain resources based on each UE's specific demands. UEs are grouped into coalitions according to criteria including perceived quality, potential for utilization, and resource accessibility. Because each UE in these coalitions has access to the radio resources it needs, disagreements over resource sharing amongst UEs are reduced and utilization costs are decreased.

Allocation of multi-dimensional radio resources in such a way that the sum of the cost-conscious utility is maximized helps to solve a difficult problem of NP-hard type. The combining of the Lagrange double decomposition method along with gradient convexity with a low-complexity approximation resolves this problem. These solutions attempt to flawless distribution of resource equalizing the diverse requirements of cohering UEs, while also factoring in the constraints imposed by the dynamicity of the wireless network. The performance of the proposed MDRA system is well established using performance comparisons and numerical simulations with many competitors of state-of-the-art approaches. Evaluation by simulation shows that the MDRA method outperforms compared benchmark systems. The simulations emphasize the efficiency of the MDRA scheme in meeting the QoS requirements the UEs minimizing the resource usage costs and ensuring fair and optimal resource allocation in the challenging dynamic 6G wireless network realm.

$$\text{Maximize } \sum_{i=1}^N U_i(\text{Resources}_{\text{allocated},i}) \quad (9)$$

Equation (9) is the target function in the MDRA system design for distribution of available resources with an overall goal of maximum utility. The goal of this activity is to improve the overall system performance at the expense of utility features for each UE, which symbolize the allocation of multi-dimensional resources to each UE. The primary importance of the ideal performance objective of the MDRA system is a great value. The objective is to achieve the highest system utility by optimizing delivery of power to each individual UE in consideration of their own utility targets. Transitioning Equation (10) defines the choice of the analogue multiple access mode for a particular UE.

$$\text{Select Analog Mode}_i = \text{argmax}_{\text{Analog Modes}}(\text{UE} - \text{specific Cost}_i - \text{Interference Cost}_i) \quad (10)$$

The choice is made by maximizing the difference between UE-specific cost and interference cost: In this equation, the system tries to choose an analog mode which minimizes total cost including UE-specific cost due to radio resource utilization, and interference cost resulting from non-orthogonal interference cancellation. Therefore, this decision-making procedure guarantees the optimal analog mode selection for each UE.

$$\text{Allocate Resources}_i = \text{argmax}_{\text{Resource Configuratiuons}}(\text{QoS Utility}_i - \text{Cost Utility}_i) \quad (11)$$

The equation (11) determines the allocation of multi-dimensional resources for U_i. It guarantees that the available resources meet UE's specific QoS requirements efficiently from a cost point of view as it improves the balance between QoS utility and cost-utility.

D. UE Coalition Formation

A control tactic that will reduce the cost of resource use while sticking to several criteria and limits is the UE coalition formation process in the proposed MDRA approach. The first goal is to form UEs' coalitions that jointly improve network efficiency to provide the best possible allocation of radio resources. The specific demands for

each UE are integral to the process, considering such aspects as the need for certain resources that encompass frequency bands and time slots. The key considerations that are discussed during the coalition formation process include resource availability, perceived QoS, and potential usage. Coalitions operate well in diverse circumstances because the procedure is adaptable enough to change along with the updated network conditions. The process of forming a coalition also considers UE-specific limitations such as resource utilization fees and preventing conflict over the sharing of resources between coalitions. The goal of optimization is to strike a balance between resource costs and user entity-specific benefits, aiming toward the highest cost-conscious utility of all. This can be quantified as the coalition selection equation. The results are validated using numerical simulations, assessing the performance of newly formed coalitions on resource utilization costs and perceived quality. The building of UE coalitions in the framework of future 6G wireless networks contributes to effective and cost-sensitive resource allocation based on the above steps performed by the MDRA approach.

$$Form\ Coalition_i = argmax_{UE\ sets}(Perceived\ Quality_i - Using\ Cost_i) \quad (12)$$

This equation governs coalition formation, which depicts sets of UEs that maximize the difference between perceived quality and use cost for UE_i . The resources' availability, perceived quality, and usability are some of the limitations considered when forming a coalition.

E. Optimization Techniques

The optimization technique within the proposed MDRA methodology used to address the NP-hard problem of maximizing utility under cost constraints is a very complex marriage of mathematical methods. First applying gradient convexity, it is possible to detect convex subproblems in the original non-convex cost-conscious utility function. This function directs the optimization and searches for the global minimum. Second, there is a low-complexity approximation technique which is incorporated to reduce the computational complexity used in solving NP-hard problems. Through this approximation, computing efficiency is balanced with the quality of the solution; therefore, computations become more viable and workable. Lastly, the Lagrange double disintegration method is employed to decompose the original optimization problem into simpler subproblems. The incorporation of constraints using Lagrange multipliers makes it possible to manage compound and high dimensional resource allocation conditions more effectively. The following is a mathematical expression for the iterative optimization process:

$$Maximize \sum_{i=1}^N U_i(Resources_{allocated,i}) \quad (13)$$

When Resources are allocated, a UE_i are multi-dimensional resources assigned to UE_i and U_i represents the Utility function for each UE_i . The Lagrange multipliers associated with restrictions facilitate the division of an issue into a dual, primal sub-problem, which simplifies the process of developing a more effective and practical solution. Numerical simulations allow validation of the effectiveness of this optimization method, proving its superiority in providing economic and successful multi-domain radio resource allocation provided by the MDRA framework for emerging 6G wireless networks.

4. Experimentation

This section presents the implementation of an infrastructure for system-level simulations. The results of the simulation are provided in this part to evaluate the multi-dimensional multiple-access technique that has been built.

A. Simulation Setup

When it comes to simulation settings and deployments, we consider just one cell and set the optimum transmit power of the BS to 33 dBm, the bandwidth of the subchannel to 2 MHz, the total number of subchannels to 12, the noise variance to -140 dBm/Hz, and the highest possible number of UEs that can be used by a single coalition to 3. The standard number of UEs is 25, as well. Please refer to Table I for the specific simulation settings. The purpose of this study is to provide a more comprehensive evaluation of the performance of the proposed MDMA

strategy by comparing the effectiveness of our scheme to the performance of two baseline schemes known as the MIMO-NOMA: Work [1] is responsible for the realization of this strategy, in which all UEs are clustered together into various clusters. The UEs that are part of each cluster are all using the same beamforming vector and are being supplied by power-domain NOMA. If many UEs share a single sub-channel, the base station (BS) will divide a portion of each user equipment's message (also known as the personal message) into a shared message that will be broadcast to all of the UEs. SDMA is used to send the rest of the private messages as well as the created common message. The common message is decoded by each UE with the assistance of SIC. Subsequently, the private message that is meant to be sent is decoded in a series of steps and then mixed with a portion of the common message that has been deciphered [2, 3]. To make RSMA conform to our structure, we allocate UEs to subchannels by the paradigm described in [4]. The RSMA protocol offers more flexibility in the mitigation of non-orthogonal interference when compared to the MIMO-NOMA protocol. When compared to the method that we have presented, the distinction resides in the fact that MIMO-NOMA and RSMA attempt to use both the spatial realm and the power domain concurrently without considering UE-specific resource limits or heterogeneous resource utilization costs in various resource domains for each resource domain.

Table 1: the available quantities of the raw materials, and the profit returned from one unit of both products in the Neutrosophic Context

Parameter	Assumption
Distance-dependent path loss(dB)	$PL_{@} = 128.1 + 37.6 * \lg_{@}, R$ in km
Bandwidth / Number of channels	20 MHz/12
Maximum transmit power of BS	33dBm
Number of Antennas	64 TX=transmitting antennas for BS= base station and 1 RX = receiving Antennas for UE =User Equipment
Number of beam spaces	10
Rician fading factor K	9
AWGN Power	-140 dBm/Hz
Number of UEs in the Macro cell	25
Path loss Model	WINNER +B1 LOS
Macrocell radius/Cellular UE Distribution	250 m/Uniform in the Macro cell
Coefficient related to the usage cost	$\rho_0 = 0.5, \rho_1 = 0.24, \rho_2 = 0.5, \text{ and } \omega_K = 0.2$

B. Results

Figure 4 illustrates the CDF of the utility that considers costs for the UE, defined by Equation (7). This utility function is meant to measure the cost-efficiency of service delivery and indicates the ability of multiple access schemes to yield acceptable QoS performance without setting in higher utilization costs for the UE. In this case, a higher utility value suggests that the bigeminal access scheme can provide better QoS execution at a cheaper cost for the UE. After visualizing the figure, it becomes clear that the MDMA scheme introduces significant superiority to all baseline schemes. The MDMA trajectory shows regularly higher values of the cost-conscious utility functions, which means more appropriate QoS performance management with reduced consumption cost due to UEs. This comparison of the MDMA index with baseline schemes highlights the performance of the enhanced cost efficiency in service provisioning over a wireless network. Furthermore, it is important to highlight the fact that the inequalities in performance displayed in the CDF corroborate a positive contribution by MDMA towards the successful realization of an appropriate tradeoff between QoS satisfaction and resource cost for UE.

The statistical data that was collected indicates that the normal utility curves for MIMO-NOMA and RSMA range from a minimum value of 0.22 to a maximum value of 0.64, with the latter spanning between 0.23 and 0.54, one after the other. The MDMA strategy that has been developed, on the other hand, has differentiated numerical improvements that make it substantially more effective than the formers. This is something that the enlarged upper

limit can demonstrate. The CDF of the downlink throughput that the UE experiences is seen in Figure 4. To begin, the MDMA strategy that was presented has been successful in achieving the best outcomes with a reasonably minimal amount of variation in the quality of communication. There are abrupt increases in the curved shape of MDMA at about 3.3 and 1.15 bps/Hz. This is because the proposed MDMA can ensure that the UE has a data rate that falls somewhere in the middle of the lowest required data rate (R_{th}) and the optimum maximum data rate (R_{max}).

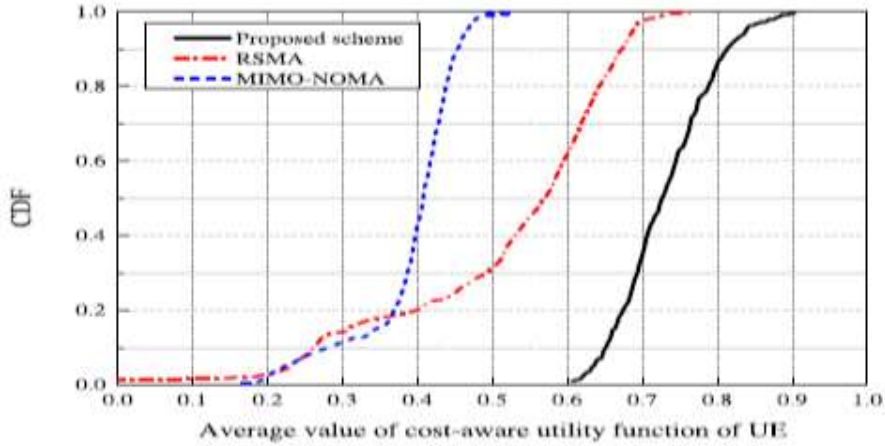


Figure 4: The CDF of the cost-aware utility function for the UE

It has been proven that our suggested MDMA can reap various dimensional manifold benefits as per the different network scenarios. While well-established multiple-access systems like MIMO-NOMA and RSMA have shown significant benefits in some resource dimensions, this is not the case. RSMA and MIMO-NOMA, on the other hand, use a fixed manifold access method for UEs despite the various circumstances. During the step of our proposed technique that involves the construction of UE coalitions, the goal is to reduce the possible cost of using radio resources that are particular to the wireless endpoint (UE). This is accomplished by selecting numerous advantageous UEs to form UE coalitions. To be more specific, the utilisation of radio resources (6) is estimated using a novel metric that is specified in formula (8) and the term used to describe this phenomenon is known as the "intensity of conflicts arising from the sharing of radio resources." This metric is solely dependent on the prolonged channel characteristics, which are location data ($d_k, _k$). To demonstrate that our suggested estimate of the resource usage cost is accurate, we provide a new simulation result. The intensity of radio resource sharing disputes may be interpreted as the top limit of the cost of radio resource utilisation, as shown in Figure 5. Furthermore, the estimated error, which is denoted by the equation $g_k - \tilde{g}_k$, is effectively addressed and managed.

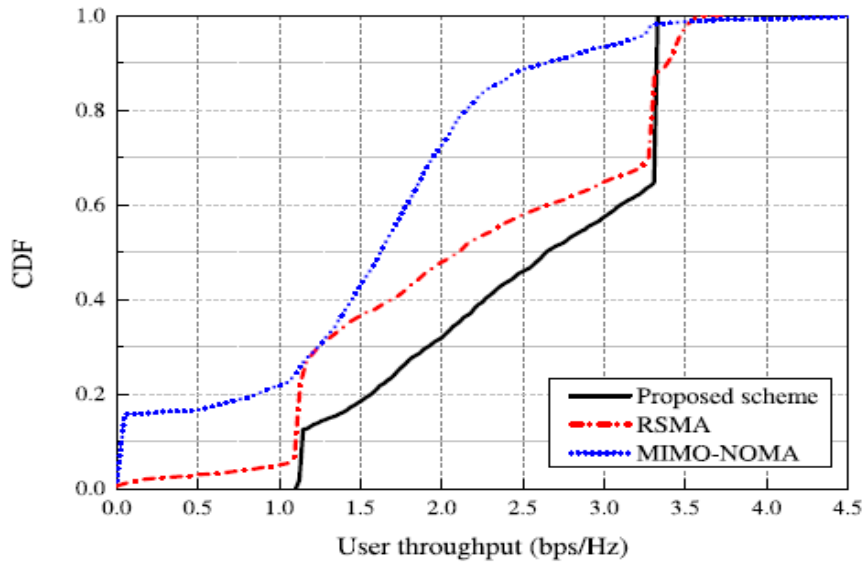


Figure 5: The CDF of the UE downlink throughput

Figure 5 illustrates the CDF of the UE downlink throughput, which serves as a metric for assessing QoS performance in this study. The downlink throughput is an important measure of the efficiency by which data migration takes place from the network to the UE. In this regard, the MDMA scheme proposed here exhibits a superior QoS compared to baselines. The significant increases in the CDF curve for MDMA suggest that it always outperforms baselines in terms of the average UE throughput. The improved QoS characteristic under the MDMA scheme indicates its more developed capacity to utilize resource dimensions in frequency, spatial, and power fields. By fully utilizing these multi-dimensional radio resources, the proposed scheme can satisfy various demands for the services offered by User equipment. We find that the MDMA scheme allows for optimal use of resources, providing a larger throughput for UEs and thereby enhancing the overall presentation of the wireless network. This comparison with baseline methods emphasizes the efficiency of MDMA in yielding better QoS outcomes based on multifaceted radio resource accessibility.

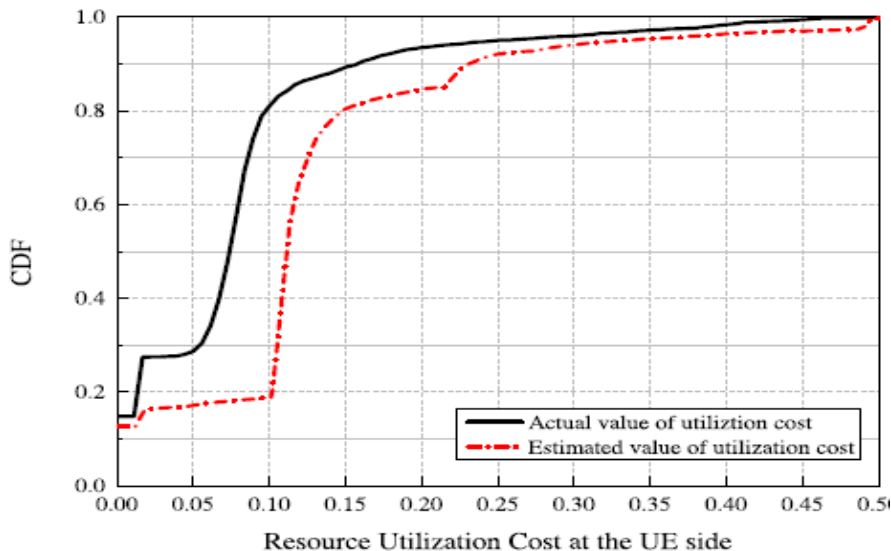


Figure 6: The CDF of radio resource sharing disputes' severity and cost of utilisation

The two most important metrics, figure 6 show the severity of radio resource-sharing disputes and their utilization cost, which presents their CDF. This figure provides useful information on the operational aspects of the system under consideration. The metric “utilization cost goes” translates to the real cost incurred deductively by the system in terms of utilization costs. A higher value means a higher cost of utilization. Instead, the “intensity of radio

resource sharing conflicts" indicates estimated utilization costs and predicts the intensity of the conflicts that will potentially arise due to resource sharing. The CDF plot helps to compare these metrics enabling an understanding of the efficiency and performance of the system. If the CDF curve for "utilization cost go" closely follows that of the "radio resource sharing conflicts ̑ intensity," it suggests the accuracy of the prediction and management of utilization costs by the system. Any differences between the two curves can help reveal where the system's forecasts deviate from the real costs, thus allowing to adjust the system based on the feedback of this discrepancy.

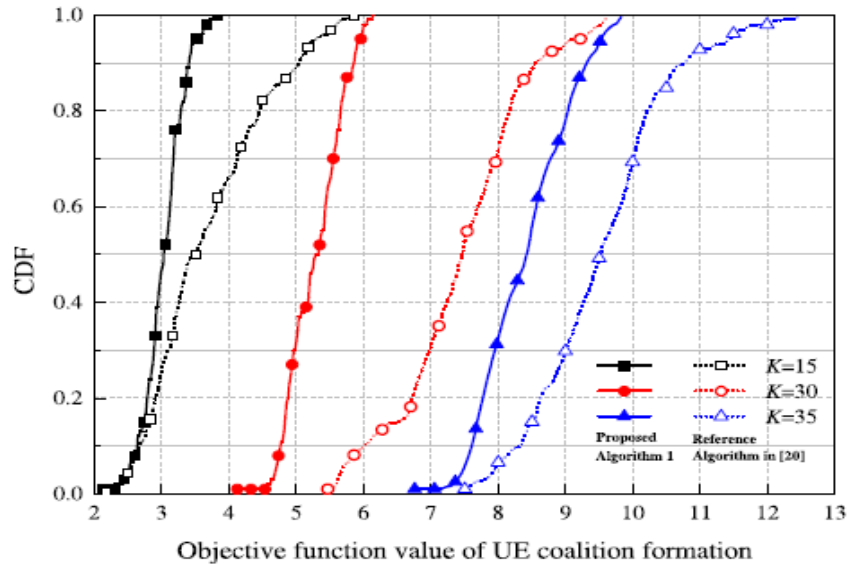
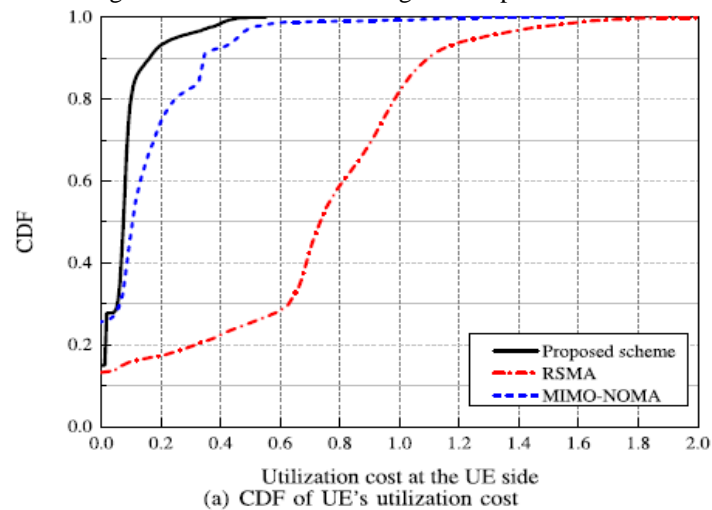


Figure 7: The CDF of the value of the variable

The CDF of the objective parameter value, P_1 , for the UE coalition building issue is shown in Figure 7. This figure depicts the many scenarios of serviced UEs. The objective function under consideration is also a weighted sum, namely, the radio resource sharing conflicts' intensity for each UE. Therefore, the CDF plot is a valuable tool for comparing the effectiveness of different matching algorithms, which allows us to understand their performance in various conditions. Considering the variety of the number of served UEs, the CDF curves shed light on the ability of the different matching algorithms to optimize the coalition formation process. If a single algorithm always has a higher CDF curve, it means that they have better performance in reducing the conflicts in the shared radio resources among the UEs and contribute to a more stable coalition formation with higher efficiency. To be more precise, Figure 6 acts as a consolidated representation tool for researchers and practitioners to assess the performance of matching algorithms within UE coalition formation. The different forms and settings of the CDF curves in various situations offer important insights into the adaptability and performance of these algorithms, which helps in selecting and refining coalition formation strategies for optimal wireless network performance.



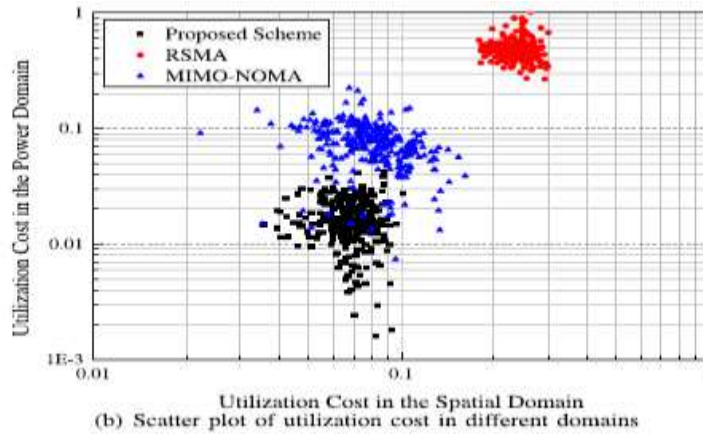


Figure 8: Performance evaluation of UE resources utilization cost

Figure 8 presents the performance evaluation of UE resource utilization cost as defined in equation (6). This cost metric is the aggregation of the handling costs of spatial-domain and power-domain radio resources used at the UE. The assessment covers a wide range of scenarios such as hardware capabilities, network conditions, and multiple access modes, enabling an equivalence between the proposed scheme and baseline schemes. The plot shows a summation of processing costs under different conditions, presenting the effect of multi-access modes and resource allocation methods in terms of UE-centric resource limitation and varying network conditions. Interestingly, the suggested scheme is costlier in terms of utilization as compared to the base schemes. This result is a sign that the flexibility and adaptive ability in the proposed approach based on dynamic network conditions and UE-specific constraints benefit efficient resource utilization, which leads to a cheaper solution for the user. In other words, Figure 8 can be a great performance indicator, which proves that the proposed scheme is quite effective in reducing the cost of resource utilization for UEs. This result supports the feasibility of the proposed method to significantly improve the overall cost-efficiency of resource allocation strategies in the dynamic and challenging environment of wireless networks.

Using the state-of-the-art multiple-to-one matching algorithm has been discussed in other studies [20], as our point of reference for evaluating the effectiveness of Algorithm 1 for the construction of UE coalitions. Coalition building is the UE's primary purpose issue P1 was the primary focus of our attention as we attempted to measure the efficiency of the matched algorithm. Each UE experiences a weighted total of the severity of conflicts related to radio resource sharing, and this objective function represents that. As shown in Figure 6, the CDF of the goal function for P1 is provided under a variety of user deployment scenarios, which are indicated by the number of UEs.

The CDF curve provided by our proposed method 1 regularly beats the reference-matched method presented in [20], demonstrating greater performance across a variety of UE quantities. Algorithm 1's skilful usage of the mutual reliance on the selection of each UE inside separate alignment, is a notion that is credited with the significant improvement that was seen. With the help of this process, the algorithm can optimize and stabilize the results of the coalition formation, which ultimately leads to outcomes that are more efficient and resilient than those determined by the reference method.

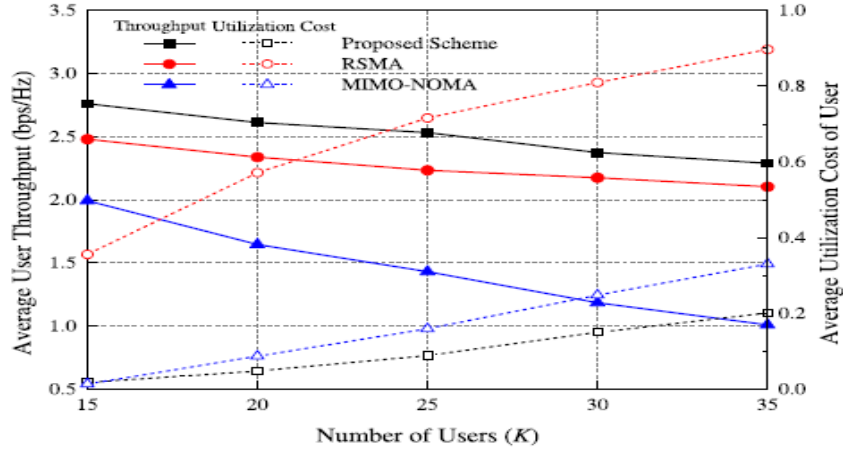


Figure 9: Mean UE downlink data transfer rate and cost of using radio resources across various multiple access schemes

Figure 9 shows a full analysis of Average UE downlink throughput and radio resource utilization cost under different bigeminal access schemes when the number of sufficient users varies. This analysis is necessary to evaluate the overall performance as well as the QoS provided by each scheme in a dynamic network environment. The plot reveals the performance characteristics of different multiple access schemes concerning two key metrics: utilization cost and downlink throughput. Importantly, the suggested framework always competes with alternatives with different loads of network traffic. It attains the minimum utilization cost, implying efficient resource utilization, whereby it also offers the maximum throughput, which represents excellent quality of service performance. The dual accomplishment highlights the strength of the proposed scheme in offering an optimum balance between resource efficiency and user satisfaction. Additionally, the proposed scheme still demonstrates an excellent “cost-gain” performance even under different traffic loads. This suggests that in any variation of the served users and the associated network parameters, the proposed scheme always yields its optimal in minimizing the utilization costs and maximizing the downlink throughput. Such reliability in performance is the essential capability to maintain a stable and high-performing network, considering the ever-changing user requirements and the network dynamics.

The execution of our suggested algorithm is topnotch to that of the reference method; however, this improvement comes at the expense of a greater number of algorithm iterations. Figure 8(a) demonstrates an analysis of the expenses associated with the consumption of resources with many dimensions under various bigeminal access techniques. In contrast to MIMO-NOMA and RSMA, among which the average cost value may reach up to 0.63 and 0.18 respectively, the usage cost nether our suggested scheme continues to be lower, with an expected average of 0.13 correspondingly. We created a UE alignment method to alleviate non-orthogonal hindrance that was caused by UE superposition and multi-dimensional resource sharing. As was stated in Section III-A, the implementation of this strategy has resulted in an important reduction in the number of resource-sharing conflicts that occur Within every UE alliance. Additionally, the suggested MDMA can alter the advantages Each UE coalition has a numerous access mode. In the meanwhile, a spread plot of the average usage cost of UE in various domains throughout each simulated drop is shown in Figure 8(b). To be more specific, the MIMO-NOMA and RSMA schemes are less successful in the process of mitigating non-orthogonal interference. When using the MIMO-NOMA approach, UEs in each cluster perceive channel directions that are aligned with one another, but there is considerable variance in the intensities of the channels. On the other hand, UEs that are in separate clusters are exposed to orthogonal channels. As a result of this, certain UE that are situated in locations with unfavorable cell coverage may experience significant interference. In comparison to the other two schemes, the usage cost of RSMA is much greater for the three reasons that are listed below: 1. The UE is required to carry out SIC to decode its clubby message, therefore, there will be a rise in the cost of the power domain therefore, particularly for UEs that have poor channel situation. Additionally, the design of the pre-coder has a significant impact on the performance of the RSMA algorithm, which is responsible for broadcasting the uniform message. It is an issue that cannot be solved, however, and the

pre-coder design is a problem. Because various user equipment combinations for sharing a single sub-channel might result in a significant performance difference, the matching of UE and sub-channel (subcarrier) RSMA is still an outstanding issue for multi-carrier data transmission. In Figure 8, a "cost-gain" Comparability of various distinct multiple access methods is shown under a variety of user deployment situations. These scenarios range from an under loaded network condition to an overloaded network environment, which is indicated by the number of UEs. When as opposed to the MIMO-NOMA and SDMA, the plan that we have shown has the highest throughput and the lowest use cost of any other scheme. Furthermore, its "cost-gain" presentation is resilient to shifting resource and network load circumstances that depend on the scenario. The reason for this is that MIMO-NOMA and RSMA always employ a fixed bigeminal access mode for user equipment (UEs), which will lead to insufficient use of the multi-dimensional resources that are already accessible. In addition to this, it demonstrates that it is essential to smartly and shrewdly adjust numerous entree modes of UE by the individual requirements of each user device and the specific resource circumstances. The outcome, in general, is by our anticipations about the MDMA strategy that was presented.

6. Conclusion

A novel MDMA system is proposed in this research to meet the individual QoS in a way that is both cost-effective and feasible, the demands and resource requirements of each user of 6G wireless networks. When all UEs coexist with the greatest sum of utility functions of UEs, it is possible to achieve various QoS variety and resource diversity effectively. The challenge that has been developed is described as a two-stage separation, namely the choice of cost-conscious duple access modes and the allocation of multidimensional radio resources. Implementing the reciprocal multiple-to-one matching concept to get the desired results, a multiple access mode that is tailored to the user is selected to make maximum use of the multiprocessing resource that is available while maintaining a cost of utilization that is acceptable to the user. After that, the convex optimization principle of moderate complexity is used to tackle the issue of resource allocation for the multidimensional radio communication system. The results of the simulation demonstrate that the suggested strategy is more efficient than the cutting-edge better performance in both schemes and quality of service performance for users, as well as the cost of using multidimensional radio resources.

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