International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 7 July 2023, pp: 280-294 www.ijaem.net ISSN: 2395-5252

Resource Allocation Algorithm for D2D Communications Based on NOMA

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Date of Submission: 05-07-2023 Date of Acceptance: 15-07-2023

ABSTRACT— The performance of the forthcoming mobile communication system may greatly improve as a result of Device-to-Device (D2D) communication and Non-Orthogonal Multiple Access (NOMA). By reducing interference between cellular and D2D users, it is necessary to boost the throughput and efficiency of D2D communication based on NOMA. This paper presents a hybrid sub-channel and power allocation algorithm for D2D communication based on NOMA to improve the uplink energy efficiency and throughput of the mobile communication system. The method uses the Kuhn-Munkres (KM) technique to assign a channel to each D2D group and formulates an optimal power allocation problem under the Karush-Kuhn-Tucker (KKT) conditions. Simulations demonstrate that the recommended approach outperforms the current state-of-the-art techniques in terms of energy efficiency and throughput under a variety of situations. The results of both the fading channels are then compared with the reference AWGN Channel.

I. INTRODUCTION

The development of world technology, especially in the cellular sector, is very fast. The 5th generation of cellular technology is in sight. 5G network technology is a fifth- generation cellular technology development that focuses on increasing network capacity and faster data transfer speeds for various application media.

In hindsight, Device-to- Device (D2D) technology has been implemented since the fourth generation (4G) Long Term Evolution (LTE)-Advanced. However, in the fifth-generation scientists have high hopes because 5G can provide 1,000 times the volume of data, 10-100 times more users, ten times more power-efficient, and five times lower latency than the previous generation[2].

The application of the method of transmitting data from the base point to each device is considered a conventional method. Therefore Device-to-Device Communication was chosen as an option for transmitting data on a 5G network which is considered more modern and more efficient in the data transmission process.

The recent unprecedented growth in the use of smart mobile devices and the increasing demand for a variety of multimedia applications in recent years, cellular networks are being greatly challenged. Non-Orthogonal Multiple Access (NOMA) allows multiple users to share the same resources in terms of time and frequency through power-domain multiplexing and serial interference cancellation (SIC) in order to improve the system throughput and energy efficiency [3].

Therefore, combining D2D with NOMA could greatly improve the quality of service of future mobile communication systems. Device-to-device (D2D) communications is considered as one of the pieces of the fifth generation (5G) jigsaw puzzle in order to improve spectral efficiency. Driven by the potential benefits of D2D communications, many works have been prompted recently under different scenarios [5].

Non-orthogonal multiple access (NOMA)

We consider orthogonal frequency division multiplexing (OFDM) as the modulation scheme and NOMA as the multiple access scheme. In conventional 4G networks, as natural extension

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of OFDM, orthogonal frequency division multiple access (OFDMA) is used where information for each user is assigned to a subset of subcarriers. In NOMA, on the other hand, all of the subcarriers can be used by each user. Figure 1 illustrates the spectrum sharing for OFDMA and NOMA for two users. The concept applies both uplink and downlink transmission.

Superposition coding at the transmitter and successive interference cancellation (SIC) at the receiver makes it possible to utilize the same spectrum for all users. At the transmitter site, all the individual information signals are superimposed into a single waveform, while at the receiver, SIC decodes the signals one by one until it finds the desired signal. Figure 2 illustrates the concept. In the illustration, the three information signals indicated with different colors are superimposed at the transmitter. The received signal at the SIC receiver includes all these three signals. The first signal that SIC decodes is the strongest one while others as interference. The first decoded signal is then subtracted from the received signal and if the decoding is perfect, the waveform with the rest of the signals is accurately obtained. SIC iterates the process until it finds the desired signal.

The success of SIC depends on the perfect cancellation of the signals in the iteration steps. The transmitter should accurately split the power between the user information waveforms and superimpose them. The methodology for power split differs for uplink and downlink channels.

NOMA for downlink

In NOMA downlink, the base station superimposes the information waveforms for its serviced users. Each user equipment (UE) employs SIC to detect their own signals. Figure 3 shows a BS and K number of UEs with SIC receivers. In the network, it is assumed that the UE1 is the closest to the base station (BS), and UEK is the farthest.

The challenge for BS is to decide how to allocate the power among the individual information waveforms, which is critical for SIC. In NOMA downlink, more power is allocated to UE located farther from the BS and the least power to the UE closest to the BS. In the network, all UEs receive the same signal that contains the information for all users. Each UE decodes the strongest signal first, and then subtracts the decoded signal from the received signal. SIC receiver iterates the subtraction until it finds its own signal. UE located close to the BS can cancel the signals of the farther UEs. Since the signal of the farthest UE contributes the most to the received signal, it will decode its own signal first.

Device-to-Device (D2D)

Device-to-Device (D2D) communication in cellular networks is defined as direct communication between two mobile users without traversing the Base Station (BS) or core network. D2D communication is generally non-transparent to the cellular network and it can occur on the cellular frequencies (i.e., in band) or unlicensed spectrum (i.e., out band).

In a traditional cellular network, all communications must go through the BS[1] even if communicating parties are in range for proximity-based D2D communication. Communication through BS suits conventional low data rate mobile services such as voice call and text messaging in which users are seldom close enough for direct communication. However, mobile users in today's cellular networks use high data rate services (e.g., video sharing, gaming, proximity-aware social networking) in which they could potentially be in range for direct communications (i.e., D2D). Hence, D2D communications in such scenarios can greatly increase the spectral efficiency of the network. The advantages of D2D communications go beyond spectral efficiency; they can potentially improve throughput, energy efficiency, delay, and fairness.[2][3]

D2D applications

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improve throughput, energy efficiency, delay, and fairness.[2][3]

Base station

Base station (or base radio station) is – according to the International Telecommunication Union's (ITU) Radio Regulations (RR) – a "land station in the land mobile service."

The term is used in the context of mobile telephony, wireless computer networking and other wireless communications and in land surveying. In surveying, it is a GPS receiver at a known position, while in wireless communications it is a transceiver connecting a number of other devices to one another and/or to a wider area. In mobile telephony, it provides the connection between mobile phones and the wider telephone network. In a computer network, it is a transceiver acting as a switch for computers in the network, possibly connecting them to a/another local area network and/or the Internet. In traditional wireless communications, it can refer to the hub of a dispatch fleet such as a taxi or delivery fleet, the base of a TETRA network as used by government and emergency services or a CB shack.

Cellular frequencies

Cellular frequencies are the sets of frequency ranges within the ultra-high frequency band that have been assigned for cellular-compatible mobile devices, such as mobile phones, to connect to cellular networks. Most mobile networks worldwide use portions of the radio frequency spectrum, allocated to the mobile service, for the transmission and reception of their signals. The particular bands may also be shared with other radio communication services, e.g. broadcasting service, and fixed service operation.
Text messaging: Text messaging, or texting, is the act of composing and sending electronic messages, typically consisting of alphabetic and numeric characters, between two or more users of mobile devices, desktops/laptops, or another type of compatible computer. Text messages may be sent over a cellular network, or may also be sent via an Internet connection.

Location awareness: Location awareness refers to devices that can passively or actively determine their location. Navigational instruments provide location coordinates for vessels and vehicles. Surveying equipment identifies location with respect to a well-known location wireless communications device.

The term applies to navigating, real-time locating and positioning support with global, regional or local scope. The term has been applied to traffic, logistics, business administration and leisure applications. Location awareness is supported by navigation systems, positioning systems and/or locating services.

Location awareness without the active participation of the device is known as non-cooperative locating or detection.

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Frequency Division Multiplexing

In PDM, we consider the transmit power is divided into multiple power segments (PSs) similar to the time-slots/sub-bands in TDM/FDM. The multiple PSs are used to concurrently deliver different information in a same channel. By analysis, we prove that PDM outperforms TDM and FDM with regard to QoS requirement.

In PD-NOMA multiplexing is performed in power domain. Signals from different users are superposed at the transmitter by allocating optimal power to each user and the subsequent signal is then transferred using the same subcarriers

What is successive interference cancellation in NOMA?

A successive interference cancellation receiver is one of the important blocks in non-orthogonal multiple access (NOMA) transmission. The quality of detection of the strongest user signals often decides about the quality of the whole system and minimizes the error propagation effect.

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Working of successive interference cancellation

Successive Interference Cancellation (SIC) is a technique used by a receiver in a wireless data transmission that allows decoding of two or more packets that arrived simultaneously (in a regular system, more packets arriving at the same time cause a collision).

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SIC is achieved by the receiver decoding the stronger signal first, subtracting it from the combined signal and then decoding the difference as the weaker signal.

A wireless network is a computer network that uses wireless data connections between network nodes.

Wireless networking is a method by which homes, telecommunications networks and business installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations. Admin telecommunications networks are generally implemented and administered using radio communication. This implementation takes place at the physical level (layer) of the OSI model network structure.

Examples of wireless networks include cell phone networks, wireless local area networks (WLANs), wireless sensor networks, satellite communication networks, and terrestrial microwave networks.

Long-Term Evolution (LTE) [7]

In telecommunications, Long-Term Evolution (LTE) is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA standards. It improves on those standards' capacity and speed by using a different radio interface and core network improvements. LTE is the upgrade path for carriers with both GSM/UMTS networks and CDMA2000 networks. Because LTE frequencies and bands differ from country to country, only multi-band phones can use LTE in all countries where it is supported.

The standard is developed by the 3GPP (3rd Generation Partnership Project) and is specified in its Release 8 document series, with minor enhancements described in Release 9. LTE is also called 3.95G and has been marketed as "4G LTE" and "Advanced 4G"; but it does not meet the technical criteria of a 4G wireless service, as specified in the 3GPP Release 8 and 9 document series for LTE Advanced. The requirements were set forth by the ITU-R organization in the IMT Advanced specification; but, because of market pressure and the significant advances that WiMAX, Evolved High Speed Packet Access, and LTE bring to the original 3G technologies, ITU later decided that LTE and the aforementioned technologies can be called 4G technologies. The LTE Advanced standard formally satisfies the ITU-R requirements for being considered IMT-Advanced. To differentiate LTE Advanced and WiMAX-Advanced from current 4G technologies, ITU has defined them as "True 4G".

LTE stands for Long-Term Evolution and is a registered trademark owned by ETSI (European Telecommunications Standards Institute) for the wireless data communications technology and a development of the GSM/UMTS standards. However, other nations and companies do play an active role in the LTE project. The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations that were developed around the turn of the millennium.

About 5G

Fifth-generation wireless (5G) is the latest iteration of cellular technology, engineered to greatly increase the speed and responsiveness of wireless networks. With 5G, data transmitted over wireless broadband connections can travel at multigigabit speeds, with potential peak speeds as high as 20 gigabits per second (Gbps) by some estimates. These speeds exceed wireline network speeds and offer latency of below 5 milliseconds (ms) or lower, which is useful for applications that require real-time feedback. 5G will enable a sharp increase in the amount of data transmitted over wireless systems due to more available bandwidth and advanced antenna technology.

5G networks and services will be deployed in stages over the next several years to accommodate the increasing reliance on mobile and internet-enabled devices. Overall, 5G is expected to generate a variety of new applications, uses and business cases as the technology is rolled out.

Working of 5G

Wireless networks are composed of cell sites divided into sectors that send data through radio waves. Fourth-generation (4G) Long-Term Evolution (LTE) wireless technology provides the foundation for 5G. Unlike 4G, which requires large, high-power cell towers to radiate signals over longer distances, 5G wireless signals are transmitted through large numbers of small cell stations located in places like light poles or building roofs. The use of multiple small cells is necessary because the millimeter wave (mm Wave) spectrum-- the band of spectrum between 30 and 300 gigahertz (Ghz) that 5G relies on to generate high speeds -- can only travel over short distances and is subject to interference from weather and physical obstacles, like buildings or trees.

Previous generations of wireless technology have used lower-frequency bands of spectrum. To offset the challenges relating to distance and interference with mm Wave, the wireless industry is also considering the use of a lower-frequency spectrum for 5G networks so network operators could use spectrum they already own to build out their new networks. Lower-frequency spectrum reaches greater distances but has lower speed and capacity than mm Wave.

5G wireless features

The lower frequency wireless spectrum is made up of low- and mid-band frequencies. Low-band frequencies operate at around 600 to 700 megahertz (MHz), while mid-band frequencies operate at around 2.5 to 3.5 GHz. This is compared to high-band mm Wave signals, which operate at approximately 24 to 39 GHz.

Mm Wave signals can be easily blocked by objects such as trees, walls and buildings -- meaning that, much of the time, mm Wave can only cover about a city block within direct line of sight of a cell site or node. Different approaches have been tackled regarding how to get around this issue. A brute-force approach involves using multiple nodes around each block of a populated area so that a 5G-enabled device can use an Air interface -- switching from node to node while maintaining MM wave speeds.

Another approach -- the more feasible one -- for creating a national 5G network is to use a combination of high-, medium- and low-band frequencies. Mm Wave may be used in densely populated areas, while low- and midland nodes may be used in less dense areas. The low-band frequencies can travel longer and through different objects. One low-band 5G node can stay connected to a 5G-enabled device for up to hundreds of square miles. This means that an implementation of all three bands will give blanketed coverage while providing the fastest speeds in the most highly trafficked areas.

5G market landscape

The speed of 5G

5G download speeds can currently reach upwards of 1,000 megabits per second (Mbps) or even up to 2.1 Gbps. To visualize this, a user could start a YouTube video in 1080p quality on a 5G device without it buffering. Downloading an app or an episode of a Netflix show, which may currently take up to a few minutes, can be completed in just a few seconds. Wirelessly streaming video in 4K also becomes much more viable. If on mmWave, these examples would currently need to be within an unobstructed city block away from a 5G node; if not, the download speed would drop back down to 4G.

Low band can stay locked at 5G over longer distances, and even though the overall speed of low-band 5G may be slower than mmWave, low band should still be faster than what would be considered a good 4G connection. Low-band 5G download speeds may be up to 30 to 250 Mbps. Low-band 5G is more likely to be available for more rural locations. Midband 5G download speeds may reach up to 100 to 900 Mbps, and it is likely to be used in major metro areas.

Benefits of 5G

Even though the downsides of 5G are clear when considering how easily mm Wave can be blocked, or less clear considering radio frequency (RF) exposure limits, 5G still has plenty of worthy benefits, such as the following:

- use of higher frequencies;
- high bandwidth;
- enhanced mobile broadband;
- a lower latency of 5 ms;
- higher data rates, which will enable new technology options over 5G networks, such as 4K streaming or near-real-time streaming of virtual reality (VR); and
- the potential to have a 5G mobile network made up of low-band, mid-band and mm Wave frequencies.

Types of 5G wireless services available

Network operators are developing two types of 5G services:

1. 5G fixed wireless broadband services deliver internet access to homes and businesses without a wired connection to the premises. To do that, network operators deploy NRs in small cell sites near buildings to beam a signal to a receiver on a rooftop or a windowsill that is amplified within the premises. Fixed broadband services are expected to make it less

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Volume 5, Issue 7 July 2023, pp: 280-294 www.ijaem.net ISSN: 2395-5252

expensive for operators to deliver broadband services to homes and businesses because this approach eliminates the need to roll out fiber optic lines to every residence. Instead, operators need only install fiber optics to cell sites, and customers receive broadband services through wireless modems located in their residences or businesses.

2. 5G cellular services provide user access to operators' 5G cellular networks. These services began to be rolled out in 2019 when the first 5G-enabled (or -compliant) devices became commercially available. Cellular service delivery is also dependent upon the completion of mobile core standards by 3GPP.

5G vs. 4G: Key differences

Each generation of cellular technology differs in its data transmission speed and encoding methods, which require end users to upgrade their hardware. 4G can support up to 2 Gbps and is slowly continuing to improve in speeds. 4G featured speeds up to 500 times faster than 3G. 5G can be up to 100 times faster than 4G. One of the main differences between 4G and 5G is the level of latency, of which 5G will have much less. 5G will use orthogonal frequency-division multiplexing (OFDM) encoding, similar to 4G LTE. 4G, however, will use 20 MHz channels, bonded together at 160 MHz. 5G will be up to between 100 and 800 MHz channels, which requires larger blocks of airwaves than 4G.

Samsung is currently researching 6G. Not too much is currently known on how fast 6G would be and how it would operate; however, 6G will probably operate in similar differences in magnitude as between 4G and 5G. Some think 6G may use mm Wave on the radio spectrum and may be a decade away.

Interference management in LTE networks and devices

The relentless growth in wireless traffic forces mobile operators to aggressively increase network capacity to meet subscriber demand. However, spectrum availability is not growing at the same rate as traffic; in fact, spectrum resources are in markedly short supply, and, as a result, their cost remains high. To increase capacity, operators have to increase spectral efficiency – packing more and more traffic into the spectrum they own. They can do so by acting on multiple fronts:

- Using new technologies like long-term evolution (LTE) and eventually upgrading to LTE Advanced
- Adopting a frequency reuse of 1 (using the same spectrum channel for neighboring cells)
- Creating multilayer heterogeneous networks (HetNets) in which small cells are located within the coverage area of macro cells and share the same spectrum channels. While these are essential tools for increasing capacity density where it is needed, they also carry a substantial price. They elevate the interference level in the network by increasing the portion of cell-edge areas where two or more base stations compete for coverage and can transmit to and receive from the same user equipment (UE) device. In turn, higher interference is reflected in a lower signal to interference plus noise ratio (SINR), a degradation of network performance and user experience, and diminished efficiency of use of network resources. Careful radio frequency (RF) planning can prevent this to an extent, but interference cannot be entirely eliminated, and in fact the successful management of contained levels of interference leads to better network performance than its aggressive suppression.

II. LITERATURE SURVEY

Degambur, Lavanya-Nehan & Mungur, Avinash & Armoogum, Sheeba & Pudaruth, Sameerchand, have described in paper [1] that, the history of wireless telecommunication networks from 1G to 3G has been described to understand the rise of 4G and 5G networks. Paper shows that, alongside bandwidth, memory space for the buffer, processor cycles, and electrical energy, form part of the resources allocated along with end-to-end network architectures.

Dito Pratama Hadyanto1, Diva Safina Novariana1 Ajeng Wulandari, have proposed in paper [2] that, this study uses a literature review method from 5G research and pre-existing device-to-device (D2D) communication. In this study, the advantages of D2D, the working principle of D2D communication, interference in D2D communication, D2D classification, security and privacy, energy consumption, relay to cost is discussed if this technology is widely applied in the future.

M. Le, Q. -V. Pham, H. -C. Kim and W. -J. Hwang, describe in paper [3], objective of the paper is to maximize the network throughput by investigating a joint resource allocation problem of user clustering, power control, and D2D mode selection. paper proposes to use a swarm intelligence approach, namely whale optimization algorithm in solving the optimization problem with an efficient solution. Through simulation results, it is shown that our proposed scheme attains a better performance than other alternative schemes.

Husam Rajab, Fatma Benkhelifa and Tibor Cinkler, have investigated in paper [4] that, opportunistic spectrum sharing for a D2D-based URLLC system. A novel performance examined a NOMA-based D2D communication system coexisting with a cellular network, where the power resource requires to be carefully allocated based on the shortage in practice. Two frequency bands are available, D2D users only use the first one, and D2D and cellular network users share the second one. D2D users use GADIA to allocate them to one of the two frequencies. GADIA is a fully distributed algorithm for finding a sub-optimal frequency band allocation to the network users. Each D2D group includes several paired devices so that the NOMA technique can be used to mitigate co-subchannel interference. Then, simulations in theoretical and practical scenarios are examined, comparing the maximum achievable rate and the EE at a given SE when using NOMA and OFDMA.

Wang, et al., in the paper [5], a resource allocation framework comprising channel allocation and power control based on Stackelberg game is proposed for distributed interference coordination between D2D and cellular communications with quality-of-service guarantee. First, base station matches the channel to D2D pairs on the basis of potential throughput gain. Second, interferences from D2D pairs to cellular users are converted into a penalty for D2D pairs through the interlayer price, and the optimization problem of system throughput is decoupled into multiple subproblems those can be solved in distributed and iterative manner in each D2D pair. Simulation results show that
two proposed distributed algorithms of channel allocation and power control on interference coordination perform well in convergence and overall system throughput.

Mohsan et al., in the article [6] aims to provide firsthand knowledge of the prominence of NOMA and DL and surveys several DL- enabled NOMA systems. This study emphasizes Successive Interference Cancellation (SIC), Channel State Information (CSI), impulse noise (IN), channel estimation, power allocation, resource allocation, user fairness and transceiver design, and a few other parameters as key performance indicators of NOMA systems. In addition, we outline the integration of DL-based NOMA with several emerging technologies such as intelligent reflecting surfaces (IRS), mobile edge computing (MEC), simultaneous s wireless and information power transfer (SWIPT), Orthogonal Frequency Division Multiplexing (OFDM), and multiple-input and multiple-output (MIMO). This study also highlights diverse, significant technical hindrances in DL-based NOMA systems. Finally, we identify some future research directions to shed light on paramount developments needed in existing systems as a probable to invigorate further contributions for DL-based NOMA system.

Rakesh Kumar Jha, et al., have a proposal [7] of group formation for resource reuse in NOMA with prioritized user application is established. The Simulations have been performed to ascertain the fair allocation of resources to the users in conformity to the application. The proposed algorithm helps in conserving power as compared to orthogonal frequency division multiplexing (OFDMA) with the Hidden Markov Model (HMM). The results demonstrate that JRPAN achieves higher system throughput and saves power while ensuring the requirement of Quality of Experience and Quality of service in comparison to OFDMA-HMM and proportional algorithm.

Na Su, et al., in this work [9], propose a channel allocation and power control algorithm for energy harvesting (EH) device-to-device (D2D) communication based on nonorthogonal multiple access (NOMA). E- algorithm considers users' quality of service (QoS) and energy causality constraint to maximize the total
capacity of D2D groups. i.e., optimal offline allocation of channel and power is realized firstly, the offline optimization results are taken as the training dataset to train the neural network to obtain the optimal model of the transmission power, e-online power allocation optimization algorithm is further proposed. Simulation results show that the offline algorithm can improve the total capacity of D2D groups, and the performance of the online algorithm is close to the offline algorithm.

Z. Ding, et al., propose [10] a correspondence, which considers non-orthogonal multiple access (NOMA) assisted mobile edge computing (MEC), where the power and time allocation is jointly optimized to reduce the energy consumption of computation offloading. Closed-form expressions for the optimal power and time allocation solutions are obtained and used to establish the conditions for determining whether the conventional orthogonal multiple access

(OMA), pure NOMA or hybrid NOMA should be used for MEC offloading.

Khan, U.A., et al., propose in this paper [11] jointly considers computation offloading and resource allocation problem in device-to-device (D2D)-assisted and non-orthogonal multiple access (NOMA)-empowered MEC systems, where each mobile device (MD) is allowed to execute its task in one of the three ways, i.e., local computing, MEC offloading or D2D offloading. We invoke orthogonal multiple access (OMA) and NOMA schemes for MDs that select D2D offloading mode, allowing them to assign tasks to their peers using OMA or NOMA. The original problem is formulated as an overall energy consumption minimization problem, which proves to be NP-hard, making it intractable to solve optimally.

Tran, et al., propose in this paper [12], they present a detailed survey of the so called D2D MHMP communications in terms of models, propose the future research directions of D2D MHMP communications. All the models, techniques, and applications for B5Gnetworks. We discuss and propose the future research directions of D2D MHMP communications. All the models, techniques, and applications as well as future research directions of D2D MHMP communications provide the useful insights into B5G networks design and optimization.

Existing Method

The recent unprecedented growth in the use of smart mobile devices and the increasing demand for a variety of multimedia applications in recent years, cellular networks are being greatly challenged. As one of the key technologies of the fifth-generation (5G) mobile communication, Device-to-Device communication enables direct communication between adjacent devices in the communication network without the support of infrastructure such as core equipment or central equipment so as to reduce the burden on the core network. Non-Orthogonal Multiple Access (NOMA) allows multiple users to share the same resources in terms of time and frequency through power-domain multiplexing and serial interference cancellation (SIC) in order to improve the system throughput and energy efficiency. Therefore, combining D2D with NOMA could greatly improve the quality of service of future mobile communication systems.

In addition to increasing the efficiency, flexibility, and intelligence of the communication network system, D2D communication also introduces additional interference. Therefore, one of the key problems has been how to coordinate the interference between the D2D system and the communication system. In traditional cellular users and D2D users independently determine their respective transmit power to maximize their utility. They use the game theory to model the trade-off between the two and achieve the highest
system energy efficiency values. In D2D users reuse resources of multiple cellular users via optimal channel selection in order to improve the throughput of the entire system. In a reverse iterative combination auction technique is proposed to realize the uplink resource allocation between the D2D and cellular users so as to optimize energy efficiency. In a relaxation-based algorithm is proposed to maximize the weighted energy efficiency value of the D2D link. However, these works use traditional Orthogonal Multiple Access (OMA) as the D2D access technology [2].

Extensive research has been conducted on the resource allocation problem of D2D communication. The works and propose a distance-based D2D resource allocation approach. In the author proposes an interference limit loop control strategy to find the appropriate cellular users to share the same spectrum resources with D2D users based on distances between users and base stations. Efficient Resource Allocation Algorithm for D2D Communications In a distance-limited resource sharing is proposed to ensure that the outage probability of D2D user communication is lower than the specified threshold value. However, the study only considers scenarios with only one pair of D2D users in the network. Similarly, resource allocation strategies are not based on long-term performance.

Considering multiple pairs of D2D users, the work in models the resource allocation problem in the D2D network as Mixed-Integer Nonlinear Programming (MINLP) and uses a heuristic algorithm to solve the problem. In D2D users are categorized into different user groups and suitably selected to minimize the impact of intra- system interference. However, the system performance still needs to be improved as the resource allocation problem in D2D communication has not yet been fundamentally solved [3].

In NOMA, reduction of mutual interference among users is crucial in improving the system throughput and energy efficiency. In a user matching technique based on a matching degree is proposed for the downlink multiple-input multiple-output (MIMO) communication system. Here, an adaptive method is used for

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 7 July 2023, pp: 280-294 www.ijaem.net ISSN: 2395-5252

optimal power allocation to increase the systems' capacity. In the POWER Allocation of two users under large base stations is analyzed to prove that NOMA can greatly improve the systems' capacity and energy efficiency compared to the traditional OMA.

Recently, some works have applied NOMA in D2D communication systems. In a new concept of D2D group using NOMA is proposed. In each D2D group, a D2D transmitter could simultaneously communicate with the two receivers using NOMA. In multiple cellular users are multiplexed on the same channel using NOMA. This can be achieved by first obtaining the power of the cellular user based on the constraints of the continuous interference cancellation demodulation sequence and subsequently allocating designated cellular users to the D2D users through a dual iterative algorithm. However, further studies on resource allocation for D2D communications based on NOMA are required. Also, the energy efficiency of such system is yet to be investigated.

In summary, considering the interference between D2D users and traditional cellular users, and the power allocation problem in NOMA, this paper proposes a joint sub-channel and power allocation algorithm for D2D communication based on NOMA. The main objective is to guarantee the communication Quality of Service (QoS) of cellular users and D2D users and to maximize the total uplink energy efficiency and throughput of the multiple D2D groups that use NOMA. In order to solve this joint problem, multiple D2D groups multiplex sub-channels of multiple cellular users by constructing a maximum matching problem of weighted bipartite graphs in graph theory, and then Kuhn-Munkres (KM) algorithm is used to ensure the communication quality of cellular users. A channel of the corresponding cellular user is allocated to each D2D group. Also, under the premise of ensuring the communication quality and transmit power. D2D users in each D2D group, the optimal power allocation scheme is obtained using Karush-Kuhn-Tucker (KKT) conditions. To demonstrate the effectiveness of the proposed algorithm, the performance in terms of energy efficiency and throughput is compared with the current state-of-the art algorithms and the traditional D2D-OMA algorithm under different system parameters and conditions.

Mixed integer nonlinear programming (MINLP) [3]

Mixed integer nonlinear programming (MINLP) refers to optimization problems with continuous and discrete variables and nonlinear functions in the objective function and/or the constraints. MINLPs arise in applications in a wide range of fields, including chemical engineering, finance, and manufacturing. The general form of a MINLP is

$$\min f(x,y)$$

$$\min c_i(x,y) = 0 \ \forall_i \in E$$

$$\min c_i(x,y) \leq 0 \ \forall_i \in I$$

$$x \in X$$

$$y \in Y \ integer$$

where each c_i (x,y) is a mapping from R^n to R, and E and I are index sets for equality and inequality constraints, respectively.Typically, the functions f and ci have some smoothness properties, i.e., once or twice continuously differentiable.

Software developed for MINLP has generally followed two approaches:

Outer Approximation/Generalized Bender's Decomposition: These algorithms alternate between solving a mixed-integer LP master problem and nonlinear programming subproblems. Branch-and-Bound: Branch-and-bound methods for mixed-integer LP can be extended to MINLP with a number of tricks added to improve their performance.

Orthogonal multiple access (OMA)

Orthogonal multiple access (OMA) techniques harmonize the access of multiple users to the network, thus preventing the collision of transmissions from different users. Preserving the orthogonality between transmissions can be achieved in the frequency domain MA, time domain MA, and code domain MA techniques that have been used in 2G and 3G. A more robust technique, known as orthogonal frequency division MA, combines time and frequency domains and was incorporated to LTE (Long Term Evolution). For 5G New Radio, the adoption of Orthogonal Frequency Division Multiplexing (OFDM)-based MA implies significant differences related, among others, to the fact that NR supports different numerologies according to the selected subcarrier spacing.

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Problem Statement

Device to Device communication (D2D) is a form of communication that enables two adjacent devices to communicate with each other, without the support of infrastructure such as core equipment or central equipment to reduce the burden on the core network. D2D communication increases the efficiency, flexibility, and intelligence of the communication network system.

However, a normal D2D Communication introduces additional interference into the system.

Thus, one of the key problems in implementation of D2D communication has been the proper coordination of interference between the D2D system and the communication system. Adding to this, efficient resource allocation in D2D communication is a major problem.

The problem of resource allocation also becomes much more complex when multiple pairs of D2D users are involved. Various previous works dealing with D2D communication, have used various types of resource allocation strategies but none of them have yielded long-term performance. Due to the system performance deficiencies, the resource allocation problem in D2D communication has not yet been fundamentally solved.

Proposed Method

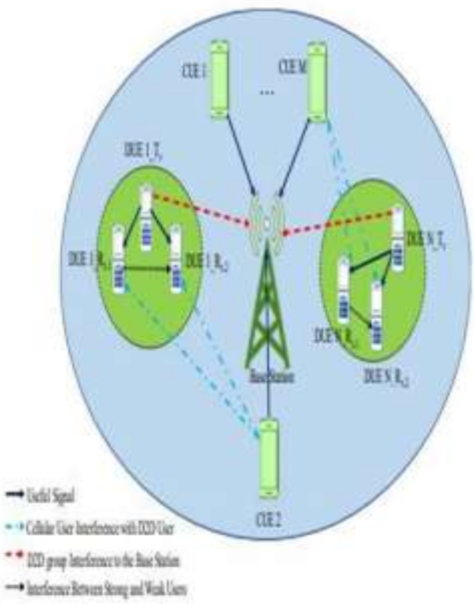

Figure 1. Block Diagram of the Proposed Method

This work focuses on the reliable multicast of common data from BS in a cell of cellular network to N user devices which are close to one another, forming a D2D-MC, as shown

We consider the quasi-static fading channel where the random channel gain remains constant over the duration of multicasting one packet. Also, assume that BS has knowledge of the instantaneous channel power gains of all D2D links at the beginning of delivering one new packet. Here, we propose the following D2D communication-based re-transmission way where all re-transmitters use a single channel rather than multiple channels based on the TDMA mode. Such a retransmission way has the good property that each D2D-MC in a cell only occupies one channel. This is significant because the total channels available in WCN are quite limited. More specifically, BS first transmits (physical layer broadcasts) the packet to all devices in the D2D-MC and each device which correctly received the data from BS sends one ACK packet to BS. Then, based on the current channel power gains of all D2D links, BS elaborately associates each NACK-device to some near ACK-device (not definitely the nearest one). Call the combination of one ACK-device and its associated NACK-devices as one subcluster. Finally, the ACK-devices having at least one associated NACK-device (called re-transmitters) retransmit the data to their respective associated NACK-devices using the same channel in the TDMA mode. The re-transmitter transmits at the lowest rate determined by the device with the lowest D2D channel power gain in this subcluster to ensure that the multicast services can be provided to all NACK-devices in the subcluster.

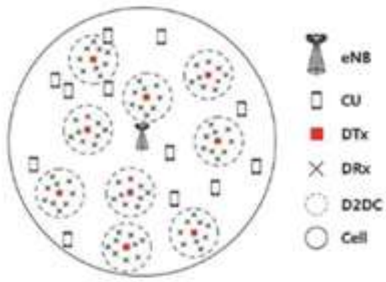

Figure 2. Formation of Clusters [1]

1. Formation of clusters with different size

In D2D cluster mode the file is directly transmitted to cluster members with multicast transmission. The required service (data rate) determines the SINR target for the transmission and the required transmission power is therefore determined by weakest D2D link between the file sharer and receiving cluster members. In cellular mode the packets are first transmitted to base station by the file sharer and packets are then multi-casted to the group on DL. Actual data flows, retransmissions, or feedback is not modelled in

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these simulations. The same service (on UL and DL) is assumed for all the devices regardless of the communication mode. Only one hop communication is considered in the cluster.

$$\sum_{i=1}^{N_{ACK}} b_{i,j} = 1, \forall j \in \mathcal{J}.$$

Furthermore let g_(i j) represent the channel power gain of the D2D link from the ith ACK-device to the jth NACK-device. For the ith subcluster, let gi represent the channel power gain of its worst D2D link, i.e.,

$$g_i = \min\left\{\frac{1}{b_{i,j}} g_{i,j} : j \in \mathcal{J}\right\}, \forall i \in \mathcal{I}.$$

So the transmission rate of the ith ACK-device (the ith subcluster) can be expressed as

$$R_i = B \cdot \log_2\left(1 + \frac{p_i g_i}{\sigma^2}\right).$$

where B is the channel bandwidth, pi is the transmission power of the ith ACK-device and σ^2 is noise power. So the transmission time of the ith ACK-device is given by

$$t = \frac{L}{R_i} = \frac{L}{B \cdot \log_2\left(1 + \frac{p_i g_i}{\sigma^2}\right)}$$

where L is the packer size in bits. Since the re-transmitters access the wireless medium in the TDMA mode, then the total time consumption (TTC) of all re-transmitters per packet delivery is

$$T = \sum_{i=1}^{N_{ACK}} t_i = \sum_{i=1}^{N_{ACK}} \frac{L}{B \cdot \log_2\left(1 + \frac{p_i g_i}{\sigma^2}\right)}.$$

2. Increasing number of D2D users:

The greater number of D2D users are used in the proposed method. If the users increase generally the complexity of the system increases. Hence, here the increased number of users are clustered as another cluster and the throughput capacity increases.

3. Code words and subcarriers:

Decoding is the process of translating received messages into code words of a given signal. There have been many common methods of mapping messages to code words. These are often used to recover messages sent over a noisy channel, such as a binary symmetric channel.

A subcarrier can carry two signals at the same moment of time. It is one of the carriers which carries Tele-communications. The function of subcarrier is utterly distinct from main carrier. Models consists of provision of color in a black and white TV system or the provision of stereo in a monophonic radio broadcast. In between subcarrier and carrier, there is no physical difference, the word sub signifies that it is a derivative of Carrier.

The Number of code words increases and the subcarriers for them also increase in order to increase the capacity of signal and using this signal the throughput capacity also increases.

The Hungarian method is a combinatorial optimization algorithm that solves the assignment problem in polynomial time and which anticipated later primal–dual methods. It was developed and published in 1955 by Harold Kuhn, who gave the name "Hungarian method" because the algorithm was largely based on the earlier works of two Hungarian mathematicians: Dénes Kőnig and Jenő Egerváry.

James Munkres reviewed the algorithm in 1957 and observed that it is (strongly) polynomial. Since then the algorithm has been known also as the Kuhn – Munkres algorithm or Munkres assignment algorithm. The time complexity of the original algorithm was 〗 O^4 (n), however Edmonds and Karp, and independently Tomizawa noticed that it can be modified to achieve an O^2 (n) running time. One of the most popular O^3 (n) variants is the Jonker–Volgenant algorithm. Ford and Fulkerson extended the method to general maximum flow problems in form of the Ford–Fulkerson algorithm. In 2006, it was discovered that Carl Gustav Jacobi had solved the assignment problem in the 19th century, and the solution had been published posthumously in 1890 in Latin.

Karush-Kuhn-Tucker (KKT) Conditions [1]

The Karush-Kuhn-Tucker (KKT) conditions, also known as the Kuhn-Tucker conditions or simply the KKT conditions, are a set of necessary conditions for solving optimization problems with inequality constraints. The KKT conditions are an extension of the Lagrange multiplier method to handle both equality and inequality constraints.

The KKT conditions are typically used in mathematical optimization problems that involve both equality constraints of the form g(x) = 0 and inequality constraints of the form h(x) ≤ 0. These conditions help identify potential solutions that satisfy the constraints.

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The KKT conditions can be stated as follows:

Stationarity Condition: The gradient of the objective function, f(x), with respect to the decision variables, x, must be equal to the weighted sum of the gradients of the constraint functions, g(x), and the inequality constraint functions, h(x), with non-negative Lagrange multipliers:

$\nabla f(x) = \sum \lambda_i \nabla g_i(x) + \sum \mu□\nabla h□ (x)$

where λ_i and μ□ are the Lagrange multipliers associated with the equality and inequality constraints, respectively.

Primal Feasibility Condition: The equality and inequality constraints must be satisfied:

$g(x) = 0$

$h(x) \leq 0$

Dual Feasibility Condition: The Lagrange multipliers associated with the inequality constraints must be non-negative:

μ□≥0

Complementary Slackness Condition: The Lagrange multipliers and the corresponding constraint functions must satisfy:

μ□ h□ (x) = 0

This condition implies that if μ□ > 0, then the corresponding inequality constraint must be active (h□ (x) = 0), and if h□ (x) < 0, then μ□ must be equal to zero.

The KKT conditions provide a set of necessary conditions for a solution to be optimal in optimization problems with both equality and inequality constraints. However, they are not sufficient conditions, meaning that even if the KKT conditions are satisfied, it does not guarantee that the solution is globally optimal. Further analysis or techniques may be required to determine the global optimality of a solution.

Stationarity Condition:

The stationarity condition requires that the gradient of the objective function, denoted as ∇f(x), is equal to the weighted sum of the gradients of the constraint functions, $\nabla g_i(x)$, and the inequality constraint functions, ∇h□ (x), multiplied by their corresponding Lagrange multipliers:

$\nabla f(x) = \sum \lambda_i \nabla g_i(x) + \sum \mu□\nabla h□ (x)$

This condition ensures that at the optimal solution, the objective function is not changing in any direction that is feasible according to the constraints. It implies that the optimal solution lies at a point where the gradients of the objective function and the constraint functions are aligned or balanced through the Lagrange multipliers.

Primal Feasibility Condition:

The primal feasibility condition states that the equality constraints,

g(x), must be satisfied:

$g(x) = 0$

These constraints are typically expressed as equalities and represent relationships that must hold at the optimal solution. The primal feasibility condition ensures that the solution satisfies the equality constraints.

In addition, the inequality constraints, h(x), must also be satisfied:

$h(x) \leq 0$

These constraints represent conditions that must be met, but they do not necessarily need to hold with equality. The primal feasibility condition ensures that the solution satisfies the inequality constraints as well.

Dual Feasibility Condition:

The dual feasibility condition requires that the Lagrange multipliers associated with the inequality constraints, μ□ , arenon-negative:

μ□≥0

This condition ensures that the Lagrange multipliers for the inequality constraints are feasible in the dual problem. Non-negativity implies that either the corresponding inequality constraint is inactive (not binding) or, if it is active, the Lagrange multiplier is positive.

Complementary Slackness Condition:

The complementary slackness condition states that the Lagrange multipliers and the corresponding constraint functions must satisfy:

μ□ h□ (x) = 0

This condition implies that if μ□ > 0, then the corresponding inequality constraint must be active (h□ (x) = 0), and if h□ (x) < 0, then μ□ must be equal to zero. In other words, either the constraint is binding, or the Lagrange multiplier associated with it is zero.

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The complementary slackness condition captures the trade-off between the objective function and the constraints. It states that either the constraint is binding, contributing to the objective function, or the Lagrange multiplier associated with it is zero, meaning that the constraint does not affect the objective function.

Satisfying all four KKT conditions is necessary for a solution to be optimal in optimization problems with both equality and inequality constraints.

Kuhn-Munkres Technique [7]

The Kuhn-Munkres algorithm, also known as the Hungarian algorithm, is an algorithm used to solve the assignment problem in combinatorial optimization. It aims to find the optimal assignment of agents to tasks, minimizing the total cost or maximizing the total benefit. The algorithm works by constructing an initial assignment and then iteratively improving it until an optimal assignment is reached.

To explain the Kuhn-Munkres algorithm, let's assume we have a square cost matrix C of size n x n, where n is the number of agents (or tasks). Each element C[i, j] represents the cost of assigning agent i to task j. The algorithm aims to find an assignment matrix X of the same size, where X[i, j] = 1 if agent i is assigned to task j, and 0 otherwise.

Here are the steps of the Kuhn-Munkres algorithm:

Step 1: Subtract the smallest element in each row from all elements in that row.
Let's denote the modified cost matrix as C'.
C'[i, j] = C[i, j] - min(C[i, k]), for all k

Step 2: Subtract the smallest element in each column of the modified cost matrix C' from all elements in that column. Let's denote the resulting modified cost matrix as C".
C"[i, j] = C'[i, j] - min(C'[k, j]), for all k

Step 3: Construct an assignment matrix X that initially has all zeros.
Step 4: Check for a complete assignment.

If there is a row or column in the modified cost matrix C" that contains only one zero, assign the corresponding agent to the corresponding task and mark that row and column as completed in the assignment matrix X.
Step 5: If a complete assignment is not found, perform the following steps iteratively:

Step 5.1: Identify the minimum number of lines (horizontal or vertical) required to cover all the zeros in the modified cost matrix C".

Step 5.2: If the number of lines equals n (the number of agents/tasks), go to Step 6.

Step 5.3: If the number of lines is less than n, subtract the smallest uncovered element from all uncovered elements and add it to all elements that are covered by two lines. **Step 5.4:** Go back to Step 4.

Step 6: Calculate the total cost (or benefit) by summing the elements in the cost matrix C that correspond to the assignments in the assignment matrix X.

The final assignment matrix X obtained after the algorithm terminates represents the optimal assignment that minimizes the total cost (or maximizes the total benefit) in the original cost matrix C.

Note that the Kuhn-Munkres algorithm has a time complexity of O(n^3), where n is the number of agents/tasks. This makes it efficient for small to moderate-sized problems but may become computationally expensive for larger instances.

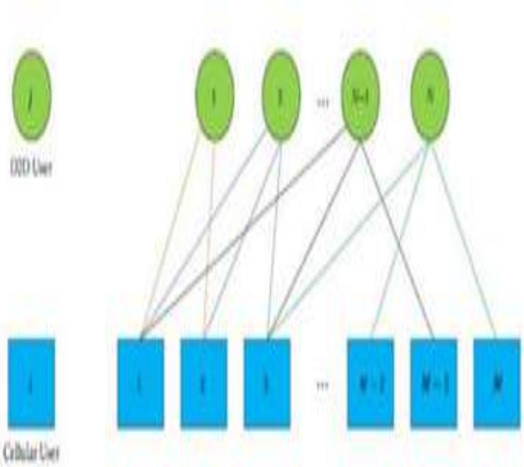

Figure 3. Maximum matching D2D groups and cellular based on Weighted Bipartite Graphs

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III. RESULTS

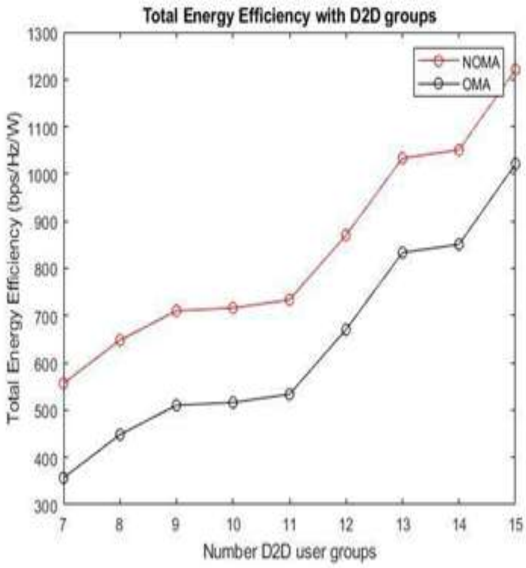

Figure 4. Total Energy Efficiency with D2D groups

From fig. 4 with the increase in the number of D2D groups, there is increase in the total energy efficiency. It is found that NOMA is more efficient than OMA by a difference of 200 bps/Hz/W. Thus, using NOMA would provide an energy efficiency of 200 bps/Hz/W than OMA.

From fig. 5 the D2D transmit power decreases with the increase in total energy efficiency as they are inversely proportional to each other. Here, we can see a difference of 200 bps/Hz/W between OMA and NOMA. Thus, NOMA is more efficient than OMA in terms of transmit power and total energy efficiency.

From Fig. 6 when the number of D2D users increase there's a sharp rise in the throughput for both NOMA and OMA but, initially when there are a smaller number of D2D users OMA is found to be more efficient than NOMA, but with gradual increase in the number of users the throughput sees a sharp rise in both, and the NOMA curve achieves higher throughput.

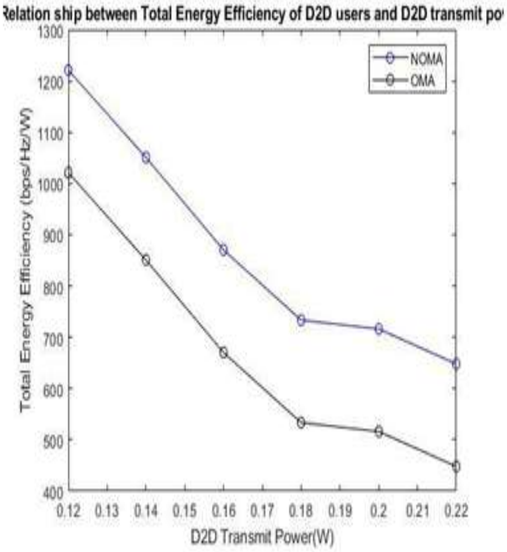

Figure 5. Relationship between Total Energy Efficiency of D2D users and D2D transmit power.

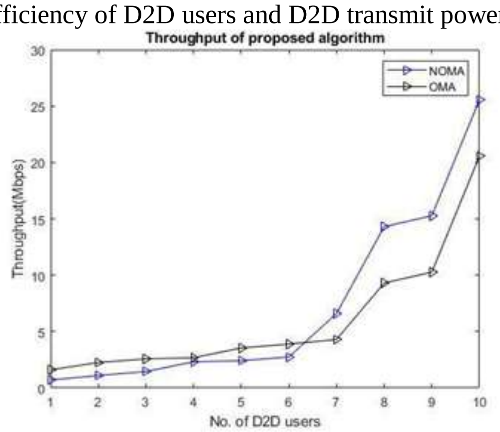

Figure 6. Throughput of proposed algorithm

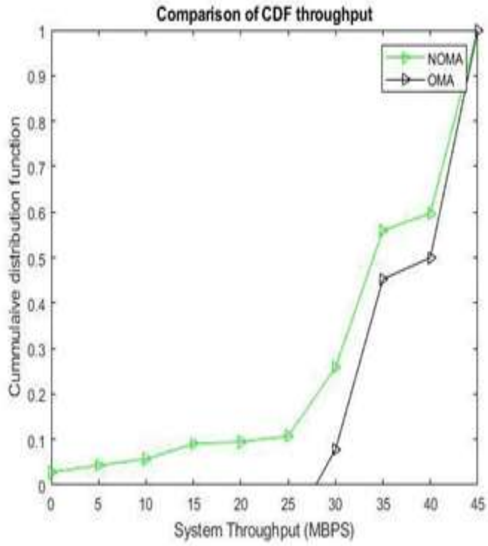

Figure 7. Comparison of CDF throughput

From Fig. 7 when system throughput increases NOMA curve sees a sharp rise at 25Mbps and then increases continuously. The OMA curve doesn't exist until the NOMA curve observes a sharp rise. Thus, in this scenario NOMA proves to be better OMA in the cumulative distribution function as it has a continuous curve throughpout.

Advantages

- The sum efficient throughput (ET) is maximized through the cellular link which guarantees a certain level of QoS.
- Higher max sum ET is provided because it allows higher transmit power of device transmitters.
- Computational cost is low.
- TTC (Total Time Consumption) strictly decreases as the computations are less.

Applications [1]

- Automotive industry that leads the next generation of connected cars
- Technology relays information such as the weather update
- Coverage extension
- Machine-to-machine (M2M) communication
- Data and computation offloading

IV. CONCLUSION

In this paper, an efficient joint resource allocation algorithm is proposed for D2D-NOMA systems. According to the interference between the D2D users and the cellular users, the algorithm applies the KM criterion to allocate the channels of the cellular users to each D2D group and then obtains the power values of the strong and weak users in each D2D group according to NOMA using the KKT conditions. The algorithm is designed to maximize the energy efficiency of the system while guaranteeing the QoS of all users and maximum transmit power of the D2D users. The simulation results under various network conditions indicate that the proposed algorithm outperforms the existing algorithms in terms of energy efficiency and throughput.

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