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In the name of God, who has enabled us to accomplish this humble scientific work, which we dedicate:
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{ وَآخرُ دَعْوَاهُمْ أَنِ الْحَمْدُ لِلّهِ رَبّ الْعَالَمِينَ }

Houria

Abstract

In recent years, we have witnessed a tremendous growth in the number of mobile phone users, which has led to a significant increase in the volume of data sent and received via cellular networks. To keep pace with this development, the focus is on developing technologies to move to the next generation of cellular networks known as "fifth generation" (5G).

Thes techniques include offloading the network core, improving frequency and power usage, reducing latency and increasing overall throughput. Device-to-device communication technology plays an important role in developing next generation systems, as it represents direct communication between devices without the need for a base station. However, this technology faces several challenges. Including improved frequency utilization and power control to reduce interference and increase overall productivity. This reduces communication delay and extends the coverage range for cells in cellular networks. Despite its benefits, this type of connection can cause interference with other cellular communications.

In this thesis, we propose to use a based genetic algorithm (GA) to reduce interference and increase spectrum utilization efficiency. The genetic algorithm is characterized by its ability to avoid a local peak and evolve towards a global peak by exploring multiple parts of the search space at the same time. Because cellular networks rely on device-to-device communication, they reduce the signal interference plus noise ratio (SINR) to ensure quality communication for cellular users. Numerical evaluations show superior performance of this technology in number of D2D served and the total achieved throughput.

Keywords

Device-to-device communication (D2D), fifth generation cellular networks (5G), interference, genetic algorithm (GA),

Résumé

Ces dernières années, nous avons assisté à une croissance considérable du nombre d'utilisateurs de téléphones mobiles, ce qui a entraîné une augmentation significative du volume de données envoyées et reçues via les réseaux cellulaires. Pour suivre ce développement, l'accent est mis sur le développement des technologies. pour passer à la prochaine génération de réseaux cellulaires dite « cinquième génération » (5G).

Ces techniques incluent le déchargement du cœur du réseau, l'amélioration de la consommation de fréquence et d'énergie, la réduction de la latence et l'augmentation du débit global. La technologie de communication entre appareils joue un rôle important dans le développement des systèmes de nouvelle génération, car elle permet une communication directe entre appareils sans avoir recours à une station de base. Cependant, cette technologie est confrontée à plusieurs défis. Y compris une utilisation améliorée des fréquences et un contrôle de la puissance pour réduire les interférences et augmenter la productivité globale. Cela réduit le délai de communication et étend la plage de couverture des cellules des réseaux cellulaires. Malgré ses avantages, ce type de connexion peut provoquer des interférences avec d'autres communications cellulaires.

Dans cette mémoire, nous proposons d'utiliser un algorithme inspiré de génétique (GA) pour réduire les interférences et augmenter l'efficacité d'utilisation du spectre. L’algorithme génétique se caractérise par sa capacité à éviter un pic local et à évoluer vers un pic global en explorant plusieurs parties de l’espace de recherche en même temps. Étant donné que les réseaux cellulaires reposent sur la communication entre appareils, ils réduisent le rapport interférence signal plus bruit (SINR) pour garantir une communication de qualité aux utilisateurs cellulaires. Les évaluations numériques montrent les performances supérieures de cette technologie en termes d'efficacité spectrale et de réduction des interférences.

Mots clés

Communication D2D, Réseaux cellulaire 5G, interference, Algorithme génétique (GA).

ملخص

في السنوات الأخيرة، شهدنا نموا هائلا في عدد مستخدمي الهواتف المحمولة مما أدى الي زيادة كبيرة في حجم البينات المرسلة والمستقبلة عبر شبكات الخلوية لمواكبة هذا التطور، يتم التركيز على تطوير التقنيات للانتقال الي الجيل التالي من الشبكات الخلوية المعروف ب "الجيل الخامس" (5G).

تتضمن هذه التقنيات افراغ نواة الشبكة وتحسين استخدام الترددات والطاقة، وتقليل التأخير وزيادة الإنتاجية العامة. تلعب تكنولوجيا الاتصال من جهاز الى جهاز دورا مهما في تطوير أنظمة الجيل القادم حيث تمثل اتصالا مباشرا بين الأجهزة دون الحاجة الى المحطة الأساسية ومع ذلك تواجه هذه التقنية تحديات عدة. بما في ذلك تحسين استخدام الترددات وتحكم في الطاقة لتقليل التداخل وزيادة الإنتاجية العامة. ولهذا يقلل من تأخير الاتصال ويوسع نطاق التغطية للخلايا في الشبكات الخلوية، على الرغم من فوائده يمكن ان يؤدي هذا النوع من الاتصال الي التداخل مع الاتصالات الخلوية الأخرى

في هذه المذكرة نقترح استخدام الخوارزمية الجينية لتقليل التداخل وزيادة كفاءة استخدام الطيف. الخوارزمية الجينية تتميز بقدرتها على تجنب الذروة المحلية وتتطور نحو الذروة المثالية من خلال استكشاف أجزاء متعددة من المساحات البحثية في نفس الوقت. نظرا لأن الشبكات الخلوية التي تعتمد على الاتصال من جهاز الي جهاز (D2D) تقلل من نسبة إشارة التداخل بالإضافة الى الضوضاء (SINR) لضمان جودة الاتصال للمستخدمين الخلوين. تقييمات عددية تظهر أداء متفوق لهذه التقنية من حيث كفاءة الطيف وتقليل التداخل.

الكلمات المفتاحية

الاتصالات من جهاز الى جهاز (D2D)، الشبكات الخلوية الجيل الخامس(5G)، التداخل، الخوارزمية الجينية (AG)

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Introduction

Introduction

In the past decade, new technologies have changed the way people exchange information among themselves while developing their needs, especially in the field of wireless communications. However, cellular networks face clear challenges in frequency use, area coverage, expansion of communication services, and energy consumption. The world is witnessing a sharp rise in demand for communications as a result of the spread of smart phones and the increase in population density in large cities, which creates new opportunities for communications between people. Global technology is developing rapidly, especially in the field of cellular communications, and we see the emergence of the fifth generation (5G) of cellular network technology that has focused on increasing Network capacity and improving data transfer speeds between devices known as device-to-device D2D technology is one of the important technologies of the fifth generation (5G).The fourth generation (4G) LTE advanced D2D communications system has begun to be used, working alongside cellular networks to expand business capabilities, improve quality of service (QOS), increase system capacity, reduce power consumption, improve end-to-end delay, and enhance blind spot coverage. Based on its potential benefits, D2D technology has greatly attracted the attention of researchers, so many various criteria have been proposed for selecting communication modes, starting with the approach based on path loss and paying attention to the amount of interference, the rate of D2D users, and the number of network conditions. However, each criterion leads to performance results different of the system. Which shows the importance of choosing the appropriate model to improve system performance. To overcome these challenges, researchers are working to reduce energy consumption and improve the efficiency of frequency use by solving the problem of resource allocation and energy control. This challenge is considered non-linear and bound by several restrictions, which makes traditional methods ineffective. Algorithms inspired by nature have been proven, such as genetic algorithms (GA). The Particle swarm optimization (PSO) algorithm is useful in providing effective solutions with less complexity. How do algorithms inspired by nature, such as genetic algorithm and optimization techniques, contribute to finding optimal solutions to solve this problem?
These algorithms were based on concepts from nature, such as genetic evolution and swarm behavior, to explore the field of solutions and find the optimal solution. Through these techniques, researchers aim to address the problem of resource allocation and energy control in D2D communication systems in cellular networks, with the aim of creating more efficient wireless networks in this era 5G.
In this thesis, we propose a based genetic algorithm to solve the problem of resource allocation for D2D communications in 5G cellular networks because of its efficiency and because it helps researchers by providing indicators for systems and methods for solving and reconciling limited resources with high demand, and it also depends on the concept of inheritance, mutations, selection, and crossover.
Genetic algorithm in which potential solutions are represented in the form of gene sequences and chromosomes. A new generation of potential solutions is generated using hybridization and mutation, where the traits of the best individuals are combined to produce future generations. The selection process is carried out by evaluating the performance of potential solutions and choosing the best individuals. Mutations are used to introduce random changes in the solutions to increase diversity, expand the scope of research, and improve the quality of solutions. Genetic algorithms are used in many fields and applications, such as assembly problems, integrated circuit design, structural optimization, neural network training, and

others. This algorithm is considered a powerful tool for finding optimal solutions in large and complex search spaces.

This thesis consists of six parts, a general introduction, four chapters and a general conclusion. The general introduction introduces this study by citing the motivation and organization of the thesis. The first chapter provides an overview of cellular networks and their generations from 1G to 5G. We focus on the fifth generation of cellular networks. We discussed its concept, 5G waveforms, characteristics, advantages and disadvantages, and then its main promising technologies. We also provide a brief overview of D2D communications in 5G technology. The second chapter presents a definition of D2D communications, its most important characteristics, its classification, and then the applications that use it. We also touched on the challenges of D2D. The third chapter presents the problem that was addressed regarding the allocation of shared channels and control capacity in D2D communications. We also present a number of related works on this topic and conclude the chapter by formulating the problem.

The fourth chapter presents a general introduction to the presented work, motivation, and how to apply the Genetic algorithm. And also the simulation and the results that were achieved. Finally, a general conclusion.

Chapter01:

5G cellular networks

Chapter01: 5Gcellular networks

1.1. Introduction:

5G is the fifth generation of wireless communication technology that supports cellular data networks. In 2019, many telecommunications companies in the world began adopting fifth generation technology on a large scale, and today most of these companies are upgrading their infrastructure to provide fifth generation technology(5G) functions [1].

In this chapter, we provide an overview of cellular networks and their generations from 1G to 5G. We focus on the fifth generation of cellular networks, the most important waveforms, their characteristics, advantages and disadvantages, and the most promising technologies for them. Finally, we will give a brief look at D2D communications for 5G cellular networks.

1.2.Cellular networks:

1.2.1. Definition:

cellular networks is a wireless communication network which provides services to mobile users covered by region consisting of multiple cells. Frequency reuse is a fundamental concept in cellular networks [3].

The mobile network consists of a group of cells in different areas, and in each cell there is one or more base stations that operate on different frequencies and have a specific frequency range.

Each of these cells can be divided into pico cells, micro cells, according to the coverage area The operating frequencies of the antennas can be reused by another group of cells at a certain distance to ensure that interference does not occur. User devices located in these cellular areas provide various services such as audio, video, live broadcast, and others.

Shared radio resources are allocated to these devices based on their traffic requirements and the area in which they are located by a group of schedulers.

The basic structure of the cellular network, as shown in the figure 1-1, includes the following elements

Core network:

The main goal of the core network (CN) is to enable the exchange of information between different users by providing the necessary methods for this. It is also known as a backbone network. It often consists of switches or routers, and switches are most commonly used.

User Equipment:

User equipment is the equipment that end users use to connect to the network and includes computers, cell phones, broadband adapters, and any device that has a wireless antenna

Radio access network:

The wireless access network performs radio functions in addition to providing 2G connectivity to the backbone network. The wireless access network consists of two main components, the base transmitter stations (BTS) and the base station controller (BSC). Basic transmission stations are the main elements that provide wireless coverage for specific areas and improve the quality of service, as each basic transmission station is connected to a cell site. These cell sites include a variety of cells based on coverage requirements.

In the 3G system, the basic transmitter station (BTS) was replaced by node B and the base station controller was replaced by the radio network controller (RNC).

In the fourth generation (4G) system, the structure of the RAN radio access network was changed by replacing (NB) with (e node B) and dividing the RNC functions between (CN)and (e NB). Thus, the RAN consists of (e NBS) connected to each other, enabling them to deal directly with traffic, while adding some additional features such as the ability to send data from several equipment to the same user. To increase the transfer rate. [7]

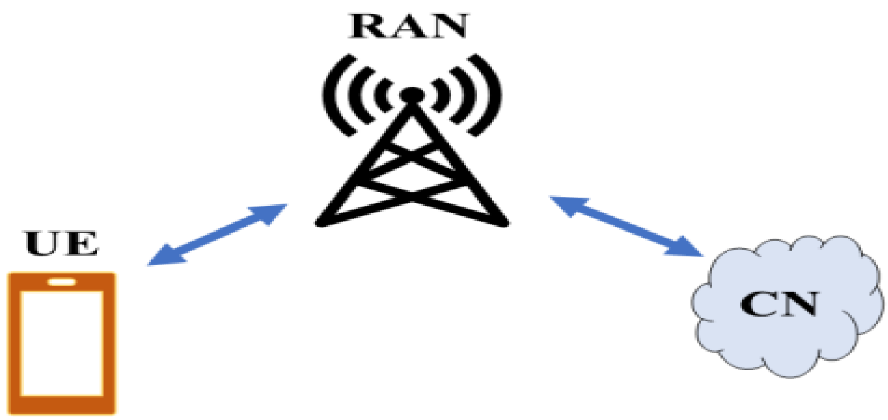


Figure 1-1:basic structure of the cellular network [7]

1.2.2. Evolution cellular networks (1G to 5G):

1.2.2.1. First Generation (1G):

1G is original of mobile networks, The beginning of development in the field of communications was represented by the emergence of analog communication standards, and with the arrival of the first generation (1G), the focus was mainly on providing basic voice services. Japan played an important role in this development by establishing the first mobile communications network in Tokyo in the late 1979's. this was followed by expanding the technology in Europe and around the world with technologies such as AMPS (advanced Mobile phone system) and NMTS (Nordic Mobile Telephones). despite these achievements, it had limitations such as the lack of sufficient channels and the high cost of equipment. It also faced challenges related to sound quality, maximum capacity, limited security and slow data transfer. The first generation relied on analog signals, and this led to low communication efficiency compared to the digital signals that were represented in the generation. Howevre, these developments laid the foundation for notable improvements in the next generation of technology [2].

1.2.2.2. Second generation (2G):

The advent of second generation (2G) mobile networks led to exceeding telecommunications system standards during 1991. The technology was normalized in finland, GSM calls in this generation provided advantages such as encryption and significantly greater clarity compared to the previous generation. Among the notable features of the second generation is the ability to send message (SMS) and picture messages (MMS), in addition to voice and picture messages. A digital signal was used to transmit data instead of analog and the unique Code Division Multiple Access (CDMA) concept was implemented. CDMA provides each user to communicate via several channels at the same time. Shortly after the emergence of the second generation, the 2.5G generation appeared in 1995, which combined voice and data through Enhanced Data Rates for GSM Evolution (EDGE) technology, which allows switching between General Packet Radio Service (GRPS) packets, making it suitable for use over the internet. Data speeds of up to 64 kilobytes per second were recorded [2].

1.2.2.3. Third generation (3G):

Third generation networks rely on wireless communication networks extended by brans, allowing support for data transfer at speeds of at least 2Mbps. It was launched in 2000's and is characterized by fast data transfer and reliability. An association known as GPP3 was created to help implement 3G networks, as they worked to define a mobile system that complies with the M2000 standard. In Europe, the mobile telecommunications system was known by several names, such as UMTS (Universal Air Mobile telephone systems). this ambitious system was developed by European union for standardization in the field of telecommunications standards MT2000, which was developed by the international telecommunications union as the ITU framework for the third generation of technology, such as CDMA technology and Enhanced Data Rates for GSM Evolution (EDGE) are also considered third generation digital networks that are several times faster than the second generation. bandwidth and data transfer rate were increased in 3G technology to accommodate web application and audio files and used the skype protocol Maximum data transfer speeds reached 100-300 MB per second [2].

1.2.2.4. Fourth generation (4G):

In this generation a noticeable change has been made namely the provision of wider bandwidth, high security, and fast access to the internet. this generation is based on long range communication technology. long term Evolution (LTE) technology is a fourth generation(4G) wireless communication standard developed by the GPP3 third generation partnership project. LTE is significantly advanced over previous generation technologies.it provides noticeable improvements in multimedia, video streaming quality, and internet access sped. LTE is also characterized by its ability to achieve high data transfer speeds, the lowest value of which the transfer rate reaches 100 MB per second. LTE technology was first launched in Stockholm and then in Oslo Norway in 2009 through the LTE long -range communication standard for the fourth generation. thanks to its availability all over the world, high-quality video streaming has become a reality for many users, thanks to the fourth generation(4G) technology that provides access fast access to the internet at speed of up to 1Gbps for users. Which enables them to ply smoothly, watch high-quality video conversations. The following Table 1.1 shows the comparison between the five cellular networks [2].

Technology / Features	1G	2G	3G	4G	5G
Start/deployment	1980's	1990's	2000's	2010's	2020's
Data Bandwidh	2Kbps	6Kbps	2Mbps	1Gbps	Higher than 1Gbps
Technology	Analog cellular technology	Digital cellular technology	Broadband with CDMA	Unified IP& seamless combination of broadband, LAN, WAN& WLAN	Unified IP& seamless combination of broadband, LAN, WAN, WLAN & w www
Service	Mobile technology (voice)	Digital voice, SMS, Higher capacity packetized data	Integrated high quality audio, video and data	Dynamic information access, wearable devices	Dynamic information access, wearable devices with AI capabilities
Multiplexing	FDMA	TDMA, CDMA	CDMA	MC-CDMA	CDMA
switching	Circuit	Circuit, packet	Packet	All Packet	All Packet
Core network	PSTN	PSTN	Packet N/W	Internet	Internet

Table 1-1: comparison between the five cellular networks **[50]**

1.3.Fifth generation(5G):

1.3.1. Definition:

5G technology is cellular network that has been in development since 2015. This technology allows communication speed exceeding 1GB per second, which aims to provide all possible applications using only one universal device and connect most existing communications infrastructure. 5G is characterized by a bandwidth of up to 40MHZ, which makes it an integrated wireless technology that greatly supports the wireless world wide web. Fifth generation technology gives us high data speeds and greater capacity, enabling us to dynamically access information and use wearable devices that have artificial intelligence capabilities [5].

1.3.2. Wave forms of 5G:

OFDM (orthogonal frequency Division Multiplexing) technology relies on the use of periodic cooling, which has achieved great success and still enjoys many advantages. Now fifth generation technology relies on other optimal waveforms that will remain in use until at least 2040 [10].

Some waveforms in fifth generation technology

FBMC: this type of technology depends on dividing the frequency spectrum into several very narrow sub-carriers, and filtering each of them individually, which allows achieving a very high level of spectral efficiency.

UFMC: this type is distinguished from FBMC in that it divides the signal into a certain number of sub-bands that are filtered, instead of filtering each sub-carrier individually, and it can be used to improve interference between symbols.

GFDM: it is a flexible transmission technology that relies on many carriers similar to OFDM technology, but the main difference lies in the carriers not being perpendicular to each other.

GFDM allows better control of out-of-band emissions and reduced power-to-average power ratio.

1.3.3. Characteristics of 5G:

5G technology is one of the promising developments in the field of wireless networks that aims to achieve significant improvements in the performance of cellular networks. The idea is to examine the performance of 4G networks and explore how to deliver 5G services. Overall, the characteristics of 5G services can be defined using a variety of specific criteria and metrics.

a. Speed

It is expected that the introduction of fifth generation technology will achieve a significant increase in spectrum efficiency compared to current technologies. This increase in performance is achieved through the use of new technologies such as.

- MIMO and Beamforming technologies contribute to enhancing the efficiency of using frequency spectrum in fifth generation networks. By using base stations equipped with a large number of transmitters/receivers, directed signal strength in unused areas, which contributes to improving spectral efficiency and reducing interference between communications.

- reducing the weight of the traffic signal in the radio frame contributes to improving the use of bandwidth for effective data exchange.

- improving the use of available bandwidth for data transfer by making better use of carriers, especially large-width wireless channels, to achieve maximum efficiency in tata transfer speed per megahertz.

- the phone must be able to access high-speed 5G networks outside buildings, such as achieving a theoretical download speed of more than 100 Mbps. At 10GHz, a theoretical data transfer rate of up to 1GB per second can be achieved, in a single frequency band 100MHz.

b. Latency:

5G technology is expected to improve the communication experience by reducing the time delay that occurs from the starting point to the end point, enabling the provision of connected services that require a very fast response, which was limited to fixed environments until now. These improvements are due to several technology including:

- Greatly reduced radio packets acknowledgment time loop
- Dynamic management of the structure of radio frames in the case of TDD (Time-Dvision duplex) mode

The provision of low- latency mobile access in 5G technology is expected to allow outside buildings, For example achieving an overall delay of less than 5ms.

c. Connectivity density:

5G technology aims to significantly increase the number of connected devices per unit area compared to current technologies, including 4G. this increase depends largely on the use of lightweight communication protocols, which consume a very small percentage of bandwidth.

5G technology expects to provide widespread access to connected devices, both indoors and outdoors, enabling hundreds of thousands of devices to be used per square km.

d. Reliability:

5G technology foresees some new uses that require highly reliable connections, with minimal downtime. The dual communication and data retransmission in HARQ (Hybrid automatic repeat request) at the planned 5G speed is expected to reduce packet loss and make communications more reliable.

It is assumed that the process of the network bypassing some parts of the fifth generation will contribute to increasing its resistance, which will reflect positively on the reliability of network

communications. Ultra-reliable 5G communications outside buildings can be available 99% of the time.

e. Modulation:

thanks to the improvement of the link features in fifth generation technology, through the development of antenna and signal processing technology, modifications can reach the quadrature amplitude modulation QAM-256 (information broadcast 8) level, which provides excellent spectral efficiency and very high data rates.

f. Access technologies:

5G technology is built on data transmission technology OFDMA (orthogonal frequency Division Multiplexing)

1.3.4. Advantage of 5G:

- It is possible that the 5G network will make work 10 times faster than 4G.

- Improved response thanks to reducing waiting time tenfold

- Improving communication capabilities to enable more users to communicate at the same time while maintaining communication quality
- A solution to the increasing traffic via mobile devices due to the significant expansion in the number of connected things that will be part of our daily lives in the future [10].

1.3.5. Disadvantages of 5G:

Despite the potential benefits of the 5G network, there are some concerns related to radio frequencies that raise great controversy about their impact on our health and environment. As the network coverage expands, there will be a need to install more towers, which may increase the periods of exposure to waves. To determine whether 5G technology poses a threat to our health, pilot experiments currently being conducted will allow measuring the levels of public exposure to waves.
Reduce energy consumption: This technology works with higher efficiency and consumes less energy, which will contribute to positively increasing the operating period of the batteries
The risk of 5G technology also refers to network security issues. 5G technology allows for prioritization, allowing 5G resources to be managed more effectively based on usage. [10]

1.3.6. 5G technology:

We'll take a look at the key promising technologies that will enable 5G

1.3.6.1. Mm wave:

Known as 5G New Radio frequency (5G NR), it is considered a key and promising technology in fifth generation cellular networks thanks to its ability to achieve massive throughput with its fifth generation demand. A frequency below 6GHZ is generally used for cellular communications while frequencies above that are mostly used for other services such as medical telemetry, remote sensing using electromagnetic waves, amateur radio, computing at terahertz frequencies and radio astronomy. A significant increase in data traffic led to congestion in the frequency spectrum of wireless networks, which reduced the bandwidth available to each user slowed down the connection and made it less reliable. Another way to solve this problem is to use frequencies above 6GHZ in this context, but recently a lot of research has been done to explore the benefits of broadcasting high-frequency waves. These waves range between 30 GHZ and 300 GHZ and are known as ultra centimeter waves because their length ranges between 1 and1 00 mm, as shown in the figure 1-2, compared to the radio waves used in the current mobile communications system, which are several centimeters. Also, some countries are currently using mm wave radio frequency for 5G networks. Such as USA, Korea, Japan, China, Sweden, EU, as shown in table 1.2

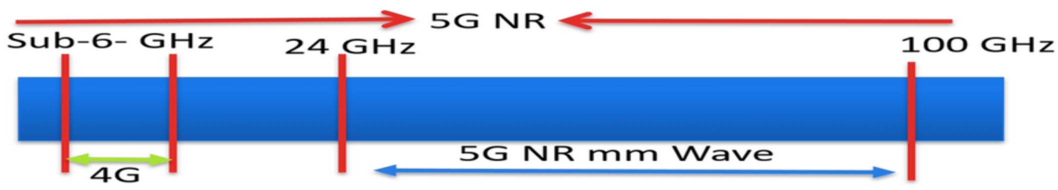


Figure 1-2:5G New Radio frequency (5G NR): the mm wave [48]

1.3.6.2. Ultra density networks:

Small cells, also known as Ultra Density Networks (UDN), are an essential part of the development of 5G networks, as they are considered a powerful solution to the challenges of increasing network density, improving the efficiency of using radio frequency, and increasing data speed per unit area. Small cells are also an essential part concept of heterogeneous networks (het net). it is estimated that proving at least ten small cells for each major location in the urban environment can help meet the increasing demand and improve usage density. [6]

Table1.2. show the mm wave radio frequency used nowadays by some country for 5G networks [9]

County	Mm Wave radio frequency
USA	27.5-28.35 GHz and 37-40GHz
Korea	26.5-29.5GHz
Japan	27.5-28.28GHz
China	24.25-27.5GHz
Sweden	26.5-27.5GHz
EU	24.25-27.5GHz

Table 1-2:mm Wave radio frequency used in some country for 5G networks

1.3.6.3. Mimo technology (multiple input multiple output):

Multiple Input Multiple Output (MIMO) technology is the result of the development of wireless communications technology and smart antenna technology. MIMO combines the benefits of multiple input, single output (MISO) antennas, single input, multiple output (SIMO) antennas, and transmitting and receiving antennas. MIMO technology improves the quality of wireless communication and significantly increases the data transfer rate without requiring an increase in bandwidth or power consumption. The multiple antenna system is an essential part of MIMO technology, and its performance is affected by the design and distribution of these antennas as well as the characteristics of the wireless communication channel [6].

1.3.6.3.1. Principe of mimo technology*:*

MIMO technology allows several different signals to be sent via multiple antennas at the same time and on close frequencies. This helps in increasing the transmission speed or range, and it is a unique technology due to the use of several antennas for transmission and reception at the same time. This improving the performance of devices, especially in facing challenges related to waves and their behavior. The transmission quality, transmission speed and coverage range are affected by the surrounding environmental conditions. shows this The figure 1-3[6].

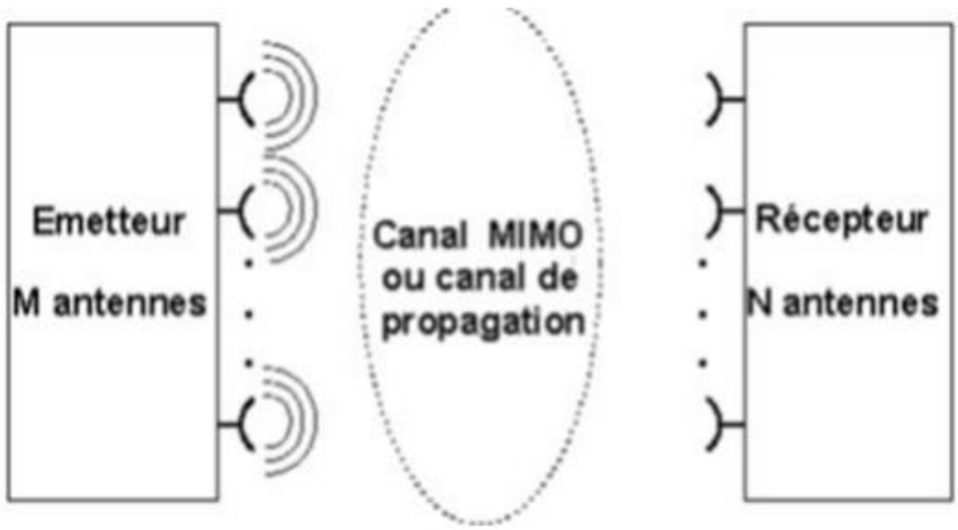


Figure 1-3:principe of MIMO [6]

1.3.6.4. Massive mimo:

Massive MIMO technology is considered one of the technologies expected to significantly enhance network performance in future generation of cellular networks. Massive MIMO technology is used in mobile networks today to achieve the ambitious goals of fifth generation technology. Massive MIMO is an enlarged version of traditional systems with multiple inputs and outputs. In the common concept of Massive MIMO technology, it is assumed that user devices have only one antenna, while the number of antennas in the base station is much greater than the number of users. Originally, the massive MIMO name corresponded to the number of antennas to infinity, as shown in the figure 1.4. The introduction of massive MIMO technology led to tremendous changes in the research and development community during the past decade, and as result, many upcoming communications technologies were adopted, such as 5G technology under 6GHZ, of which massive MIMO technology was the main one. Studied also show a growing interest in Massive communication applications for massive machine-type communication (m MTC) devices that are intermittently active [8].

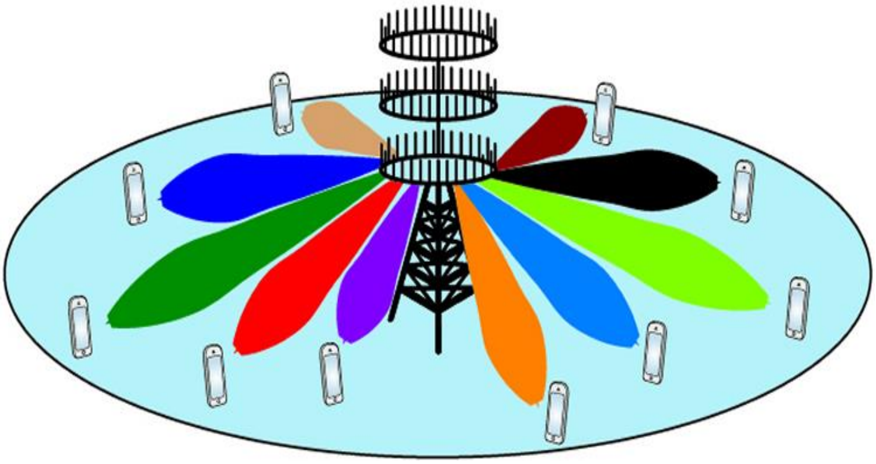


Figure 1-4: Massive mimo for 5G networks [6]

1.3.6.4.1. Massive mimo types:

1.3.6.4.1.1. Single-User mimo (Su-mimo)

Due to the physical difficulties facing the station devices. the SU-MIMO system is classified as Case 1 when a number of antennas are equipped at the base station. It thus benefits from the differentiation of transmission channels in the presence of favorable conditions for channel migration. However, SU-MIMO channels can be highly interconnected due to the short distance between the antennas on the station's antenna and the high depth of direct connection. From a power efficiency standpoint, it may not be wise to use a large antenna array to serve a single transmitter or a small number of transmitters. Therefore, the benefits achieved from MIMO technology may be limited in cases such as the SU-MIMO system.

1.3.6.4.1.2. Multiple-User mimo(mu-mimo):

This system enhances the overall capacity of each base station by allowing communication with multiple devices using the same resources, making the hardware subside almost limitless. Simultaneous use of the antennas of multiple devices allows the creation of virtual MIMO channels over a range, which increases wireless transmission speeds without increasing bandwidth consumption. Scaling values [11].

1.3.6.5. Beamforming:

Beamforming technology is the process of improving the signal, as its primary goal is to direct the beam towards the signal of interest (soi) and reduce or eliminate interference in other directions. Beamforming technology is implemented in multiple ways in the time and frequency domain and depends on the speed of processing and the diversity of the signals being dealt with. This technology allows the base station to adapt the antenna radiation pattern, it helps it find a suitable path to deliver data to the user, and it also reduces the occurrence of interference with other users along the path, as shown in the figure1-5. The effectiveness of beamforming technology depends on the ability to implement it in different ways in future networks. For massive MIMO systems, beamforming technology enhances spectrum efficiency, while in the case of millimeter waves, it helps increase data rates. In massive MIMO systems, the base station can send data to the user from multiple paths. Beamforming regulates the movement of data and the timing of its arrival to enable more users to send data simultaneously [6].

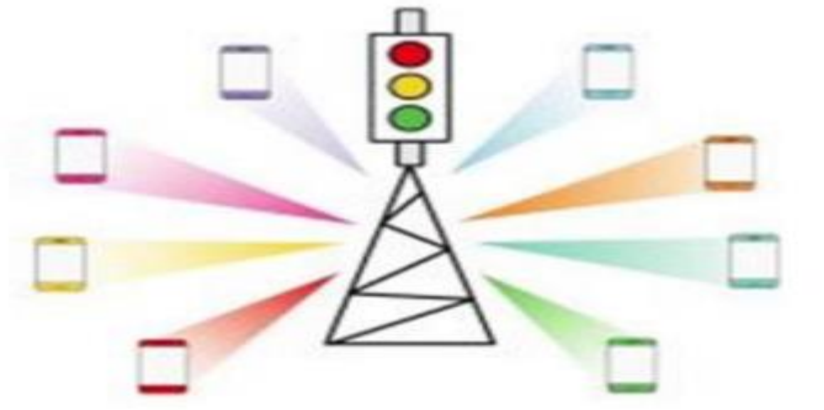


Figure 1-5: technology Beamforming [6]

1.3.6.6. Network slicing:

Network segmentation technology is part of the family of virtualization technologies related to networking. Such as Software Defined Networking (SDN) and Network Function virtualization (NFV), these technologies are driving the realization of today's networks. SDN and NFV can provide greater flexibility for the network to simply virtualize elements. Network slicing technology enables the creation of multiple virtual networks over a shared physical infrastructure.

Network slicing technology allows the creation of dedicated segments for separate, self-segmented slicing network functions [1].

1.3.6.6.1. Software defined network (SDN)

In SDN, a central, logical entity called a controller controls the organization of the data structure of the network using an application programming interface (API), which enables it to configure transport tables for network devices such as network switches to handle incoming data packets and the necessary arrangements. The SDN approach makes it easier to configure and expand the architecture

1.3.6.6.2. Network function virtualization (NFV):

It works as a complement to SDN and promises significant benefits in terms of cost savings, increased flexibility, and easier network infrastructure deployment. NFV is based on the actual use of data center infrastructure, which plays a crucial role in providing many services for Internet applications such as Google and Amazon [6].

1.3.6.7. 5G Network slicing:

According to the 5G Americas report, one of the clear benefits of network slicing technology in 5G networks for network operators is the ability to deploy only the functions necessary to support the relevant customers and specific market segments.

This allows for cost savings compared to the need to deploy complete functionality to support devices that may only benefit from a portion of this functionality

Network slicing has the potential to deploy 5G systems faster, since it requires less functionality to be deployed, allowing access to the market faster. Some specialized companies, such as Ericsson, believe that network slicing technology will be the main key to achieving the technical needs of 5G networks in the new era of connectivity. Which will be represented by fifth generation technology.

The usage will be characterized by its wide variety and diverse requirements in terms of power, frequency and speed. According to Ericsson, the greater flexibility provided by network slicing will contribute to addressing the cost, efficiency and flexibility requirements required in the future. as shown in the figure1-6

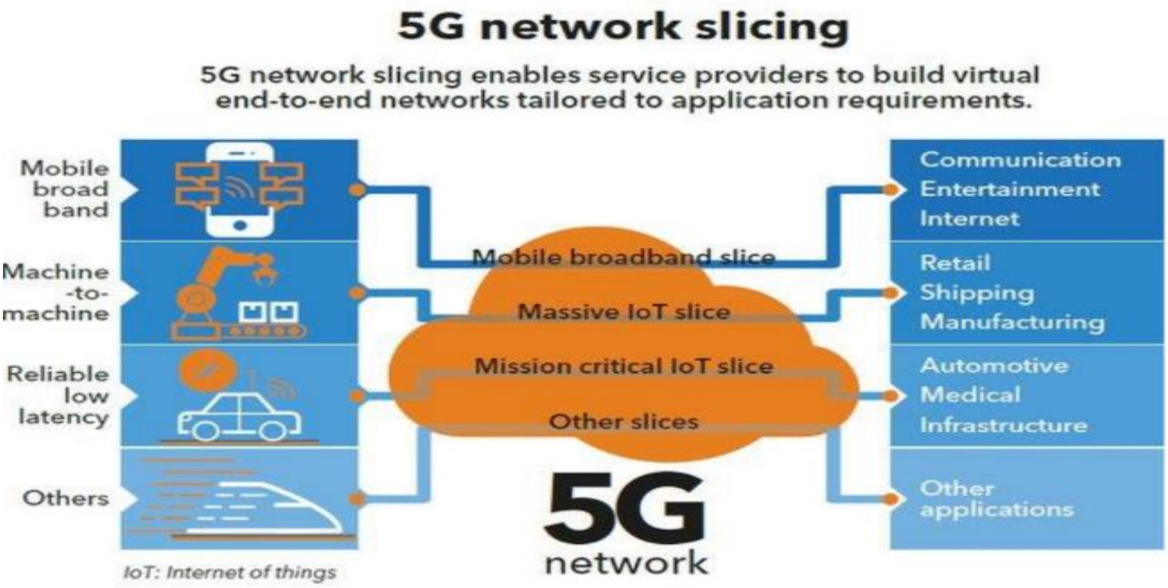


Figure 1-6:5G network slicing [1]

1.4.Communication D2D for 5G:

Device-to-device communication is considered a promising technology to enhance spectrum efficiency in fifth generation cellular networks. D2D takes advantage of the short distance between connected devices to improve data transfer rates, exploit available resources efficiently, increase network capacity, and reduce delays.

The research community is constantly working hard to explore a model of device-to-device communication with the aim of effectively integrating it into future cellular networks and making the most of its potential. Device-to-device communication is direct communication between devices or user equipment (UE) without participation or limited intervention from the base station [6].

1.5.Conclusion:

Technology is changing our world as well as our personal lifestyle. Fifth generation technology has come a long way in meeting the needs of our current era, in which speed and high availability are among the greatest standards. In this chapter, we provided an overview of cellular networks and evaluated the cellular mobile phone network from 1G to 4G. We discussed the fifth generation(5G) network further in this chapter under 5G cellular technology, and presented its characteristics, advantages, disadvantages, and promising technologies, starting with mm wave followed by massive MIMO, which We discussed its characteristics, the principle of limiting it, and its most important features, then the beamforming technique, and finally the network division technique. We presented it as an input for device-to-device communications in 5G cellular, which we will detail in the second chapter.

Chapter02
D2D communications

Chapter02: D2D communication

2. Introduction

The evolution of wireless communications has been marked by a growing need for speed and quality of connection for end users. With the rise of connected devices, meeting this demand has become a major challenge. To address these challenges, researchers have looked into solutions such as strengthening communication spectrum and improving energy efficiency through Device-to-Device (D2D) communication. This approach, integrated into future wireless infrastructures, promises more efficient spectrum utilization, reduced energy consumption, and an enhanced user experience through more powerful networks and increased data rates.

The concept of D2D communication relies on direct links between devices in close proximity, bypassing the need to go through a base station for voice and data transmission. In case of malfunction with the base station, D2D communication can also serve as a backup network. However, the adoption of D2D communication is not without its challenges, particularly in terms of interference between cellular users sharing the same resources and between D2D pairs using the same resources.

2.1. D2D communication:

Device-to-Device (D2D) communication is a wireless communication technology that enables direct communication between devices without the need for passage through an intermediary point such as a base station. This means that nearby devices can exchange data directly, allowing for improved resource utilization efficiency and reduced communication latency. D2D technology is used in various applications such as file sharing, text messaging, multiplayer gaming, live media streaming, and more. D2D communications can enhance user experience and increase radio spectrum efficiency, leading to overall network performance improvement and energy savings.

Device-to-Device (D2D) communication is anticipated to be a fundamental component of the upcoming 5G mobile communication networks. D2D can function in both licensed and unlicensed spectra and typically operates transparently to the cellular network. This allows nearby user equipment (UE) to bypass the base station (BS) and establish direct links with each other. Through these links, they can either share their connection and act as relay stations or directly communicate and exchange information [13].

2.2.Characteristics of D2D communication:

Existing technologies that facilitate direct connections between cellular devices in close proximity are broadly known as peer-to-peer (P2P) solutions, with WiFi Direct and Bluetooth being the most popular options. However, both technologies face scalability limitations. WiFi Direct and Bluetooth operate within the unlicensed spectrum, which exposes them to uncontrolled interference from other devices such as microwave ovens and wireless speakers that share the same spectrum. Consequently, they offer D2D connectivity with low densities, typically fewer than 10 users. Moreover, WiFi Direct's two-step discovery process exacerbates battery impact exponentially as the number of users increases, thereby compromising its energy efficiency. The constraints of existing direct-connectivity technologies have sparked interest in D2D services within cellular systems, enabling direct communication between two mobile users without routing through the base station (BS). Incorporating D2D services into cellular networks yields several advantages from a technical perspective. D2D users communicate directly with each other instead of routing data through base stations, thereby enhancing spectrum utilization and conserving energy. By bypassing the BS, cellular traffic can be offloaded, reducing network congestion. Given D2D networking's short range, users can transmit data at high rates with low end-to-end delays. D2D communications also extend the cellular link range through user-to-user relaying. In scenarios where cellular coverage is unavailable, a group of D2D users can establish a self-organizing network, with one user acting as a clusterhead to synchronize, manage radio resources, and schedule transmissions. In Figure2.1, we illustrate potential benefits of D2D communications in cellular systems [12]

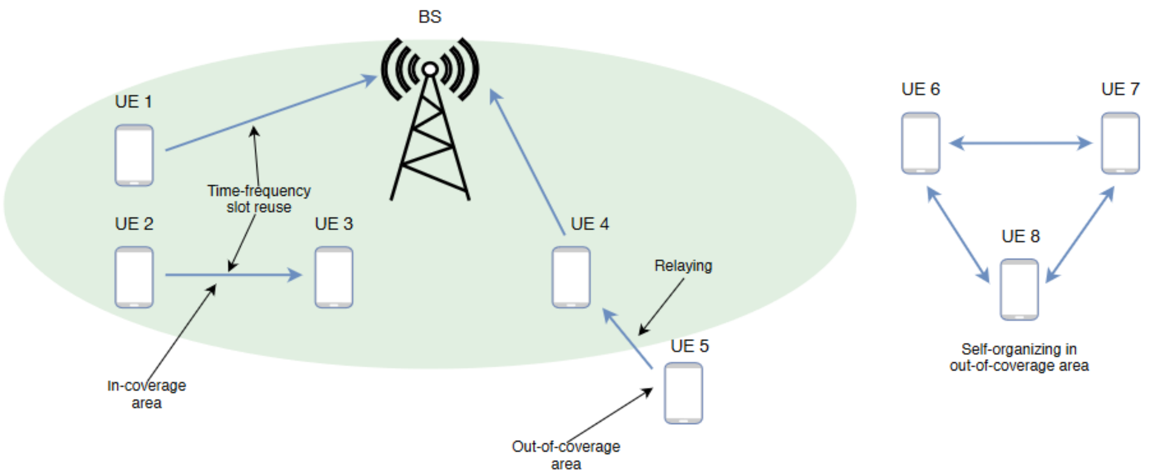


Figure 2-1:Potential benefits of D2D communications in cellular systems [12]

Potential D2D use cases include proximity-based services triggered when communication parties are in close proximity, such as local information sharing, mobile advertising, vehicle-to-vehicle (V2V) communication, mobile gaming, and social applications. Additionally, D2D networks support emergency services, leveraging proximity features to establish ad-hoc networks even in cases of network infrastructure damage during natural disasters like hurricanes and earthquakes, or in crowded events such as FIFA World Cup games.

In a D2D network, two users can establish a link if they are in proximity to each other, requiring a peer discovery process before initiating a D2D link. Generally, D2D communication involves a two-phase process: the discovery phase, where users identify potential nearby peers, and the communication phase, which includes channel estimation, mode selection, resource allocation, power control, and actual information transmission [14].

2.3.Classificaion of D2D communication:

D2D communications are classified into Inband D2Dand D2D Outband Communications. In D2D inbandcommunication, the cellular spectrum is used for D2Dand cellular links. The goal is to achieve QoS and highcontrol over the cellular spectrum because there is lessinterference so that efficiency spectrum increases and QoS is preferred. Whereas in outbandcommunication, D2D works under an unlicensed spectrum so there is no interference between D2D and cellular links. Unlicensed spectrum requires an extra interface and usually adopts other wireless technologies, such as Wi-Fi Direct, ZigBee, or Bluetooth [15].

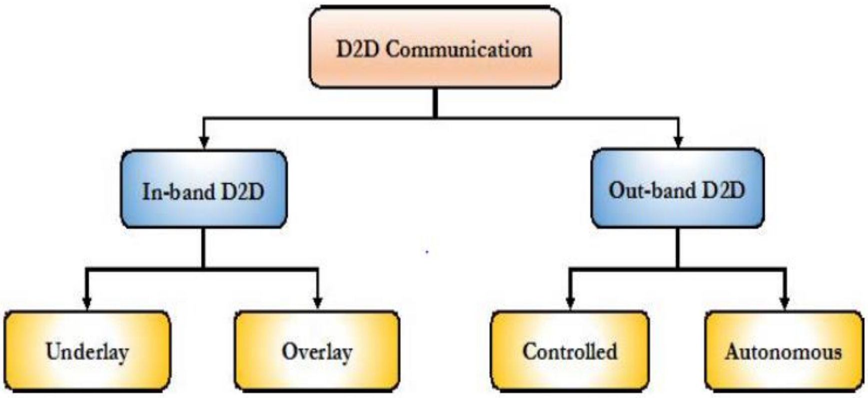


Figure 2-2:Classification of D2D communication [15]

2.3.1. In-band Communication

The motivation for selecting the in-band D2D (IBD) commu-nication was its high ability to control a licensed spectrum; however, it suffers from interference between D2D users and cellular networks. Furthermore, it is also consid-ered as one of the 5G technologies with spectrum efficiency that could be improved through reusing the frequency and time resources by the D2D users, in which resource sharing or allocation between D2D users could be performed in two ways, namely; underlay and overlay modes [15].

2.3.1.1. Underlay In-band D2D mode:

Underlay inband mode has shown promise in enhancing various performance metrics such as spectrum efficiency, energy efficiency, and cellular coverage through diverse techniques including diversity schemes, interference mitigation, resource allocation, and network coding, which leverage advanced mathematical methodologies. Many works in the field propose novel algorithms and interference management strategies aimed at bolstering overall capacity and addressing mode selection challenges in cellular networks and D2D systems. Although these approaches often entail higher computational complexity, they offer superior performance benefits. In order to elevate the system performance of D2D cellular systems while adhering to Quality of Service (QoS) and power constraints, the adoption of advanced techniques becomes imperative. These techniques encompass stochastic optimization, nonlinear programming, and integer optimization.

Numerous research papers are dedicated to mitigating interference and improving the efficacy of D2D cellular systems, underscoring the ongoing quest for optimized solutions and strategies in this dynamic domain [15].

2.3.1.2. Overlay In-band D2D:

mode In the Overlay In-band D2D mode, specific cellular resources are allocated for both cellular and D2D communications. These resources are subtracted from cellular users to minimize interference for D2D communications within cellular transmissions. A proposed method involves BS-assisted scheduling and D2D power control to mitigate D2D interference. This method suggests utilizing the BS as a secondary transmitter for D2D transmission and employing multiple D2D users as relays for multicasting. The proposed methods and algorithms demonstrate performance under low complexity, making them feasible for real-world scenarios. Additionally, a network-controlled algorithm is proposed to maximize cellular network spectrum reuse and enhance performance for D2D users [16].

2.3.2. Out-band D2D communication:

Out-band D2D (OBD) communication represents a captivating and compelling field for numerous researchers today due to its utilization of an unlicensed spectrum commonly employed in various industrial, scientific, and medical (ISM) applications. Additionally, being a 2.4 GHz technology, it poses challenges for interference between cellular and D2D communications. Nevertheless, OBD faces challenges due to the unregulated nature of the unlicensed spectrum. To utilize the unlicensed spectrum band effectively, an additional interface supporting Wi-Fi Direct, Bluetooth, or Zigbee is essential. OBD communications are categorized into two modes based on the occurrence of other interfaces, namely controlled and autonomous modes, which are briefly outlined as follows [16].

2.3.2.1. Controlled mode:

In this OBD communication mode, the cellular network or base station is regulated by radio interfaces. Previous research has explored advanced management techniques within cellular networks aimed at enhancing the reliability and efficiency of D2D communications. These techniques also aim to enhance system performance in terms of power efficiency and throughput [16].

2.3.2.2. Autonomos mode:

The passage describes a mode of D2D communication that doesn't require changes to existing cellular networks or base stations. In this mode, D2D interfaces operate autonomously, meaning they are managed and coordinated by the users themselves, without requiring intervention from the cellular network infrastructure. This autonomous operation helps in reducing the overhead on the cellular network, as the users take on the responsibility of managing their direct device-to-device connections. Furthermore, the text mentions that these autonomous D2D interfaces can utilize technologies like Bluetooth or Wi-Fi Direct for communication. These technologies enable devices to establish direct connections with each other without the need for a centralized network infrastructure, making them suitable for D2D communication scenarios [16].

the Table 2-1 highlights the key differences between in-band and out-band D2D communication, focusing on aspects like diversity, interference, resource utilization, and the necessity of additional interfaces .

In-Band D2D communication	Out-Band D2D communication
Diversity spatial diversity, resulting in enchanced spectral efficiency	Does not result in an impoved spectral efficiency
Base stations control results in better Qos management	No control neded at the base station. Thus,better Qos management is not supported

Hight interference levels between D2D communication,and among D2D users	Interface problem avoided by different bands of operation between cellular and D2D communication
No extra interface is needed(e.g. Wi-Fi) by the device	Devices require an additional interface.Thus,two interface are nedded for a successful device operation
High possibility of ressource wastage	More accessible ressource allocation without wastage
No coding decoding involed; only a single interface is used	Coding and decoding of packets are essential as different interfaces use different protocols

Table 2-2: Comparaison between in-band and out-band D2D communication[16]

2.4.D2D communication applications:

D2D communication finds utility across various short-range applications such as video streaming, vehicular communication, data and voice transmission, and, as depicted in Figure 2.3. Additionally, D2D technology can be applied in online gaming, multicasting, local advertising, cognitive communication, cooperative communication, and the Internet of Things (IoT), and lot of application D2D communication finds utility across various short-range applications such as video streaming, vehicular communication, data and voice transmission, and, as depicted in Figure 2.3. Additionally, D2D technology can be applied in online gaming, multicasting, local advertising, cognitive communication, cooperative communication, and the Internet of Things (IoT), and lot of application

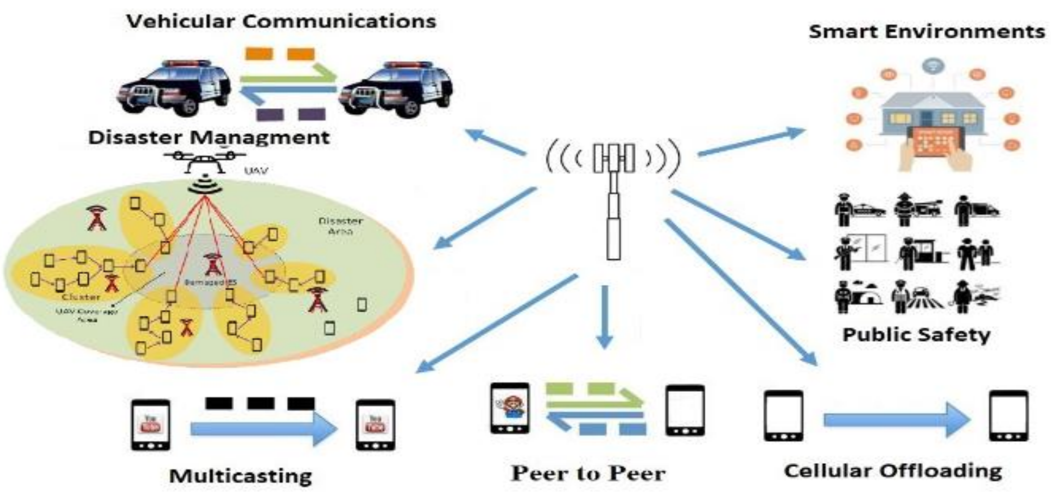


Figure 2-3:Samples of device-to-device (D2D) applications [49]

2.4.1. Data service and local voice:

The exchange of data services between two devices within D2D coverage zones can be accomplished through D2D communication. Implementing D2D technology could lead to enhanced data rates and reduced latency. Furthermore, D2D facilitates the support of voice chat services within limited coverage areas like cubicles or large halls, enabling delivery to nearby devices. Consequently, leveraging D2D technology for local voice transmission could enhance network performance in terms of data rates, Quality of Service (QoS), and latency, addressing limitations associated with real-time voice transmission [15].

2.4.2. Video streaming

According to Cisco, it is anticipated that video sharing over the Internet will account for more than 90% of internet traffic in the near future. Video streaming entails transmitting data or content

in a compressed format via the Internet in real-time, enabling viewers to access content without having to wait for the entire video file to download. Nevertheless, Point-to-Point (P2P) technology holds promise in enabling users to share videos directly through communication channels, cellular networks, and offloading, representing an alternative and enhanced method of video streaming.

In contrast, D2D technology surpasses conventional cellular networks in facilitating video streaming, video conferences, and video chats among devices within the same cellular network or adjacent networks. Recognizing the future network demands for video streaming, the quality of experience (QoE) is significantly influenced by video quality adaptation. Thus, a novel quality adaptation technique was proposed for scalable video in D2D communication networks

In addition to an extensive survey, studies have conducted discussions on video transmission and QoE, addressing challenges and suggesting potential solutions to enhance video quality and manage interferences between cellular and D2D links [15].

2.4.3. Machine to Machine

Machine-to-Machine (M2M) communication is considered one of the promising technologies for M2M telemetry, involving devices and objects equipped with communication and computing capabilities without requiring human intervention. M2M is often used to monitor certain automatic data transmissions collected from remote sensors to a central unit for analysis. This is achieved through software agents or humans. M2M technology has numerous applications, including car automation, smart homes, environmental monitoring, industrial automation, military operations, and more. Additionally, M2M machines are often positioned close to each other in many applications to deploy Device-to-Device (D2D) connections within a building. Implementing a direct D2D route in M2M technology will result in load distribution and latency reduction in deployed networks. Furthermore, cognitive M2M could be used to maximize energy efficiency using a recently developed joint optimization algorithm that integrates power control, peer discovery, channel selection, and time allocation issues [15].

2.4.4. Emergences Networks

Urbanization is rapidly increasing in both developing and developed nations. Presently, over half of the global population resides in urban areas, and this figure is anticipated to rise significantly in the coming years. Hence, it is crucial for adaptable and dependable communication networks in densely populated urban regions to safeguard cities worldwide against unforeseen terrorist attacks, such as the 9/11 tragedy in New York City and the 7/7 metro bombings in London. Additionally, during natural disasters and search and rescue missions, base stations may become overwhelmed or shut down, offering limited services to only a specific number of users or devices. Therefore, in emergencies, direct device-to-device communication can be utilized [15].

2.4.5. V2V communication

Vehicle-to-Vehicle (V2V) communication facilitates data exchange between vehicles in motion, while Device-to-Device (D2D) communication allows direct interaction between nearby users. Both approaches have distinct advantages in enhancing communication efficiency and reliability. V2V communication enables seamless data exchange among vehicles, enhancing road safety and traffic management. On the other hand, D2D communication emphasizes proximity, enabling efficient data transfer between nearby devices while reducing reliance on network infrastructure. This reduces congestion and delays, enhancing overall network performance. Moreover, D2D offloading of the Evolved Node B (eNB) helps alleviate timing issues inherent in V2V communication, ensuring smoother and more reliable data exchange between vehicles [17].

2.4.6. Smart sities:

Introducing the concept of D2D communication in small cities, where the seamless exchange of data among devices becomes paramount, the landscape of Fifth Generation (5G) wireless systems anticipates connecting a vast array of "smart" objects, ranging from expansive "Smart Cities" to compact "Smart Homes." In this evolving ecosystem, Long Term Evolution-Advanced (LTE-A) assumes a fundamental role within the Internet of Things (IoT) domain, providing a cohesive infrastructure and extensive wireless connectivity to devices However, LTE-A, initially designed to support high data rates and large data sizes, necessitates innovative solutions to efficiently utilize radio resources for transmitting the small data packets prevalent in IoT applications within "smart" environments.[18] Additionally, the substantial energy consumption inherent in cellular communications presents a significant obstacle to large-scale IoT deployments, especially in scenarios characteristic of Smart Cities. To address these challenges, Network-assisted Device-to-Device (D2D) communications emerge as a promising solution to reduce device energy consumption. Despite the potential advantages, concerns regarding wireless vulnerabilities persist, particularly in IoT device-to-device (D2D) communication. This issue sparks significant debate, especially in environments where sensitive information exchange is prevalent. Efforts to address these security challenges are imperative to ensure the integrity and confidentiality of data in IoT ecosystems [19].

2.4.7. Disaster Management Using D2D Communication

Communication during disasters presents significant challenges, affecting individuals worldwide who are impacted by unexpected events like earthquakes, tsunamis, floods, and heavy rains. Despite the diversity of disasters, their management encounters similar recurring problems, including the complexity of the field, interoperability issues, and socio-cultural factors. Effective disaster communication relies on strong voice and data connections between responders and victims. To address these challenges, the proposed solution Device-to-Device (D2D) technology. D2D facilitates high-throughput communication over short distances and supports multiple users simultaneously. Integrating D2D with LTE-Advanced (LTE-A) systems enhances spectrum efficiency, energy conservation, and security for proximity-based D2D communication, meeting the requirements of Public Safety Networks (PSNs). a D2D-enabled energy harvesting (EH) cellular network, where relays and user equipment (UE) harvest RF energy from base stations for D2D communication. Additionally, a user-cooperation-based clustering scheme is introduced to minimize UE power consumption [21].

2.5.challenges of D2D communication

D2D communication technology 5G is a new generation communication system developed after 2020 in order to meet the market communication needs. Compared with the previous comparison, it is not a single wireless communication Table 2

Communication mode	Using ressources	Spectrum utilization
Multiplexing mode	Non-orthogonal	High
Dedicated mode	Orthogonal	Low
Cellular mode	Traditional honeycomb	No

Table 2-3: D2D mode selection in cellular network

The table explains the D2D (Device-to-Device) mode selection in cellular networks and how these modes affect spectrum utilization:

A. Multiplexing Mode

In this mode, resources are utilized non-orthogonally, meaning D2D devices share the spectrum without clear separation. This lack of separation can lead to interference among devices, affecting system efficiency. Therefore, spectrum utilization is high in this mode.

B. Dedicated Mode

Here,resources are allocated orthogonally to each D2D device, ensuring clear separation between them. This individual resource allocation reduces interference and enhances system efficiency. Due to this dedicated allocation, spectrum utilization is low in this mode.

C. Cellular Mode

This mode,represents the network as a traditional cellular grid, with the geographic area divided into small cells, each served by a central base station. This cellular division reduces interference between devices and improves spectrum utilization efficiency.

In summary, The table 2-2 illustrates how different resource allocation methods impact system efficiency, with individual resource allocation enhancing efficiency while shared resource usage increases interference and decreases system efficiency**.**

Selection of D2D modes in cellular networks involves determining the communication mode, resource utilization, and multiplexing mode. D2D communication enhances traditional cellular networks by significantly improving transmission rates, resource utilization, and reducing latency, while ensuring wide area coverage and user Quality of Service (QoS). As mobile Internet traffic is expected to increase dramatically, the advancement of D2D communication within the broader context of 5G systems is critical.

D2D communication, also known as proximity services, enables direct communication between users without relying on base stations typical in traditional cellular networks. It offers various applications and expansions, addressing single-hop or multi-hop issues in cellular networks and supporting high-rate services like online gaming and video sharing. D2D communication operates either in-band, sharing frequency resources with cellular users under base station control, or out-of-band, using unlicensed spectrum like WLAN and Bluetooth

In in-band D2D, base station oversees D2D discovery, link establishment, resource allocation, and interference coordination. Out-of-band D2D allows for user or base station control, offering advantages such as interference-free operation and simplified resource allocation

The coexistence of D2D and traditional cellular networks introduces interference challenges, addressed through resource management techniques including mode selection, resource allocation, and power control and other challenges. These methods optimize D2D integration within cellular environments, ensuring efficient operation and minimal interference.[20]

2.5.1. Mode selection:

Mode selection, there are currently three traditional modes of Device-to-Device (D2D) communication: cellular mode, dedicated mode, and non-orthogonal sharing. Cellular mode implies that D2D communication operates similarly to traditional cellular mode, with communication conducted through the base station. Dedicated mode refers to an overlay mode used for D2D communication alongside cellular, though this mode may lead to resource wastage and low resource utilization. Sharing mode entails D2D using the same resources as cellular users, indicating an underlay mode where interference between the two may occur, yet resource utilization is expected to increase significantly [20].

2.5.2. Resource allocation:

In the communication system, D2D can utilize resources exclusively allocated to it or share the uplink/downlink resources of cellular users. The interference scenarios under multiplexing are depicted in Figures (2-4) and (2-5), respectively. When D2D multiplexes uplink resources, the base station experiences interference from D2D transmissions, and the base station can manage this interference by adjusting the transmission power of D2D. When D2D shares cellular resources.

The downlink resources, the cellular user's recipient, are subject to interference from D2D. The geographical location between the two determines the eNB scheduling. Due to the future asymmetry of uplink and downlink resource traffic, D2D communication will preferably use uplink resources because the utilization of the cellular uplink frequency band is lower than that of the downlink frequency band. Additionally, the transmission power used is lower than that of the eNB, so the victims of D2D interference are primarily the eNB for cellular communications. With this in mind, the eNB can easily perform interference coordination. However, multiplexing of uplink resources requires the user terminal to have a Single-Carrier Frequency Division Multiple Access (SC-FDMA) receiver, as opposed to Orthogonal Frequency Division Multiple Access (OFDMA), which increases system complexity.

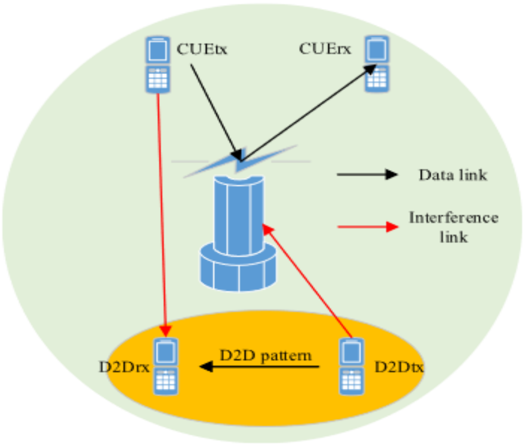


Figure 2-4: D2D interference to multiplexed CUE uplink resources [20]

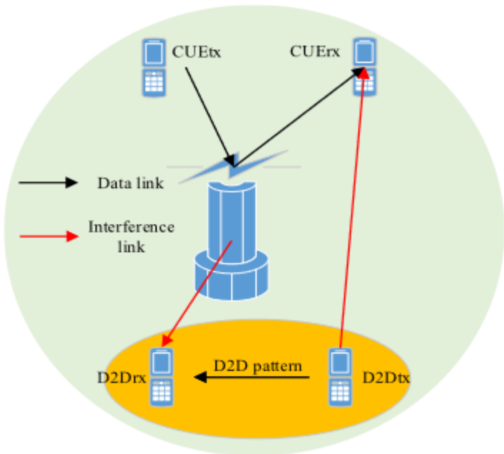


Figure 2-5: D2D interference to multiplexed CUE [20]

2.5.3. Power allocation:

Allocation of power involves determining the suitable transmit power for both D2D and CUE (Cellular User Equipment). Effective power control manages interference between the two entities in cases where the D2D pair shares cellular resources. By ensuring a consistent communication rate for both, overall system throughput is enhanced.[20]

2.5.4. privacy:

D2D communication introduces significant challenges in the realms of security and privacy. Concerns such as data theft, hacking, eavesdropping, misuse of data, and privacy violations can arise at any point during the implementation of D2D technology. What's particularly concerning is that, given D2D's signal relay mechanism between devices, user locations may become easily traceable based on signal transmission data, rendering user security vulnerable. However, on the flip side, this could be advantageous for authorities during emergencies. For instance, in cases of terrorism or natural disasters, information dissemination to cellular service users remains feasible even if there are malfunctions in the cellular infrastructure. Consequently, authorities like police and paramedics can swiftly identify locations or vulnerable areas to expedite evacuation procedures. The risk of security threats is expected to escalate with the advent of the 5G network. With the substantial increase in connected devices and the inherent direct connections between adjacent devices in D2D communication, security challenges are compounded. Their system employs a lightweight AEAD (Authenticated Encryption with Associated Data) cipher to encrypt communications using tokens as associated data, ensuring data integrity throughout the transmission process. This approach not only prioritizes energy efficiency but also guards against crimes like impersonation, eavesdropping, and location spoofing [21].

2.6.Low energy consumption:

One of the challenges of integrating D2D technology into 5G networks is the issue of energy consumption. D2D-based communication offers improved energy efficiency for devices compared to communication reliant on the base station. D2D facilitates a transmission process directly between the closest devices, minimizing energy wastage compared to conventional transmission methods. In conventional transmission, devices need to actively search for signals from specific base stations, leading to continuous operation to optimize signal reception and resulting in significant energy consumption. One effective method to enhance energy efficiency in applying D2D technology to 5G networks is to temporarily deactivate base stations with fewer users. This is due to the substantial energy consumption associated with base station operation in this technology application. By temporarily deactivating less-utilized base stations, devices initially connected to them can relay signals either from busier base stations or from other nearby devices still within signal range of other base stations [21].

2.6.1. COSTS:

Costing remains an unresolved issue when considering the widespread application of D2D technology. While conventional cellular technology allows for tracking data usage based on the amount of data transmitted to users through the base station, D2D implementation poses different challenges. Various schemes have been proposed, such as incentivizing devices that relay signals directly by paying fees to the relayed device. However, the implementation of such designs is still uncertain. Another scheme permits D2D device users to sell access relays to nearby D2D user [21].

2.6.2. Device Discovery

Further investigation into various domains of D2D communication is necessary to support its integration within cellular communication systems. When a device intends to engage in D2D communication with other nearby devices, the initial step involves discovering these nearby D2D devices, a process known as device discovery [22].

Device discovery, can be categorized into two main approaches: distributed discovery and centralized discovery. In distributed discovery, optimal resources and permissible transmission power are allocated with the base station's approval. However, this approach entails complex signaling overhead and the coordination of multiple transmitters, adding to its complexity Conversely, centralized device discovery is effectively managed by the base station, with resource allocation handled by a central system.

Additionally, proximity services such as commercial announcements, public transport information, municipal updates, local programs, and spontaneous social and corporate interactions contribute to reduced energy consumption and latency. Hence, in D2D-enabled centralized networks, facilitating the coexistence of multiple devices poses a challenge for device discovery to enable proximity services. Nonetheless, recent reviews have emphasized the critical nature of the device discovery issue within D2D communication, acknowledging it as a vital problem that requires resolution [23].

2.7.Mobility Issues of D2D communications:

D2D communication occurs when two devices directly communicate without relying heavily on the base station. Mobility management poses a significant challenge for any wireless communication system. In cellular mode, maintaining uninterrupted service when devices change locations is relatively straightforward. However, in D2D mode, effective mobility management becomes crucial as there is still no developed algorithm capable of handling it seamlessly. Establishing low-latency, reliable data communication between moving devices remains a challenging task yet to be fully developed.

There has been limited discussion on this topic in existing literature. In scenarios where multiple base stations are involved in handover processes, latency can increase due to the exchange of control signals, rendering D2D communications impractical during movement. Achieving low-latency, seamless mobility management is critical, especially considering the importance of vehicle-to-vehicle (V2V) communication. Prolonged latency could have severe consequences in this context

some mobility management solutions are proposed, demonstrating potential benefits under specific assumptions for small cell networks. The authors have categorized two intelligent solutions aimed at mitigating the negative impact of mobility management[47].

2.8.conclusion

D2D technology within 5G represents the future of communication networks. In this chapter, we begin by defining the concept of D2D (Device-to-Device) communication, which refers to the direct communication between mobile devices without routing through the base station or core network. This technology is characterized by low latency, high data rates, and improved spectrum efficiency. D2D communication can be classified into in-band and out-band categories. In-band D2D uses the licensed cellular spectrum, while out-band D2D utilizes unlicensed spectrum, both having their unique advantages and challenges.

Nevertheless, its implementation faces various challenges, including performance issues, interference, spectrum and power efficiency, as well as concerns regarding privacy and security, among others. These obstacles must be addressed to ensure the successful deployment of D2D technology in the future.

The advent of this technology holds the promise of catering to diverse human needs, particularly in the realm of information technology, such as in IoT, Big Data, and cellular networks. Additionally, it is anticipated to play a crucial role in disaster mitigation and evacuation efforts due to its capabilities

Chapter 03
Related works

Chapter03: Related work

3. Introduction:

Device-to-device (D2D) communication is generating great interest thanks to the reusability of cellular network resources. This technology has the ability to increase efficiency and productivity by improving resource allocation, which contributes to enhancing the performance of wireless networks in general. In this chapter, we first begin by defining resource allocation and then present some work related to resource allocation. And after that we discuss the formulation of resource allocation and power control problem for D2D communications in cellular networks. In last, we present our proposed solution for this problem, which is Genetic Algorithm (GA).

3.1. Resource allocation:

The diagram in Figure 3.1 illustrates the concept of D2D communication operating alongside a cellular network. In this setup, "BS" denotes a Base Station, and "UE" denotes User Equipment. Similar to conventional cellular networks, UEs can receive service from the BSs. Additionally, they have the capability to establish direct communication with each other through D2D links. A notable aspect is that both types of communication utilize the same spectrum, necessitating precise coordination [25].

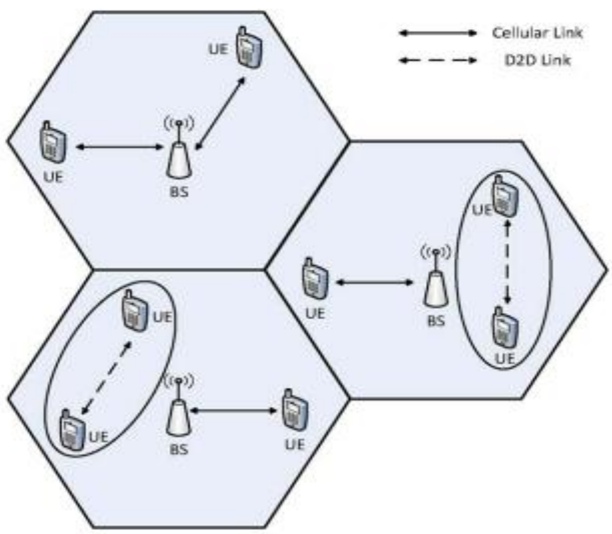


Figure 3-1:D2D communication as an underlay to a cellular network [25]

A. dedicated mode, cellular network assigns a specific portion of resources exclusively for direct communication between D2D device pairs. This allocation ensures there is no interference between the cellular and D2D communications

B. cellular mode, D2D devices function similarly to traditional cellular devices, and their communications are routed through the Base Station (BS)

C. reuse mode, D2D communications utilize either a portion or the entirety of the resources allocated to the cellular network. This mode includes both downlink reuse (DLre) and uplink reuse (ULre), wherein the shared resources are utilized for D2D communications, potentially causing interference with the downlink or uplink transmissions of cellular users [25].

3.2.Power Control in D2D Communications

Power control is very important to manage interference between users who share the same spectrum, particularly for enabling the coexistence of device-to-device (D2D) and cellular users. Initially, efforts were directed towards maximizing the capacity of D2D connections while minimizing interference to cellular users, akin to the principle in cognitive radio where secondary users must avoid harmful interference to primary users. However, recent studies suggest that overall system performance can be enhanced by giving slight priority to D2D links [25].

3.3.Resource Allocation in D2D Communications:

Resource allocation in Device-to-Device (D2D) communication plays a pivotal role in optimizing spectrum utilization and enhancing overall network performance. It involves jointly considering mode selection and power control to maximize data rates or spectrum efficiency while minimizing interference with cellular users [25].

3.4.Related work of Resource Allocation for D2D Communication:

Many strategies have been developed in the literature in the field of D2D communications, focusing on spectrum sharing and power control. These schemes aim not only to enhance network throughput but also to optimize various other metrics. Resource allocation in D2D communication is an important part, cover the allocation of spectrum and the management of power levels to facilitate efficient communication between nearby devices while minimizing interference and maximizing overall network performance, here are some works related to this regard:

Genetic algorithm (GA) is an optimization approach inspired by natural selection that improves solutions to a given problem by combining the positive properties of different solutions. GA is based on the concept of individuals, genes, cross-division, mutation, and generating new generations of solutions. The work of GA is to create a set of primitive solutions, then gradually improve these solutions by applying cohesion and change processes to them, until the optimal solution to the given problem is reached. Mathematical analysis of the GA process allows us to understand how changing the probabilities of the crossover and mutation processes leads to improved performance and better solutions. The number of developmental generations and the total number of generations that the population goes through are important keys in the genetic algorithm process. It is noted that these values change dynamically and increase as the developmental process progresses. In the first stage of the algorithm, the similarity between individuals is very low. Therefore, the value of the hybridization rate must be low to ensure that the distinct genetic traits of individuals are not destroyed [26].

in the reference [27], Devireddy Pranav and his colleagues propose research aimed at improving resource exchange in device-to-device communications, where methods such as using genetic algorithms and Ant Colony Optimization (ACO) theory are proposed to improve system performance and increase overall traffic speed. Device-to-device communication has been proposed as a model in which spectrum is reused within the cell. It also relies on technologies such as computing at the edge of the network and NOMA techniques to reduce the computational burden and improve the user experience and quality of service. The network is also used to help devices determine the appropriate timing of communications, transmission power and available resources. The communication is via a direct D2D link or via the base station. Finally, a new resource allocation method is presented using a sequential secondary pricing auction to increase the performance of device-to-device communications in cellular networks.

In [28] the authors reviewed the D2D device-to-device communication problem in cellular networks, where the mode is divided into cellular, ad hoc and reuse mode. In ad hoc mode, part of the qualitative resources are allocated to D2D communications without interference with cellular users, while in multimode there is no difference in frequency usage between D2D and cellular communications. This study presents a new idea for using D2D in mixed mode under resource utilization, and it is also discussed how to achieve Resource allocation and power control using power partitioning variables. Currently, D2D device-to-device communication in cellular networks is improved using a variety of methods. As Hungarian algorithm, Gale-shaley algorithm, particle swarm optimization algorithm (PSO) algorithm and game theory. PSO is a popular intelligent algorithm that can solve multidimensional optimization problems. With Orthogonal Side Frequency Multiple Access (OFDMA) technology. PSO is used to optimally distribute the data rate and sub loads to users, effectively increasing the overall system throughput. In addition, PSO optimization algorithms are used to solve interference problems between users in D2D communications, which increases overall system efficiency.

The authors suggested in [29] processes optimizing resource allocation and power control for D2D communication within MCC environments using deep reinforcement learning, In the proposed learning approach, D2D pairs learn strategies, such as channel selection and power control, by interacting with the environment. On the other hand, the algorithm's performance remains consistent even with an increasing number of multiplexed channels. Due to diverse MCC service requirements, D2D users can promptly select channels for service transmission without disrupting the normal communication of cellular users. Experimental findings indicate convergence of the learning process under different discount factors and user configurations.

The authors discuss in [30] the importance of efficient allocation of energy resources for Device-to-Device (D2D) communication in fifth-generation (5G) wireless personal area networks. They point out that network overload due to multiple devices can degrade performance and propose solutions such as using directional antennas and wise management of resources like bandwidth and energy to optimize performance. The proposed model, the

Efficient Energy Resource Allocation Model (EERAM), aims to reduce energy consumption and extend device lifespan by enhancing D2D communication efficiency through effective resource allocation, thereby reducing overall communication costs and environmental impact through reduced energy usage. in [31] a control method was used Power Control Based on Multi-Agent Deep Q Network for D2D Communication" it is a method used for employs reinforcement learning, particularly the Multi-Agent Deep Q Network (MADQN), its goal is improvement power control in Device-to-Device (D2D) communication links. The researchers examined the power control issue within a single-cell setup, proposing a reinforcement learning technique along with Deep Q Network to dynamically regulate power levels, ensuring Quality of Service for Cellular Users (CUs), thereby enhancing network throughput and minimizing interference.

In another study in [32] discusses efficient resource allocation in D2D networks using deep learning It highlights the importance of Ultra-Reliable Low-Latency Communication (URLLC) in 5G networks for critical applications and identifies D2D networks as a potential solution due to their proximity, this is what leads to reinforcement wireless communication performance and reliability. In the proposed framework utilizes deep neural networks for resource management, demonstrating comparable performance to baseline algorithms while being more time-efficient due to its end-to-end structure. Additionally, been suggested a novel algorithm for resource allocation in overlay D2D networks, and it was benefited deep neural networks to support URLLC services.

In the study [33] the authors proposed several researches to manage resource allocation for D2D communications under QoS constraints. A resource allocation strategy for D2D communications is presented to maximize the total data rate of the uplink link in networks within a single cell. A joint admission control and resource allocation scheme was also proposed to provide QoS support for both DUES and CUEs in the network, and the importance of managing interference between D2D communications and users in cellular networks was highlighted. There are multiple solutions to reduce interference from D2D communications by selecting the mode (cellular mode or D2D mode). Enables D2D links to use uplink resources. Uplink also enhances resource utilization.
When DUES participates in the downlink, base stations become strong interference for DUES receivers, and DUES transmitters can lead to increased interference to cellular CUES on the same channel. This study also proposed different classical optimization techniques to address the resource allocation problem. A resource allocation strategy for D2D communication is proposed to optimize the data rate of the entire network in a single cell. Two resource allocation systems based on PSO (partial swarm optimization) and hybrid PSO-GA (genetic algorithm) are proposed. While a joint admission control and resource allocation scheme is proposed to provide QoS support for both DUES and CUEs in the network.

In [34], many algorithms were studied to allocate resources in device-to-device (D2D) communications, to achieve better performance and improve the quality of service. These algorithms include the use of advanced algorithms such as genetics and adaptive bat improvement to achieve effective solutions, and genetics outperformed partial swarm calculation in some cases. Some studies suggest the use of hybrid techniques such as simulated cooling optimization with PSO to avoid local optimum points. Other research highlights specific applications of these algorithms, such as high-speed data transfer between devices or resource allocation for D2D communications in health or healthcare. This research aims to improve the efficiency of resource use and improve the overall performance of communications networks

In [35] the works presented in this study in the field of multi-channel wireless communications, the authors improved the distribution of resources such as bandwidth and regulation between D2D communication links and control between electronic devices capable of efficient use of resources. Research on achieving this goal is varied, such as determining detailed ranges of resources by distance or, using group consensus algorithms, optimal matching between links. A joint development of deep band assignment and power assignment using the interferometric wind plotting method is carried out. However, some research suggests sharing critical resources with D2D links that do not comply with the TE-A standard. There are also suggestions to distribute resources according to specific specifications, such as keeping the strength of D2D links constant or ignoring interference from dynamic links to D2D links. In many of these works, multiple channels are assumed to be assigned to D2D links. Game theory has been used to allocate resources for D2D connections. In some works, this includes using an auction to allocate resources, and the Brass Stackle game to connect resources between points of sale and D2D links. Non-cooperative game formulation has also been relied upon to design Resources for D2D Novel, Francisco's interactive cross-media resource allocation game.

In this study [36] Zhou et al proposed solution focused addressing the content distribution problem in multi-hop Device-to-Device (D2D) communication networks with decentralized content providers. It involves a cross-layer optimization approach that jointly optimizes the frequency, space, and time dimensions to minimize network average delay. The solution formulates the problem as a coalitional game based on the payoffs of content requesters and employs a time-varying coalition formation algorithm to efficiently spread popular content within the network. Simulation results demonstrate the effectiveness of the proposed approach in achieving fast content distribution across the network while significantly reducing average delay compared to other heuristic methods. According to a study [37], power allocation is a critical factor in Device-to-Device (D2D) communication systems that utilize Simultaneous Wireless Information and Power Transfer (SWIPT). Efficient power allocation optimizes spectrum resource utilization and enhances overall system performance .in this study it was done examined the issue of power allocation for D2D communications alongside simultaneous wireless information and power transfer (SWIPT). In formulating the problem was used a novel game theoretic model inspired by Stackelberg games. To enhance network energy efficiency, each D2D pair adjusts its transmission power to reach a Nash equilibrium according to the game model and pays a specified fee to the BS utilizing pricing strategies.

In [38] Zhang et al studied a new method for managing tasks and resources in mobile edge computing (MEC) networks. This method, based on Proximal Policy Optimization (PPO), tackles the challenge of offloading computations from user devices to MEC servers with the help of D2D communication. The researchers built a model that reflects real-world MEC network conditions and leverages a technique called Markov decision process (MDP) to minimize wasted time and energy consumption. By enabling collaboration between devices through D2D communication, this approach improves how resources are used and boosts overall computing efficiency. The MDP model is solved using a deep reinforcement learning algorithm called PPO, which helps determine the best strategy for offloading tasks and allocating resources. This approach outperforms existing methods in terms of reducing latency (delays), minimizing energy use, and achieving faster convergence (reaching optimal performance).

The authors in [39] investigated resource allocation for D2D communication between vehicles. They focused on a scenario where three user types, each requiring different levels of service (QoS), contend for the same uplink resources. Their proposed approach optimizes resource allocation to maximize the capacity of vehicle-to-infrastructure (V2I) links while considering limitations. This method calculates the ideal power levels for both V2V and V2I communication and utilizes advanced techniques based on hypergraphs to efficiently match users and allocate resources. Additionally, the study explores how factors like a user's signal-to-interference-plus-noise ratio (SINR) can affect V2I link capacity. They further examine potential challenges introduced by situations where vehicles are outside the network coverage area and by the use of relays in D2D-based V2V communication.

In a previous study [40] the goal was to effectively enhance the overall system data rate by managing uplink and downlink resource allocation, while ensuring quality of service for all users and live devices. The study used the allocation of uplink and downlink subcarrier resources to devices to achieve this, and in addition, it proposed strategies that combine access control and resource allocation to provide continuous support for quality of service in device-to-device D2D communications and cellular networks. It achieved a noticeable improvement in the satisfaction of cellular and D2D links, in addition to a significant reduction in energy consumption. For the study, which used game theory, it focused on allocating resources between the mm wave and cell bands for several D2D pairs. This study used an alliance formation game to achieve the superiority of this approach over other scientific methods in rate. Total system.
The problem of optimizing resource allocation in D2D device-to-device communications over a variety of mm wave frequency bands in heterogeneous cellular networks is addressed. A deductive method is proposed to increase the system throughput. An algorithm has also been developed that jointly allocates sub bands and power for D2D communications using NOMA technology. The goal of the algorithm was to achieve maximum energy efficiency and transmission rate of mobile communications systems. The KM technique was used for channel allocation and the KKT criteria was implemented to formulate the optimal power allocation problem. Resource allocation planning for D2D communications in a MIMO-NOMA cellular network was introduced to improve spectrum efficiency. An optimization problem was formulated to achieve this goal and the simulation showed consistency. This technique improves on traditional D2D communication methods in MIMO-NOMA cellular networks that rely on mm wave. Efficient D2MD groups were developed for content sharing in 5G networks using a group content sharing context, which took into account the social characteristics of mobile phone users. Adjusting the power and channel distribution between D2MD groups using this method, which led to a significant increase in the transfer rate in cellular networks. A model concerned with quality of service for allocating dynamic resources in industrial Internet of Things applications was presented, where the focus was on middleware such as fog computing. Which showed the impact of this model significantly, especially in the context of the tactile Internet. An efficient method of task offloading and channel resource allocation using differential evolution algorithm is proposed. This approach reduced energy consumption and showed good improvement in convergence, and focused on offloading tasks and allocating resources to multi-device broadband networks.

In this study [41] the researchers investigated wireless sub-communication between D2D devices by enabling improved energy and spectrum efficiency of the network by reusing cellular resources. However, this connection causes increased cross-interference in cellular networks, requiring effective interference management to maintain quality of service. Janis and his colleagues proposed a system that uses cellular power control mechanisms to ensure that the quality of service to users is not compromised. Studies have also been conducted on achieving D2D communications in LTE-A networks, including power control and resource allocation. In the current context, we must consider the balance between achieving the maximum transfer rate for the entire network and achieving fairness in resource allocation. Applying the Max min and Round Robin algorithms can improve the fairness of the system, but it may also lead to a decrease in the data transfer rate. On the other hand, the proportional fairness algorithm seems to be the most appropriate choice as it can effectively deal with the discrepancy between transfer rate and fairness. Hence, using this algorithm can help improve overall system performance.

In the following table 3.1 we summarize the workers [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], As follows:

· Method Used: This describes the specific approach employed by the worker.

· Resource Allocation & Power Control: This indicates whether the worker's method addresses resource allocation and power control challenges (marked as "yes" or "no").

· D2D Count: This shows the number of device-to-device (D2D) communications involved in the worker's scenario.
· Objectives Improved**:** This specifies the goals or performance aspects that the worker's method aims to improve

Reference	Method	Resource allocation solved	Power control solved	D2D nbr	Objectif
26	Genetic Algorithm (GA)	Yes	No	many	Throughput
27	Power portioning,hungarian algorithm,pso	Yes	Yes	many	Throughput
28	Deep Reinforcement Learning	Yes	Yes	many	QoS
29	Efficient energy resource allocation model EERAM	No	Yes	many	Energy efficient
30	Multi-agent deep Q network(MADQN)	No	Yes	many	Throughput, Qos
31	Deep Learning	Yes	No	One	URLLC
32	Classical optimization(PSO,PSO-GA)	Yes	Yes	Many	Throughput
33	Genetique algorithme hybrid techniques(PSO-simulated cooling)	Yes	Yes	Many	Throughput ,Qos
34	Game theory(auction, braaess stackelberg),group consensus algorithms	Yes	Yes	Many	Channel allocation fairness
35	Cross-layer optimization	Yes	No	Many	Content distribution
36	Stackelberg game-inspired model	No	Yes	many	Energy efficient
37	Proximal policy optimization (ppo)	Yes	Yes	One	MEC

38	Hypergraph-based technique	Yes	Yes	One	Interface management
39	Game theory	Yes	Yes	Many	QOS
40	Cellular power control ,propotional fairness	Yes	Yes	One	Throughput, fairness

Table 3-1: A summary of resource allocation solved and power control solved for D2D communication

3.5.System formulation:

This study analyzes a system consisting of a base station and a certain number of communication (including 'nbC' cellular User Equipment (UE) and 'nbD' D2D pairs). The system assumes that D2D communications use overhead resources, however they are subject to interference from users' cellular devices. In this type of system, the D2D pairs have the ability to communicate directly, while the base station manages the channel allocation and facilitates the establishment of communications between the devices. Communications, whether cellular or D2D, are represented as follows

$$\boldsymbol{T} = [\boldsymbol{T_1}, \boldsymbol{T_2}, \dots, \boldsymbol{T_{nbC}}, \boldsymbol{T_{nbC+1}}, \dots, \boldsymbol{T_{nbr}}]$$

In this context, Ti defines i-th communication between a group of cellular user devices or D2D users. The spectrum is divided into M of RB_s, and the set of these band channels is represented as follows

$$\boldsymbol{BR} = [\boldsymbol{br_1}, \boldsymbol{br_2}, \dots, \boldsymbol{br_M}]$$

We set the assignment matrix $A \in \{0,1\}\ nbr\ , M,$ where each element $A_{i,r}$ represents the value of 1, which means that the band channel r-th is used by connection i-th while when $A_{i,r} = 0$, it means that the band channel r-th does not belong to connection i. According to Shannon's equation [43], we may express the transmission rate on the band channel r-the while it is used by the i-th communication as follows:

$$\boldsymbol{Thput}(\boldsymbol{i}\text{-}\mathbf{th}) = \boldsymbol{B}\log_2(\mathbf{1} + \boldsymbol{SINR_{ir}})$$

The available bandwidth is known as B, and the signal-to-noise ratio is determined by $SINR_{ir}$. $the\ SINR_{ir}$ is expressed as follows:

$$\boldsymbol{SINR_{ir}} = \frac{\boldsymbol{G_{ii}\, P_i\, A_{ir}}}{\boldsymbol{WGN} + \sum_{j \in E, j \neq i} \boldsymbol{G_{ji}\ \ P_j\, A_{jr}}}$$

When A_{ir} equals 1, this means that the communication device uses a specific band channel (r-th), and when the value of is 0, it means that the communication device does not use that channel. The transmission power used by communication r-the is p_i, and in addition to that, we use the white noise symbol with the sinusoidal standard, wGN. As used in [44]. We prefer to use an Urban Microwave System (UMi). The UMi system is characterized by the presence of a single small cell with high traffic loads and large user density in dense urban distances [45], and uses the Rayleigh vanishing path loss model [46]. The path loss model is expressed by

$$\boldsymbol{PL = 36.7\log_{10}(d) + 22.7 + 26\log_{10}(F)}$$

We assume that i-th and j-th are the sender and receiver respectively. The distance between communication i-th and j-th is represented by d (in meters), and the communication frequency is represented by F (in GHz). Therefore, between users, the channel coefficient is expressed as $G_{i,j}$ and is expressed as follows

$$\boldsymbol{G_{i,j} = 10^{-PL/10}}$$

Therefore, the expression for the transfer rate of cellular devices is the sum of the transfer rates of all cellular devices.

$$\boldsymbol{CThput = \sum_{i=0}^{nbC}\sum_{r=1}^{M} B\log_{10}(1 + SINR_{ir})}$$

The transfer rate for each D2D user expresses the sum of the transfer rates for all D2D communication pairs and can be written as follows

$$\boldsymbol{DThput = \sum_{i=nbrC+1}^{nbr}\sum_{r=1}^{M} B\log_{2}(1 + SINR_{ir})}$$

The sum of equations (7) and (8) is the total transfer rate and can therefore be expressed by the following equation

$$\boldsymbol{Thput = CTput + DThput}$$

By replacing each entity with its equivalent entity and simplifying the expression, we obtain the following equation

$$\boldsymbol{Thput = \sum_{i=1}^{nbr}\sum_{r=1}^{M} B\log_{2}(1 + SINR_{ir})}$$

By distributing resources effectively and controlling the transmission power of devices, it aims to achieve the maximum transmission rate for the network in general. The problem of achieving maximum rate for power distribution and channel allocation jointly is mathematically expressed as follows:

$$Max\ Thup = Max\ \sum_{i=1}^{nbr}\sum_{r=1}^{M} B\log_{2}(1 + SINR_{ir})$$

Subject to:

$$\boldsymbol{P_i \leq P_{dma}\ \forall\ i = nbC + 1 \ldots nbr} \qquad \textbf{(1)}$$

$$\boldsymbol{P_i \leq P_{cma}\ \forall\ i = 1 \ldots nbr} \qquad \textbf{(2)}$$

$$SINR_{i,r} \geq SINR_{min} \; \forall \; i = 1 \dots nbC, \forall r = 1 \dots K \qquad (3)$$

$$A_{i,r} \leq 1 \; \forall \; i = 1 \dots nbc, \forall \; r = 1 \dots K \qquad (4)$$

Constraints (1) and (2) ensure that the transmission powers pi of both CUS and D2D device-to-device communication pairs do not exceed the permissible limits, P_{cmax} and P_{dmax}, respectively. Constraint (4) states that the value of $A_{i,r}$ must be either 0 or 1. This means that each BR can be assigned to only one CU at a time. As for constraint (3), it is required that there be a minimum signal-to-interference ratio limit ($SINR_{min}$) for cellular control units, while allowing device-to-device communications to share the same BR, provided that the restriction imposed on the signal-to-interference ratio (SINR) is met.

All symbols used to formulate the system are presented in the following table 3.2:

Symbols	Explanation
nbc/nbd	CU and D2D pairs number respectively
RB	Resource blocks set
M	Resource blocks number
WGN	white Gaussian Noise
F	Carrier frequency
B	Bandwidth
PL	path loss
G_{ij}	Gain between UE_i and UE_j
A	Matrix of allocation
$\mathbf{p_{dma}}$	D2Dpairs maximum power
$\mathbf{p_{cma}}$	CUs maximum power
T	The set of users

Table 3-2: symbols used to formulation system of resource allocation for D2D communication

3.6. Genetic algorithm:

We used genetic algorithm to solve the resource allocation problem in machine-to-machine communications for several reasons. Among them, it helps in finding solutions that suit changing conditions and improves system performance. It also enables it to deal with complex resource allocation issues that require complex interactions between variables. Finally, the genetic algorithm enables us to find excellent solutions at the right time. This is important in a communications environment that requires rapid response

Genetic algorithm is a method of improving performance that follows Darwin's theory of the survival of the strongest through a group of competing individuals that evolve from one generation to another. To simulate the evolutionary process of a genetic algorithm, two basic processes are used:

3.6.1. Crossover operation

This process is essential for imitating reproductive behavior and ensuring diversity of solutions. Crossing over involves combining genetic information from two individuals. Each one represents part of the solution to produce new offspring bearing new genetic characteristics. The intersection threshold is known as Th _C. In our study, we present an algorithm that uses the one-point intersection technique. The breakpoints for the chromosomes of the two parental individuals are determined randomly by selecting one connection from the total number of connections (ranging between 1 and nbr).

$$\boldsymbol{Individual_1} = \{\mathrm{UE}_1, \mathrm{UE}_2, \mathrm{UE}_3, \mathrm{UE}_4, \mathrm{UE}_5, \dots, \mathrm{UE}_{\mathrm{nbr}}\}$$

$$\boldsymbol{Individual_2} = \{\mathbf{UE_1}, \mathbf{UE_2}, \mathbf{UE_3}, \mathbf{UE_4}, \mathbf{UE_5}, \dots, \mathbf{UE_{nbr}}\}$$

In this scenario, we randomly select the third connection for the crossover process and accordingly, the offspring will consist of two parts, which can contain one parts from each parent. This is clearly demonstrated as follows

$$offerspring_j = \{\mathrm{UE}_1, \mathrm{UE}_2, \mathrm{UE}_3, \mathbf{UE_4}, \mathbf{UE_5}, \dots, \mathbf{UE_{nbr}}\}$$

$$offerspring_j = \{\mathbf{UE_1}, \mathbf{UE_2}, \mathbf{UE_3}, \mathrm{UE}_4, \mathrm{UE}_5, \dots, \mathrm{UE}_{\mathrm{nbr}}\}$$

3.6.2. Mutation operation

Genetic mutations occur occasionally in the genes of offspring, and the probability of this mutation occurring depends on the mutation threshold (th_M). For example, the mutation process could be to select two random connections within an offspring's chromosome and exchange their resource block (BR) allocations. This process is explained more clearly below. The connections selected must be of the same type. If a device-to-device pair is selected, the partner with whom the resource block is to be exchanged must also be a device-to-device user, and likewise for cell users.[42]

$$Brood = \{\mathrm{UE}_1, \boldsymbol{UE_2}, \mathrm{UE}_3, \mathrm{UE}_4, \boldsymbol{UE_5}, \mathrm{UE}_6 \ \dots, \mathrm{UE}_{\mathrm{nbr}}\}$$

3.7.Conclusion

In this chapter, we discussed resource allocation and its connection to D2D communication within cellular networks. Initially, we provided definitions for resource allocation and power control. Subsequently, we outlined the problem of resource allocation and power control specifically within the context of D2D communications. Moreover, we examined recent publications addressing this area of research. To summarize, the chapter delved into the intricacies of managing resources and power for D2D communication within the framework of 5G cellular networks, while also highlighting the latest advancements in related stud

Chapter 04

Genetic algorithm for resource allocation in D2D communication

Chapter 04: Genetic Algorithm for Resource allocationinD2D communication

4. Introduction:

In this chapter, we present the work that has been done to solve the resource allocation problem in device-to-device communications within the 5G network. Our proposal is based on using random to generate the initial population of solutions which will be improved using a genetic algorithm. Which can be very effective in improving performance and achieving a better balance between different resources. We also review how increasing D2D pairs affects cellular transmission and overall throughput, which enhances network efficiency by reducing the load on base stations and transferring data directly between devices. It also leads to significant improvements in transmission efficiency and overall throughput, which contributes to a better experience for end users and higher effectiveness in Use of network resources. In addition to the effect of the minimum rate requirement for cellular users, communication networks face problems of signal interference and low performance in areas with a high density of users, which negatively affects the overall productivity and increases the minimum cellular transmission.

4.1.Work environment:

4.1.1. Hardware environment:

We present detailed results and evaluation steps to choose the effectiveness of our model. The results of our experiments were based on a set of cellular and D2D devices. All experiments were conducted on an HP computer equipped with a processor Intel ® Celeron ® CPU N3060 @ 1.60GHZ 1.60 GHZ and 8GO OF RAM and dell computer equipped with a processor Intel® Celeron ® CPU N3350 @ 1.10GHZ 1.10 GHZ and 4GO.

4.1.2. Software environment:

There are many programming languages and packages that can be used, but in this field we chose the Dev C++ programming language and analyzed the results in the Matlab programming language.

Dev C++:

Dev C++ is a versatile programming language developed as an extension of C in 1985. It adds features for object-oriented programming, advanced memory management tools, and a rich standard library. DEV C++ retains low-level capabilities for fast hardware and memory access, making it ideal for developing operating systems, IoT software, and video games. It shares most of its syntax with C, requiring source code to be compiled into machine language before execution and using control structures like loops, if-else statements, and switch statements as shown in the figure [51].

Figure 4-1:logo of dev C++ [52]

Matlab:

MATLAB, short for Matrix Laboratory, is a proprietary software application and programming language developed by MathWorks. Designed by Cleve Moller, MATLAB is used for a variety of complex data analysis tasks, such as implementing algorithms, interacting with other applications, and manipulating data matrices. It serves as a multipurpose programming language for numerical computation as shown in the figuree [53].

Figure 4-2: logo of Matlab [54]

4.2.Motivation

The resource allocation problem is a nonlinear problem and is bound by several nonlinear constraints, which makes it difficult to solve using traditional methods. Many solutions have been proposed for this problem, including algorithms inspired by nature, such as pso algorithm, which have shown an adequate effectiveness. We resort to nature-inspired methods because of their effective properties of self-organization, sustainability, scalability and adaptability. This algorithm helps researchers provide indications of systems and solution methods that are compatible with limited resources and increasing demand.
Therefore, we proposed a genetic algorithm to solve the problem of resource allocation for device-to-device communications within fifth generation cellular networks

4.3.Genetic Algorithm:

The Genetic Algorithm uses three optimization operators to solve the problem of resources allocation for device-to-device communication in 5G, as we mentioned previously. We first present the objective function which we use to evaluate the fitness of solutions, then we present the optimization operators of the GA algorithm.

4.3.1. Throughput (fitness):

The evaluation function, as evaluates the proximity of the selected solution to the ideal solution to solve the chosen problem. This function determines the suitability of the solution provided. For the resource allocation problem that aims to improve network bandwidth. The fitness function was introduced in the previous chapter. It is expressed as follows.

$$\boldsymbol{Thput} = \sum_{i=1}^{nbr} \sum_{r=1}^{M} \boldsymbol{B} \log_2(\mathbf{1} + \boldsymbol{SINR_{ir}})$$

Subject to:

$$\boldsymbol{P_i} \leq \boldsymbol{P_{dma}} \; \forall \, \boldsymbol{i} = \boldsymbol{nbC} + \mathbf{1} \ldots \boldsymbol{nbr}$$

$$\boldsymbol{P_i} \leq \boldsymbol{P_{cma}} \; \forall \, \boldsymbol{i} = \mathbf{1} \ldots \boldsymbol{nbr}$$

$$\boldsymbol{SINR_{i,r}} \geq \boldsymbol{SINR_{min}} \; \forall \, \boldsymbol{i} = \mathbf{1} \ldots \boldsymbol{nbC}, \forall \boldsymbol{r} = \mathbf{1} \ldots \boldsymbol{K}$$

$$\boldsymbol{A_{i,r}} \leq \mathbf{1} \; \forall \, \boldsymbol{i} = \mathbf{1} \ldots \boldsymbol{nbc}, \forall \, \boldsymbol{r} = \mathbf{1} \ldots \boldsymbol{K}$$

4.3.2. Crossover operation:

This process is essential for imitating reproductive behavior and ensuring diversity of solutions. Crossing over involves combining genetic information from two individuals. Each one represents part of the solution to produce new offspring bearing new genetic characteristics. In our study, we present an algorithm that uses the one-point crossover technique. The crossover point for the chromosomes of the two parental individuals is determined randomly by selecting one position from the total number of positions community-Size ues. This is implemented in the code within the crossover function, where a random crossover point is selected, and the genetic information is exchanged between the parents to create two new offspring. Specifically, if the type of device is non-vital (type 2), the genes are swapped based on the crossover point, ensuring the creation of various solutions. as shown in the figure 4.1:

```
void crossover(UE parent1[], UE parent2[], UE child1[], UE child2[]) {
    int crossoverPoint = rand() % 20 + 10;

    for (int i = 0; i < communitySize; ++i) {
        if (parent1[i].type == 1) {
            child1[i] = parent1[i];
            child2[i] = parent2[i];
        } else if (i < crossoverPoint) {
            child1[i] = parent1[i];
            child2[i] = parent2[i];
        } else {
            child1[i] = parent2[i];
            child2[i] = parent1[i];
        }
    }
}
```

Figure 4-3: crossover process

This function ensures that new offspring are generated by combining parts of the parents' genetic information, enhancing the diversity of solutions in the algorithm.

4.3.3. Mutation operation:

Pendant le processus de reproduction, une légère modification des gènes de certains descendants se produit dans plus de 70% des cas, ce qui est connu sous le nom de mutation. Dans la solution proposée, la mutation est appliquée en fonction d'une probabilité appelée seuil de mutation. Dans ce processus, nous sélectionnons aléatoirement un gène parmi les enfants, puis nous sélectionnons aléatoirement une autre solution, après quoi nous échangeons le gène sélectionné entre ces deux entités. Le gène sélectionné doit être du même type de connexion (D2D ou cellulaire), c'est-à-dire que si le gène sélectionné représente une connexion D2D, l'autre gène doit également être une connexion D2D, et si le gène spécifié représente une connexion cellulaire, alors l'autre gène doit également être une connexion cellulaire. Ce processus contribue à la diversité des descendants et améliore les chances de découvrir de nouvelles solutions à la question de l'allocation des ressources, comme illustré à la figure 4.2:

```
void mutation(UE child[], int minRB, int maxRB, double mutationRate) {
    for (int i = 0; i < communitySize; ++i) {
        if (child[i].type == 2) {
            int mutationChance = rand() % 100;
            if (mutationChance > (mutationRate * 100)) {
                child[i].nRB = rand() % (maxRB - minRB + 1) + minRB;
            }
        }
    }
}
```

Figure 4-4: mutation process

slight modification occurs in the genes of some young children by more than 70%:

```
for (int i = 0; i < 5; ++i) {
    UE child1[communitySize], child2[communitySize];
    crossover(eliteIndividuals[i], individuals[i + 1], child1, child2);

    mutation(child1, 1, K, 0.7);
    mutation(child2, 1, K, 0.7);
```

Figure 4-5: application of 70% mutation

The process of crossover and mutation is repeated several times during 100 cycles, then the best solution in terms of productivity is taken in each cycle before and after applying GA.

4.3.4. Effect of increasing Number of D2D:

This time we study the impact of increasing the number of d devices on a cellular network with device-to-device (D2D) communication. At different times the total throughput (data transfer rate) is calculated for different numbers of D2D devices. This helps in understanding how the number of D2D devices affects the total throughput and resource efficiency in a cellular network with D2D communication.

This segment of code the main program loop iterates over different numbers of D2D devices (from 10 to 100 in increments of 5) creates an array of UE objects to represent all UEs (cellular and D2D) and then calculates the total throughput, cellular throughput and D2D throughput for all UEs. After the loop, Prints the total throughput of cellular, D2D and all devices.

```
for (int numD2D = 10; numD2D <= 100; numD2D += 5) {
    int totalUEs = cellulardevices + numD2D;
    cout << "Number of D2D devices: " << numD2D << endl;
    cout << "Total number of UEs: " << totalUEs << endl;

    for (int individualIndex = 0; individualIndex < 1; ++individualIndex) {
        UE ues[totalUEs];

        for (int i = 0; i < totalUEs; ++i) {
            ues[i].id = i + 1;
            ues[i].type = (i < numD2D) ? 2 : 1;
            Sleep(1000);
            srand(time(0));
            ues[i].nRB = rand() % K + 1;


            if (ues[i].type == 1) {
                for (int j = 0; j < i; j++) {
                    if (ues[i].nRB == ues[j].nRB && ues[j].type == 1) {
                        srand(time(0));
                        ues[i].nRB = rand() % K + 1;
                        j = -1;
                    }
                }
```

Figure 4-6:the effect of increasing D2D on cellular productivity and total throughput

4.3.5. Minimum throughput of cellular:

In this part, we study the effect of increasing the minimum cellular productivity and then we apply the genetic algorithm and notice changes in productivity every time:

```
double fitnessFunction(const vector<UE>& ues, double minThroughputCellular) {
    double totalThroughput = 0;

    for (int i = 0; i < communitySize; ++i) {
        double sinr = 0;
        for (int j = 0; j < K; ++j) {
            if (ues[i].nRB == j) {
                sinr += calculateSINR(ues[i].power, dBToWatts((rand() % 23) + 1), 1, 1, 1, const_cast<UE*>(ues.data()), i);
            }
        }

        double throughput = calculateThroughput(sinr) / 1000;

        if (ues[i].type == 1) {
            throughput = max(throughput, minThroughputCellular + rand() % 512);
        }

        totalThroughput += throughput;
    }

    return totalThroughput;
```

Figure 4-7:application of minimum cellular throughput

In figure 4-5 explaine how to set the minimum cellular throughput and calculate the throughput each time.

As explained in figure 4-6 how is the procees crossover and mutation donne.

```
vector<UE> crossover(const vector<UE>& parent1, const vector<UE>& parent2) {
    vector<UE> offspring = parent1;

    int crossoverPoint = rand() % communitySize;
    for (int i = crossoverPoint; i < communitySize; ++i) {
        offspring[i] = parent2[i];
    }

    return offspring;
}

void mutate(vector<UE>& individual) {
    int mutationPoint = rand() % communitySize;
    individual[mutationPoint].nRB = rand() % K + 1;
    individual[mutationPoint].power = dBToWatts((rand() % 23) + 1);
}
```

Figure 4-8:GA process crossover and mutation

After the process (croissover and mutation), the results are printed for each cellular minimum before and after the genetic algorithme.

4.4.Simulation and results:

We evaluate the performance of the genetic algorithm through a series of simulation experiments. the experiments are shown in the following table.

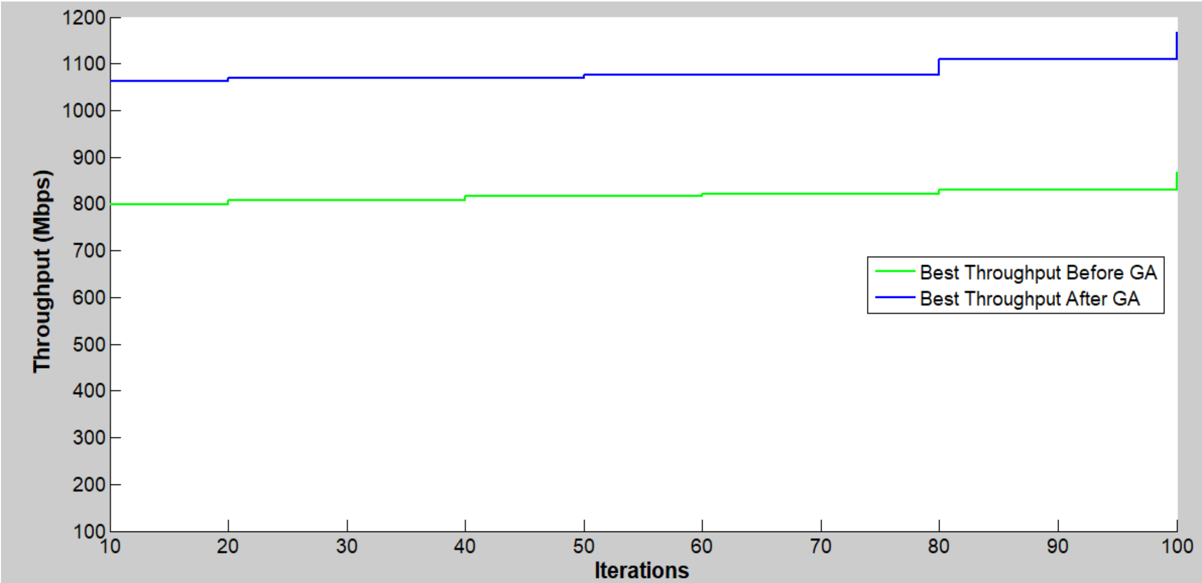
Parameters	Values
Channel bandwidth	1000000 Bandwidth in HZ
Total number of ues	30
Number of cellular users	10
Maximum transmission power	23dBm
White Gaussian noise	pow(10, ((-174 - 30) / 10)) in watts

Table 4-1:simulation parameters

We study the impact of the number of D2D users on network performance by increasing the number of D2D users and monitoring the bandwidth in the network. We also studied two scenarios. In the first scenario, we did not specify the rate requirements required for D2D users. As for the second scenario, we imposed a required rate requirement for all users (cellular or D2D). This is done with a discussion of the three simulated results.

4.4.1. Convergence of the Genetic Algorithm:

The algorithm used in this study is iterative in nature, which makes it important to achieve rapid convergence. Therefore, we evaluate the convergence of this algorithm by placing a number of n cellular users equal to 10 next to pairs of d2d users 20. Figure 4.3 shows that the total network throughput is lower before putting in GA, and after putting in GA the values are increasing, which indicates that GA contributes to improving network throughput. And you do this in a reasonable time. While it tends to converge towards ideal local solutions.



Fgure 4-9:convergence performance GA

4.4.2. Number of D2D pairs :

This graphic displays the effect of the number of D2D devices on transfer rates in the system, displaying the results before and after applying the improvements. The horizontal axis represents the number of d2d devices. While the vertical axis represents transfer rates in Mbps. We notice that the cellular-throughput-before starts at 255.799 Mbps and begins to decrease sharply until it reaches nearly zero when the number of devices is greater than 60 devices and remains low after that. As for the total throughput_d2d_before, it starts at 137.85Mbps and decreases significantly until it reaches about 500Mbps when the number of devices is greater than 20 devices. Total-throughput-after shows a consistent increase from 393,649 with a small number of d2d devices to around 1300 Mbps as the number of d2d devices increases. Cellular-throughput-after. It starts from 255,799 and increases, then remains constant as the number of devices increases. d2d-througput-after shows an increase from about 100Mbps with a few devices to about 900Mbps with the increase in d2d devices. Before the improvement, the cellular transfer rate was stable with the increase in the number of D2D devices, as shown in the figure. Which led to an increase in the overall transfer rate. It can also be concluded that the improvements that were applied led to improving the system’s performance in general, while achieving a better balance between the cellular transfer rate and D2D.

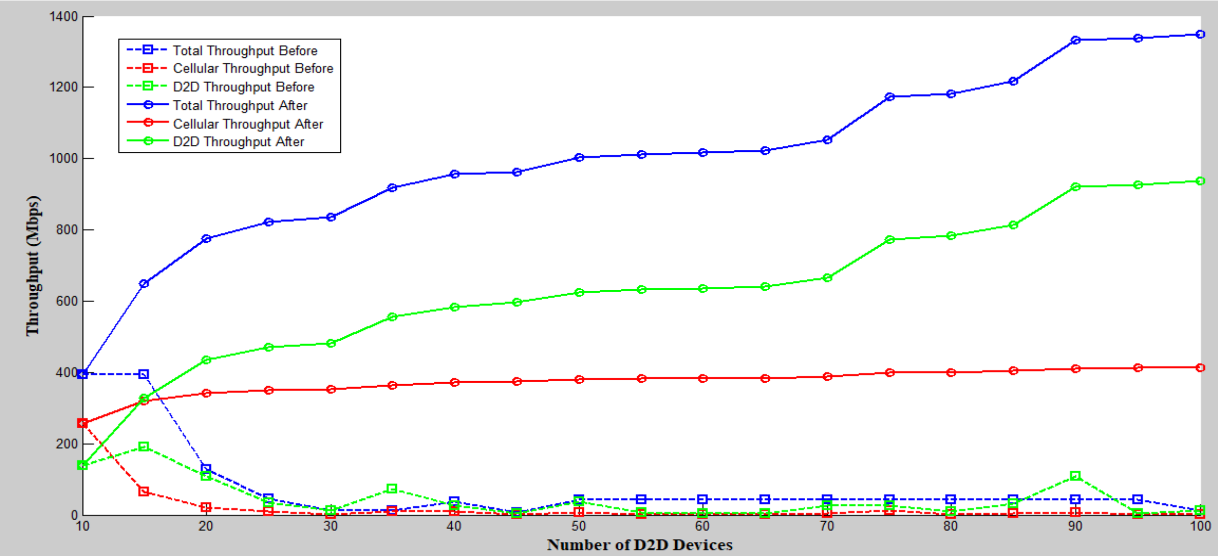


Figure 4-10: effect of D2D pairs number on network throughput

4.4.3. Minimal effect on cellular productivity:

This graph shows the relationship between the minimum cellular transfer rate in Mbps and the total transfer rate in Kbps. The black line represents the change in the total transfer rate after using GA when the minimum cellular transfer rate increases from 500 Kbps to 3000 Kbps, while the green line represents when GA is used. The change in the total transfer rate is at the same lower limits as the cellular transfer rate. We notice that at 500 Kbps the total transfer rate is less than $10^4 * 2$ kpbs for the black line. And about for the$10^4 * 1.5$ green line. From about 1000 to 2000 kbps the black line remains approximately constant around $10^4 * 2.5$ kbps. While the green line continues to increase at a constant rate, at 300kbps. The black line reaches about $10^4 * 4.5$ kbps. While the green line continues to increase at a steady pace. As shown in the figure, it is clear that by increasing the minimum cellular transfer rate, the total transfer rate increases, but the black line shows more dramatic changes compared to the green line. Which is increasing steadily. This indicates that the genetic algorithm gives us good improvements that affect the overall performance.

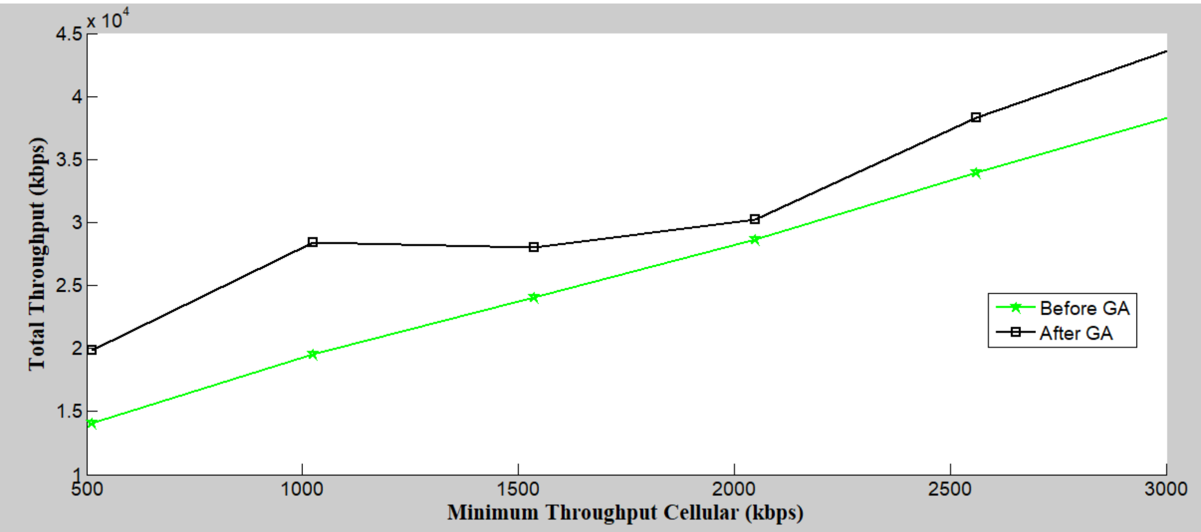


Figure 4-11:minimal effect on cellular productivity before and after GA

4.5.Conclusion

In this study, we investigated the efficiency of a genetic algorithm inspired by nature in allocating channels and the capacity that ensures d2d device-to-device communication in 5G networks. The setup and presence of several pairs of d2d users who share the same network resources with the cellular user was the primary goal. It is to increase the total network throughput while maintaining minimum throughput rates for cellular users. The genetic algorithm was used to avoid solutions that were not possible. The simulation results showed that the genetic algorithm excelled. Through the speed of convergence, the quality of solutions, and the achievement of practical solutions

conclusion

conclusion:

D2D device-to-device communication is a key technology in the development of fifth generation networks and beyond, as it contributes to enhancing network performance and expanding coverage. Thresholding, channel allocation and power monitoring are major challenges facing, D2D applications. Our thesis focuses on solving this problem through a comprehensive study targeting D2D communication applications in 5G cellular network architecture. As a new technology that is expected to witness significant development in the future, which will provide more convenience to users of traditional mobile phones in terms of choosing D2D communication modes and allocating resources.

In this thesis, we focused on solving this resource allocation problem for D2D communication in 5G networks. First, we provide a basic background on communications networks, starting from the first generation, up to the fourth generation, and then the fifth generation, touching on the waveforms, its main technologies, and its most important characteristics, advantages, and disadvantages. Next, we provide detailed information about D2D communication. Including classifications, characteristics, challenges, and communication applications, we clarify the problem of resource allocation. Then we reviewed an overview of resource allocation and energy control and some of the work related to it and explained the formulation of the problem. It became clear to us that the problem of resource allocation is bound by several restrictions, which makes it difficult to solve by traditional methods. Therefore, we proposed the use of genetic algorithm to solve this common problem in D2D communication within 5G networks. The genetic algorithm relies on crossover and mutation as it searches to represent each possible solution to a particular problem as an individual in a population. To give optimal sweets in a short time. We compared it with selecting random solutions. To enhance the first solution, we proposed a system called the effect of increasing the number of D2D pairs on the total throughput and throughput of the cellular network. To find the optimal solution to the problem of spectrum and capacity allocation in D2D communication within fifth generation networks. We found that the results were good. Thirdly, we presented the effect of improving the results on the minimum cellular throughput after applying the genetic algorithm. Finally, as a future suggestion for this work, given that reducing interference is an important aspect of D2D communication in fifth generation networks. Interference can be reduced through optimal placement and allocation of resources. We believe that adding the mode selection problem to the shared channel allocation problem can significantly enhance D2D performance by choosing the best communication method, whether in cellular or D2D mode, which improves spectrum and energy efficiency and increases network throughput.

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