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Device-to-Device (D2D) Communication in 5G Wireless Networks: A Review

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ABSTRACT

In 5G networks, the Device-to-Device (D2D) communication architecture offers a helpful framework to support various applications. Through the use of cellular or ad hoc networks, D2D communication increases the network's capacity to use spectrum, system throughput, and energy efficiency, setting the stage for user devices to initiate close-quarters communications. This paper's goal is to prepare a survey based on D2D communication and review the body of literature that covers the D2D paradigm, various application scenarios, and use cases in a comprehensive manner. Furthermore, fresh evidence in this field points to unsolved D2D communications in cellular network research issues. It has lately been suggested that device-to-device (D2D) communications be implemented over a cellular infrastructure in order to improve energy and spectrum efficiency. A key function in cooperative networks is relay selection. In D2D communication, the communication from the source node to the destination node will not be successful if the relay that is selected is not the optimal relay. Additionally, when selecting the best relays, keep in mind that a higher feedback loop and a longer latency between the source and relay nodes will reduce spectral efficiency. A review of relay selection methods for D2D communications is provided, along with an analysis of the difficulties and design concerns in integrating D2D into a 5G cellular network.

KEYWORDS- Device-to-Device communication, relay selection, 5G, D2D, 5G networks, Cellular network etc.

1. INTRODUCTION

The fifth generation (5G) will shortly be introduced to cellular connectivity. Replace 4G systems with 5G ones in order to suit all of the subscribers' requests for faster data speeds and multiple apps. The Third Generation Partnership Project (3GPP) has been working on developing an improved Long-Term Evolution (LTE) radio interface known as LTE-Advanced (LTE-A) in light of the fact that current 4G technologies cannot close the enormous gap between the actual communication performances and the upcoming user expectations. The massive Multiple-Input Multiple-Output (MIMO), carrier aggregation, low-power nodes, and D2D communication features of the LTE-A radio interface are designed to significantly improve the current cellular technologies (4G) in terms of system capacity, coverage, peak rates, throughput, latency, user experience, etc. [1]

The development of 5G is the result of the use of a number of different technologies, including Massive MIMO, Cognitive Radio Networks (CRNs), and mm-Wave communication... In spite of the fact that the first four generations of cellular networks were entirely reliant on the base station (BS), the fifth generation of cellular networks is moving in the direction of a device-centric strategy. This implies that the devices themselves will be responsible for managing the network configuration.

As seen in Figure 1, there has been a consistent increase in the amount of traffic passing across networks throughout the course of the years, and this trend is expected to continue in the years to come. The upshot is that the base station (BS) becomes overloaded as a consequence. An rise in the demand for electricity is occurring as a consequence of the rising load that is being placed on the base station (BS)

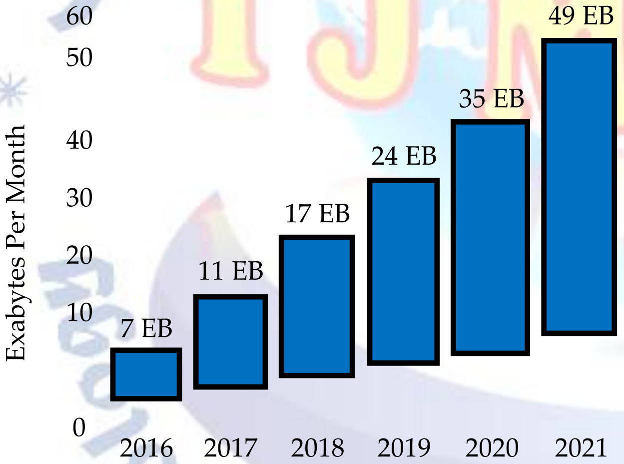

Figure 1:Cisco predicts 49 Exabytes of mobile data volume per month by 2021

The communication between devices is extremely important in this situation because it is offloaded from the base station. D2D communication makes it possible for devices to communicate with one another without going via the base station, which results in a significant reduction in the amount of burden that is placed on the base station.

As a result of the quicker speeds and more ample bandwidth, some people have hypothesized that Wi-Fi offload will become less important once 4G networks are in existence. A number of high-usage devices, such as powerful smartphones and tablets, have been drawn to 4G networks. As a result, 4G plans are now subject to data caps that are comparable to those of 3G plans. According to forecasts made by Cisco, the amount of Wi-Fi offload that occurs on 4G networks is higher than that which occurs on lower-speed networks, both today and in the future. The percentage of traffic that was offloaded from 4G networks was 63 percent at the end of 2016, and it is projected to increase to 66 percent by the year 2021, as shown in Figure 2 [2].

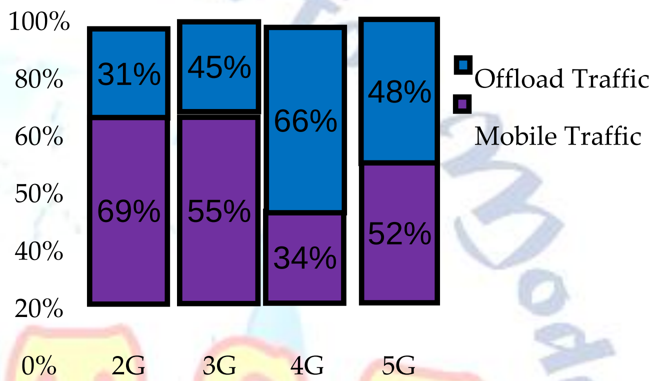

Figure 2: Mobile offload and data traffic

For a number of decades, wireless communication technology that is utilized in wireless devices has seen significant development. A significant amount of progress has been made in the field of wireless communication technology, beginning with the voice-only 1G and continuing all the way up to the 4G of today and the impending 5G of tomorrow [3]. Each new generation brings about an increase in the speed at which data transfers are carried out, and the technology that is employed to accomplish this is also subject to change. A speed of 2 kbps was offered by 1G, 64 kbps was offered by 2G, which is based on GSM, 2 Mbps was offered by 3G, and the current 4G technology delivers speeds of 100 Mbps to 1 Gbps [4]. In order to accommodate a significantly bigger number of wireless devices and user needs, the primary objective of 5G is to deliver a significantly faster speed, which might be in the range of 1 Gigabit per second to 10 Gigabits per second, while at the same time minimizing the power requirements.

Only voice communications were supported by the initial generation of cellular technology, and the phones that were available at the time had a battery life that was extremely short and a transmission speed of 2.4 kbps. A digital cellular technology of the second generation was able to offer voice as well as text message services (data and voice services) at a transmission speed of 64 kbps. This technology served both voice and text message services. A communication service that was both secure and dependable was provided by the 2G network. It was in the year 2001 that the third-generation cellular networks were made available for commercial distribution.

During the third generation of smartphones, new technological features such as email, web surfing, video downloading, and image sharing were offered. 3G makes it possible to use a wide variety of apps, offer enhanced capacity, and increase the amount of data that can be transmitted at a very cheap cost. In addition to providing extremely low-cost voice and data services, the fourth generation was developed with the intention of delivering high speeds and quality, enhanced security, multimedia, and internet over IP [5]. Fourth-generation wireless communication networks are helpful for a variety of applications, including mobile web access, Internet Protocol (IP) telephones, high-definition television, online gaming, three-dimensional television, videoconferencing, and cloud computing. Despite the fact that the applications and benefits of 4G wireless networks are significantly larger than those that were experienced in 3G wireless networks, there is a pressing need to upgrade to the next generation of wireless technology, which is fifth generation (5G).

2. LITERATURE REVIEW DEVICE-TO-DEVICE (D2D) COMMUNICATION

One of the components that is being evaluated for inclusion in 5G networks is device-to-device (D2D) connectivity. It is anticipated that the application of the D2D communication technique will result in improvements to communication characteristics such as system capacity, throughput, spectrum efficiency, and latency [6.7]. An explanation of the evolutionary development of cellular communication generations can be found in [8]. Figure 3 provides a summary of the diverse range of services that have been made available by successive generations of cellular communications.

While working on the D2D technology, a number of tough challenges, including interference control, radio resource allocation, procedure management, and communication session setup, occur in the cellular network. These issues have been reported in the most recent literature [9-12]. There are a number of taxonomies of probable D2D architectures that have been proposed by A. Asadi and others [3]. To be more specific, device-to-device (D2D) communications can be broken down into two primary categories: in-band and out-band. Although the first group makes use of radio spectrum that is present on the cellular spectrum, the other categories make use of spectrum that is not licensed.

When the communication takes place in the unlicensed spectrum, the coordination between radio interfaces is either controlled autonomously by mobile terminations (MTs) or by base stations (BS), which means that it is controlled. In-band device-to-device (D2D) communications present a number of challenges, the most significant of which is interference mitigation between cellular and D2D communications. Several research initiatives have been initiated with the purpose of investigating this issue [10]. When it comes to out-band device-to-device (D2D) connections, the research is centered on the architectural design of inter-technology and the amount of power that is consumed [13]. Every one of these propositions highlights the potentialities of the various techniques with regard to the amount of bandwidth resources and the amount of energy that is consumed.

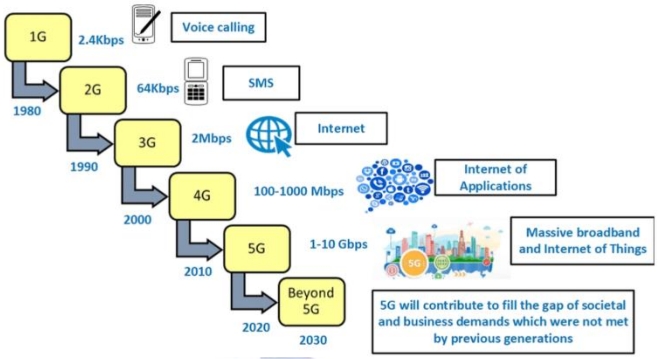

Figure 3: Generation of cellular communication

When it comes to in-band device-to-device (D2D) communication, one of the most significant issues is figuring out how to allocation spectrum for this kind of communication. A representation of the categorization of device-to-device communication as resource allocation can be found in Figure 4. There are now three different resource allocation modes that can be utilized for the purpose of recycling licensed spectrum resources [14]:

- **Underlay Mode:** In this mode, device-to-device (D2D) pairs and cellular user equipment (UEs) share the same spectrum resources. This allows for the highest possible spectrum efficiency to be achieved. In the underlay mode, it has been observed that one of the most important challenges is to effectively regulate the interference that occurs between D2D and cellular devices as well as between cellular devices and D2D devices.

- **Overlay Mode:** Through the use of the Overlay Mode, dedicated frequency resources are assigned to device-to-device (D2D) communications, while the remaining portion of the frequency is assigned to cellular communications. In this mode, there is no problem with interference between device-to-device (D2D) connections and cellular communications. One of the primary areas of attention for research is the optimization of the resource allocation ratio.

- **Cellular Mode:** Instead of talking directly with one another, D2D user equipment (UEs) communicate with the eNB, which acts as an intermediary relay. This mode of operation is identical to the conventional cellular system.

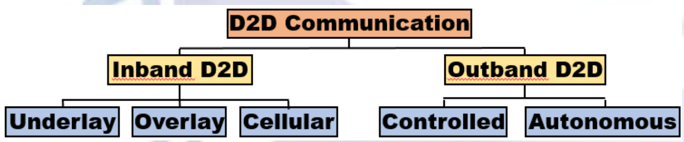

Figure 4: D2D Communication Category

In conventional wireless communication, the devices only connect with one another through the base station. This method of operation is known as the cellular mode. However, since the deployment of device-to-device (D2D) communication, the modes of communication have been expanded to include cellular communication, device-to-device communication, and hybrid communication, which is a combination of both [15s], as depicted in Figure 5.

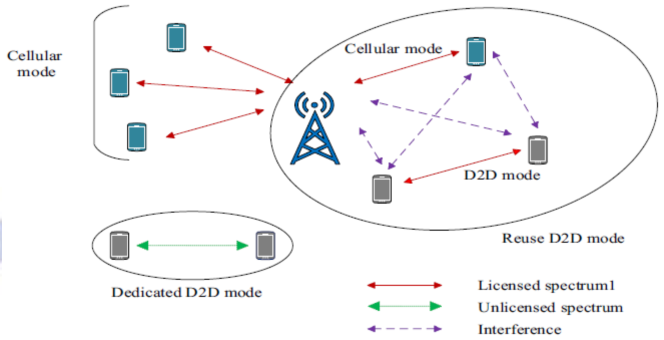

Figure 5: Mode selection represented systematically in D2D

3. ALLOCATING RESOURCES IN D2D

This section reviews recent research that concentrate on resource allocation approaches and describes the current algorithmic design for resource management [16-18].

As was shown in the section above, when given the right study focus, D2D communication concerns and challenges—such as mode selection, peer discovery, security and privacy, interference management, and resource management—will improve system performance. The spectrum is shared by cellular and D2D devices in order to preserve QoS and enhance system performance. The history of D2D resource management, D2D communication optimization issues, and different resource allocation algorithms and techniques have all been examined and tallied. A thorough examination of the literature has been conducted in order to present a comparative study of different resource allocation strategies. This section provides an overview of prior research and illustrates how the suggested future study is innovative in comparison to previous research.

A. SCHEMES FOR ALLOCATING RESOURCES

All network operators face challenges in meeting the growing demand for greater bandwidth due to the proliferation of devices and bandwidth-hungry applications. The sharing of content between devices that are closer in proximity has also significantly risen. Large amounts of resources are needed for content distribution and spread, and when they go through the base station, a significant volume of data traffic is generated there with an increased latency. Due to restricted and scarce spectrum resources, contemporary 4G cellular technology cannot meet these expectations. In order to lower latency and please mobile device users, the base station must offload a larger volume of traffic due to the growing network density and number of devices. All users in a network should have equitable access to communication, regardless of their position or status. To ensure that the devices' batteries endure a long time, their power consumption should also be reasonable. Consequently, D2D communication in 5G can satisfy the requirement for a spectrum and power efficient [19] system with enhanced latency, fairness, and throughput, as it is effective and beneficial in all the previously listed aspects.

The architecture of traditional cellular communication has changed to include two-tier cellular communication as a result of the introduction of D2D communication. There are two layers in the updated architecture. The macro-cell tier is the top tier. The conventional communication between the Base Station and the cellular devices is known as the macro-cell tier. The communication between two devices that are close to one another occurs at the Device-tier, which is the second layer. D2D communication occurs at the device tier, whereas typical cellular communication occurs at the macro-cell tier.

Researchers are paying more attention to resource allocation since it can cause interferences with wireless communication. As was discussed in the previous section, inband D2D communication [20] has two types of spectrum allocation: overlay and underlay. The latter type eliminates interference by supporting a separate dedicated licensed spectrum for both D2D and cellular communications. In the context of underlay D2D communication, where cellular and D2D devices share spectrum resources, inefficient resource allocation and management would inevitably result in interferences.

As a result, interference management is the most crucial topic out of all those covered in the previous section. A communication network's interferences can be eliminated by modeling the interference signal and then deducting the estimated model of the interference from the signal that the receiver receives. The intended signal and the unwanted interference signal are both present in the receiver; the unwanted interference is subtracted from the total received signal by the receiver, leaving only the desired signal.

Nonetheless, effective resource allocation is crucial to the engagement of interference reduction and avoidance. Resource allocation not only helps to reduce interference but also boosts the data rate of wireless communication systems in unstable channel situations. Effective resource allocation and sharing can facilitate the efficient use of limited resources, supporting D2D communication while mitigating the potential for conflicts arising from resource sharing. Thus, efficient resource allocation is in charge of reducing interference in a communication system and enhancing throughput, data rate, and system sum-rate. The following equations [21–22] are used to calculate the aforementioned metrics.

B. RESOURCE MANAGEMENT TYPES

There are different types of resource management, and they are characterized according to the level of involvement of the base station. As can be seen in figure 6, the resource allocations can be broken down into three distinct categories: centralized resource allocation, distributed resource allocation, and semi-distributed resource allocation. The method of centralized resource distribution requires signal exchanges between the Base Station and the D2D transmitter that is requesting resource allocation, as shown in figure 6(a). The distributed resource allocation method is device-centric, meaning that the devices themselves are responsible for sensing the spectrum that is actually accessible. The sole reason that the Base Stations are engaged is because they are responsible for freezing the spectrum that the D2D devices require.

As was said in the section that came before this one, centralized resource allocation systems are extremely efficient when it comes to managing and controlling interference in the network. D2D users or devices communicate with the base station in order to offer information regarding the local channel quality measurements received. When everything is taken into consideration, it is clear that the base station possesses comprehensive knowledge of the Channel State Information (CSI) that is present in the network. The channel gain of a cellular user and the base station, as well as that of a D2D user and the base station, is likewise well known at the base station side. This is because the devices that send their CSI to the base station are both cellular and D2D devices. At the same time, it is challenging for the Base Station to compute the channel quality between two devices that are connected to each other via device-to-device (D2D) and between one cellular user and one D2D device. Because of this, resource allocation is carried out even in a D2D communication underlaying cellular system that has incomplete CSI [22].

In a similar vein, the condition is referred to as a partial CSI when the CSI is not known at the Base Station. When a central entity or the base station is responsible for allocating resources, this is an example of centralized resource allocation. Therefore, partial CSI presents a barrier for the type of resource allocation that is centralized within D2D.

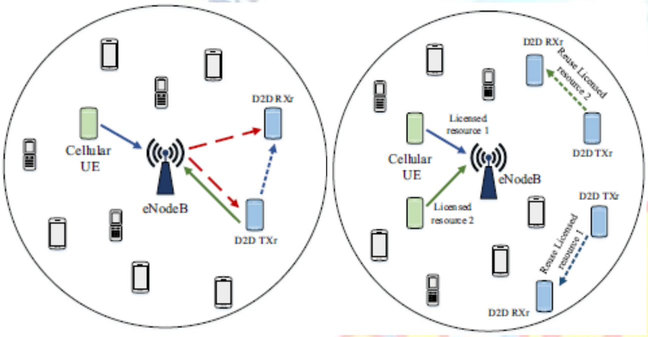

Figure 6: (a) Centralized D2D resource allocation b) Distributed resource allocation

4. D2D COMMUNICATION'S DIFFICULTIES AND DESIGN PROBLEMS IN 5G NETWORKS

The integration of D2D communication in cellular networks presents some technical problems and is regarded as an unexplored area of research [23-24].

Relay Selection: When it comes to cooperative D2D networks, the most important problem is relay selection. Increasing the effectiveness and maximization of this process is one of the design goals. It is possible for the selection of relays in a cellular network to be either centralized or distributed. One of the most critical design questions concerns the role that the network plays in the relay selection.

Interference Management: In order to take advantage of the numerous research opportunities available in this field, it is necessary to build a smart interference management strategy for D2D users for the device tier. There is also the issue of interference cancellation in full-duplex radio networks, which is still a subject that needs to be investigated.

Peer Discovery: In order to locate and establish D2D connections in a timely manner, the process of peer discovery ought to be performed in an effective manner. Additionally, it is essential for ensuring that the system is efficient and that resources are distributed appropriately, and there is a gap in the research that has to be filled.

Resource Allocation: The allocation of radio resources is an essential component in improving the spectrum efficiency of device-to-device communication.

Network Security: When exchanging information through relays in D2D communication network security is the major concern and there exists an open area for research.

5. D2D COMMUNICATION'S ADVANTAGES

There is a significant amount of research being conducted in the field of device-to-device (D2D) communications technology in order to enhance the quality of services and facilitate their delivery. In a nutshell, these services can be classified into three primary groups, which are detailed below.

Emergency Communications: In the case of natural disasters like hurricanes, earthquakes etc., the traditional communication network may not work due to the damage caused. Ad-hoc network can be established via D2D which could be used for such communication in such situations [25].

IoT Sweetening: Creating a wireless network that is truly interconnected will be accomplished through the combination of D2D and IoT. The increase in Internet of cars (IoV) is an example of a D2D-based Internet of Things augmentation. In the event that two cars are traveling at high speeds, a vehicle can alert other vehicles in the vicinity about the speed or other information by using the D2D mode [26].

Local Services: Local service involves the direct transmission of user data between terminals, and thus does not include the network side. For example, social media applications, which are based on proximity service, might be considered local service [27].

Despite the fact that D2D communications are comparable to MANETs in many respects [28], there are a few key distinctions that are readily apparent. First, device-to-device (D2D) communications can operate on licensed or unlicensed spectrums depending on the circumstances, whereas MANETs operate independently on unlicensed spectrums under certain circumstances. Interference is the most significant issue that arises in MANETs because of the difficulty of controlling the spectrum on unlicensed spectrums. On the other hand, D2D control of core networks focuses on efficient spectrum resource consumption and aims to minimize the interference that occurs between links. On the other hand, under the Out-of-Coverage scenario, device-to-device (D2D) communications take place either on unlicensed spectrums, such as MANETs, or on licensed spectrums, as in the case of Public Safety Networks [29-30].

Furthermore, in the realm of device-to-device (D2D) communications, it is possible for core networks and D2D nodes to collaborate in order to carry out activities such as resource allocation, node discovery, route search, and security management. Core networks can also control these operations. When it comes to MANETs, every node is responsible for carrying out the aforementioned actions on its own.

In conclusion, the routing patterns are the single most distinguishing feature between MANETs and device-to-device connections. In the realm of MANETs, the most significant and challenging concerns that must be taken into consideration are the issues of multi-hop routing. Device-to-device (D2D) communications primarily involve the incorporation of single-hop communications into services. The fact that device-to-device (D2D) connections, such as MANETs, encounter the same challenges in multihop routing should be taken into consideration in the Out-of-Coverage scenario.

6. CONCLUSION

An in-depth investigation into device-to-device (D2D) communication is carried out in this work. This article provides a comprehensive description of the various methods of D2D communication and the architectures that are supported. An investigation of relay selection algorithms in device-to-device (D2D) communication for 5G cellular networks revealed the problem as well as the solution that was implemented in the algorithm to address the issue. This article elaborates on the challenges and research directions in device-to-device (D2D) communication for 5G cellular networks.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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