A Survey of Device to Device Communication in 5G

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Abstract

Device-to-device (D2D) communication is expected to play a significant role shortly as it promises ultra-low latency for communication among users. With the advanced communication technology, the number of users and applications are increasing exponentially and leading towards the shortage of resources and an increase in power consumptions, demand for higher data rates. The data traffic on the base station also increases with the number of users. To fulfill the needs of cellular users in 5G, D2D communication considered a famous solution. However, there are several challenges associated with D2D communication. In this paper, various methods for resource management for D2D communication are discussed extensively. Other important aspects such as security and interference management are taken into consideration. In this paper, we discuss the key characteristics of D2D communication and its usage scenarios, specialised features, and areas of effective research. Finally, we conclude with the potential future research directions.

Keywords: - *Device to Device Communication (D2D), Security, Interference Management, Resource Management, Latency, 5G.*

INTRODUCTION

Recently the number of mobile devices (i.e., smartphones and tablets) has been growing significantly, more than other computing devices. The new mobile UEs are powerful in data resources, such as sensors and camera, applications, user interfaces like speakers and colourful screens. The Net connectivity gives their users the ability to communicate through social networking and online gaming. Moreover, mobile users can share their daily lives with friends and followers by using text, pictures, or video clips. Accordingly, mobile devices are noticeably the most significant contributors to social networks [I][II]. As a result, data traffic increases day by day, and advanced mobile devices must handle these functionalities.

The existing wireless technologies such as 3G and 4G are not enough to fulfil the presumptions and challenges of the near future. The fifth-generation (5G) technology was introduced as a futuristic solution to meet demands. 5G will provide services like lower cost, ultra-low latency, higher data rates, less traffic etc., and Device to Device

(D2D) communication is one of the promising technologies of 5G that provides such services. D2D improves network performance, energy efficiency, throughput, QoS specific communication, delay constrained and spectrum utilisation [III]. Device-to-Device (D2D) communication in cellular networks is defined as direct communication between two mobile users without passing through the Base Station (BS) or any other core network or any other physical infrastructure. The main purpose of D2D is to fulfil the challenges that are addressed in4G.

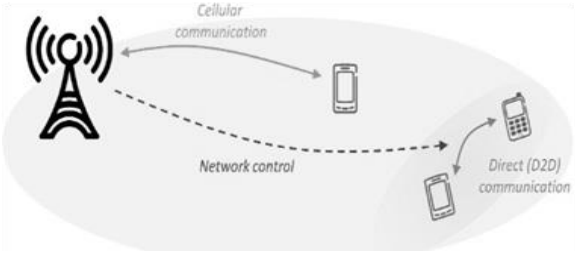

Figure- 1 D2D Overview [IV]

A good taxonomy of D2D communications is given in [IV], where D2D communication is classified based on the spectrum in which D2D communication occurs, as illustrated in fig.2. It can occur on the cellular spectrum (i.e., inband) or unlicensed spectrum such as Wi-Fi(i.e., outband). The inband D2D can be further classified in (i) underlay inband D2D mode and (ii) overlay inband D2D mode. The outband result seeks to eliminate the interference between D2D and cellular link, but it requires extra interfaces such as Wi-Fi Direct or Bluetooth. It can be further classified as (i) controlled mode (i.e., by the BS/AP (access point)) and (ii) autonomous mode (i.e., By the users).[IV]

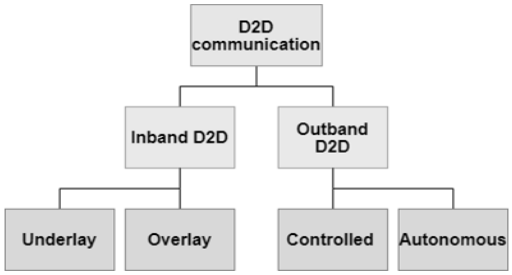

Figure- 2 Classification of D2D

In this paper, we present a survey of the challenges related to D2D communications and suggest the development of protocols, which could be helpful in the establishment of 5G D2D networks. First, we discuss some works presenting an overview in the direction of D2D networks. In this paper, we provide our comprehensions regarding the inadequacies in existing techniques, and suggest enhancements, providing the reader with a clearer understanding of how current techniques need to be evolved for workability in future 5G D2D networks. To inspire the reader of the new research trends in D2D networks, a unique proposition is laid on the characteristics such as vehicle-to-vehicle (V2V) communications, relaying in D2D communications, content Distribution, proximity-based networks, which have not been focused on in previous surveys. We aim to spotlight the many challenges related to 5G D2D networks and provide future directions, and highlight problems that require further attention.

The remaining paper is organised as follows. Section 2 presents an overview of D2D needs and challenges. Section 3 offers latency regarding challenges and future directions, and section 4 presents resource management in D2D, section 5 presents security challenges and future work in D2D networks. In section 6, we have concluded on the matter of 5G D2D networks.

OVERVIEW OF D2D NEEDS AND CHALLENGE

With continuous improvement/development of data traffic, mobile network, and software-defined network (SDN), no. of connected device users & mobile users (MU) has increased rapidly. The International Telecommunication Union (ITU) predicted that the overall mobile data traffic would reach astonishingly 5 zettabytes (ZB) per month. Due to this increment in mobile devices and tablets, the uttermost effect has been on wireless and mobile networks, which trigger the challenges for mobile devices worldwide.[II] In 4G also there are some imposes like high latency, low coverage, limited security power, limited spectrum, etc. These challenges are difficult to address in next generation networks (e.g. 5G). The main purpose of D2D is to fulfil the challenges that are addressed in 4G. D2D has the following features.[V] Reduced Latency, High Data rate, Spectrum Reusability, Increased coverage Area, Energy Efficient. One of the main advantages is its flexibility; so that D2D can be integrated with different technologies to enhance the network's performance, such as vehicle-to-vehicle (V2V) technology, mmW technology, Internet of Things (IoT), mode selection, Machine learning(ML) and Artificial intelligence (AI).[VI] D2D can be applicable in different applications and scenarios like voice and data service, video streaming, Machine-to-machine communications, emergency network situations in which connection failure occurs during a natural disaster.

D2D assisted network need to focus on the following challenges.

1. Interference management: it is crucial to design the D2D mechanism so that D2D users do not disrupt the cellular services. Interference management is usually addressed by power and resource allocation schemes, although the characteristics of D2D interference are not well understood yet.[XXXIII]
2. Power allocation: efficient power allocation becomes important for preventing congestion, collision problems, and intersystem interference.

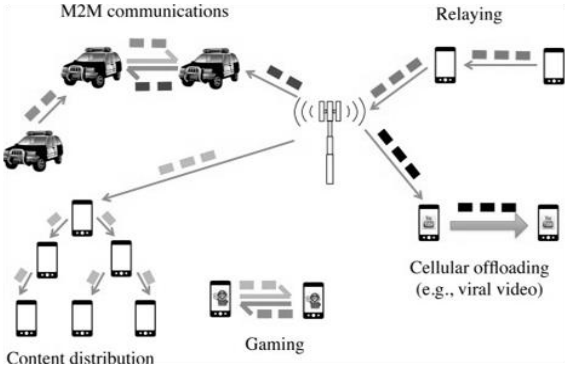

Figure- 3 D2D communication in Cellular network [IV]

3. Resource allocation: It is another vital aspect of D2D communication. Effective resource allocation can increase D2D communication as well as play vital role in achieving higher data rate and energy saving.[XX]
4. Energy consumption: D2D communication can potentially improve the energy efficiency of the UE. However, this depends entirely on the protocol designed for device discovery (DD) and D2Dcommunication.
5. Security: D2D communication affords more anonymity and data privacy than conventional cellular communication since the data are not stored at a central location. However, various common attacks like eavesdropping, denial of service, man-in-the-middle, node personification, IP spoofing, malware attack, etc., can paralyse D2D links.[VII] Users would also like to protect their private information,

e.g., by limiting the availability of their sensitive personal data. The equivalent lack of a central authority makes it troublesome to implement security and privacy measures.[VII]

6. Mobility: Most D2D-related research has focused on fixed users while cellular networks effectively provided to mobile users. [VIII] More analysis is needed to understand how the performance gains increase in dynamic scenarios (from pedestrian to vehicular speeds) and what interference handling and handover mechanisms are needed as UEs move within and around cells. [IX]

7. Pricing: This is one of the most important issues for cellular operators. The complex question raised is how to control the direct link between the devices and charge the users in D2D links and cellular links.

8. [X]Operators can also offer taxable services like security during D2D communication.[XI] Other economic models in the context of D2D communication include how D2D UEs in a cluster may buy or sell data items and how cellular users can sell their bandwidth to D2DUEs.[XII]

9. Latency: Latency is the most challenging aspect of D2D. It is essential to deliver contents with minimum delay. As per 5G requirements, users demand minimum latency for communication.

ULTRA-LOW LATENCY

Ultra-low latency can be achieved in the following ways: 1. Low Latency Enabler 2. High capacity mm-Wave links 3. Proximity-based Computing 4. Low Latency Enabler 5. Edge Machine Learning 6. Low Latency Enabler 7. Proactive Computing. [XIII]

Panagiotis Sarigiannidis et al. proposed probabilistic-oriented learning process Downlink to Uplink Ratio Determination (DIANA) framework for adjusting the uplink-downlink configuration of the LTETDD framing structure in [XIV]. Latency in network discovery could affect the system performance. In [XV], a device selection mechanism is introduced for both indoor and outdoor network environments. The analysis of the proposed system states that spectrum reuse by D2D users decreases cochannel interference, which impacts the network discovery and latency. Sun et al. [XVI] present a resource allocation and power control scheme for realising V2V communications. Latency and reliability are recognised as the severe act metrics for V2V communications. [XVII]H Hsu et al. proposed a joint strategy to implement caching in infrastructure and mobile devices at once, which in general transforms into device-to-device (D2D) communication.[XVIII] The authors state that their proposed system reduces latency for requesting Internet contents and can be implemented via slight modifications to present cellular systems.

INTERFERENCE MANAGEMENT

Proper allocation of frequency resources is essential for maintaining the necessary level of QoS in the network. With the addition of D2D users in cellular networks, the issue of interference turns out to be more complex [XIX] [XX] [XXI] [XXII] [XXIII].

With the combination of D2D communication, the cellular architecture is divided into a two-tier cellular system. A two-tier cellular network includes a macro cell tier and a device tier. Two

types of interference can occur in this two-tier scenario: co-tier and cross-tier. Co-tier interference occurs between D2D pairs when a similar resource block is assigned to more than one D2D user inside the same tier network. Cross tier interference occurs between cellular users and D2D users. Cross-tier interference occurs when a resource block committed to a cellular user is reused by one or many D2D users. Different interference mitigation approaches exist in literature, which can be broadly categorized into centralized[XXIV][XXV] distributed[XXVI] [XXVII] [XXVIII] [XXIX] and semi-distributed[XXX] [XXXI][XXXII].

Selection of Mode, channel allocation, Resource management and interference reduction are closely related and often combinedly optimised. Several centralised, distributed, and hybrid algorithms have been proposed for these three kinds of problems, but research is still active. [XXXIII] Xiao et al. [XXXIV] proposed a heuristic algorithm for power allotment in OFDMA-based cellular systems. Their proposed system performs power allocation and mode selection using the existing subcarrier and bit allocation algorithms. Via simulations show that integrating their proposed heuristic with the current algorithms in [XXXV] improves the downlink power consumption of the network by around 20% compared to the traditional OFDMA system without D2D. Transmit power of CU and D2D users can be adjusted for reducing interference. [XXXVI] Transmit power levels can be manipulated to control the magnitude of interference suffered by the communication links. An uplink power control scheme based on SINR thresholds (SINR-T) is presented in [XXXVII]

RESOURCE MANAGEMENT

The next generation of the cellular network addresses limited resource spectrum allocation due to the dense deployment of small cells. It gives rise to increased network traffic, channel allocation, and interference management. Thus, an efficient resource allocation mechanism is required to deal with delay-sensitive applications and services. [XXXVIII] Radio resource (e.g., subcarriers) allocation is an important step (especially in inband mode) in establishing and providing direct links between D2D pairs in a cellular network. A general but straightforward resource allocation framework is proposed in [XXXIX] for inband multicell architecture. In the overlay, uplink spectrum is partitioned into two orthogonal segments with portion η assigned to D2D communicationand$1-\eta$ to cellular communication; in underlay, the spectrum is divided into B bands, and D2D UEs can randomly and independently access βB ($\beta \in [0, 1]$) of them. Different resource management schemes can be planned by changing the optimisation objectives and adding additional constraints. In [XL] li et al. proposed an optimal social- community aware resource allocation (OSRA) algorithm for D2D communication to limit the period of D2D communications taking advantage of users' social characteristics. The solution represents a centralised behaviour that allows a reduction of data transmissions but overloads the base station (BS). In [XLI], the authors confronted the increasing storage space issue, proposing that the distributed file caches be mistreated by cellular networks, replacing cellular links with local D2D links to reduce mobile traffic and improve spectrum utilisation. While a D2D device is caching data requested by the

neighbouring user equipment (UEs), a procedure to create a cluster for multicast communications can be started. [XL]. Yu et al. [XLII] analysed methods to share resources to maximise the throughput in D2D communications performed in cellular networks. In [XLIII], min et al. proposed a power optimisation framework handling interference from cellular users by presenting a δD interference-limited control scheme. In [XLIV], the authors considered peer and service discovery as the first step to start D2Dcommunications.

SECURITY

Although D2D communication provides low latency services, higher data rate, and lower outage probability scenarios at the cell edge regions, certain loopholes are to be addressed. These ambiguities defined as the low computational ability, device power constraint and shared channel. Various security attacks such as eavesdropping, denial of service, man-in-the-middle, node impersonification, IP spoofing, malware attack, etc., can harm D2D links. Users would also wish to protect their confidentiality, e.g., by restricting the availability of their sensitive personal information.

Security model proposed in [XLV] having three dimensions visually 1) Insider or outsider 2) active or passive 3) local or extended. Authors in [XLVI] model threats in a three-dimensional space: (1) whether the attacker is internal or external, (2) whether the attacker is active (e.g., it modifies in-transit data) or passive (e.g., it only interferes on data), and (3) whether the attack is local or expanded across the network. Several proposals to protect the D2D networks are reviewed in [XXXII][XLVII].

CONCLUSION

Device to Device (D2D) communication shows excellent potential as one of the most promising and favourable standards for future networks. In this paper, a detailed survey on the available literature is done, considering the main characteristics of D2D communication such as security, resource management and inference management that enables its implementation. This paper has also exhibited the advantages of D2D and various Use cases of D2D in forthcoming 5G technologies. Although D2D communication is a relatively new idea, a significant amount of research in D2D has recently opened a range of related research issues that should be investigated in the future. This survey will help future researchers better understand the D2D concepts and technologies and enable them to have a good understanding of future research opportunities that have been identified in the area of D2D communication.

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