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Recent Developments in D2D Communication in Cellular Networks

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Abstract

This paper gives us the detailed information about Device-to-Device (D2D) communication techniques and how it is being used in the cellular networks. D2D technique enables the users to exchange information between nearby places without using the base stations and mobile switching centers. At first in the development of this system has planned to use it with mobile communication by which spectral density improvement and the delay reduction can be achieved in the communication. Then it is known that this D2D communication becomes inevitable due to following reasons, less traffic for base stations which reduces the delay, increased energy efficiency and avoids congestion in the cellular network communication. Since many mobile devices like tablet, computers and smart phones are used today which increased the network traffic and so the study in recent technologies of D2D communication will give a way to find the suitable techniques that even more improves the performance metrics in paradigm.

Keywords: D2D Communication,D2D Protocols,Relay assignment, Spectral efficiency, Traffic offloading

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1 Introduction

In the regular cellular network based systems, devices do not communicate directly with each other; instead devices communicate via base stations [1]. Hence it poses a limitation of larger latency due to longer signal traversal path. Also, the modern days cellular communication network's subscribers increasing demands necessitate the increase in the network capacity. Further, emergence of new applications such as social networks, mobile gaming, video conferencing and High Definition (HD) content distribution and location-aware advertisement introduces additional data traffic in the network [2]). It is expected that the future cellular network will have billions of devices to be supported by the network. Further, such systems are heterogeneous in nature with different data rates, high efficiency, throughput, and lesser delay. However, the available spectrum resources are insufficient and hence there is a need for alternate technology to be adopted by the network service providers to cope with the increasing demands. A recent method to sort out the demand of the high data rate to describe a latest networks technology is D2D communication.

D2D communication function methodology effectively not been utilized in the previous generations of cellular network based systems. This is widely used because it has been largely accepted as a method to decrease the cost of provision for local service, which is been calculated as a part while compared to past on the market statistics of cellular operators [3]. Figure 1 shows the simplified architecture of D2D communication.

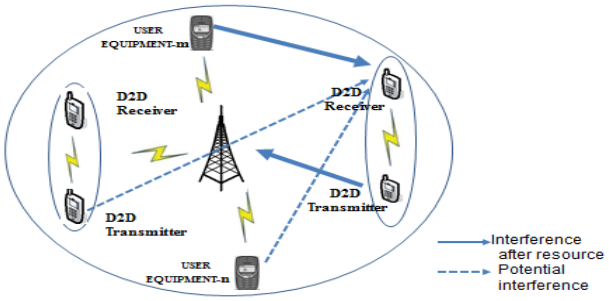

Figure 1 Simplified architecture of D2D communication

One popular solution which is being adapted in the market today is that Device-to-device (D2D) communication. It uses various technologies like Ultra-wideband (UWB), Bluetooth, LTE Direct, Wi-Fi-direct, Near Field Communications (NFC), or Zigbee [4]. Some of the short distance communication techniques include Bluetooth, LTE Direct and Wi-Fi direct, etc. The distance coverage and the data rate of these techniques are presented in Table 1. It reveals that Wi-Fi- direct has higher data rate, while having lesser distance coverage. Also, the LTE direct has the highest distance coverage with lowest date rate.

Table 1: Short range wireless technologies in D2D

Technology	Maximum Data rate (Mbps)	Maximum Distance (Meters)
Blue tooth 5	50	240
LTE Direct	13.5	500
Wi-Fi Direct	250	200

2 Key Terminologies and Classification

Inband D2D (licensed spectrum) and Outband D2D (unlicensed spectrum) are the two important branches or classifications in D2D communication. This has been further classified into various sub types which are dealt in Figure 2

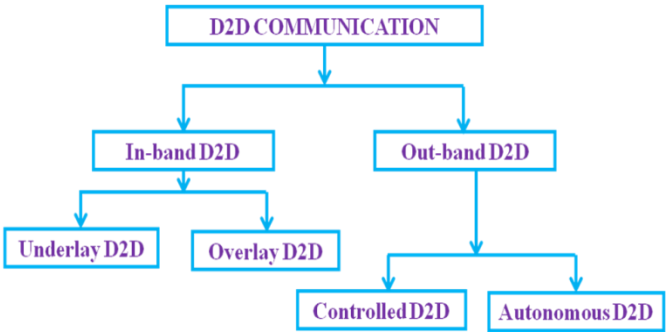

Figure 2 Classification of D2D Communication

2.1 In-Band D2D Communication

In this case, the same spectrum is used for both cellular technology and D2D communications. It is divided into two divisions namely underlay in-

band D2D and overlay in-band D2D.

2.1.1 Underlay In-Band D2D Communication

The reuse technique is adopted here in order to maximize the spectral density. The interference with the cellular network by the D2D users is a drawback and by using complex resource allocations this can be removed but it requires additional computation resources at the base station.

2.1.2 Overlay In-Band D2D Communication

In this it uses the dedicated portion of cellular resources for D2D communication between destination and source. As it uses different spectrum bands so that interference between the cellular communication and D2D can be avoided. It improves the spectral density and signal strength in relay assignment and it also improves the power control and scheduling in D2D communication.

Figure 3 gives an overview of In-band D2D and Out-band D2D communication techniques. Further, an architecture level comparison is also presented in this figure.

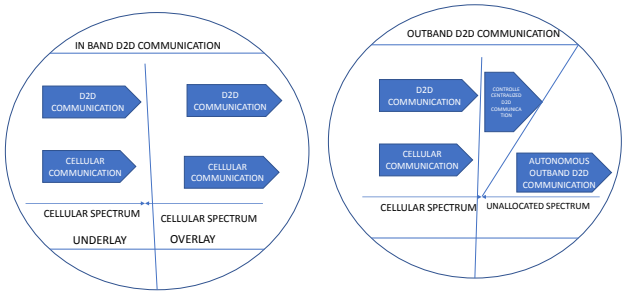

Figure 3. In-band D2D and Out-band D2D communication techniques.

2.2 Out-Band D2D Communication

When cellular network uses the licensed spectrum then the unlicensed spectrum is used by the D2D communication which eliminates the signal interference between cellular users and D2D users. In Wi-Fi and Bluetooth it will be the key technology. It is further branched into Controlled D2D and

Autonomous D2D.

2.2.1 Controlled Out-Band D2D Communication

The D2D communications coordinates between radio interphases like BT and Wi-Fi is controlled directly by base station. The pre-allocations is done to spectrum resources to utilize the ISM band. Further, BS can prioritize the data transmission over the network to fulfil the Quality of Service (QoS) requirements. This leads to increase in through put and effective resource management. But the limitation in this is increase in signal overhead with the network size enlargement and it results in long delay in the performance.

2.2.2 Autonomous Out-Band D2D Communication

If BS controls the cellular network, then devices which are communicating using D2D mode is responsible for D2D communication. Identification of devices and allocation of resources to newly entering system is done by the D2D network.

In the beginning days, the D2D communication was proposed as a standard to enhance network performance by offloading data traffic at BS in cellular networks. The optimum spectrum efficiency and resource utilization are additional advantage [5]. The D2D communication takes place in three stages namely (i) Reuse mode (common channels are shared by D2D and cellular systems), (ii) Dedicated mode (dedicated channels are allotted for D2D systems), and (iii) Cellular mode (every communication is relayed by BS) [6].

In D2D assisted devices, the traditional cellular communications are not applicable but it can be redesigned to fulfill the requirements. Therefore to take the advantages of D2D connectivity new techniques were proposed. These techniques pave way for the development of the 5th generation wireless systems and next generation mobile communication system. It improves the communication capability of the communication system by minimizing communication delay and power consumption. D2D has become a promising technology because of the following reasons [7], (i) Ultra-low latency for communication among users, (ii) supports to traffic offloading, and (iii) increases spectral efficiency. Connectivity such as HOTSPOT needs a Data Offloading in the device. Base station allows offload/cache data in the device during the maximum time to other devices which is used to download the data on the device from the direct links.

3 Related survey

A recent survey on D2D communication is presented in the advancement in offloading technologies in cellular networks is shown, followed by existing efforts, the important aspects such as cooperative communication, energy efficiency, time-spectrum allocation and really assignment is presented and also provided some of open research problems in this field. Another survey includes the focusing of design issues and challenges of the D2d communication [8] are also shown. It elaborates the development in cooperative communications in D2D assisted network and challenges the limiting factors such as multicasting, power consumption, relay selection. It also explains the design issues and approaches to overcome the problems. Another survey includes the focusing of the advantages of D2D communication and major challenges like resource allocation, peer discovery, etc., are presented in[9].This paper also gives a brief on the ongoing standardization processes and research projects in D2D communication

The presentation of another survey focusses on the main attitude of D2D communication such as architecture, usage scenarios, and areas of effective research. Another important system is network security which decides its performance. This also gives the novel architecture for security enhancement under the framework of 3GPP LTE in D2D Communications.

This survey is prompt required to the increase in energy consumption, data traffic and data speed by the battery operated systems, the researchers have produced the diverse in the new techniques. These surveys review various algorithms to find out issues that may provide techniques to improve the spectrum efficiency or spectral efficiency.

4 Algorithms in D2D Communication

Researchers have provided the several algorithms to solve the major issues like traffic offloading, relay assignment, energy efficiency, etc., in the field of D2D. This categorizes each algorithm and explains pros and cons of these algorithms. Table 2 lists some of the tools / algorithms used in D2D communication.

Table 2 Analytical Tools Used in D2D Communication.

S.No	Name of the Tools	Key metric / year
1	Mixed Integer nonlinear Programming	2010
2	Heuristic Algorithm	2011
3	Lagrangian Multipliers	2011
4	Linear Programming	2011
5	Discrete Time Markov Chain	2012
6	Distributed algorithms	2012
7	Poisson Point Process	2013
8	Queuing Theory	2013
9	Hungarian Algorithm	2014
10	Lyapunov Optimization	2014

D2D communication allows any two devices in the vicinity to communicate or interchange data between each other without a base station involved or with minimum BS involved using in a licensed bandwidth.Some of the popular integrated technologies of D2D communication include cognitive D2D, ultra dense network, and millimeter wave D2D.

4.1 Traffic offloading Techniques

D2D communication has hot topic now-a-days because of it benefits in offloading data traffic. Mobile data offloading enables us to use the complementary networks and innovative method in the transfer of data in cellular networks in order to avoid the congestion. The growth in average traffic per device, the data traffic problem arises, mainly due to increasing mobile network connections speeds and increased battery life in mobiles [10].

Wi-Fi offloading addresses the time-to-capacity issue for the additional network capacity. They are two types (i) on-the-spot , (ii) delayed. On-the-spot offloading uses spontaneous connectivity for Wi-Fi and data transfer on the spot and it has being used by many smart phones. In delayed offloading it is associated with deadline and whenever the getting in the average of Wi-Fi

is complete, the data transfer is resumed until the transfer is complete. The cellular network completes the transfer when the transfer does not finish within its deadline.

4.2 Co-Operative Communication In D2D Communication

Interestingly between nodes, outage probability and Mutual information uses cooperative communication in both AF(amplify and forward) and DF(decode-and-forward) mode.

The most relevant work includes (i) Energy efficiency (ii)Relay assignment (iii) Time spectrum allocation [11].

4.3 Energy Efficiency

It has two major different schemes in wireless sensor networks (i)virtual-MISO(multiple-input-single-output). (ii)Decode-and-forward [12]. The energy efficiency in wireless area network is less .The power allocation problem is analyzed with outage probability. The energy consumption is minimized by the consideration of taking amplifier power and circuit power in wireless sensor network due to demand of modern communication technology [13].

4.4 Relay Assignment

It assigns and develops a methodology to select the best relay based on instantaneous channel condition measurements, that the same diversity multiplexing trade off as protocols are coordination and distributed space time coding[14]. We should minimize the outage probability by proposing best relay selection based on the optimal power allocation algorithm.

4.5 D2D Protocols

The D2D device pair has several protocols like MAC, Packet convergence Protocol (PCP), extra PHY, and Radio Link Control (RLC) for direct communication [15].The encapsulation of LTE PDCP packet units(PDUs) into Wi-Fi to the D2D receiver should be done to give away a protocol stack which connects LTE and Wi-Fi direct protocols [16].

4.6 Network Security

Security is yet another important parameter that determines the success

of D2D services. A security enhanced D2D architecture using 3GPP LTE framework is presented in [17]. This paper also presents a survey on the network security techniques for D2D network.

5 Comparison of Various Technologies

Table 3 details a brief comparison of various wireless technologies. It mainly compares the five most relevant technologies with D2D communication technology. It is being compared in terms of seven most fundamental parameters like coverage area, frequency band, network topology, maximum data rate, etc.

Table 3. Comparison of various wireless technologies

NAME OF THE FEATURE	D2D COMMUNICATION	WI-FI DITRECT	ZIG-BEE	BLUETOOTH LOW ENERGY(BLE)	BLUETOOTH 4.0	ULTRA-WIDE BAND (UWB)
Standardization	3GPP LTE-Advanced	802.11	802.15.4	Wibree and BLEEE	Bluetooth SIG	802.15.3a
Transmission Coverage Area	10-1000m	200m	30 to 100 meter	10meter	10meter	<10 meter
Frequency band	Licensed band for LTE- Advanced	2.4 Ghz, 5Ghz	ISM	2.4Ghz	2.4Ghz	3.1 to 10.6Ghz
Network Topology			Mesh or Star	Star	Star	Star
Maximum Data Rate (bits/Sec)	1 G	250 M	250 K	1M	3-24 M	480 M
Uniformerly of Service provision	Yes	No	No	No	No	No
Applications	1. Cellular relay 2.Content Sharing 3. Public Safety 4.local Advertising	1.Device connection 2.Group Gaming 3.Content Sharing	1.Environmental Monitoring 2.Home Entertainment and Control	1.Small devices 2.Mobile terminals 3.Single mode chips 4.Dual mode chips	1.Object Exchange 2.Peripherals connection	1.High-Definition Video 2.Auto radar 3.precision Location and tracking systems 4.wireless USB

5.1 Open Issues

D2D communication is used in the cellular networks as a part in various applications. Figure 4 shows some of the applications of it.

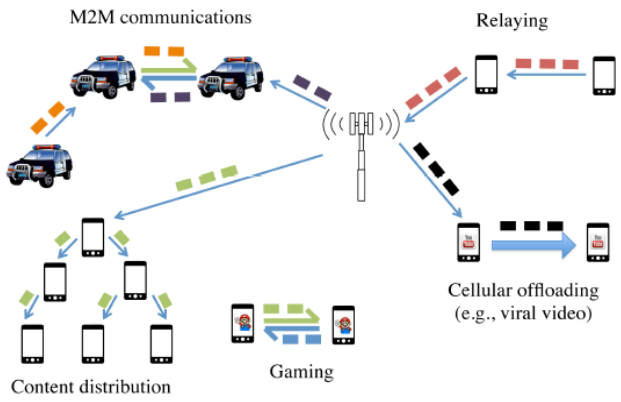

Figure 4. Applications of D2D communication in Cellular networks

The applications include machine -machine communication, content distribution, traffic offloading, gaming, location aware advertisement, etc. Some of the performance metrics to be improved and are considered as open issues. Some of the open issues are given below,

(i) Financial reasons: Due to some financial issues the D2D communication has not provided by the cellular networks. This will be changed by context aware and location discovery service.

(ii) Technical and Business issues: As D2D communication systems are being widely adapted in many practical scenarios. However, there are certain business and technical issues that are to be rectified in order to exploit the advantages of the D2D communication in cellular based systems.

(iii) Security: Security other prime factor that decides the success of the D2D communication system. Though it offers several benefits like minimizing communication delay, reducing power dissipation, etc. , several new techniques have to evolve to enhance the security in D2D communication systems.

(iv).Interference control: Controlling interference in a D2D communication is to be improved to very high extent as thre are very few techniques focusing on this issue. Improving interference control gives additional benefits of reduced communication delay, and improved spectral efficiency.

(v) Other issues: It include power control, interference management, Quality of service (Qos) etc...In future, new techniques and mathematical tools can be developed for D-2D communication which enhances the performance of cellular networks [18].It has a good scope for novel techniques like the data rate boosting and the latency reduction in D-2D communication based cellular networks.

6 Conclusion and Future Directions

Device-to-Device (D2D) communication is being a growing trend and most widely used in combination with cellular mobile networks. It enables devices in D2D network to interchange the data or communicate with each other without the support from fixed infrastructures in Cellular mobile communication. This paper has presented an overview of impact in cellular networks by the D2D communication. This survey has revealed the fact that in cellular networks, D2D communication has provided multiple techniques to solve various performance issues such as traffic off loading, synchronization, improving spectral efficiency of the cellular network, and reducing transmission delay. This makes a statement that in realizing 5G wireless networks,D2D communication will be a vital one or play a vital role.

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