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4G Advanced LTE Device to Device Communication for Connected Vehicle Application

Deepthy J [1]

Assistant Professor, School of Computer Science (PG), De Paul Institute of Science & Technology, Kerala, India[1]

ABSTRACT: In conventional cellular networks, users or devices are not allowed to transfer data directly even if they are adjacent to each other. All the communication must take place through the BS or base station which acts as an intermediary between devices. This reduces the spectral efficiency and delays the communication. For such scenarios and also in cases where cellular communication fails in emergency or disaster hit times, D2D or Device-to-Device Communication plays a pivotal role. D2D aims to provide spectral efficiency, increased throughput and reduced delay in information transfer. It is a hybrid technology encompassing cellular links and ad hoc links. D2D can either use cellular spectrum (inband or outband) or the unlicensed spectrum for establishing communication. This paper gives an overall idea about D2D communication, techniques to achieve device to device communication, the issues that arise when it is implemented using unlicensed frequencies, benefits of using cellular frequencies for D2D transfer and how it can be used to enhance the services in Vehicle to Vehicle Communication (V2V) using Internet of Things or IoT.

KEYWORDS: Device to Device Communication (D2D); Long Term Evolution; Internet of Things; Vehicle to vehicle; spectral efficiency; inband; outband

I. INTRODUCTION

Today, there has been a massive increase in the number of connected devices and applications that require enormous data rates. This has led to the need of refinement in the already available data rates. Device to device communication has emerged as an outstanding and innovative feature for next generation wireless networks. Device-to-device (D2D) communications was initially proposed in cellular networks as a new paradigm for enhancing network performance.. The studies showed that D2D communications has advantages such as increased spectral efficiency and reduced communication delay. However, this communication mode introduces complications in terms of interference control overhead and protocols [4]. IoT is not a new concept, it has been discussed since 1982, but with the advent of low cost sensors, ubiquitous wireless networking and machine learning, IoT's leap in device control & automation and communication is being felt immensely. When the components in an IoT system are vehicles, such a communication system is called Vehicle to Vehicle (V2V) communication.

Using D2D, devices can communicate directly without the centralized control of cellular base station. D2D communication allows communication between two devices, without the participation of the Base Station (BS), or the evolved NodeB (eNB) [1]. Proximate devices can directly communicate with each other by establishing direct links [1]. Due to the small distance between the D2D users, it supports power saving within the network, which is not possible in case of conventional cellular communication. It provides improvement in energy efficiency, throughput and delay. It has the potential to effectively offload traffic from the network core or the base station. Hence, it is a very flexible technique of communication, within the cellular networks [1]. D2D communications can be roughly categorized into two types. First category is one which uses unlicensed frequency band such as 2.4GHz to establish communication using Wifi or Bluetooth interface. For example, Bluetooth 5 supports a maximum data rate of 50 Mbps and a range close to 240 m, WiFi Direct allows up to 250 Mbps rate and 200 m range while LTE Direct provides rates up to 13.5 Mbps and a range of 500 m [3]. The second category deals with licensed cellular frequency band.

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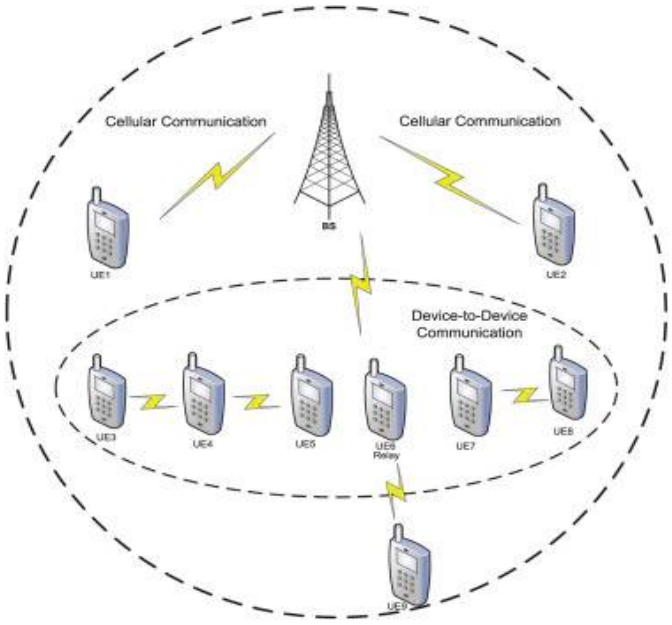

Fig.1. Cellular communication & D2D communication [3]

Fig.1 shows a traditional cellular system and a D2D system. It can be seen that even if the devices are in close proximity and are capable of direct communication, still all the information transfer must pass through the core network or the Base Station (BS). So by using direct Device to Device communication, we are able to greatly reduce the communication delay, increase spectral efficiency and data throughput.

II. RELATED WORK

There will be billions of connected devices in the near future [1]. Such a large number of connections are expected to be heterogeneous in nature, demanding higher data rates, lesser delays, enhanced system capacity and superior throughput [1]. Device to device communication will play a significant role in exchange of information between these "data-hungry" devices. In [12], authors explained that D2D is similar to Mobile Ad hoc networking with the exception that the former involves cellular network in the control plane. Related work can be arranged on the basis of steps taken to establish device to device communication [12]. In establishing a D2D session, there are mainly two steps. They are peer discovery and resource allocation. Interference management and security are yet other areas that need to be looked into. In [11], a low power peer discovery scheme is mentioned. It is done by making use of spatial correlation of wireless channels. Simulation results are a proof that peers could be discovered with very low power consumption and it provides a very accurate method of peer discovery. Peer discovery techniques can be any of the two types: restricted discovery and open discovery [8]. In case of restricted discovery, the user equipments or UEs cannot be detected without their prior permission. This ensures security and user privacy. In case of open discovery, UEs can be detected during the duration for which they lie in proximity of other UEs. From the perspective of the network, device discovery can be controlled by the base-station either tightly or lightly [14] [15].

The next major step after peer discovery is resource allocation. Since we live in a world where resources are very much constrained, we need to look upon techniques that would minimize the resource usage but at the same time provide ubiquitous connectivity. Resource allocation schemes could be either centralized or distributed. Centralized techniques [9] cause complexity in large networks while distributed techniques [4] tend to decrease the device complexity. Another technique for resource allocation is provided in [16], which maximizes the throughput of the network. The cellular services are given the higher priority over the D2D communication.

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The authors of [17] consider Device-to-Device (D2D) communication underlaying cellular networks to improve local services and throughput of the network. Cellular services were given prime importance over D2D communication. Performance was evaluated for both single cell and multi cell scenarios. Results prove that by proper resource management, D2D communication can effectively improve the total throughput without generating harmful interference to cellular networks [17].

III. D2D COMMUNICATION

Device to Device communication can use two techniques in order to form links between the User Equipments (UEs). It may use licensed frequency spectrum which is called inband or unlicensed frequency band ie outband. Inband is again classified into underlay and overlay types. In underlay, cellular and D2D share the same radio resources. In overlay, a portion of cellular resources from cellular is given for D2D communication. Underlay is more popular and efficient than overlay due to its high spectral efficiency. Inband is able to provide a transmission distance of upto 1km and data rate of around 1Gbps. Also in inband method, as radio resources are used by both cellular and D2D links, the same spectral resources are reused more than once within the same cell. This is called frequency reuse and it aids in increasing the spectral efficiency. There is no need to make modifications to the existing cellular infrastructure. The pre-existing structure would support services and improves current applications. In outband, communication occurs in the Industrial, Scientific, Medical (ISM) band. It aims to rule out the issues of interference among cellular and D2D links. Outband is classified into control and autonomous. When using controlled, the interfaces such as Bluetooth or Zigbee are controlled by the cellular network whereas in autonomous, these interfaces are controlled by the devices themselves. There occurs no issue of interference among cellular users and D2D users in outband however, data rates and transmission distance must be compromised.

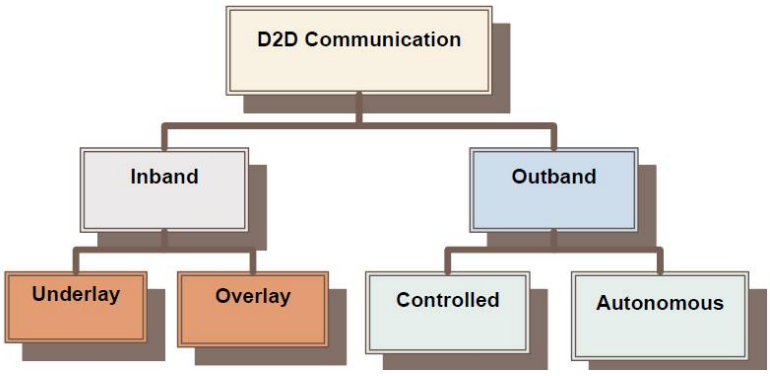

Fig. 2. Types of D2D communication [3]

IV. D2D Vs ADHOC

Ad hoc means for this purpose. As the name implies, ad hoc wireless networks are those which are formed temporarily for a particular data transfer. They are no longer present after the completion of that communication session. It is a self-configuring and decentralized type of network. As mentioned earlier, D2D can from links using either licensed or unlicensed spectrum. Here we analyze the advantages of using inband method or licensed frequency bands for forming direct links between devices in D2D communication. Although ad hoc and D2D networks are similar in ways by which they form a communication network without a centralized control, there are quite a lot of differences between them. Examples of wireless ad hoc networks are those formed by Bluetooth, WiFi etc. Let us take the case of Bluetooth and compare it with D2D communication using cellular frequency ie inband.

- Unlicensed band
  Bluetooth works in the unlicensed spectrum of 2.4GHz. This is not an issue when the number of devices in close proximity is low. But in today's scenario, there is a rapid proliferation in handheld devices and also in location based applications. Throughput and network performance would suffer in such conditions due to the interference among the devices using the ISM band of frequency.
- Security

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Another major drawback is regarding security. Compared to public cellular systems, Bluetooth is less reliable in terms of security provisions. They can't be relied upon in cases of public safety or emergency services.

- Pairing
  Bluetooth or WiFi requires manual pairing for devices to enable communication among them. This poses a serious threat when considering dynamic nature of connectivity of proximity services.
- Transmission distance and data rate
  Bluetooth offers only around one tenth of the transmission distance and data rate when compared to inband D2D communication. While D2D is able to attain a transmission distance of 1000m and a theoretical maximum data rate of 1Gbps, Bluetooth is only able to offer 10m of transmission distance and around 20Mbps.

V. D2D DISCOVERY

For device to device communication to take place, nodes or user equipments should discover devices that are in their vicinity. Since D2D is gaining popularity, the peer discovery process must be made efficient, quick and less power consuming. There are two types of peer discovery: restricted and open [4]. In the first case, devices cannot be discovered by the end users without their permissions. In the second case, devices can be discovered whenever they lie in the proximity of other users. From network perspective, peer discovery can be controlled *lightly* or *tightly* by the BS [4]. There is coordinated discovery and non-coordinated discovery. In non-coordinated discovery mechanism, a device sends pilot signals to its surrounding without any knowledge about the location of the intended peer. This is an energy consuming method. In coordinated discovery technique, devices have knowledge about the location of intended peers. This is achieved when devices which are willing to participate in D2D communication send a request to the network. The device may also specify the type of service it is interested in. Then the network will initiate the peer discovery process when a suitable peer comes in the vicinity of the requested device. There are many other proposals for peer discovery. In [5], authors have proposed a social-aware peer discovery technique. The scheme enhances the network performance by improving the data delivery ratio, using the social information only [1] [5]. An effective network-assisted technique for device discovery has been proposed in [6] for the support of device-to-device communication in LTE networks [1].

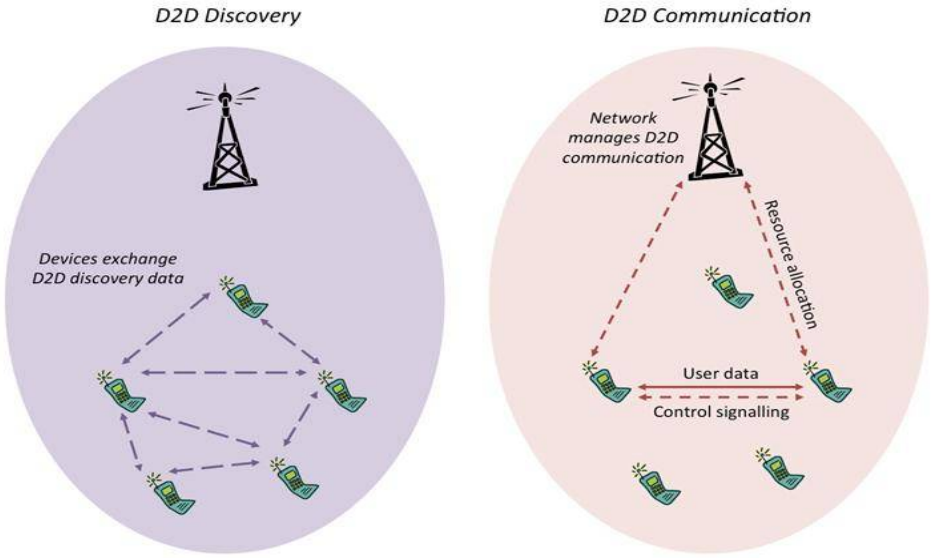

Fig.3. D2D Peer Discovery and Communication [1]

In fig.3, D2D peer discovery and communication are shown. Devices can discover peers without base station's intervention. Peers are able to start their data transfer session after obtaining radio resources. This is slightly controlled by the LTE core network.

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VI. D2D RESOURCE ALLOCATION

After device discovery, resource allocation for data transfer is the most important step in D2D communication. It should be done without adding interference to the system and at the same time increase the spectral efficiency. There are two types of resource allocation- centralized and distributed. When the size of network is large, centralized technique adds burden to the network. Distributed schemes offer freedom to the devices and make the network more scalable. For inband, a portion of spectrum from cellular frequencies is allocated for D2D communication. In the case of outband, D2D communication occurs through ISM band. D2D communication can operate in a number of modes [1]:

- Silent: Due to lack of resources, D2D devices cannot transmit and they remain silent.
- Dedicated: Resources are dedicated for D2D devices and they can transfer information.
- Reuse: D2D users can reuse the uplink and downlink frequencies of cellular users.
- Cellular: D2D users are assigned independent cellular frequencies.

When the D2D links and cellular links reuse the same resources, it is referred to as non-orthogonal sharing [1], and when they do not share the same resources, it is referred to as orthogonal sharing. Better resource utilization efficiency is achieved by non-orthogonal sharing [1].

VII. D2D FOR V2V

IoT or Internet of Things represents a system where all its components are equipped with sensors and they will be attached to the Internet via wired or wireless connections. These components can use either local area connections such as Bluetooth, Zigbee, RFID etc or they can have wide area connections such as GSM, 3G, LTE etc. D2D when integrated with Internet of Things (IoT) can present great improvement in the area of wireless communication. Device to device communication would become an integral part of IoT. Vehicle to Vehicle (V2V) communication is a system in which vehicles transmit data wirelessly. The goal of V2V communication is to prevent accidents by allowing vehicles in transit to send position and speed information to one another over an ad hoc network [9]. Depending upon how the technology is implemented, the vehicle's driver may simply receive a warning should there be a risk of an accident or the vehicle itself may take preemptive actions such as braking to slow down [9]. Thus, V2V has been proposed for road safety as they could send information regarding the speed and location about themselves to other vehicles. Nevertheless, using D2D underlay for V2V communications, if performed blindly, may cause significant degradation to system performance due to the interference introduced by resource reuse [10]. Also, to guarantee the required latency and reliability is still a challenge that needs to be tackled for V2V services. Hence, radio resource management (RRM) becomes a key design aspect to enable D2D-based V2V communications [10]

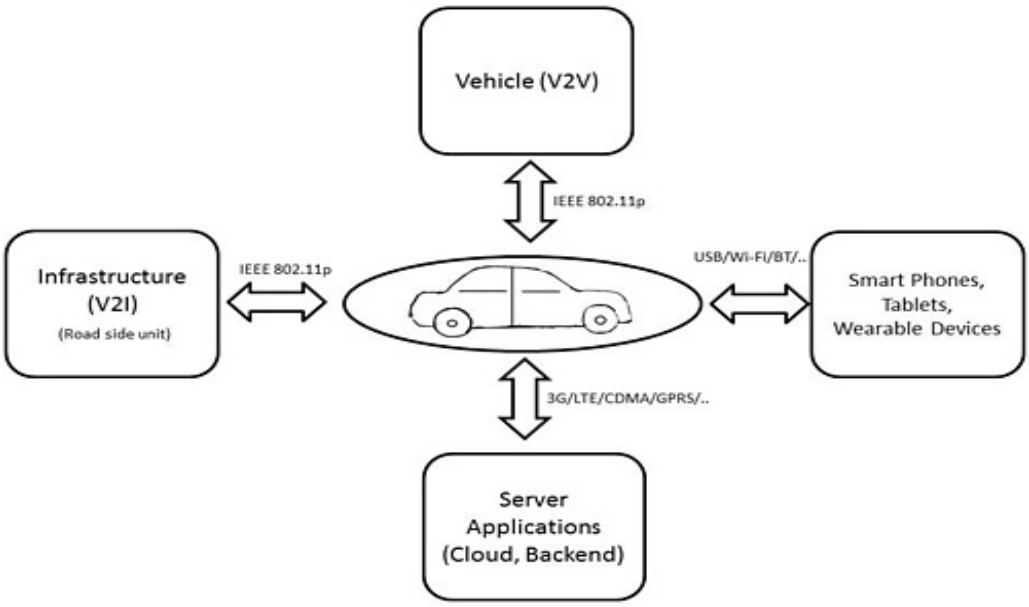

Fig.4. Connected Car system using D2D in V2V [11]

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Fig.4 shows a connected car system where consumer electronics including sensors are integrated into it and connectivity is ensured. Modern cars are able to exchange information with external sources through Bluetooth, WiFi, LTE networks etc. To establish seamless connectivity with outside world, a robust vehicle communication gateway along with communication inside the vehicle is very important.

VIII. CONCLUSION

Device to Device (D2D) communication has emerged as a new technology for enabling direct communication between user equipments. This proves to be very useful in situations of emergency when cellular communication fails. D2D can use cellular spectrum or unlicensed spectrum for forming links between devices. However, the issue of interference must be dealt with. The two steps involved in D2D communication are Device Discovery and Resource allocation. D2D can be used in conjunction with IoT to implement various applications. One such use case is Vehicle to Vehicle (V2V) communication where D2D can be used to avoid road accidents by alerting the users to coordinate braking system among vehicles.

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