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A Study on Device Discovery for D2D Communication

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Abstract: The next generation network, the future of wireless communication 5G, offers a wide range of techniques to improve the existing network characteristics. Among them, a dominant technology to improve the spectrum efficiency and throughput of a network is the Device to Device (D2D) communication. This enables the mobile devices in close proximity to communicate directly by reusing the channel allocated to the corresponding cell. It also improves the data rates, reduces latency and increases system capacity. Identifying the potential candidate for D2D communication is the first and most important step in setting up the D2D communication. In this paper a study on the latest mechanisms to implement device discovery for D2D communication in cellular network is done. Different aspects in three different perspective are presented here.
Keywords: Cellular System, D2D Communication, Peer Discovery, Interference.

I. INTRODUCTION

The boundary of communication is growing day by day through the evolution of wireless networks from analog to digital. The existing spectrum and other infrastructure are not being able to serve the massive requirement of in exponentially growing number of users. Along with this, the requirement of many applications, in the new generation hand-held devices, like multimedia and other applications introduced the demand of high data rates and uninterrupted services in the network. We can see the increase in data rate in various generations from 1G to 4G. But the demand of spectrum is a major issue in the later generations of wireless networks. The spectrum management was done with a careful channel allocation mechanism in these generations. There are many channel allocation strategies in a cellular network[1]. It can be Fixed, Dynamic or Hybrid channel allocation strategies. From a previous study it was found that a hybrid channel allocation (HCA) strategy is best suited for current network demands. In HCA a set of channels will be allocated to each cell initially and when all these channels are being used and a new request arrives, the cell takes channels from a common pool. After the connection is terminated the channel will be freed to the common pool of channels. We can see an exponential growth in the users of cellular networks with multiple devices or devices with multiple connections. Now a days the cellular phone is used primarily to access Internet and voice call is just an application in it, which is also becoming internet based. Now we are in the door step of 5G. We are expecting many technologies incorporated in 5G to serve the needs of above said situations. Among them device to device (D2D) communication[2] is one of the promising technologies to improve the spectral efficiency by reusing channels, data rates, reducing latency etc. In a cellular network, device to device communication enables mobile devices to communicate directly, if they are in close proximity as shown in Fig. 1.

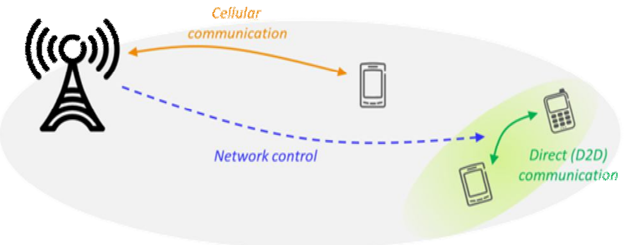

Fig. 1 Device to Device Communication [7]

The direct involvement of the base station is eliminated[3] in this mechanism.. It reuses the spectrum allocated in the specific cell itself. The most popular applications of D2D include public safety services, cellular offloading, vehicle-to-vehicle (V2V) communication, content distribution, etc. These various implementations are depicted in Fig 2. Earlier the D2D communication in an unlicensed spectrum was present in various wireless standards using infrared, Bluetooth or radio waves. While in the licensed spectrum, the implementation is difficult as the available spectrum is limited and which introduces the risk of interference between the limited channels in the licensed band. This introduces the need of careful planning of network topology while implementing the device to device communication. D2D communication was introduced as part of LTE - Advanced, which is the version of 4G standards. The device to device communication is mainly categorized into two. Underlay and Overlay communications. In the case of Underlay communication D2D User Equipments access resources occupied by cellular users, resulting in improved spectral efficiency. Underlay communication enhances the performance of cellular networks by reusing the resource blocks assigned to the cellular users by D2D transmitter for direct communication. It causes interference in cellular communication by D2D communication and vice versa. While In overlay communications, the part of the cellular spectrum is dedicated for D2D communication. This reduces the interference problem as both types of communications take place in their separate spectral bands.

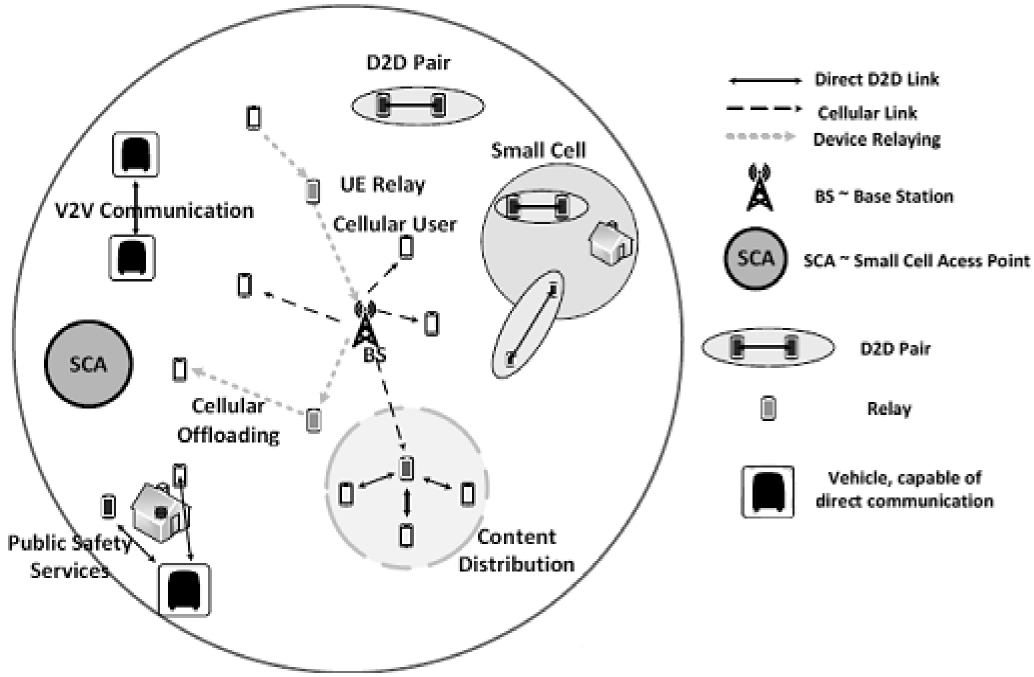

Fig 2 A General Scenario supporting device-to-device (D2D) communication [8]

Three scenarios are supported by D2D in the cellular network. They are;

1) *In-Coverage:* This scenario occurs when the User Equipment (UE) is within the range of eNodeB (eNB).
2) *Out of Coverage:* This scenario occurs when the UE is out of the coverage of eNBs.
3) *Partial Coverage:* This scenario occurs when some UEs are within the coverage of eNBs and some UEs are not.

The mechanism is composed of five aspects of networking namely, device discovery, mode selection, resource management, mobility and security[3][8]. The device discovery is done either centralized by the eNodeB or in a distributed manner by the mobile devices itself. Mode can be either cellular mode, where the mobile devices communicate through the eNB or the D2D mode where they communicate directly. The mode selection depends on the ability of the mobile devices and opportunity to establish a direct link between the mobile devices. Resource management is the major task in introducing D2D communication in a cellular network. Because, only through a careful resource allocation, stable D2D link are established. The major risk in a cellular network with D2D link is the chances of interference. In normal scenario the possible interferences are co-channel interference and adjacent channel interference. Introducing a minimum distance between channels which are of same frequency and using good channel filtering mechanisms are the conventional ways to manage the two types of interferences respectively. Mobile devices are dynamic in nature. It must be designed by considering the moving nature of the mobile devices. Since D2D links are distance depended the consistency of D2D links need special attention. In conventional systems, when the devices crosses a predefined threshold the D2D link breaks and the mode changes to the normal cellular link. The wireless communication is always susceptible to attacks. Here since the devices are communicating directly the risk is increasing. The genuinely of the connection initiating device cannot be verified in the normal scenario.

Among the above discussed aspects device discovery is the basic step of D2D communication establishment. Here in this paper a study is conducted on various device discovery mechanisms. The paper is organized as follows. Various device discovery mechanisms are discussed in Section II. An inference is drawn in Section III and the paper is concluded in Section IV.

II. DEVICE DISCOVERY IN D2D COMMUNICATION

The efficiency of device discovery process results in quick D2D link discovery and establishment. It also ensures optimum throughput, efficiency and resource allocation within the system. Establishing direct links for D2D communication requires devices to discover each other first. Once discovered, the next step is to set up direct links, and then occurs transmission over those links. Generally, device discovery in D2D communication can be categorized in two types (1) Centralized Discovery and (2) Distributed Discovery. In centralized discovery, devices discover each other with the help of a centralized entity or typically a eNB (Base Station). The device informs the eNB regarding its intention to communicate with nearby devices. The eNB initiates the message exchange between two devices to obtain essential information such as channel conditions, interference and power control policies based on the network requirements. The participation of the eNB during the device discovery process can be complete or partial based on the pre-configured suite of protocols. The distributed discovery approach allows the devices to locate each other without the involvement of eNB. The devices transmit the control messages periodically to locate the nearby devices. However, issues of synchronization, interference and power of beacon signal frequently arise in the distributed mode. There were many efforts put forward in order to find an optimal device discovery mechanism. Few of them are discussed below.

A. Asynchronous Device Detection

Bin Li *et al.* proposed an asynchronous device detection for D2D communication[4]. They claimed that coordination from eNB can affect the fallback publicity safety scenarios and the implementation of out-of-coverage applications. But the timing issues with a dynamic network set up arise when there is no central entity in the system. They have considered the combination of dynamic spectrum sharing (DSS) and D2D, known as cognitive D2D (C-D2D) focusing on the non-coordinated and asynchronous scenarios. In the conventional sensing approaches, the signal is first detected, and then the signal is estimated, but in their new scheme detection and estimation is jointly accomplished in order to make use of all statistic information available in received signals. They have adopted a new concept of random finite set (RFS). By unifying the binary existence of target signals and the associated state of object as one generalized random variable, RFS has become one powerful analysis tool to deal with object tracking problems. For spectrum sensing, a Primary User (PU) device will occupy a frequency band, while the Secondary User (SU) manages to identify whether this band is occupied and utilizes a Dynamic Spectrum Sharing strategy to avoid interference. If the band is unoccupied, a SU will access and talk with another proximity device; otherwise, it will sense another band. For direct device detection, a UE will sense the specific channel to find one potential device in proximity for data transmission. This process is also blind, in the case of out-of-coverage D2D scenario, as in spectrum sensing.

In this research work, they design a novel deep sensing paradigm to combat destructive effects from unknown Link Information States. The underlying dynamics of two unknown states are fully concerned, and a sequential Bayesian scheme is proposed, which acquires the varying timing drifts and fading channels when directly performing device detection. To solve the complex Mixed Detection and Estimation problem, the two-stage recursive estimation is implemented, and the particle filtering (PF) - based numerical approximation is further used to alleviate the computation complexity. Two types of timing drifts are considered and the detection/estimation performance is numerically evaluated. It is demonstrated that, by dynamically tracking unknown drifts and fading gains, the detection performance will be improved significantly, compared to the expectation-based likelihood method.

B. Unsupervised Indoor Peer Discovery

Nam Tuan Nguyen *et al.* proposed a novel approach for indoor peer discovery process[5], which is the enabler for indoor D2D communications in LTE networks. It is a coordinated mechanism with the eNB. They called their approach as ROOMMATEs, which is a middleware framework that integrates WiFi and LTE networks for enabling WiFi localization to assist the peer discovery of D2D communication in LTE networks. The approach provides two critical information for UEs, i) a suggested wireless signal power to reduce interference, and, ii) different granularity location information. It targets indoor D2D users to achieve a more stable connection among them. There are many problems with WiFi to use for D2D communication. Traffic cannot be offloaded through WiFi, there are many places where WiFi is not accessible, and WiFi operates on unlicensed bands and is not QoS guaranteed. Here the approach only uses WiFi scans. It is an unsupervised approach where it runs on the background of the UEs and automatically profiling rooms, setting up D2D connections between peers. ROOMMATEs aim to address the problems of WiFi scans for device discovery like noisy wireless environment, different hardware configurations, power consumption, missing data (missing at random and missing not at random), and device-to-device distance approximation. Here only a fraction of all UEs are invoked for D2D discovery, saving energy and convergent time drastically. It is a Lightweight online classification technique which reduces the power consumption.

The ROOMMATEs consists of three units, an Indoor Place Identification unit, a D2D Communications Unit, and eNodeB, functioning as a moderator between UEs. They claim that the mechanism substantially reduce mobile device consumed power and cross-device interferences. It also provides a mechanism to track UEs' locations precisely and unsupervisedly.

C. Energy-Efficient Device Discovery

Zeeshan Kaleem *et al.* proposed a D2D discovery maximization (D2D-DM) iterative algorithm[6], which provides the capability to switch the discovery mode from half-duplex to in-band full-duplex, when signal-to-interference-noise ratio falls below a predefined threshold. Here the authors considered an overlay communication scenario in D2D user discovery. Here the discovery resources repeat periodically in time domain after certain number of subframes. This work presents the system-level performance of an overlay D2D discovery scenario under the 3GPP long-term evolution (LTE) frame structure as recommended for half duplex (HD) and in-band full-duplex (IB-FD) modes. In HD mode, a user that transmits the beacon cannot listen to the beacon, whereas in IB-FD mode the user can transmit and receive beacon during the same time which in turn will increase the RBs utilization efficiency by simultaneously enabling UL and downlink beacon transmissions. Thus, Public Safety (PS) users can discover more users within less time during emergency situations in IB-FD mode. The HD to IB-FD mode switching scheme is also proposed to increase the number of discovered PS users. Apart from that they formulated the discovery success ratio maximization problem, by considering the remaining power and SINR threshold constraints.

III.CONCLUSIONS

In this paper apart from the simple proximity based device discovery, three different scenarios are considered. The first work deals with an un-coordinated scenario which is a common situation D2D links in out of coverage regions and safety critical application. Whereas the second work is dedicated for D2D communication in indoor scenario, which is a very common situation in organizations. Here basically WiFi scan is used for device discovery and other mechanism also can be incorporated. The third work mainly focuses on the energy efficiency of network setup while discovering the devices. The beaconing in HD and IB-FD modes are switched on demand for energy efficiency and identifying more peer devices. In any mechanism to manage the D2D establishment we can implement any of this device discovery technique for better performance by identifying more peers, better data rate, better energy efficiency and many more.

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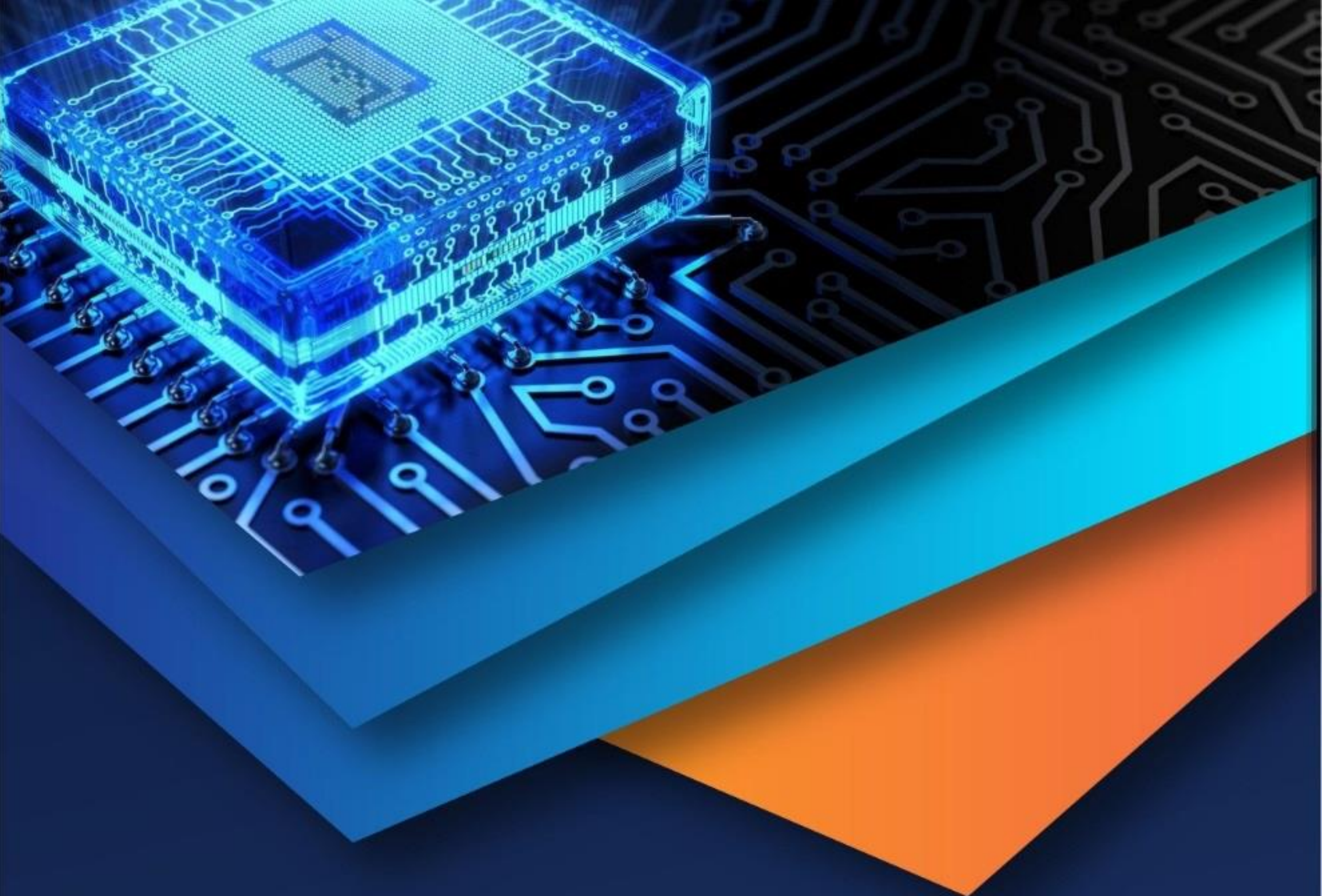

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