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Fifth Generation (5G) Network: Device to Device (D2D) Communication Interference Management

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Abstract: ***The new generation of the cellular network, Fifth-Generation (5G), is already in implementation. On this network, Device-to-Device (D2D) communication is allowed. D2D communication refers to direct communication between devices without data traffic going through any infrastructure node. D2D communication exposes some advantages for improving spectrum, communication delay, as well as the interference problem. D2D users can share the same spectrum with cellular users. The principal challenge in D2D communication in 5G network is interference management. To address this challenge, we propose a Time Division Multiple Access (TDMA) based cooperative Medium Access Control (MAC) protocol for multi-hop networks.***

Keywords: Fifth-Generation, Device-to-Device communication, Interference Management, Time Division Multiple Access, Medium Access Control

1. Introduction

In recent times, users' demand for higher data rates and capacity of the network is growing every day. The existing Fourth-Generation (4G) of cellular communication resources allocated and technology employed are insufficient to fulfill users' needs. 5G is a new generation of mobile networks, which is beyond Long-Term Evolution (LTE) mobile networks. With the predominance of smart terminals and explosive growth of network traffic, there is a more precise and more urgent need for evolution to 5G technology. In 4G technology, devices never communicate directly with each other. A Base Station (BS) has been included in the process. However, to reduce the burden on the BS, D2D communication is proposed as part of 5G. D2D communication allows communication between two User Equipments (UE), while D2D using an LTE air interface to establish a direct link without going through Evolved Node B (eNB) and possibly Core Network (CN).

Interference management is a frequent issue when D2D users share the same spectrum with cellular users. Nevertheless, D2D communication has many benefits as compared to the traditional cellular network such as traffic offloading and spectral efficiency. However, coexistence between D2D users and cellular users can cause harmful interference to each other. In this paper, we focus on interference management and TDMA-based cooperative protocol in multi-hop wireless mesh 90-=networks. The rest of the paper is organized as follows: section II introduces D2D communication type and architecture. Section III discusses interference management and neighbors discovery. Section IV gives the proposed cooperative MAC protocol, followed by concluding remarks in Section VI.

2. D2D Communication and Architecture

In this section, we present D2D communication types and architecture.

2.1 D2D Communication Types

There are four types of D2D communications, namely: Device Relaying with Operator-Controlled link establishment (DR-OC), Device Relaying with Device-Controlled link establishment (DR-DC), Direct Communication with Operator-Controlled link establishment (DC-OC), and Direct Communication with Device-Controlled link establishment (DC-DC), which are illustrated in Figure 1 [1]. In DR-OC type, a device is located at the edge of a cell with a BS, which is accomplished by relaying the information contained in it through other devices. In this way, the device can acquire a higher quality of service and greater battery life. Furthermore, the operator communicates with the relaying devices for partial and full control link establishment. In DR-DC, the source and destination devices coordinate between themselves and communicate with each other with the help of relays between them. The operator is not involved in the process of link establishment. Therefore, source and destination devices are liable for coordinating communication utilizing relays between each other. In DC-OC, the source and destination devices exchange data and communicate with each other without the need for a BS, though they are supported by the operator for link establishment. In DC-DC, the source and destination devices have direct communication with each other without any operator control. Furthermore, source and destination devices use the resource in such a way as to assure limited interference with other devices in the same tier and the macro cell tier.

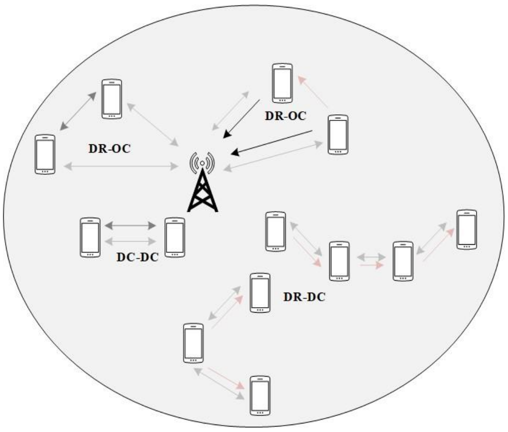

Figure 1: D2D Communication Types

2.2 D2D Communication Architectures

D2D communication allows proximity User Equipment (UE) to communicate with each other on a licensed cellular bandwidth without involving a Mobile Base Station (MBS) or with a very controlled involvement of an MBS. There are four application scenarios in the D2D such as in-coverage, relay- coverage, out-of-coverage, and reduce network traffic, as shown in Figure 2. Note that, in relay-coverage and out-of- coverage scenario, the devices may not be capable to build connections to the cloud server.

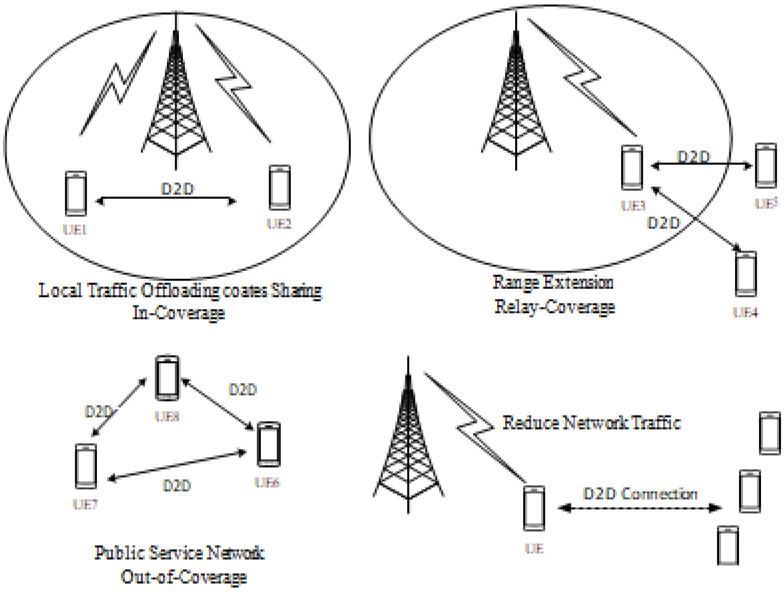

Figure 2: D2D Communication Architecture

3. Neighbor Discovery and Interference Management

In this section, we discuss neighbor discovery and interference management in D2D communication for 5G.

3.1 Neighbor Discovery

In the work in [2], the device in D2D uses the Up-Link (UL) and Down-Link (DL) resources for cellular communication. But in this paper, we expect that device discovery uses UL resources based on reusing the UL transmission chain according to [3]. To guarantee the best performance of device discovery, shared radio resources are suggested alternately with dedicated radio resources. D2D devices are interesting in the discovery. It helps in choosing Radio Resource Blocks (RRB) among the intermittent discovery radio resources. A case of the discovery period and RRB is shown in Figure 3. The D2D devices can transmit their discovery signal on their chosen RRB one time and tune for the reception of discovery signals from other D2D devices. During the discovery period, each D2D device takes an interest in the discovery procedure only, and other sorts of communications are not allowed. Each device surveys all RRB's received power level and selects the RRB which has the most reduced power level [4]. Several devices located far away can pick a similar resource, on the other hand, every device randomly chooses RRB resources for discovery signal transmission.

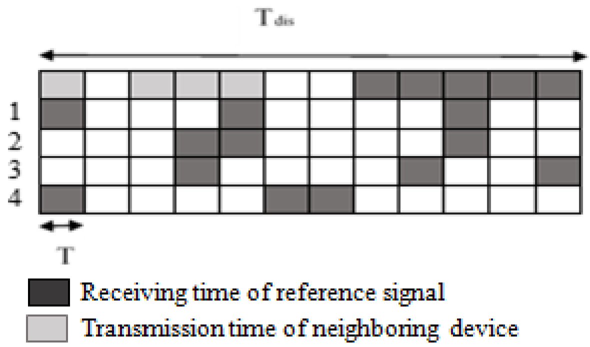

Figure 3: Receiving time of reference signal and transmission time of neighboring devices

We focus on a random choice because of the human mobility model [5]. There are two models for device discovery that depend on mobility such as haphazard walk and velocity models. The haphazard walk model does not depend on environment changes, whiles mobility depends on context and velocity, which might be unknown or partially known or measurable by some models [6]. The sensing-based determination is wasteful when the sensing outcomes are rapidly obsolete, for example, under a high-mobility situation. When two or more devices reuse similar discovery resources in the vicinity, a collision may happen because of the asynchronous transmission [7]. Accordingly, these neighboring D2D devices can neither distinguish each other nor be recognized because of mutual interference.

Looking at the demand of the D2D network, there should be an efficient method for discovering peers. This means a UE should be able to discover other nearby UEs quickly and with low power consumption. From the user perspective, there are two types of peer discovery techniques such as restricted and open. In restricted types, devices cannot be discovered by the end-users without their permission. In open types, devices can be discovered whenever they lie in the proximity of other users. From a network perspective, peer discovery can be controlled lightly or tightly by BS [8]. In a multi-cellular network, it is very difficult to get cooperation from adjacent BSs, making peer discovery a challenging job [9].

A system model for device discovery where R is the radius of a sphere made by the discovering device is shown in Figure 4. In our analysis, we define our extension of synchronous D2D device discovery, such that all D2D devices are in time synchronization and coverage area reference is obtained from the BS DL transmission. This significantly devours less energy and discovery time compared with asynchronous. For synchronous device discovery, each D2D device can be dynamic within a predefined discovery time, which shows up intermittently, such as D2D device occasionally awakes to achieve the discovery process employing the D2D RRB. After finishing the periodic discovery, D2D devices start dozing until the subsequent discovery period starts. When a D2D device has discovered a fancied target D2D device by accepting a signal, it can build up a D2D interface for direct communication. In cellular network topology, the transmission of mobile devices has been relied on base station [10].

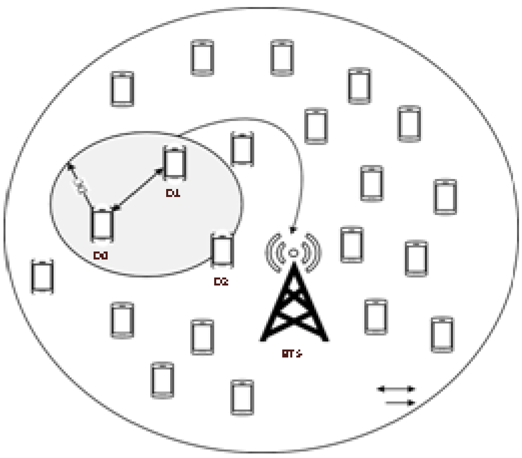

Figure 4: D2D signal and control signal.

If several cellular devices have a place with various cells or reuse a common resource in a cell edge, a cellular device signal interferes with the neighboring base station. Then again in D2D systems, there coexist numerous D2D devices which can be both receiver and transmitter. Under this topology, radiated signals from various transmitting D2D devices will reach the proximal D2D device's receiver. Note that several receivers are possibly presented to endure high interference by numerous D2D links. Admitting the quantity of D2D devices in D2D systems, the greatest number of D2D links is k (k − 1), which has a polynomial ratio [4].

3.2 Interference Management

There are some methods for interference management in 5G networks, which we give a summary. Nam et al. [13] proposed advanced receiver equipment to avoid interference in UE-side. This equipment aims to detect, decode, and remove interference from receiving signals. Additionally, the network-side interference is managed by joint scheduling, which selects each UE according to the resources needed such as transmission rate, time, frequency, and schemes of multiple cells. Joint scheduling is implemented in a centralized or distributed manner. It requires a coordination mechanism among the neighboring cells.

Hossain et al. [14] proposed distributed Cell Access and Power Control (CAPC) schemes for handling interference in multi-tier architectures. CAPC schemes include Prioritized Power Control (PPC), Cell Association (CA), Resource-aware CA, and PPC (RCA-PPC). Prioritized Power Control (PPC) assumes that UEs working under Small-cell Base Station (SBS) have a low-priority than UEs working under a Macro-cell Base Station (MBS), and hence, low-priority UEs set their power so that the resulting interference must not exceed a predefined threshold. CA considers dynamic values of resources, traffic, distance to a MBS, and available channels at a MBS for selecting a MBS with the optimum values of the parameters. Resource-aware CA and PPC (RCA-PPC), which is a combination of the first two methods, allows a UE to connect simultaneously with multiple BSs for the UL channel.

The authors in [2] measured the inter-user interference channel, and the allocation of UL and DL channels by an MBS, to mitigate inter-user UL-to-DL interference in a single-cell full-duplex radio network. In multi-cell full-duplex radio network case, interference mitigation becomes more complex, because of the existence of interference in UL and DL channels between multi-cells' UEs that work on identical frequency and time.

4. Proposed Scheme

As we have known, TDMA allows multiple users to access a single frequency channel without interference by allocating time slots to each user. Further, TDMA shares the available bandwidth in the time domain. Each frequency band is divided into several time slots.

In this work, we proposed MAC protocol, called Cooperative Relaying TDMA (CR-TDMA). CR-TDMA is a 802.11-based cooperative MAC protocol that increases aggregated throughput in a way that high data rate nodes assist low data rate nodes to forward their data packet. Furthermore, the CR- TDMA allows a packet that is pre-assigned to a busy relay node to be reassigned to a neighbor node with an empty queue, like a helper node. With the support of helper nodes, the relay node can process multiple packets during only one frame.

In CR-TDMA each node pre-selects a relay for cooperation and enables it to transmit simultaneously by using distributed space-time coding to obtain optimal network performance [11]. In [12], cooperation is executed in an idle slot which means that cooperation is available only if there exists a free slot. The proposed MAC protocol makes use of a control mini- slot to dynamically and efficiently allocate channel resources not only for direct transmission but also for cooperative transmission. Also, access priority is always given to cooperative transmission through an optimal relay node. The optimal relay is determined by fulfilling a timer-based-relay selection algorithm which is executed across nodes in a distributed manner.

The benefit of the proposed scheme is not only that the collision could be efficiently avoided but the relay selection time, which is generally not negligible could also be finished within the inherent time of the system, i.e., control mini-slot time.

5. Conclusion

In this paper, we studied D2D communication types and architecture, neighbor discovery, and some proposed solutions to avoid interference in D2D communication. Furthermore, we studied the CR-TMDA to manage the interference in D2D communication over 5G network. We concluded that CR- TDMA is a scheme that allows a packet that is pre-assigned to a busy relay node to be reassigned to a neighbor node with an empty queue. This has become a promising scheme to manage interference in D2D communication over 5G network.

6. Acknowledgment

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