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Review

Device-to-Device Communication in Cellular Networks: A Survey

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ABSTRACT

A constant need to increase the network capacity for meeting the growing demands of the subscribers has led to the evolution of cellular communication networks from the first generation (1G) to the fifth generation (5G). There will be billions of connected devices in the near future. 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. The available spectrum resources are limited and need to be flexibly used by the mobile network operators (MNOs) to cope with the rising demands. An emerging facilitator of the upcoming high data rate demanding next generation networks (NGNs) is device-to-device (D2D) communication. An extensive survey on device-to-device (D2D) communication has been presented in this paper, including the plus points it offers; the key open issues associated with it like peer discovery, resource allocation etc, demanding special attention of the research community; some of its integrant technologies like millimeter wave D2D (mmWave), ultra dense networks (UDNs), cognitive D2D, handover procedure in D2D and its numerous use cases. Architecture is suggested aiming to fulfill all the subscriber demands in an optimal manner. The Appendix mentions some ongoing standardization activities and research projects of D2D communication.

Contents

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1. Introduction

Today the number of hand-held devices is drastically increasing, with a rising demand for higher data rate applications. In order to meet the needs of the next generation applications, the present data rates need a refinement. The fifth generation (5G) networks are expected and will have to fulfill these rising demands. A competent technology of the next generation networks (NGNs) is Device-to-Device (D2D) Communication, which is expected to play an indispensable role in the approaching era of wireless communication. The use of D2D communication did not gain much importance in the previous generations of wireless communication, but in 5G networks, it is expected to be a vital part. The rising trends (Astely et al., 2013) pave way for this emerging technology. With the introduction of device-to-device (D2D) communication, direct transmission between devices is possible. This is expected to improve the reliability of the link between the devices, enhance spectral efficiency and system capacity (Chai et al., 2013), with reduced latency within the networks. Such a technique is essential for fulfilling the chief goals of the mobile network operators (MNOs).

D2D communication allows communication between two devices, without the participation of the Base Station (BS), or the evolved NodeB (eNB). Proximate devices can directly communicate with each other by establishing direct links. 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 promises improvement in energy efficiency, throughput and reduce delay. It has the potential to effectively offload traffic from the network core. Hence, it is a very flexible technique of communication, within the cellular networks.

Qualcomm's FlashLinQ (Wu et al., 2010) was the first endeavor towards the implementation of device to device (D2D) communication in cellular networks. It takes advantage of orthogonal frequency division multiple access (OFDMA) in conjunction with distributed scheduling for peer discovery, link management and synchronization of timings. Another organization involved in examining D2D communication in cellular networks is 3GPP (Third Generation Partnership Project) (3GPP, 2013a', 2014a', 2013b). D2D communication is under investigation by the 3GPP as Proximity Services (ProSe). It is expected to function as a public safety network feature in Release 12 of 3GPP. The task of standardization of device-to-device communication and the ongoing projects are briefly discussed in Appendix A and B. A next generation network scenario, supporting device-to-device (D2D) communication along with some general use cases is depicted in Fig. 1. The most popular use cases of D2D include public safety services, cellular offloading, vehicle-to-vehicle (V2V) communication, content distribution.

In spite of the numerous benefits offered by device-to-device (D2D) communication, a number of concerns are involved with its implementation. When sharing the same resources, interference between the cellular users and D2D users needs to be controlled. For this, numerous interference management algorithms have been proposed in literature. Other concerns include peer discovery and mode selection, power control for the devices, radio resource allocation and security of the communication.

1.1. Contributions

Existing surveys (Liu et al., 2014; Asadi et al., 2014) on device-to-device (D2D) communication provide an extensive literature on the various issues in D2D communication. The authors in Liu et al. (2014) comprehensively describe the state-of-the-art research work. on D2D communication in LTE-Advanced networks. In Asadi et al. (2014), the literature available on D2D communication is presented as Inband D2D and Outband D2D. This survey, on the other hand, draws upon the growing need for switching towards the device-to-device (D2D) technology. Architecture for device-to-device (D2D) communication has been proposed, which clearly depicts the scenario of the next generation networks (NGNs) and is the prime focus of this survey. It aims to aid the cellular networks in near future by allocating resources optimally to the D2D users in the network and the cellular users as well, with the use of sectored antennas at the base station (BS). Such architecture has the potential to efficiently serve the rising demands of the subscribers and meet the requirements of the network operators. Additionally, a mathematical analysis has been discussed, which is the basis of any resource allocation technique, for analyzing network throughput. Number of features can be integrated with D2D communication, to enhance its utility in existing cellular systems. These have been discussed in this survey. A number of challenges exist, pertaining to the implementation of device-to-device (D2D) communication. Few important algorithms in relation to these issues have been discussed. Thus, focus of this survey is to brief about different aspects of D2D communication.

The organization of the survey is as follows: Following the introduction, a roadmap to D2D communication has been presented in Section II. An overview of device-to-device (D2D) communication has been presented in Section III. The various features which can be integrated with D2D communication to further enhance their utility and performance in cellular networks are discussed in Section IV. Incorporating D2D communication in existing cellular networks engenders a number of challenges, which have been discussed in Section V. Architecture has been proposed in this section, to overcome the issue of radio resource management. Since the architecture uses sectored antennas at the base station, interference between D2D users and cellular users within the networks is overcome to a large extent. In the next generation networks, a number of applications are expected to be supported by D2D communication, and are discussed in Section VI. Lastly, the paper concludes in Section VII.

2. The roadmap to device-to-device (D2D) communication

Telegraphy was demonstrated by Joseph Henry and Samuel F.B. Morse, in 1832. In 1864, James Clerk Maxwell postulated wireless propagation, which was verified and demonstrated by Heinrich