D2D COMMUNICATIONS IN LTE-ADVANCED CELLULAR NETWORKS

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Abstract: The Long Term Evolution-Advanced (LTEAdvanced) networks are being developed to provide mobile broadband services for the fourth generation (4G) cellular wireless systems. Device-to-device (D2D) communications is a promising technique to provide wireless peer-to-peer services and enhance spectrum utilization in the LTE-Advanced networks. In D2D communications, the user equipments (UEs) are allowed to directly communicate between each other by reusing the cellular resources rather than using uplink and downlink resources in the cellular mode when communicating via the base station. However, enabling D2D communications in a cellular network poses two major challenges. First, the interference caused to the cellular users by D2D devices could critically affect the performances of the cellular devices. Second, the minimum quality-of-service (QoS) requirements of D2D communications need to be guaranteed. In this article, we introduce a novel resource allocation scheme (i.e. joint resource block scheduling and power control) for D2D communications in LTE-Advanced networks to maximize the spectrum utilization while addressing the above challenges. First, an overview of LTE-Advanced networks, and architecture and signaling support for provisioning of D2D communications in these networks are described. Furthermore, research issues and the current state-of-the-art of D2D communications are discussed. Then, a resource allocation scheme based on a column generation method is proposed for D2D communications. The objective is to maximize the spectrum utilization by finding the minimum transmission length in terms of time slots for D2D links while protecting the cellular users from harmful interference and guaranteeing the QoS of D2D links. The performance of this scheme is evaluated through simulations.

1.INTRODUCTION:

With increasing demand of high data rate wireless access for multimedia services, the Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) has been proposed to develop new technology components that can meet the requirements of IMT-Advanced systems. International Mobile Telecommunications-Advanced (IMT-Advanced) systems are mobile broadband communication systems which offer high bandwidths up to 100 MHz to support a wide range of services (e.g. multimedia services). One of the main issues in IMT-Advanced systems is how to improve the local-area services and spectrum efficiency. Device-to-device (D2D) communications enable short-range ad-hoc networks underlaying the cellular networks by sharing the same radio resources. D2D communications technology is a promising add-on component to LTE-Advanced systems for enhancing spectrum utilization, increasing the cellular capacity, improving the user throughput, and extending the battery lifetime of UEs.

The concept of D2D communications underlaying an LTE-Advanced network is shown in Fig. 1. Instead of using uplink and downlink resources in the cellular mode, a direct connection between UEs is allowed through peer-to-peer communications. Some example applications of D2D communications are multimedia downloading, video streaming, online gaming, and peer-to-peer (P2P) file sharing. Recently, wireless local-area network (WLAN) technologies (e.g. based on the IEEE 802.11 standards) and wireless personal-area network (WPAN) technologies (e.g. Bluetooth, Ultra Wideband [UWB] technologies) have been increasingly used because they provide Internet access and local services with low cost and fast access through the license exempt bands (e.g. industrial, scientific and medical [ISM] radio bands). However, communications on a licensed band of a cellular network can be better in terms of interference avoidance under a controlled environment. Moreover, the local services through the above-mentioned techniques require users to manually pair the peers or connect to the access points. Therefore, D2D communications could be more convenient for users because the base stations (BSs) can handle the pairing and provide better user experiences. Although D2D communications provide several benefits for local-area services in cellular networks, the extensive use of D2D communications can cause harmful interference to cellular users when sharing the same resources and also may not satisfy the quality-of-service (QoS) requirements of D2D and cellular users. In this article, we deal with the problem of resource allocation (i.e. joint resource block...
scheduling and power control) for D2D communications underlaying LTE-Advanced networks. First, an overview of the LTE-Advanced networks is given and the integration of D2D communications into the LTE-Advanced networks is discussed. The major research challenges and the current state-of-the-art of D2D communications are then described. Then, a resource allocation algorithm is proposed for D2D communications in LTE-Advanced networks. The objective is to maximize the spectrum utilization (i.e. minimize the transmission length in terms of time slots) subject to the interference constraints for cellular users and the QoS requirements of D2D links. Due to the NP-completeness of the problem (as will be discussed later in this article), we propose a column generation method to obtain the near-optimal solutions with low complexity.

2. D2D COMMUNICATIONS IN LTE-ADVANCED NETWORKS:

D2D communications enable fast access to the radio spectrum with controlled interference levels. With underlay spectrum sharing, D2D communications can enhance the spectrum efficiency and network throughput which are two important requirements for LTE-Advanced networks. D2D communications engage four types of gains [4]. The first gain is **proximity gain**, where the short range communication using a D2D link enables high bit rates, low delays, and low power consumption. The second gain is **hop gain**, where D2D transmission uses one hop rather than two hops (i.e., communicating via a BS in which case both uplink and downlink resources are used). The third gain is **reuse gain**, where D2D and cellular links can simultaneously share the same radio resources. The last gain is **pairing gain**, which facilitates new types of wireless local-area services and a UE can select either cellular or D2D communication mode. Furthermore, [5] suggested that the overall throughput in the network with D2D communications may increase up to 65 percent compared to the case that all the D2D traffic are transmitted through the cellular mode. Also, the D2D operation can be fully transparent to the users and manual pairing or access point definition is not required like WLAN or Bluetooth. The cellular network conceals the complexity of setting up the D2D connection from the users. To enable D2D communications in the LTE-Advanced networks, [5, 6] proposed two mechanisms of D2D connectivity based on Session Initiation Protocol (SIP) and Internet Protocol (IP). LTE systems with System Architecture Evolution (SAE) employ these protocols to operate fully in the packet-switched domain. In the SAE architecture, the mobility management entity (MME) works together with the Packet Data Network (PDN) gateway to take care of the UE context, setting up the SAE bearers, IP tunnels and IP connectivity between the UEs and the serving PDN gateway. A D2D session can be initiated either via the serving PDN by detecting the potential D2D traffic, or via the users or applications directly by selecting the SIP Uniform Resource Indicator (URI) format with a local extension, such as .direct, .local, .peer, or .short, with the URI of the destination UE. To set up a D2D session, the evolved Node B (eNB, is equivalent to the base transceiver station) requests the UE units to check whether both UE units are in the communication range and D2D communication provides higher throughput or not. If these criteria are met, the eNB sets up a D2D bearer for the direct communication between the two UE units. The eNB still maintains the SAE bearer between the UEs and the gateway for the cellular communication mode and control the radio resources for both cellular and D2D communications. The UEs can then transmit packets using the IP address of the peer UE via the D2D connection without the eNB or SAE gateway being involved in routing.

3. RESEARCH ISSUES AND CHALLENGES FOR UNDERLAYING D2D COMMUNICATIONS IN LTE-ADVANCED NETWORKS:

This section describes some challenges and research issues in D2D communications as an underlay in LTE-
Advanced Networks. In the next section, we will review the current state-of-the-art approaches to deal with some of these challenges.

**MODE SELECTION**

1. TRANSMISSION SCHEDULING
2. POWER CONTROL AND POWER EFFICIENCY
3. DISTRIBUTED RESOURCE ALLOCATION
4. COEXISTENCE WITH HETEROGENEOUS NETWORKS
5. COOPERATIVE COMMUNICATIONS
6. NETWORK CODING
7. INTERFERENCE CANCELLATION AND ADVANCED RECEIVERS
8. MULTIPLE ANTENNA TECHNOLOGY AND MIMO SCHEMES
9. ROBUST RESOURCE ALLOCATION
4. CONCLUSION:

We have presented an overview of D2D communications in LTE-Advanced cellular networks and discussed the related research issues. We have proposed a resource allocation scheme for D2D communications underlaying a cellular network. This joint resource block scheduling and power control scheme considers maximizing the spectrum utilization while addressing two crucial issues in D2D communications which are interference to cellular devices and QoS provisioning for the D2D links. The performance evaluation results have shown that our proposed scheme can increase the spectrum utilization (i.e. reduce the transmission length) considerably by scheduling multiple D2D links to spatially reuse the same resource block. Although the overall transmission power increases with increasing spectrum reuse, the proposed scheme can significantly decrease the transmission length. Overall, it improves the spectrum utilization significantly with small increase in power consumption especially when the number of D2D links in the network is large. In our future work, the proposed methodology will be extended for a hybrid of dedicated and reuse mode for resource allocation depending on the density of D2D devices.

REFERENCES