International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 4 Issue 3, March-2015, pp: (33-35), Impact Factor: 1.252, Available online at: www.erpublications.com

Device to Device Communication

Avi Kandhol
RIMT Chidana, Sonipat, Haryana

Abstract: In this paper, we introduce two innovative concepts which have not been present in cellular systems for IMT-Advanced so far: Device-to-device (D2D) communication and network coding. Both of them are promising techniques to increase the efficiency of cellular communication systems, especially from a network point of view. First, we study the potential gains from D2D communication as an underlay to the downlink of a cellular network in an interference limited multi-cell indoor scenario. Our results show that multi-antenna receivers are required to achieve sufficient SINRs that allow device-to-device communication when the D2D connections re-use cellular resources within the cell. Then we investigate applying network coding for cooperative transmission and relay-based communications in networks. For the cooperative transmission, we propose to combine wireless diversity and the capability of increasing max-flow of network coding. We show designed non-binary network codes can substantially decrease outage probability and frame error rate (FER). For the relay based networks, we propose a novel network coding protocol applied to uplink cellular traffic protocol with an efficient decoding approach at the receiver.

INTRODUCTION

Future wireless cellular networks (IMT-advanced) are essentially characterized by high speed, large capacity and a high QoS for millions of subscribers. Next to high throughput, the energy efficiency is an important target to enable broadband wireless access for battery driven handheld devices. In this paper, we discuss two independent but related technologies: device-to-device (D2D) and network coding. Both of them are aimed to increase energy-efficiency and QoS of wireless networks. Contrary to competing D2D technologies like Bluetooth and WiFi, cellular D2D communication can give local service providers access to licensed spectrum with a controlled interference environment to avoid the uncertainties of the license exempt band when making investment decisions.

The design of an efficient device-to-device communication mode as underlay to a cellular network is a key problem to be solved. we have investigated the sum rate optimization of D2D and cellular communication in a single cell scenario. By utilizing power optimisation and optimal mode selection the sum rate increases sevenfold for a D2D connection separated by 10% of the cell radius. The sum rate increase is still threefold when giving a rate guarantee to the cellular user.

In this paper we extend the scenario to an interference-limited multi-cell indoor scenario and study D2D communication sharing the downlink with the cellular network. Reusing the downlink resources is more challenging than reusing uplink resources since the cellular receiver can be anywhere in the cell. We study the achieved signal-to-interference plus noise ratio achieved for the D2D links with limited degradation to the cellular network. The D2D communication between terminals is an enabler of terminal cooperation through network code.

Network coding (NC), as a new class of information processing and transmission techniques, is currently emerging in multi-hop or multi-user wireless networks. Comparing to traditional routing techniques, network coding allows information processing in the intermediate nodes. Performance gains in e.g., energy-efficiency, fairness, robustness, or coverage are obtained.

In this paper we investigate applying network coding for user cooperation and for relay based communications in cellular networks. For user cooperation, we propose to combine wireless diversity and the capability of max-flow achieving of network coding. We show carefully designed non-binary network codes can substantially decrease outage probability/frame error rate (FER), for multiple-user cooperative communications. The performance is significantly better than that of binary network codes.

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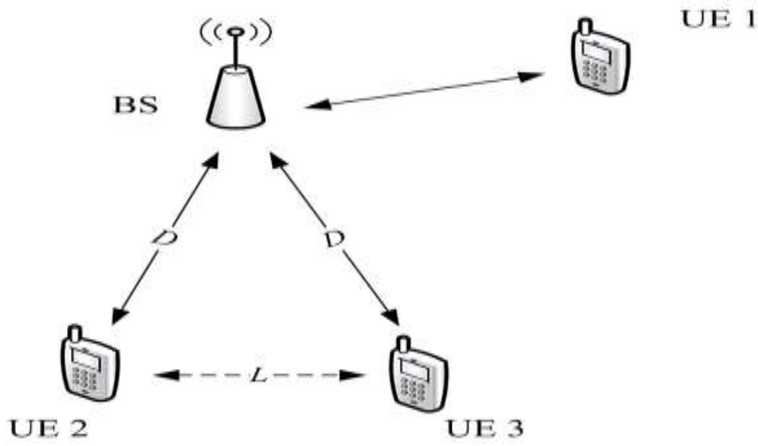

Fig. 1: D2D communication reusing cellular resources.

2. DEVICE TO DEVICE COMMUNICATION AS UNDERLAY TO AN LTE - A NETWORK

Device to device (D2D) communication as an underlay to an LTE-A cellular network operation is illustrated in Figure 1. UE2 and UE3 are engaged in direct device to device communication, while UE1 communicates with the BS. Both the cellular network and the D2D communication use the same resources.

The BS is in control of the OFDMA resource blocks that are used by UE2 and UE3 for D2D communication. In particular we study D2D connections that reuse cellular downlink resources, i.e. the D2D transmitters transmit on the same resources as the cellular BS and generate interference to the receiving UEs in the cell. The performance of the D2D connections is evaluated in an interference limited multicell scenario illustrated in Figure 2. The scenario captures the characteristics of indoor environments with small rooms, representing stores or offices, a larger open area and longer rooms representing, for example corridors. We consider the downlink of a synchronized

LTE-Advanced cellular network operating on a 100 MHz band using time division duplex (TDD). The 100 MHz band is split into five sub-bands of 20 MHz to keep backward compatibility with LTE Release 8.

One cellular UE and one D2D communication pair is assigned to each sub-band and transmit and receive on the whole sub-band. The D2D terminals forming the connectionpair are generated at random positions, with the restriction that they must be located in the same room. We utilize the interference-aware sub-band allocation in [8] that maximizes the minimum pathloss between cellular receivers and D2D terminals within a cell to provide some separation between D2D and cellular receivers. The separation can be utilized to increase the D2D power without harming the cellular communication. The D2D transmit power is set to a value that keeps the signal to interference plus noise ratio (SINR) degradation of the cellular downlink receiver below 3dB at the 10 percentile of the cellular downlink SINR cumulative distribution function. The numerical results in Section 4 show the achievable SINR for D2D connections with two antenna receivers.

Special Issue on Device-to-Device Communications in Cellular Networks

Device-to-device communications may have advantages such as:

1) improved performance for devices;
2) improved spectrum reuse and system throughput;
3) offloading in cellular networks;
4) improved energy efficiency;
5) extended coverage;
6) creation of new services.

It also poses new problems and challenges. A issue is how to share resources dynamically (e.g. spectrum and energy) between cellular communication and ad hoc D2D communication to accommodate larger volumes of traffic and to provide better service to users. Other challenges include: identification of services for which D2D communication is useful; radio resource allocation and resource management; self-organizing direct links; proximity-based offloading, and capacity evaluation and performance comparison.

The special issue addresses research advances that enable D2D communications in cellular networks. The goal is to report on the most up-to-date contributions in this area. Device-to-device communication must be central to all topics that include, but are not limited to, the following.

- Power and interference management
- Proximity-based detection and offloading
- Self-organizing device discovery
- Cognitive and cooperative D2D communication
- Device vs operator controlled link establishment
- Link management and mode selection
- Capacity analysis and energy efficiency evaluation
- Group communication and broadcasting
- Multi-hop D2D communications
- Quality improvement for real-time applications
- Channel measurements and modelling
- Mobility measurements, modelling and management
- New services and applications

CONCLUSIONS

Visualising traffic information for assisting the driver is a highly relevant topic for successfully integrating Device to device(D2D) communication services into the automotive domain. In the framework of this thesis, a driver assistance system named D2D location manager has been designed and implemented as an Android application. The system provides the user with traffic information from two different sources: it is able to receive and analyse messages from D2D communications (notably from Cooperative Awareness Messages (CAMs) and Decentralized Environmental Notification Messages (DENMs)) and generate warnings if appropriate. If activated a message receiver service runs as a background thread all the time. In this case warnings could be adapted to prevent an information overflow under difficult traffic situations. Modern applications could more and more use these techniques to further increase traffic safety and driving convenience.

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