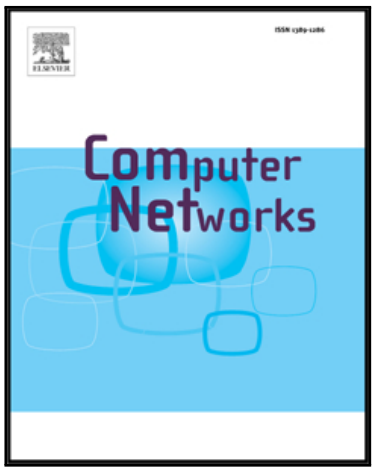

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Opportunistic Network Coding Based Cooperative Retransmissions in D2D Communications

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Abstract

Device-to-Device (D2D) communications can improve the performance of the next generation cellular networks by facilitating the transmission of cellular traffic without additional infrastructure. In D2D communications, cooperative retransmission can be employed to assist the recovery of lost packets at proximity devices by sending coded packets. However, most existing work did not consider the issue of how the transmissions among neighbor devices can be well scheduled to support efficient network coding based retransmissions. Decoupling transmission scheduling from coding decision making can lead to inefficient D2D packet retransmissions and thus reduced overall network performance. In this paper, we study how to use opportunistic network coding based transmission scheduling to assist the cooperative packet recovery in D2D environment. For this purpose, we first formulate the problem of jointly optimization of transmitting device selection and also their coding patterns as minimum latency scheduling problem, which is known to be NP-hard. We further present a low complexity centralized algorithm and a distributed mechanism that does not require synchronization (either global or local) among devices. We derive the complexity of the proposed algorithms. Simulation results show that the performance of centralized algorithm is very close to the theoretical lower bounds and the distributed mechanism can achieve high performance in accelerating packet recovery.

Index Terms

Network coding; D2D; Cooperative communications.

1 INTRODUCTION

Recently, the explosive growth of smart phones has led to exponential increase of cellular traffic. According to a recent report of Bell labs [1], mobile traffic is increasing 25 times from 2011 to 2016. Therefore, to offload the heavily used cellular systems without deploying additional infrastructure, Device-to-Device (D2D) communications has been identified as a key technology for the 5th generation (5G). D2D communications is defined as direct communication between two mobile devices without traversing a Base Station (BS) and can occur on cellular spectrum (i.e., inband) or unlicensed spectrum (i.e., outband). However, due to the natures of shared wireless channel and half-duplex transmissions, in D2D environment, sending sequences or scheduling algorithms will have big impact on the overall network throughput performance. Thus, the information exchange among a set of D2D devices still faces scheduling problem.

For many cellular services, the same content (e.g., a *batch* of packets) is to be disseminated simultaneously from a BS to multiple devices and each device should receive all the packets in the batch with minimum latency. However, packet losses and thus retransmissions are inevitable at mobile devices due to different channel conditions experienced by different devices. In conventional cellular systems, packet retransmissions are usually done by the BS, which may lead to more retransmissions if the quality of the links between some devices and the BS suffers from deep fading. It will take a long time for the BS to disseminate the entire batch of packets correctly to all devices in that case. Due to this concern, cooperative retransmissions [2] has attracted great attention such that some devices that have received certain packets in the batch can retransmit these packets to those devices that failed to receive them to avoid using the deep fading link of BS. The latency of the batch dissemination time will be largely reduced as a result. Fig. 1 illustrates the idea of D2D communications and cooperative retransmission.

Recently, opportunistic network coding has demonstrated a wide range of applications for improving the performance of wireless networks. It is well known that opportunistic network coding can reduce the total number of transmissions by mixing different packets into a single transmission. Fig. 2 gives a typical example showing how opportunistic network coding decreases the total number of transmissions, wherein each node equips an omnidirectional antenna. In the example, nodes n_1 and n_3 try to send packets pkt_1 and pkt_2 to each other, respectively, via a common relay node n_2. After n_2 receives both pkt_1 and pkt_2, it will generate a new coded packet by performing "pkt_1 XOR pkt_2" and then broadcast it. Upon receipt of the new coded packet, both n_1 and n_3 can get their wanted packets by using the packet information that they stored, respectively. In this way, the number of transmissions is re-