Performance Analysis of Network Coding Schemes in Network Assisted D2D Communications

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***Abstract*—Network assisted device-to-device (D2D) communication can increase the spectrum and energy efficiency of proximity communication sessions in cellular networks. For cellular networks supporting D2D communications, network coding (NWC) has been proposed as a means to further increase the spectral and energy efficiency. Specifically, 2 time slot (2-TS) NWC has been shown to be a viable complement to D2D capable cellular networks. In this poster, we consider a 3-TS NWC scheme as an additional technique and propose an adaptive mode selection algorithm that is able to select between D2D mode without NWC, traditional cellular transmission, 2-TS NWC and 3-TS NWC. We use a realistic system simulator and show that the system with the extended NWC capability and mode selection outperforms existing D2D mode selection algorithms.**

I. Introduction

Device-to-device (D2D) communication in cellular spectrum assisted by a cellular network enables direct communication between pieces of user equipment (UE). The advantages of D2D communication over traditional cellular transmission include not only the proximity gain in terms of improved link budget, but also the so called reuse and hop gains [1]. Recognizing the potential of D2D, the research community has proposed efficient scheduling, resource allocation, and power control algorithms that help realize the gains of local communications, while at the same time protecting the cellular layer from interference caused by local traffic. Recognizing the potential, the 3GPP has recently launched a work item to specify the technology components of incorporating D2D communications in long term evolution advanced (LTE-A) networks [2].

Physical layer network coding (NWC) improves the spectrum efficiency by facilitating resource reuse by multiple transmissions and taking advantage of advanced signal processing techniques [3]. This form of NWC (sometimes referred to as 2 time slot, 2-TS NWC) uses only 2 orthogonal resources to facilitate bidirectional communication between two user equipment and is therefore comparable to establishing a direct D2D link. Despite the obvious differences between cellular network-integrated D2D and NWC technologies, both aim to improve spectral efficiency and increase network capacity by enabling tighter reuse of resources. 3-TS NWC (Figure 1) has emerged as a technique that can potentially take advantage of network coding in terms of reducing the number of required orthogonal resources for bidirectional proximity communications but at the same time allowing for decoding at the relaying node and thereby improving the end-to-end signal-to-noise-and-interference-ratio (SINR) [4].

This work has been partially performed in the framework of the FP7 project ITC 317669 METIS.

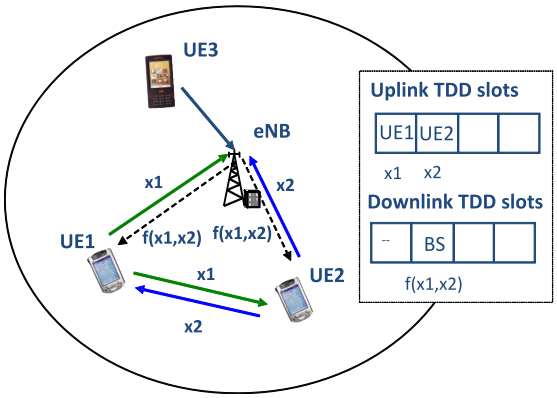

Fig. 1. D2D and NWC technologies integrated in a cellular network using 3-TS NWC. In uplink TS-1, UE1 transmits x_1. In uplink TS-2, UE2 transmits x_2 and finally in downlink TS-3, the eNB transmits the network coded data $f(x_1, x_2)$.

II. Signal Model

Introducing NWC in cellular networks that support D2D communication is non-trivial, because various forms of NWC require different forms of measurement and signaling support and it is not well understood which forms of NWC are advantageous in terms of increasing the spectral and energy efficiency of LTA-A networks. Therefore, in the current poster paper, we explore the application of various forms of NWC (Figure 2) in cellular networks and report system simulation results that provide insights in the application of NWC and D2D technologies in evolving cellular networks.

The signal models for the various forms of NWC and D2D (direct) transmission are summarized by Figure 3, that also shows the presence of interferers that must be taken into account in the end-to-end SINR analysis.

III. Numerical Results

To gain insights in the performance of D2D and NWC integrated in cellular networks, we consider the following transmission modes:

- D2D: Direct transmission between two user equipment within the coverage area of a cell;

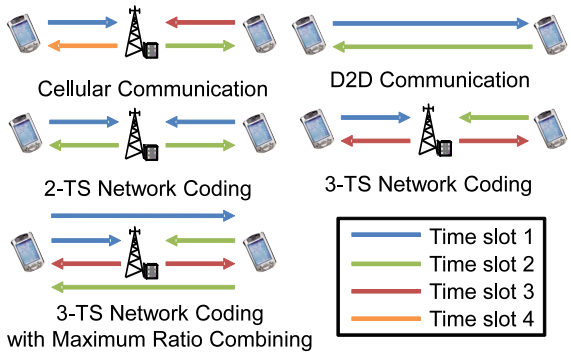

Fig. 2. An overview of the available transmission modes for proximity communications. The fifth transmission mode (3-TS NWC with maximum ratio combining) integrates D2D and NWC in a joint scheme.

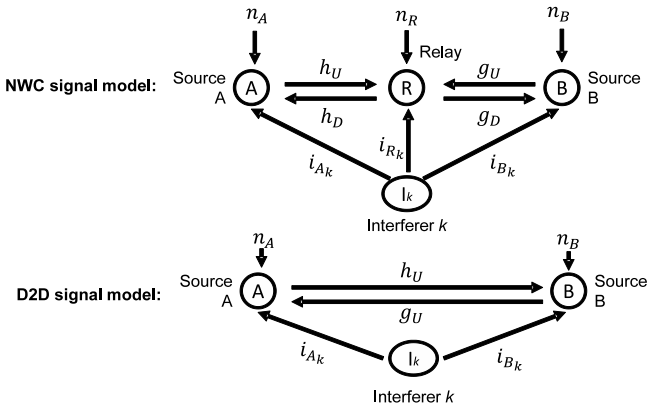

Fig. 3. Signal models for NWC and D2D transmissions. Source A transmits signal x_A with power P_A while source B transmits signal x_B with power P_B. NWC transmission involves a relay node (in this case is the base station) while direct D2D transmission does not.

- Adaptive Mode Selection (MS-1) with NWC: In this scheme an adaptive mode selection scheme is employed that attempts to maximize the achieved SINR without considering the number of used orthogonal resources (time slots);
- Adaptive Mode Selection (MS-2) with NWC: This MS algorithm tries to maximize the achieved spectral efficiency using SINR prediction and the used number of resources;
- 2-TS NWC: Analogue NWC using 2 time slots and amplify and forward relaying at the base station;
- 3-TS NWC: Three time slot NWC, in which the BS uses decode and forward relaying between the devices of a D2D pair requiring 3 orthogonal resources for the bidirectional communication.
- 4-TS scheme: Traditional cellular communication that does not employ either D2D or NWC techniques.
- Adaptive Mode Selection (MS) without network coding: this scheme adaptively selects cellular or D2D transmission mode but does not use NWC.

IV. Conclusions

Our key insight is that the joint application of D2D and NWC can increase the energy and spectral efficiency of cellular networks provided that proper adaptive mode selection

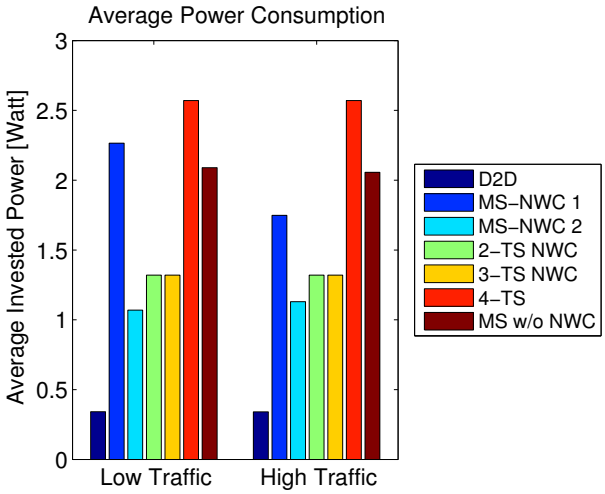

Fig. 4. Power efficiency comparison of the examined transmission modes. Direct D2D and adaptive mode selection are superior in both low and high traffic scenarios.

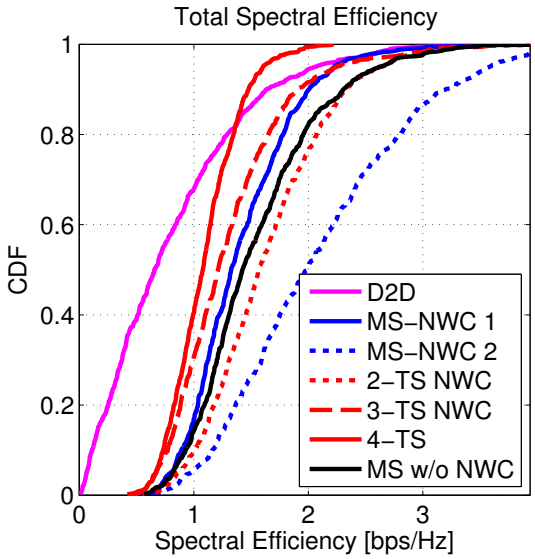

Fig. 5. Spectral efficiency: Adaptive mode selection is superior to all other proximity communication modes.

is employed together with D2D and NWC. In particular, our proposed MS scheme that aims at maximizing spectral efficiency strikes a good balance between energy and spectral efficiency.

References

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