

# Energy-efficient interference management in LTE-D2D communication

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**Abstract:** This paper focuses on one of the key enabling technology that will compose future 5G network, the Direct-LTE communication underlying a cellular infrastructure, also commonly known as Device-to-Device (D2D). Energy efficiency algorithms are proposed for the communication between D2D users and cellular users (CUs) and, following the Lagrangian duality theory, an optimal power and rate control solution is given for D2D users, while satisfying the interference limits related to CUs. Finally, the new algorithm is used to achieve proportional fairness between D2D users and CUs and to show with numerical results that the interference to CUs can be limited to always be under a predefined threshold.

## 1 Introduction

In 2011, the 3GPP long term evolution (LTE) standard for broadband communications was completed. Its purpose was to provide significant innovation to wireless connectivity and along with its enhancement, the so called LTE-Advanced (LTE-A), is being more and more deployed in several parts of the world. The necessity for increased spectrum efficiency led the LTE standard to incorporate more network tiers, i.e. small cell coverage. Unfortunately, network densification is reaching its maximum limit of efficiency, as an excessive small cell deployment has already revealed several unwanted side effects, e.g. bounds in performance due to intra-tier interference, bottlenecks in the backhaul etc.

Moreover, energy consumption and environmental sustainability of small cells are becoming a pressing issue. In fact, although small cells work at significantly lower-power levels, their abundance and unplanned deployment can cause uncompromising energy waste. In order to reduce energy expenditure and make cellular structure more economically sustainable, operators and network providers face the need to adopt more agile technologies.

Among others, device-to-device (D2D) [1] is one of the most innovative wireless technology that have recently received increasing interest of manufacturers, operators and end-users, especially due to its capacity to swiftly adapt to the new wireless reality. The term 'D2D' commonly refers to technologies that empower wireless devices with direct communication and data exchange capabilities without the need of a fixed infrastructure, though the latter may still be responsible for controlled management of resource allocation, radio link control and other important tasks. A first subset of D2D features in the licensed spectrum was already standardized by LTE-A [2], where directly communicating devices can reuse cellular bands. Normally, D2D communication within licensed spectrum takes place under the central supervision of the base station, which controls device discovery and manages mobility through the core network architecture of 3GPP LTE. The evolved node B (eNB) maintains the cellular communication mode and radio resource control for both devices. D2D communication also offers a smooth yet powerful way for spatial spectrum reuse and cellular traffic offloading, increases energy and area spectral efficiency, improves cellular coverage, lowers end-to-end latency, and reduces handset power consumption [3]. In spite of these potential gains, the co-existence of D2D and cellular communication in the same spectrum is challenging due to the increased complexity of interference management [3]. Specifically, the undetected D2D signal

becomes a new source of interference. As a result, cellular links experience cross-tier interference from the D2D transmissions, whereas the D2D links need to combat not only the inter-D2D interference, but also the cross-tier interference from the cellular transmissions. Therefore, interference management is essential to ensure successful co-existence of cellular and D2D links.

Power control [4, 5] is an efficient method to restrict the interference for handling the co-existence problem between D2D and cellular user (CU). It is mainly used for improving the system EE and decreasing the interference on CU. One of the main challenges in applying power control method in D2D network is to jointly control the capacity and power of the link. For example, as shown in Fig. 1, when the data of a D2D session goes through multiple links, all the related links in the path need to provide enough capacity for the D2D session. On the other hand, to increase link capacity, the transmitter (eNB) should increase the power of D2D link, which causes interference to other D2D links.

Therefore, the objective of this paper is to jointly optimize the power and data rate to increase the EE of D2D network. Afterwards, the solution provided by optimisation is used to achieve proportional fairness between the D2D sessions through utility-based fairness algorithm.

### 1.1 Related work

There has been considerable interest in power control techniques for D2D underlying cellular networks. A simple power control scheme is proposed in [6] for a single-cell scenario and a deterministic network model, which regulates D2D transmit power to protect the existing cellular links. A two-stage resource allocation scheme which employs both the centralised and distributed approaches is proposed in [7]. A three-stage resource allocation scheme which combines admission control, power allocation and link selection can be found in [8]. A reverse iterative combinatorial auction-based resource allocation scheme is discussed in [9] for optimising the system sum rate. The throughput performance of the D2D underlying communications with different resource sharing modes is evaluated in [10]. SE enhancement of D2D communications for wireless video networks is studied in [11]. Resource allocation for D2D communications underlying cellular networks powered by renewable energy sources is studied in [12]. A comprehensive overview and discussion of resource management for D2D underlying communications is provided in [13]. Power control [14] and interference management through multiple

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