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Editorial

Recent Advances on Cellular D2D Communications

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Device-to-device (D2D) communications have attracted a great deal of attention from researchers in recent years. It is a promising technique for offloading local traffic from cellular base stations by allowing local devices, in physical proximity, to communicate directly with each other. Furthermore, through relaying, D2D is also a promising approach to enhancing service coverage at cell edges or in black spots. Besides improving network performance and service quality, D2D can open up opportunities for new proximity-based services and applications for cellular users. However, there are many challenges to realizing the full benefits of D2D. For one, minimizing the interference between legacy cellular and D2D users operating in underlay mode is still an active research issue. With the 5th generation (5G) communication systems expected to be the main data carrier for the Internet-of-Things (IoT) paradigm, the potential role of D2D and its scalability to support massive IoT devices and their machine-centric (as opposed to human-centric) communications need to be investigated. New challenges have also arisen from new enabling technologies for D2D communications, such as non-orthogonal multiple access (NOMA) and blockchain technologies, which call for new solutions to be proposed.

This special issue aims to present a collection of exciting papers, reporting the most recent advances in cellular D2D communications. Through invited and open call submissions, a total of ten excellent articles have been accepted, following a rigorous review process that required a minimum of three reviews and at least one revision round for each paper. The list of accepted articles includes one review and nine original research articles on addressing many of the aforementioned challenges and beyond.

The first paper by *Höyhtyä*, *Apilo* and *Lasanen* [1] is a review article that analyzed the latest energy consumption models of 3GPP standardized LTE (long-term evolution) and WiFi interfaces, with recommendations on energy saving options for D2D communications in a set of application scenarios.

Distributed resource sharing and allocation are amongst the most important issues in cellular D2D networks. *Hong*, *Wang*, *Cai* and *Leung* [2] investigated the issue of fairness in cooperative D2D computational resource sharing, and proposed a blockchain-based credit system where user's computational task cooperation are recorded on public blockchain ledger as transactions, and their credit balance can be easily accessed from the ledger. The performance of the proposed credit system is demonstrated by incorporating it into a connectivity-aware task scheduling scheme to enforce fairness among users in the D2D network.

Radio resource is another resource type that must be efficiently managed. The next four papers explore different strategies for allocating radio resources such spectrum and transmit power for D2D communications. *Jiang*, *Wang*, *Ren* and *Xu* [3] studied the problem of spectrum resource and transmit power allocation for underlay multicast D2D communications, and presented a heuristic and low-complexity resource and power allocation scheme that aims to maximize overall energy efficiency, while satisfying the QoS (quality of service) requirements of both cellular and D2D users. Similarly, for underlay D2D communications, *Ban* [4] proposed a practical scheme with low

complexity and signaling overhead for distributed radio resource management. The scheme does not require any channel feedback, and each D2D pair can transmit on its own, based on simple bitmap information broadcast by the base station and an optimal threshold value derived to maximize the average sum-rates.

To address the issue of mitigating multicell D2D underlay interference, *Katsinis*, *Tsiropoulou* and *Papavassiliou* [5] proposed a two-step approach, which involves solving the initial resource block allocation problem by formulating it as a bilateral symmetric interaction game, and then addressing the transmit power allocation problem by using a linear programming approach to minimize the total interference of the network. In order to respond to changing network conditions, there is a need for the resource allocation mechanism to be adaptive. The paper by *Khan*, *Alam*, *Moullec* and *Yaacoub* [6] presented a cooperative reinforcement learning algorithm for adaptive allocation of resource blocks and transmit power to D2D users in a cellular network. By efficient control of the interference level, the proposed algorithm results in improved overall system throughput, D2D throughput and fairness among D2D users.

The spectrum efficiency problem in group D2D communications is next addressed by *Anwar*, *Seet*, and *Li* [7] who proposed a QoS based non-orthogonal multiple access (Q-NOMA) scheme in which D2D users in a NOMA transmission are ordered according to their QoS requirements. Using stochastic geometry tools, the authors modeled the spatial relationships and interferences between the group D2D users, which led to a closed-form expression for characterizing their outage performance.

In human-centric D2D communications, the social and trust relationships between users are humanistic features that can be leveraged for enabling more secure and reliable solutions. *Militano*, *Orsino*, *Araniti* and *Iera* [8] exploited the social relationships among D2D users to model the trust level between them, and proposed a social trust-based solution for enhancing the performance of D2D-enhanced cooperative content uploading in the presence of packet dropping or corrupting malicious nodes for narrowband-IoT cellular environments. In another cooperative design, *Chiti*, *Fantacci* and *Pierucci* [9] considered the problem of relay-assisted cooperative multicast (one-to-many) D2D communications, and presented a relay selection scheme that considers both propagation link conditions and relay's social trust level with the constraint of minimizing end-to-end delay in an integrated social–physical network.

Besides multicast, broadcast (one-to-all) is another communication option that can be supported by D2D. This special issue concludes with a paper by *Nardini*, *Stea* and *Virdis* [10], who proposed a message broadcast solution appropriate for vehicular networks based on multihop D2D communications. The proposed solution allows a user to specify its target area without being constrained by cell boundaries. It relies on application-level device intelligence and standard D2D resource allocation methods of LTE-A to enable fast, reliable and resource-efficient message broadcast services.

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