I t has been more than a decade since the multihop cellular network (MCN) architecture was first proposed and analyzed in 2000 [1]. As the transmission range decreases $k$ times, the number of simultaneous transmissions and hop count increase by $k^2$ times and $k$ times, respectively, which leads to $k$ times cellular capacity increase. Fundamental research projects have demonstrated the benefits of MCN in terms of system capacity, service coverage, and network connectivity. Many special issues have been devoted to this stream of research [2–6]. The actual concept behind the MCN architecture could be regarded as a hybrid of mobile ad hoc networks (MANETs) and cellular networks. This concept of “relaying within a cell” also pushed standard bodies to consider solutions embedded with mesh or ad hoc architectures, such as IEEE 802.11s [7], IEEE 802.15.5 [8], and IEEE 802.16j [9]. Now, in the recent standards of the Third Generation Partnership Project (3GPP), Proximity-Based Services (ProSe) [10, 11] related work items also cover the MCN concept. In addition to device-to-device (D2D) direct communications, user equipment (UE)–UE relay and UE–network relay are also supported features. Both infrastructural and infrastructureless architectures are considered. Among many use cases, the most urgent one is public safety. These show that MCN architecture realization is ongoing.

**From Standards to Systems and Applications**

From another aspect, there are various radio access technologies (RATs) enabling pervasive communications for people and devices to meet requirements in mobility, spectrum, and transmission distances. When devices equipped with single/multi-RATs reside in a local spot, considering cost effectiveness, bandwidth aggregation, and power saving, a multi-RAT MCN could be constructed by those devices and the infrastructure. As shown at Mobile World Congress 2013 in Barcelona, limited to the simple I/O interface of some devices, near field communication (NFC) could be used to trigger Bluetooth or Wi-Fi Direct communication for big file transmission, which might further trigger other communications for cloud access. As Wi-Fi-only devices could have Internet access via 3GPP/Wi-Fi dual-mode smartphones, multi-RAT MCN now offers more interesting service models and is starting to be applied to the real world.

After much research on protocols and architectures for the IEEE series, specifications have been created for single-RAT MCN based on analytical models and simulations, and other issues related to implementation, deployment, and operations have emerged. From the 3GPP aspect, many research issues are still pending, such as D2D discovery, path switching between direct/infrastructure link, ID allocation and mapping, authentication, and group management. For multi-RAT MCN, further research has to be done considering the RAT capabilities of devices. New business models, such as social networking, advertising, and machine-to-machine communications, could be foreseen.

**In This Issue**

This Feature Topic serves as a state-of-the-art snapshot of these exciting developments. We present five original articles describing the current standardization status of 3GPP, D2D discovery, resource allocation for D2D communications, synchronization issues in relay-aided MIMO environments, and a dynamic graph framework for MCN modeling. Their brief summaries are listed below. We hope readers enjoy the interesting and insightful articles in this issue.

**Architecture in 3GPP**

In addition to IEEE series standards, MCN is an ongoing topic at 3GPP. Because of the fundamental differences, such as network architecture and management mechanisms, many issues need new consideration at 3GPP. “Direct Mobile to Mobile Communication: Paradigm for 5G” explains the architectural and technical challenges for D2D communications in the 3GPP standard. From the radio access network (RAN) aspect, modulation, frame structure, synchronization, hybrid automatic repeat request (HARQ), channel measurement, and power control are addressed. From the system architecture aspect, the protocol stack and bearer management are discussed. In addition, some real-life applications and use cases are described.

**D2D Discovery**

In an MCN, before a device can communicate to its target device, it must first find, identify, and communicate with other proximate devices so that data can be routed to the final destination. “Device Discovery for Multihop Cellular Networks” first reviews the current solutions for the unlicensed band communications technique, such as IrDA, Bluetooth, and Wi-Fi Direct. However, for fundamentally different cellular networks, which operate on licensed band and centrally controlled radio resources, some issues need to be reconsidered to make the discovery scheme more efficient. This article addresses the discovery principles and unique design issues in a cellular network, and provides a practical device discovery design example for Long Term Evolution (LTE) systems, placing the emphasis on implementation complexity and energy efficiency.
RESOURCE ALLOCATION FOR D2D COMMUNICATIONS

“Fine-Grained Resource Allocation for Cooperative Device-to-Device Communication in Cellular Networks” proposes to adopt cooperative communication (CC) for D2D communications. However, new challenges, such as relay selection, channel allocation, and transmission scheduling, are raised for efficient resource allocation. By dividing each CC transmission into broadcast and relay phases, which can be scheduled individually, the fine-grained resource allocation scheme exploits the benefits of slot-by-slot scheduling by both space-division and frequency-division multiplexing. Based on this scheme, the authors study the problem of maximizing the minimum rate among multiple wireless links by jointly considering relay assignment, transmission scheduling, and channel allocation.

SYNCHRONIZATION ISSUE FOR RELAY-AIDED COOPERATIVE MIMO

A relay-assisted cooperative MIMO network is proved to improve the cell edge performance in perfect initial synchronization scenarios. However, practical cooperative systems cannot guarantee reliable operation near the cell edge without robust synchronization techniques. In “Synchronization Issues in Relay-Aided Cooperative MIMO Networks,” various cooperative initialization synchronization procedures corresponding to a variety of relay-assisted cooperative MIMO scenarios are analyzed. The authors characterize the mean acquisition time (MAT) and mean frame acquisition time (MFAT), as well as the relaying delay of DS-CDMA and OFDMA/TDD, respectively. In addition, both the detrimental and beneficial factors affecting the attainable synchronization performance in relay-aided cooperative non-coherent MIMO environments are highlighted. The design guidelines proposed will be beneficial to both researchers and practicing engineers involved in investigating or implementing cooperative communication systems.

MCN MODELING FRAMEWORK

To investigate the MCN performance is a continuous effort. However, existing works considered this issue under a small-scale network. “A Dynamic Graph Optimization Framework for Multihop D2D Communication Underlying Cellular Networks” aims to investigate theoretical performance limits and study the optimal system design for large-scale systems. By using the reformulation linearization technique (RLT), the objective flow maximization and the associated constraints of flow conservation and resource allocation are transformed into linear expressions of decision variables. Thus, the formulated maximization problem falls into the category of linear programming problems. In addition, the authors use a realistic cellular network deployment to quantitatively analyze and assess the capability of the proposed framework.

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