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A Review on Communication Infrastructures in 5G Cellular Networks

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ABSTRACT- Device-to-device (D2D) communication commonly refers to a type of technology that enable devices to communicate directly with each other without communication infrastructures such as access points (APs) or base stations (BSs). Bluetooth and WiFi-Direct are the two most popularD2D techniques, both working in the unlicensed industrial, scientific and medical(ISM) bands. Cellular networks, on the other hand, do not support direct over-the-air communications between users and devices. However, with the emergence of context-aware applications and the accelerating growth of Machine-to-Machine (M2M) applications, D2D communication plays an increasingly important role. It facilitates the discovery of geographically close devices, and enables direct communications between these proximate devices, which improves communication capability and reduces communication delay and power consumption. To embrace the emerging market that requires D2D communications, mobile operators and vendors are accepting D2D as a part of the fourth generation (4G) Long Term Evolution (LTE)-Advanced standard in 3rd Generation Partnership Project (3GPP) Release 12.

1. INTRODUCTION

As LTE systems are reaching maturity and have been deployed, the future fifth generation (5G) cellular networks have drawn great attention from researchers and engineers around the world. 5G cellular networks are envisioned to attain 1,000 times higher mobile data volume per unit area, 10-100 times higher number of connecting devices and user data rate, 10 times longer battery life, and five times reduced latency. Although it is still too early to give an exact definition of 5G, current research trends have shown that the above ambitious goals can potentially be achieved by a multi-tier and heterogeneous network architecture along with the aggregation of several key technologies, such as spatial modulation, millimeter wave (mmWave), visible light communication (VLC), and massive MIMO. Among these potential technologies, D2D communication is considered as one of the pieces of the 5G jigsaw puzzle. Apart from the research issues that need to be addressed before D2D is completely standardized in LTE Advanced, there will be new challenges to support D2D in 5G. In the following, we discuss two challenges in developing D2D communication technology in 5G cellular networks.

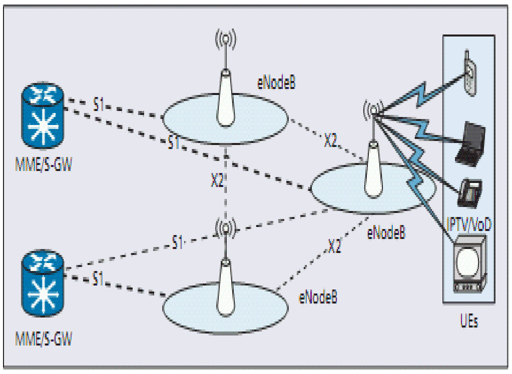

Fig.1. An LTE Network

2. D2D IN MMWAVE NETWORKS

mmWave communication is a promising technology for future 5G cellular networks to provide very high data rate (multi-Gbps) for mobile devices, since it operates over a large frequency band from 30 GHz to 300 GHz. However, it also has several unique propagation features different from those of the microwave band, which lead to challenges to achieve seamless coverage and reliability. First, the propagation loss is much higher since the received signal power is proportional to the square of carrier frequency. Therefore, high-gain directional antennas are favored to compensate for the tremendous propagation loss and reduce shadowing effect. Second, the short wavelengths of mmWave bands result in difficulties in diffracting around obstacles. Line-of-sight (LOS) transmissions can be easily blocked by obstacles, which results in link outage. Third, it is difficult for mmWave signals to

penetrate through solid materials, which confines outdoor mmWave signals to streets and other outdoor structures, although some signal power might reach inside the buildings through glass windows
and wood doors.

2.1 Opportunities & Advantages in enabling D2D Communication

The above propagation features provide opportunities and advantages in enabling D2D communications over directional mmWave networks. First, mmWave can be applied to D2D-enabled wireless devices for direct short range communications between users or machines in close proximity. Moreover, D2D communication can also establish a path between two wireless devices and between wireless devices and mmWave BSs by relay if LOS links between them are blocked. Second, in contrast with 4G cellular networks where communications between BSs are perform via fiber links, mmWave communication with highly directional antennas provides wireless connections with a high data rate for BS to BS (B2B) communications. Third, interference management is one of the most important challenges to harvest the performance gain in D2D communications. Due to the directional antennas and large propagation loss, mmWave communication has relatively low multi-user interference (MUI), which can support simultaneous communications over the same radio spectrum. By allowing multiple concurrent D2D links, the network capacity and spectrum efficiency can be greatly improved. Therefore, new network architectures and resource sharing schemes accounting for the directional interference sources are necessary in mmWave 5G cellular networks to fully exploit the advantages of both technologies
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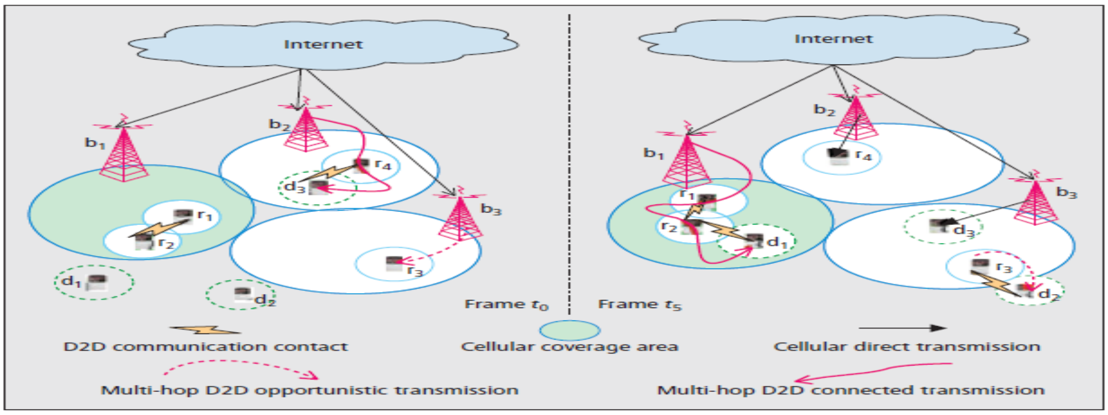

Fig. 2 Device to Device Communication in a cellular Network

3. D2D-ENABLED ULTRA- DENSE DEPLOYMENT WITH SMALL CELLS

One of the main drivers behind 5G is the need to increase the capacity to cope with the mobile data traffic explosion. Ultra-densification, which means deploying more active nodes per unit area and Hz, is one of the “big three” 5G technologies along with mmWave and massive MIMO. In fact, making the cells smaller has been demonstrated as a straightforward but extremely effective way to increase the network capacity over several cellular generations. This is mainly due to the higher reuse of spectrum across a geographic area and the ensuing reduction in the number of users competing for resources at each BS. In 4G LTE Advanced networks, the term “small cells” refers to several quite different technologies, all of which have low-power short-range operator-owned nodes integrated in the cellular infrastructure to enhance its coverage and/or capacity. Such communication nodes go under names such as femto, pico- or micro-enhanced Node Bs (eNBs).Both D2D and small cells can be used to offload traffic from the macro-eNBs. However, D2D focuses on offloading the proximity services, while small cells are more suitable for offloading hot-spot traffic. Therefore, integrating these two technologies to provide D2D-enabled ultra-dense deployment with small cells in 5G is an appealing solution for localized data transfers as well as general purpose downloading. However, it also poses several challenges and risks, which are centered on complex interference scenarios. When frequency reuse is applied to improve resource utilization, the interference among macro-cell cellular links, small-cell cellular links, and D2D links all should be considered and efficiently managed. Moreover, a D2D pair can be from different cells, which further complicates interference control. Therefore, it is necessary to investigate how to achieve efficient interference management and develop practical inter-node signaling mechanisms .

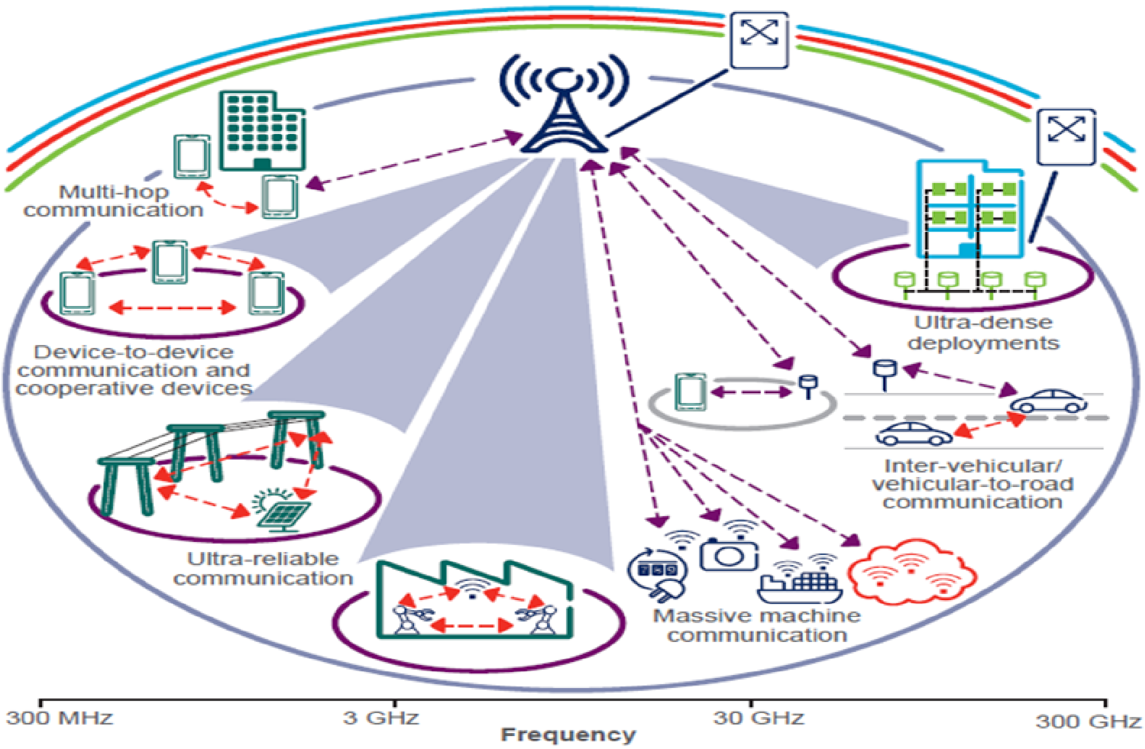

Fig. 3 D2D-Enabled Ultra-Dense Deployment with Small Cells

4. CROSS- LAYER RESOURCE CONTROL, UNDER BURSTY DATA TRAFFIC

Resource management for D2D communications in cellular networks mainly includes three function blocks: mode selection, power control, and resource allocation. Compared with the resource management in traditional cellular networks, there are more degrees of freedom in D2D communications. First, a pair of D2D terminals can either communicate directly over-the-air, or communicate via a BS. Moreover, the direct over-the-air link or D2D link may reuse radio resources with other cellular or D2D links. Finally, as signaling can be exchanged directly between a pair of D2D terminals due to their proximity, some of the resource management actions can be performed in a distributive way and offloaded to the D2D terminals from the BS. Such flexibility provides both opportunities and challenges in designing optimal resource control policies. Related works in the literature usually assume that theD2D and cellular terminals are saturated with infinite backlogs, and focus on optimizing the PHY layer performance metrics (such as sum throughput and power consumption).However, the data arrival process at each terminal is dynamic and bursty in real-life applications. Moreover, latency and reliability are critical performance measures in 5G, which need to be quantified and evaluated in terms of delay and packet dropping rate under a bursty traffic model. To derive the optimal resource allocation policies for bursty data traffic, cross-layer design and stochastic optimization, which take advantage of both the channel state information (CSI) and the queue state information (QSI), should be applied. Although cross-layer performance evaluation and resource optimization in conventional cellular networks and wireless multihop networks have been well studied, these research issues in D2D communications require further research.

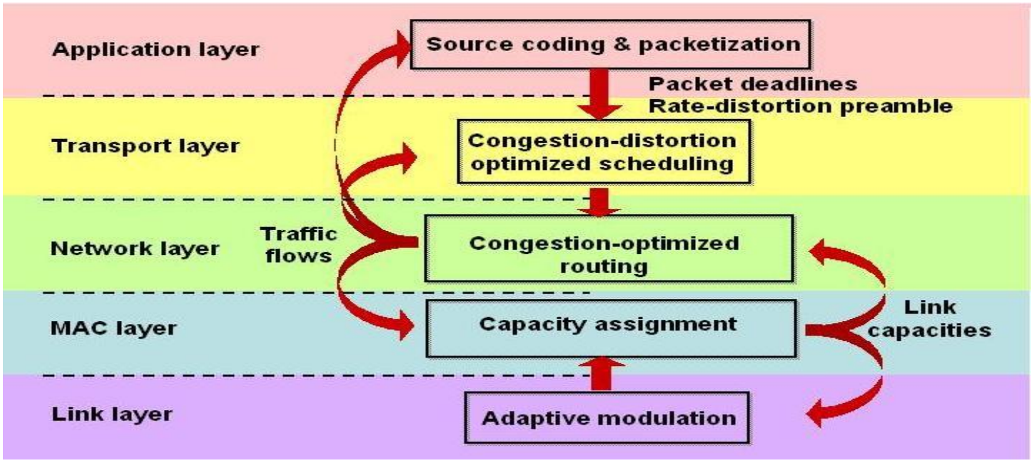

Fig.4 Cross-layer Resource Control under Bursty Data Traffic

5. CONCLUSION AND FUTURE PERSPECTIVES

Resource management for D2D communications in cellular networks mainly includes three function blocks: mode selection, power control, and resource allocation. Compared with the resource management in traditional cellular networks, there are more degrees of freedom in D2D communications. First, a pair of D2D terminals can either communicate directly over-the-air, or communicate via a BS. Moreover, the direct over-the-air link or D2D link may reuse radio resources with other cellular or D2D links. Finally, as signaling can be exchanged directly between a pair of D2D terminals due to their proximity, some of the resource management actions can be performed in a distributive way and offloaded to the D2D terminals from the BS. Such flexibility provides both opportunities and challenges in designing optimal resource control policies. Related works in the literature usually assume that the D2D and cellular terminals are saturated with infinite backlogs, and focus on optimizing the PHY layer performance metrics (such as sum throughput and power consumption).However, the data arrival process at each terminal is dynamic and bursty in real-life applications. Moreover, latency and reliability are critical performance measures in 5G, which need to be quantified and evaluated in terms of delay and packet dropping rate under a bursty traffic model. To derive the optimal resource allocation policies for bursty data traffic, cross-layer design and stochastic optimization, which take advantage of both the channel state information (CSI) and the queue state information (QSI), should be applied. Although cross-layer performance evaluation and resource optimization in conventional cellular networks and wireless multihop networks have been well studied, these research issues in D2D communications require further research. In conclusion, D2D communication, which is currently being considered as a part of 4G LTE-Advanced standards in 3GPP Release 12, is envisioned to continuously evolve into the 5G cellular networks to efficiently support a much larger and more diverse set of devices and applications. Although there have been intense research activities on D2D communications in recent years, there are still many challenging issues to be addressed, especially in terms of network architectures, physical layer features, and performance requirements in 5G. I hope that you enjoy reading this Editor's Note and find it interesting and helpful.

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