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Designing a framework for Device-to-Device Communications In LTE-Advanced Network

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ABSTRACT*:* **Device-to-device (D2D) communication is a promising new feature in LTE-Advanced networks. In conventional cellular networks, devices can only communicate with the base station via uplink or downlink paths. It fails to meet the ever-increasing demand of proximity-based social/commercial services and applications. The innovative architecture of D2D underlying LTE networks is therefore brought up to enable efficient discovery and communication between proximate devices. With D2D capability, devices in physical proximity could be able to discover each other using LTE radio technology and to communicate with each other via a direct data path. Apart from the general social/commercial use, the LTE D2D is further expected to address Public Safety communities.**

This thesis is concerned with the design, coordination and testing of a hybrid D2D and cellular network. Design requirements and choices in physical and MAC layer functions to support D2D discovery and communication underlying LTE networks are analyzed. In addition, a centralized scheduling strategy in base station is proposed to coordinate D2D data communication operating in LTE FDD downlink spectrum. The scheduling strategy combines multiple techniques, including mode selection, resource and power allocation, to jointly achieve an overall user performance improvement in a cell. Finally the performances of D2D data communication underlying LTE system are calibrated in a multi-link scenario via system-level simulation. D2D data communication is scheduled by base station with the proposed scheduling method and the hybrid D2D and cellular system is compared to pure cellular system, in which all traffics must go through base station.

The simulation results show that considerable performance gains are achieved by enabling direct D2D data paths to replace conventional uplink-plus-downlink data paths for local data traffic between proximate devices, and by allowing non-orthogonal resource reuse between D2D and cellular downlink transmission. The initial tests demonstrate that the proposed scheduling method successfully mitigates interferences resulting from the intra-cell resource reuse.

Keywords: D2D transmission, LTE networks, cellular system, link expiration, network lifetime, packet delivery ratio, end to end delay, overhead.

I. INTRODUCTION

The concept of Device-to-Device (D2D) transmissions underlying LTE-Advanced network involves signals transmitted from one cellular user equipment (UE) being received at another cellular user equipment without passing through cellular infrastructural nodes (e.g. eNB, HeNB, etc.). This thesis is concerned with the usage prospects, design issues, coordination and testing of a hybrid D2D and cellular network. Direct D2D technologies have already been developed in several wireless standards, aiming to meet the need for efficient local data transmission required

by variant services in personal, public and industrial areas. Examples are Bluetooth, ZigBee in wireless personal area networks (WPANs), and Wi-Fi Direct in wireless local area networks (WLANs).

The need of frequent communication between nearby devices becomes critical now with the capability of smart devices for content share, game play, social discovery, etc. whereas the conventional UL/DL transmission mode in cellular network fails to address this demand efficiently. Proximity-based social/commercial services and applications show great prospects. In order for operators to address this huge market and to offer their subscribers ubiquitous connections, operator-controlled direct D2D transmissions are studied in the context of next-generation wireless communication systems, such as LTE-Advanced and WiMAX. The D2D technologies aim to support the local discovery, identification and to enhance the network capacity and coverage.

A. Implications for Mobile Operators

For the wireless service suppliers the increasing quality of mobile communications is nice news. The enlargement of wireless omnipresence can result in a rise of customers World Health Organization access and place confidence in mobile networks. However, whereas the traffic load on mobile networks is predicted to grow exponentially throughout the approaching years, the financial gain is sadly not essentially directly coupled to the present growth. The overwhelming majority of mobile operators charge a monthly expected value for broadband mobile access to the web. The most important value objection covering wireless service suppliers these days is that the backhaul network. This infrastructure is incredibly dearly-won to take care of and hard to measure. The surge of knowledge traffic is pushing several mobile networks to their capability limit. A lot of antennas area unit needed to accommodate all users and succeed acceptable signal coverage.

B. D2D Communications

In order to solve the issues mentioned in the previous paragraph, to enhance the communication capacity and capabilities and to introduce new area, research is performed on many subjects. A recent research topic is D2D communications as an underlay to cellular networks. A D2D link is a direct connection between two communicating Devices, in spectrum managed by the cellular network. The goal of using D2D links is to: (a) increase the spectral efficiency, (b) reduce the load on the network and (c) introduce and facilitate new services.

As the range of human action devices increasing, the spectrum during which the signals area unit present becomes jam-pawncked. In mobile access networks, if the backhaul and backbone portions of the network area unit dimensioned properly, the limiting issue (the bottleneck) is the air interface. As the name of this work proposes, the D2D correspondence happens under the umbrella of a cell system. This shows that the D2D sessions happen inside the same waveband on the grounds that the cell correspondence. Hence, the sessions happen underneath the superintendence of the cell system. In apply this shows that the baccalaureate covering square measurement amid which the gadgets are blessing is in control, provisioning and dealing with the correspondence joins. This administration common sense is basic if the D2D correspondence happens inside the approved waveband, as a consequence of the obstruction created by D2D interfaces on the traditional cell correspondence ought to be contained. At no time D2D correspondence could hinder cell correspondence. To boot, D2D interfaces conjointly meddle with each other. These obstruction issues are the most test once encouraging D2D correspondence fundamentally

II. CLASSIFICATION OF D2D COMMUNICATION

D2D communication in cellular network can be categorized into both In band D2D and Out band D2D based on the spectrum in which D2D communications occurs [6]. D2D communications is divided into two modes or categories called ' Inband underlay mode ' when the D2D communications use the cellular resources and spectrum and ' Inband overlay mode 'when cellular resources are allocated for the two D2D end devices that communicate directly (eg, Fig.1). High control over licensed spectrum is the key motivating factor for choosing the In band D2D communication. In other hand, the main motivation of using Outband D2D communications is the capacity to eliminate the interference between D2D links. Furthermore, Outband D2D communications is faced with a lot of challenges in the coordination between different bands.

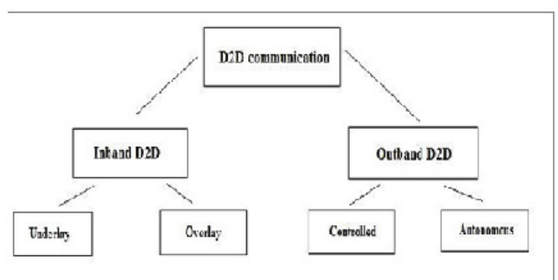

Fig.1. Classification of D2D communication.

III. BASICS OF D2D COMMUNICATION

In this section we give an overview of the D2D direct and D2D LAN communication scenarios.

For both types of these communications the D2D users can access the spectrum in two different ways:

• **Overlay spectrum sharing:** This approach can completely eliminate intra-cell interference between cellular services and D2D communication by dividing the licensed spectrum into two parts through orthogonal channel assignment. One part is a set of channels to be used by the cellular users, while the other part will be used by the D2D users.

• Underlay spectrum sharing: This approach allows D2D users to use the same spectrum simultaneously with cellular users, increasing spectrum utilization and efficiency. However, the interference among users must be carefully controlled and avoided.

The overlay approach is easier to realize. However, it results in low spectrum utilization and efficiency as the different parts of spectrum cannot be flexibly and opportunistically accessed by cellular and D2D users. On the other hand, the underlay approach requires relatively larger signaling overhead and controlling information. Nevertheless, it can achieve better system performances due to the frequency reuse with cellular users. In this article we mainly focus on the underlay approach. Figure 1 shows the network with two tiers, the D2D and cellular tiers, and interference in such a network can be classified as follows:

• Cross-tier interference: This is the interference between users in different tiers. The transmission of an aggressor (e.g. a D2D user) interferes with that of a victim (e.g. a cellular user).

• Co-tier interference: This is the interference between users in the same tier. The transmission of the aggressor (e.g. a D2D user) interferes with that of the victim (e.g. another co-channel D2D user). Therefore, to reduce the appearance of dead zones (i.e. the zones that users cannot transmit data due to strong interference) within the cellular networks and successfully enable D2D communication, interference avoidance, randomization, or cancelation techniques must be effectively applied. For this, the spectrum allocation needs to consider the interests of the cellular network (operator) and mobile users (cellular users and D2D users). Unlike traditional resource allocation in orthogonal frequency-division multiple access (OFDMA) networks, the resource allocation in D2D involves the assignment of a D2D user to proper resource blocks (RBs), which affects the co-channel interference (CCI) from the co-channel cellular user. Specifically, the network radio resource allocation can be performed in the following ways:

• Local radio resource allocation: The radio resource allocated to cellular users is considered to be fixed, while that of D2D users can be adjusted.

• Global radio resource allocation: The radio resource of both cellular and D2D users can be controlled jointly. Distributed radio resource allocation algorithms can be designed based on game theory. In particular, a game theory model can be developed to study the interactions between a cellular network, which has some commodity or service to sell (in this example, the commodity is radio spectrum), and a number of cellular and D2D users interested in obtaining the service so as to optimize their objective functions, respectively. To this end, auction theory offers such a set of mathematical tools to design the parameters of the whole network, so as to efficiently allocate the radio resources for D2D direct communication. With regard to D2D LAN, the network-controlled mobiles can perform group communication, and thus realize various functionalities based on a specific application scenario. Similar to D2D direct, these mobiles in the D2D LAN can also work as an underlay to cellular networks for spectrum reuse. The scenarios are as follows:

• Group communication: When a large number of similar requests are received by the eNB, the D2D LAN can be used to efficiently offload data. For example, in stadium or concert networks, when many mobile users request for the same content, some UEs as “seeds” can be first selected to obtain the complete information from the eNB, and then these seeds can share the data with the rest of the mobiles.

• Multi-hop relay communication: When some users are out of the coverage of the eNB, the mobiles in the D2D LAN can serve as relays for completing the file delivery among mobiles.

• Collaborative smartphone sensing: Smartphones have the capability of environment sensing, and the sensed data can be collaboratively aggregated to some “sink” UEs and then transmitted to the eNB.

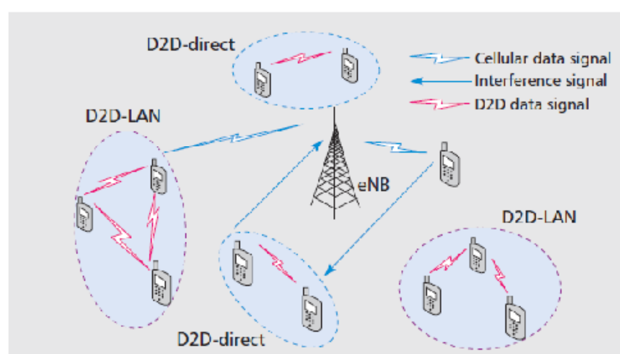

Fig. 2. D2D communication system.

The Major Challenges: D2D is a significant departure from the normal mode of operation in LTE (and other cellular networks) and it introduces some interesting design challenges for 3GPP. Here are just a few:

- A choice between LTE uplink and downlink for D2D communication (with implications for interference, capacity, handset complexity and regulation).
- A choice between OFDMA and SC-FDMA for D2D communication (with consequences for handset complexity in particular).
- A choice between static or dynamic allocation of radio resources for D2D discovery and communication.
- Different propagation characteristics for D2D communication (where both ends of the link are low and mobile) compared with traditional cellular networks (where one end of the link is generally high and fixed).
- Co-existence of D2D and normal LTE (e.g. interference caused by a mobile operating in D2D mode adjacent to a mobile operating in normal LTE mode, if one is transmitting and the other is receiving in the same band).
- Division of D2D control functions between the network and mobile devices when in coverage (to achieve efficient operation while maintaining the integrity of radio resource management and security).
- Division of D2D control functions between mobile devices when out of coverage (e.g. uniformly distributed or centralized).
- Reuse of existing LTE features and protocols where possible.
- New features and protocols to accommodate unique aspects of D2D (e.g. resource management, synchronisation, power control, error control, channel measurements).
- Algorithms for choosing between LTE base station communication and LTE D2D communication on a case-by-case basis.
- A choice between synchronous D2D discovery (to conserve battery life) or asynchronous D2D discovery (for flexibility).
- Capacity and frequency of D2D discovery (to achieve a complete and current view of local devices without sacrificing battery life).
- The nature and quantity of information provided by mobile devices during D2D discovery (to satisfy the needs of proximity-based services without compromising battery life or performance).
- Control of privacy and security during D2D discovery and communication.
- Flexible billing options based on a variety of approaches (e.g. per user, per discovery event, per D2D connection, per MB).

While the basic principles of D2D have been established, many of the details are still being studied and developed. Some of these could have far-reaching consequences. For example, the design of the D2D discovery mechanism could make or break D2D. Get it right and D2D will be an essential tool for social networks and other Internet applications. Get it wrong and the service could be unattractive to application providers, unacceptable to users concerned about privacy, or a major drain on device battery life. The design of the D2D communication mode is equally crucial. Get it right and D2D will provide a highly efficient method of off-loading traffic from existing LTE networks, with light but firm control by the network operators. Get it wrong and D2D could have a detrimental effect on existing services, or operators may lose their grip on network traffic.

Not surprisingly, 3GPP is taking a measured approach. It is actively investigating all of the issues mentioned above (and more). However, the specific features introduced in 3GPP Release 12 will be confined to a D2D solution for public safety organisations. Other aspects will be addressed in future releases.

There is no doubt that D2D is a major opportunity for network operators. It has the potential to create a major new revenue stream at the heart of future Internet services, to provide a valuable communication mode for public safety organisations, and to establish a new, efficient mode of network operation. However, D2D also marks a significant shift in network design, in which the network relinquishes some control over the traffic it carries and new modes of radio resource usage impinge on existing users. In the short term the impact of D2D on the network will be relatively small, but D2D sets a precedent and it is not clear where this might lead in the long term. Network operators must seize the opportunity from D2D, while steering its future development in the right direction.

IV. RELATED WORK

In [Y. Li, D. Jin, J. Yuan and Z. Han, 2014], the authors highlighted a uplink resource allocation problem for multiple D2D and cellular users from a game theory point of view is addressed. Next combing different transmission modes, mutual interferences, and resource sharing policy in a single utility function, authors propose a coalition formation game based scheme. Hence by theoretical analysis, it is proved that it converges to Nash-stable equilibrium and further approaches to the system optimal solution with geometric rate.

In [J. Jiang, S. Zhang, B. Li and B. Li, 2016] the authors have discussed about LTE-advanced cellular networks, device-to-device (D2D) communication which has emerged as an effective way to offload cellular traffic and improve system performance.

Conventionally, a device exclusively relies on cellular communication to retrieve the content it desires. With D2D communication, however, if the same piece of content is available in the vicinity of the device, the content can be directly retrieved from one of its neighbouring devices. Naturally, the key problem becomes how to maximize content sharing via D2D communication. Existing works on content sharing are mainly concerned with a multi-hop communication setting, while works on D2D communication have primarily focused on the communication aspects, including interference avoidance and energy efficiency. Here they have studied the problem of maximizing cellular traffic offloading with D2D communication, by selectively caching popular content locally, and by exploring maximal matching for sender-receiver pairs.

In [M. Ni, L. Zheng, F. Tong, J. Pan and L. Cai,2015] the authors have presented Device-to-device (D2D) communications in cellular networks are promising technologies for improving network throughput, spectrum efficiency, and transmission delay. In this paper, the concept of guard distance to explore a proper system model for enabling multiple concurrent D2D pairs in the same cell is introduced first. Considering the Signal to Interference Ratio (SIR) requirements for both macro-cell and D2D communications, a geometrical method is proposed to obtain the guard distances from a D2D user equipment (DUE) to the base station (BS), to the transmitting cellular user equipment (CUE), and to other communicating D2D pairs, respectively, when the uplink resource is reused. By utilizing the guard distances, authors then derive the bounds of the maximum throughput improvement provided by D2D communications in a cell.

In [Usman *et al.,* 2015] the authors have presented a hierarchal D2D communication architecture where a centralized software-defined network (SDN) controller communicates with the cloud head to reduce the number of requested long-term evolution (LTE) communication links, thereby improving energy consumption is proposed. The concept of local and central controller enables our architecture to work in case of infrastructure damage and hotspot traffic situation. The architecture helps to maintain the communication between disaster victims and first responders by installing multi-hop routing path with the support of the SDN controller. In addition, authors highlight the robustness and potential of our architecture by presenting a public safety scenario, where a part of the network is offline due to extraordinary events such as disaster or terrorist attacks.

In [O. N. C. Yilmaz *et al.,* 2014] the authors have highlighted the work on Direct device-to-device (D2D) communications is regarded as a promising technology to provide low-power, high-data rate and low-latency services between end-users in the future 5G networks. However, it may not always be feasible to provide low-latency reliable communication between end-users due to the nature of mobility. For instance, the latency could be increased when several controlling nodes have to exchange D2D related information among each other. Moreover, the introduced signaling overhead due to D2D operation need to be minimized. Therefore, in this paper, several mobility management solutions with their technical challenges and expected gains under the assumptions of 5G small cell networks are proposed in this article.

In [M. Maso, C. F. Liu, C. H. Lee, T. Q. S. Quek and L. S. Cardoso,2015] the authors have presented a novel energy-recycling single-antenna full-duplex (FD) radio is designed, in which a new three-port element including a power divider and an energy harvester is added between the circulator and the receiver (RX) chain. The presence of this new element brings advantages over the state of the art in terms of both spectral efficiency and energy consumption. In particular, it provides the means of performing both an arbitrary attenuation of the incoming signal, which in turn increases the effectiveness of the state-of-the-art self-interference cancellation strategies subsequently adopted in the RX chain, and the recycling of a non-negligible portion of the energy leaked through the non-ideal circulator. The performance of this architecture is analyzed in a practically relevant four-node scenario in which two nodes operate in FD and two nodes in half-duplex (HD). Analytical approximations are derived for both the achievable rates of the transmissions performed by the FD and HD radios and the energy recycled by the FD radios.

In [Wang, *et al.,* 2015] the authors have discussed full duplex for heterogenous networks that accommodate the coexistence of device-to-device communications. The short link distance and lower transmit power of device-to-device communications make them excellent candidates to exploit full duplex in band transmission. By incorporating power allocation for self-interference cancellation based on antenna isolation, analog cancellation, and digital cancellation, full-duplex device-to-device, FD-D2D, nodes can potentially improve spectrum efficiency in HetNets. Authors provide a comprehensive overview on FD-D2D communications in Het-Nets. Additionally, we identify several challenges, provide potential solutions to interference mitigation based on power control, beam forming, and resource scheduling, and further discuss applications of FD in 5G networks. In [Maghsudi and Stańczak, 2016] the authors have presented the basic idea of device-to-device (D2D) communication is that pairs of suitably selected wireless devices reuse the cellular spectrum to establish direct communication links, provided that the adverse effects of D2D communication on cellular users are minimized and that cellular users are given higher priority in using limited wireless resources.

Despite its great potential in terms of coverage and capacity performance, implementing this new concept poses some challenges, particularly with respect to radio resource management. The main challenges arise from a strong need for distributed D2D solutions that operate in the absence of precise channel and network knowledge. To address this challenge, this paper studies a resource allocation problem in a single-cell wireless network with multiple D2D users sharing the available radio frequency channels with cellular users. They have considered a realistic scenario where the base station (BS) is provided with strictly limited channel knowledge, whereas D2D and cellular users have no information. They have proven a lower bound for the cellular aggregate utility in the downlink with fixed BS power, which allows for decoupling the channel allocation and D2D power control problems. An efficient graph-theoretical approach is proposed to perform channel allocation, which offers flexibility with respect to allocation criteria (aggregate utility maximization, fairness, and quality-of-service (QoS) guarantee). They have model the power control problem as a multiagent learning game.

In [Z. Dai, J. Liu and C. Wang,2015] the authors have studied and considered a spectrum sharing problems in the heterogeneous wireless networks where different device-to-device (D2D) users coexist with the cellular users. They have proposed a novel scheme, called `spectrum partition-based D2D transmission' (SPDT), to improve spectrum efficiency of the D2D and cellular networks. In SPDT, the D2D users assist the cellular transmissions to gain some spectrum released from the cellular system. Then, the obtained spectrum is divided into several frequency bands and each band is assigned to a different D2D pair for its data transmission. Under the quality-of-service (QoS) constraints of both the D2D and cellular users, the authors exploit the tradeoff in the power allocation of the D2D transmitters and show that the number of the allowed accessing D2D pairs can be maximized by optimizing the D2D transmitter power for SPDT. For comparison the power optimization problem is also investigated with the objective of maximizing the number of allowed users accessing D2D pairs in the power control scheme, called `underlay D2D transmission' (UDT). This is where the D2D users access the spectrum being used by the cellular users with power control while ensuring that the QoS of the cellular transmissions is satisfied.

V. PROPOSED SYSTEM

The proposed system has the following objectives.

- Study about D2D communication.
- Mathematical modeling for D2D communication system.
- Implementation of D2D communication system and performance analysis.
- Implementation of D2D communication using game theoretic approach and performance analysis.
- Implementation of Uplink and downlink scheduling for QoS improvement.
- Implementation of efficient approach for resource-allocation
- Spectral efficiency improvement and load decrement for cellular networks
- Performance analysis for mobility models in communication
- Comparative study of game theoretic approach with other state-of-art techniques.

Methodology

Coalition Formation Game for Group Communication — In the coalition formation game a set of players (i.e. D2D users) intend to form cooperative groups (i.e. coalitions). A coalition represents an agreement among the players to act as a single entity formed by players to gain a higher payoff, and the worth of this coalition is called a coalitional value. Two common forms of coalitional games are strategic form and partition form. In the strategic form the value of a coalition depends on the members of that coalition only. In the partition form the value of a coalition also depends on how the other players outside the coalition are structured. Coalitional game models can be developed with either transferable payoff or nontransferable payoff. In a transferable payoff coalitional game, utility serves like money and can be allotted to different players. In a nontransferable payoff coalitional game, different players have different interpretations of utilities, and the utilities cannot be distributed arbitrarily among players. For the strategic-form coalitional formation games, a typical algorithm is the merge-and-split algorithm with the two following operations:

• *Merge:* coalitions merge to a single coalition whenever mutual benefits exist.

• *Split:* a coalition splits whenever this splitting can provide better payoffs.

It has been proved that the merge-and-split algorithm will always converge to a set of stable coalitions, in which no individual player has interests in changing coalition through a merge or split operation to achieve a higher utility. Driven by commercial interests, popular content distribution, as one of the key services in many hotspots such as stadium networks or concert networks, has recently received considerable attention.

In this subsection we focus on one most representative scenario: *group communication*. Figure 2 presents a simple scenario to distribute a popular file to a D2D LAN through traditional cellular networks. We introduce the use of a coalitional game for efficient content dissemination. In this scenario N users want the same file from the Internet, while only K "*seeds*" have already downloaded it. Instead of using more RBs to download the file directly from the eNB, the rest $N — K$ "*normal*" UEs can ask the seeds to send the file using D2D communication. The performance of this approach is determined by which RBs are selected and with which D2D links they share their RBs.

A coalition formation game can be employed in this scenario, which consists of the following components:

• *Players:* N D2D UEs and M cellular UEs.

• *Coalition:* each coalition contains one and only one cellular UE. The rest of the members are the D2D UEs using the same RB.

• *Coalition Value:* in a specific coalition the seeds and the normal UEs form D2D links between each other. The coalition value is the sum rate of all the D2D links and the cellular link.

Since each coalition uses a different RB, the links in different coalitions do not interfere with each other, and thus the coalition formation game has a strategic form. The algorithm for this game can be based on a "switch" operation, which describes that a player may leave the current coalition and join a new coalition if the total value of both coalitions is strictly increased. The switch operation can be simply seen as a combination of a split and a merge. As the total value of the entire system strictly increases by each switch operation, we can expect a set of stable coalitions in which no switch operation is preferred.

VI. POSSIBLE OUTCOME

(i) Extensive literature study in this field

(ii) Existing approaches for D2D communication and their drawback

(iii) Improved performance for D2D communication

(iv) Throughput and resource allocation performance enhancement

(v) Efficient uplink and downlink scheduling for QoS improvement.

VII. CONCLUSION

Integrating D2D into LTE-Advanced networks is a promising method to support ever-increasing demand of proximity-based social/commercial services and applications. The objective of this work has been the analysis, design, development and evaluation of a hybrid D2D cellular system.

This thesis begins by a brief introduction to the research interests on D2D technologies in next-generation wireless communication systems, as well as to the academic research history and existent D2D technologies in other wireless standards.

The next section is concerned with background survey of D2D technologies and standardization process of LTE D2D. Potential usages, opportunities and risks of this new network architecture are analyzed. The contributions include:

• An informative survey of existent widely used D2D technologies in other wireless standards and a detailed comparison of usage cases, market prospects, network structure, PHY/MAC characteristics, etc.

• A thorough literature review of coexistent D2D and cellular networks and a presentation of D2D features in LTE standardization process.

• An analysis of LTE D2D potential usages, general functions that need to be provided, and implementation challenges.

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