A Study on Device To Device Communication in Wireless Mobile Network

Chithra B Das

***Abstract*— With the emerging demands for local area services of popular content downloading Device to Device communication is conceived as a vital technological component for next generation cellular communication networking to enhance the system capacity by increasing the spectral efficiency. Targeting the application of mobile content Downloading we investigate the fundamental problems and how D2D communication improves the system performance of mobile networks and what is the potential effect of D2D communication, with the help of the optimal solutions for the system resource allocation and mode selection obtained under the realistic user and mobility conditions. Specifically, by formulating the max-flow optimization problem that maximizes the content downloading flows from all the cellular base stations to the content down loaders through any possible ways of transmission, and we obtain the theoretical upper bound to system content downloading performance.**

***Index Terms*—3GPP, Device-To-Device Communication (D2D), LTE, Mobile Network , QoS.**

I. INTRODUCTION

As telecom operators are struggling to accommodate the existing demands of mobile users, a new data intensive applications are emerging in daily routines of mobile users. Moreover, 4G cellular technologies, which have extremely efficient Media Acess Control and physical layer performance, are still lagging behind mobile users' increasing data demand. Therefore, researchers are seeking for new paradigms to revolutionize the traditional communication methods of cellular networks. Device to-Device (D2D) communication is one of such paradigms that appears to be a promising technique in next generation cellular technologies.D2D communication in cellular networks is defined as direct communication between two mobile users without traversing the Base Station (BS) or core network. The main reason for incorporating D2D communication in cellular networks is to exploit the proximity of UEs when engaged in local communication sessions such as social networking, media sharing, or proximity-based services.

II. EXISTING SYSTEM

In a traditional cellular network, all communications must go through the Base Station even if both communicating parties are in range for D2D communication. These device can only communicate with the base station via uplink or downlink paths. This architecture suits the conventional low data rate mobile services such as voice call and text message in which users are not usually close enough to have direct communication. It fails to meet the ever-increasing demand of proximity-based social/commercial services and applications.

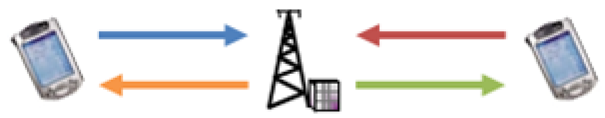

Fig .1. Cellular Communication

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.

III. PRPOSED SYSTEM

Device-to-Device (D2D) communication was initially proposed in cellular networks as a new paradigm to enhance network performance. Mobile data traffic, especially mobile video exchange, has dramatically increased in recent years with the emergence of tablets, smart phones, and various new applications. It is hence essential to increase network capacity to accommodate these bandwidth consuming applications. (D2D) communication is a promising concept to improve user experiences and resource utilization in cellular networks, both for unlicensed and licensed spectrum. It enables two mobile devices in proximity of each other to establish a direct local link and to bypass the

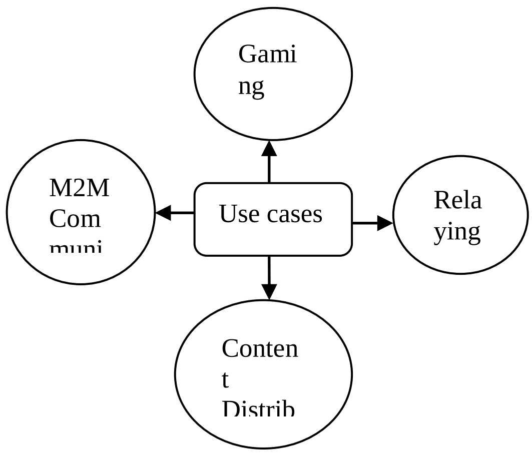

Fig. 2 . Use cases Of D2D Communication

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base station or access point.D2D communication may either be network-regulated where the operator manages the switching between direct and conventional cellular links, or the direct links may be regulated by the devices without operator control. The D2D technologies, aim to support the emergence of new applications such as the local discovery, to enhance the network capacity and coverage proximity-based social/commercial services and applications, Content distribution and location-aware advertisement show great prospects for D2D communications in cellular networks.

IV. CLASSIFICATION OF D2D COMMUNICATION

D2D communications propose to use the cellular spectrum for both D2D and cellular communications (i.e., underlay inband D2D). These works usually study the problem of interference mitigation between D2D and cellular communication. In order to avoid the aforesaid interference issue, some propose to dedicate part of the cellular resources only to D2D communications (i.e., overlay inband D2D). Here resource allocation gains utmost importance so that dedicated cellular resources be not wasted .Other researchers propose to adopt outband rather than inband D2D communications in cellular networks so that the precious cellular spectrum be not affected by D2D communications. In outband communications the coordination between radio interfaces is either controlled by the BS or the users themselves. Outband D2D communication faces a few challenges in coordinating the communication over two different bands because usually D2D communication happens on a second radio interface.

A. *Inband D2D*

The motivation for choosing inband communication is usually the high control over cellular (i.e., licensed) spectrum. Some researchers consider that the interference in the unlicensed spectrum is uncontrollable which imposes constraints for QoS provisioning.

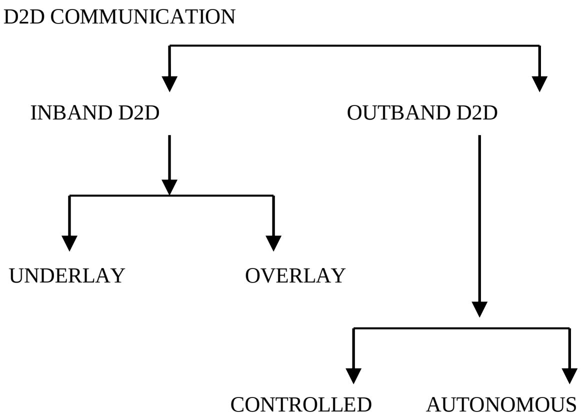

Fig. 3. Classification Of D2D Communication

Inband communication can be further divided into underlay and overlay categories. In underlay D2D communication, cellular and D2D communications share the same radio resources. In contrast, D2D links in overlay communication are given dedicated cellular resources. Inband D2D can improve the spectrum efficiency of cellular networks by reusing spectrum resources (i.e., underlay) or allocating dedicated cellular resources to D2D users that accommodates direct connection between the transmitter and the receiver (i.e., overlay).

B. *Outband D2D*

Here the D2D links exploit unlicensed spectrum. The motivation behind using outband D2D communication is to eliminate the interference issue between D2D and cellular link. Using unlicensed spectrum that requires an extra interface and usually adopts other wireless technologies such as WiFi Direct, ZigBee or bluetooth .

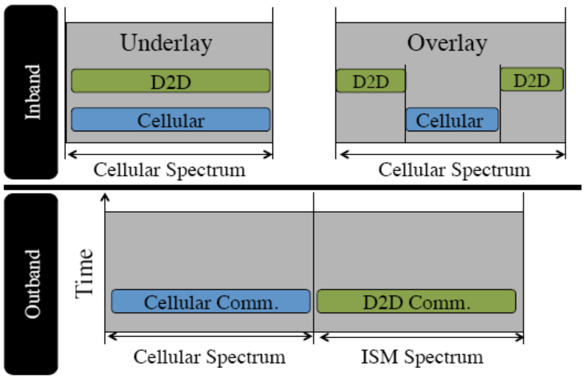

Fig. 4. Schematic representation of overlay inband, underlay inband, and outband D2D.

Some of the work on outband D2D suggest to give the control of the second interface/technology to the cellular network (i.e., controlled). In contrast, others propose to keep cellular communications controlled and leave the D2D communications to the users (i.e., autonomous). Outband D2D uses unlicensed spectrum which makes the interference issue between D2D and cellular users irrelevant. On the other hand, outband D2D may suffer from the uncontrolled nature of unlicensed spectrum.

V. ANALYSIS ON D2D COMMUNICATION

1. *Underlaying Inband*

A. *Spectrum Efficiency*

D2D communication can improve the spectrum efficiency greatly. This improvement can be achieved by exploiting techniques such as interference reduction among D2D users and cellular [25], [22], [23], [24], [10], [16] or interference avoidance [5],[16], [9], [23]. Among these papers, [23], [11] and [6] adopt more advanced mathematical techniques than the others. The proposed methods in these papers can be either self-organized [4] or network controlled [8], [7], [25], [9], [10], [20], [23], [12]. The self-organized methods proposed in [4] introduce less overhead and are more efficient in comparison to network controlled methods. It should also be noted that using advanced mathematical techniques, such as non-linear programming [25] and game theory [11], can result in higher gain than simpler interference reduction/avoidance methods based on heuristics. However, they also introduce higher computational overhead which should be taken into account when comparing the performances of the proposals.

B. Power Efficiency

It was observed that D2D communication can result in increased power efficiency of the network. A common technique to achieve this is to dynamically switch between cellular and D2D modes. The authors in [18] and [17] propose heuristic algorithms to solve the mode selection problem, while [8] employs the brute force technique. The performance of the method in [8] is thus better than those in the other two, but it also requires much more computations.
Performance with QoS/Power Constraints

C. Performance with QoS/Power Constraints

Improving the performance of D2D-enabled cellular systems with QoS/power constraints usually requires advanced techniques such as stochastic optimization, nonlinear programming, and integer optimization. As expected, the solution of these approaches and their derived sub-optimal heuristic can indeed improve the system performance with QoS/power constraints. However, they do not seem to be good candidate for time-stringent application with limited computational capacity. Nonetheless, the authors of [14] and [15] derived the closed-form of the optimal solution, that in fact reduces the computational complexity.

2. Overlaying Inband D2D

A BS-assisted scheduling and D2D power control was proposed in [15] in order to reduce D2D interference. Differently, the authors of [12] and [15] focus on relaying use-case of D2D. Specifically, [12] proposes to use the BS as a relay (backup re-transmitter) for the D2D transmission and [10] uses multiple D2D users as relays (re-transmitters) for multicasting. Both methods proposed in [14] and [10] have low complexity which makes them practical for real world scenarios. The algorithm proposed in [15] is much more complex, and it exhibits very high performance when the maximal distance between D2D users is short.

3. Outband D2D

Here considering use-cases of D2D communication. The authors in [2] and [1] use clustering and game theory to boost the throughput performance as well as energy efficiency and fairness. For the first time, they designed a detailed protocol for outband D2D communications in [3]. The work in [13], [14], [4] and [5] aim to improve the performance of content distribution. The methods proposed in [12], [13] are simple, while that of [4] is more complex. The performance of both methods is evaluated to be good. In addition to content distribution, the authors in [5] also consider user mobility and deadline-based content, for which they provide comprehensive evaluations under a realistic simulation setup including real time video transmission.

VI. DISCUSSIONS AND FUTURE WORK

1. Common Assumptions

Most of the papers in literature assume the BS is aware of the instantaneous CSI of cellular and/or D2D links. This assumption is essential because their proposed solutions need the BS's participation to make scheduling decision for cellular and D2D users. Alternatively, when the D2D users decide on the their transmission slots, the common assumption is that D2D users are aware of the cellular and D2D links. To mitigate possible interference from D2D transmission to cellular transmission, assumes that D2D users are aware of minimum interference threshold of cellular users. With the latter assumptions, the D2D users can opportunistically choose the transmission slots in which they do not interfere with the cellular users.

2. Inband Or Outband..??

Majority of the papers propose to reuse the cellular resources for D2D communications. However, outband communication is attracting more and more attention now a days. Before comparing the two approaches, we summarize the advantages and disadvantages of each approach.
Inband: Inband D2D is advantageous in sense that:
(i) underlay D2D increases the spectral efficiency of cellular spectrum by exploiting the spatial diversity
(ii) any cellular device is capable of using inband D2D communication (the cellular interface usually does not support outband frequencies)
(iii) QoS management is easy because the cellular spectrum can be fully controlled by the BS.

The disadvantages of inband D2D communications are:
(i) cellular resources might be wasted in overlay D2D.
(ii) the interference management among D2D and cellular transmission in underlay .
(iii) power control and interference solutions usually high complexity methods.
(iv) user cannot have simultaneous cellular and D2D transmissions.

It appears that underlay D2D communication is more popular than overlay.
Outband: OUTBAND D2D of D2D communications has merits such as:
(i) there is no interference management between cellular and D2D users
(ii)there is no need of dedicating cellular resources to D2D spectrum like overlay inband D2D
(iii) the resource allocation becomes easier because the scheduler does not require to take the frequency, time, and location of the users into account; and

Nevertheless outband D2D has some disadvantages which are:
(i) the interference in unlicensed spectrum is not in the control of the BS.
(ii) only cellular devices with two radio interfaces (e.g., LTE and WiFi) can use outband D2D communications.

3. Maturity Of D2d In Cellular Networks

We believe D2D communication in cellular networks is a relatively young topic and there is a lot to be done/explored in this field. We support this belief by looking into the analytical techniques and evaluation methods which are used in the available literature.

4. How Far Is D2d From A Real World Implementation?

Although D2D communication is not mature yet, it is already being studied in the 3GPP standardization body. 3GPP recently decided that the focus of D2D in LTE would be on public safety networks. Moreover, Qualcomm has shown interests in this technology and they also built a prototype for D2D communications in cellular network which can be used in different scenarios such as social networking, content sharing, and soon. This confirms that D2D communication is not only a new research topic in academia.

5. D2d Implementation Challenges In Real World

Although D2D communication triggered a lot of attention and interest in academia, industry, and standardization bodies, it is not going to be integrated into the current communication infrastructure until the implementation challenges are resolved. Here, we explain some of the major challenges faced by D2D communications. Interference management: Under inband D2D communication, UEs can reuse uplink/downlink resources in the same cell. Therefore, it is important to design the D2D mechanism in a manner that D2D users do not disrupt the cellular services. Interference management is usually addressed by power and resource allocation schemes, although the characteristics of D2D interference are not well understood yet. Power allocation: In inband D2D, the transmission power should be properly regulated so that the D2D transmitter does not interfere with the cellular UE communication while maintaining minimum SINR requirement of the D2D receiver.

6. Analytical Method

In comparison to other fields such as opportunistic scheduling , the number of techniques used in the literature and their popularity is very low. The majority of the literature only proposes ideas, architectures, or simple heuristic algorithms. Some of the papers formulate their objectives as optimization problems but leave them unsolved due to NP-hardness. Therefore, there is need for investigating optimal solutions for interference coordination, power management, and mode selection.

VII. APPLICATION

A decade ago D2D was first proposed for relaying purposes in cellular networks. Researchers put forward new use-cases for D2D communications in cellular networks such as video dissemination, multicasting, peer-to-peer communication, M2M communication and cellular offloading It is believe that D2Dcommunication can have more applications in the telecommunication world. For example, it would be interesting to see the application of D2D communication in social networking, location-aware services, vehicular networks, smart grids etc.

VIII. FUTURE WORK

As we mentioned earlier, the use of mathematical tools and optimization techniques in the state of- the-art are very limited. The current literature definitely lacks optimal mode selection techniques and interference and power control mechanisms. The queue stability analysis using techniques such as stochastic Lyapunov optimization can be also an interesting issue to tackle. This can be further extended to provide throughput-based utility, throughput-power tradeoff, delay bounds, and delay analysis of D2D communications in cellular networks.

IX. CONCLUSION

In this work, an extensive study on the available literature on D2D communications in mobile networks is provided. Here categorized the available literature based on the communication spectrum of D2D transmission into two major groups, namely, outband and inband. The works under inband D2D were further divided into underlay and overlay. Outband D2D was also sub-categorized as controlled and autonomous.

The major issue faced in underlay D2D communication is the interference management and power control between D2D and cellular users. Overlay D2D does not have the interference issue because D2D and cellular resources do not overlap. However, this approach allocates dedicated cellular resources to D2D users and has lower spectral efficiency than underlay. In outband D2D, there is no interference and power control issue between D2D and cellular users. Nevertheless, the interference level of the unlicensed spectrum is uncontrollable, hence, Quality Of Service guaranteeing in highly saturated wireless areas is a challenging task. This study showed that D2D communication is immature and there are still numerous open issues such as interference management, power control, QoS etc. We also formulate some possible research directions needed to improve the understanding of D2D potentialities for real world applications.

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