Demo: 4G LTE-assisted Distributed Device-to-Device Communication using Android Smartphones

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ABSTRACT
Device to Device (D2D) communication has been proved to be an effective way to enhance cellular network capacity, which enables direct data exchange of localized traffic of users in proximity. Current D2D links are mainly based on WiFi Direct technology. In this paper, we propose a 4G LTE-assisted distributed D2D communication network. Information of user devices will be uploaded to a D2D server periodically via commercial 4G LTE network. The D2D server then will initialize a D2D network after collecting the device information. A Token sharing strategy is proposed to control the process of D2D networking, based on the information of SINR, location, battery power, as well as service QoS demand. Finally, our proposed system is demonstrated by Android smartphones.

CCS Concepts
•**Networks→Mobile networks**

Keywords
Device to Device Communication; Distributed networks; LTE

1. INTRODUCTION
Device to Device (D2D) communication has recently drawn a significant attention due to its great potential in improving cellular network capacity. D2D communication involves the utilization of a physical link between D2D users to directly exchange data without routing packets through cellular network infrastructures. Current solutions of D2D communication, are mainly based on WiFi Direct technology, which supports a quick establishment of D2D links and multi-hop communication after protocol optimization [1]. However, due to the contention-based channel access, this solution may fail to guarantee user's QoS demand, especially when the concurrent D2D links are in a large number.

In order to maximize system throughput and resource utilization, the 3rd Generation Partnership Project (3GPP) prefers that D2D links are established under the central control of a cellular base station (BS), i.e. LTE BS. The cellular BS holds a global view of wireless environment. Thus, by a proper management of D2D links, the QoS of each D2D user's service can be guaranteed, while channel utilization and power consumption can also be improved.

MobiHoc'16, July 04-08, 2016, Paderborn, Germany
ACM 978-1-4503-4184-4/16/07.
http://dx.doi.org/10.1145/2942358.2942399

In addition, D2D network topology needs to be designed flexibly, because of the mobility of mobile users, especially when users in D2D network are located in different cellular cells. The coverage of cellular network is larger than that of D2D network. Thus, the management of D2D network is more efficient with the help of cellular network.

In this demo, we attempt to design a novel LTE-assisted distributed D2D communication system. Different from WiFi direct, users in distributed D2D network can communicate with each other without a router or virtual Access Point (AP). A D2D server is designed to play the role of D2D network management, including wireless resource allocation and user scheduling. Besides, electric quantity and location of user devices are taken into consideration, to guarantee the fairness among D2D users.

The contribution of this demo paper can be summarized as follows: 1) implementation of LTE-assisted distributed D2D network, in which users can communicate with each other without a router or AP; 2) a novel joint power control and channel access strategy of devices, considering users' SINR condition, location, QoS demands of services, electrical quantity of devices, as well as network load; 3) the first proof-of-concept prototype of 4G LTE-assisted D2D communication.

2. SYSTEM DESIGN
The most significant feature in our design is that user devices would send their D2D requests to D2D server via commercial 4G LTE network, with information of QoS demand, SINR condition, battery power, and geometry location (if GPS signal exists). The server then will generate or update a device information table, according to which the D2D network is established and a certain network management strategy can be applied. The detailed D2D network setup process is shown in Fig. 1.

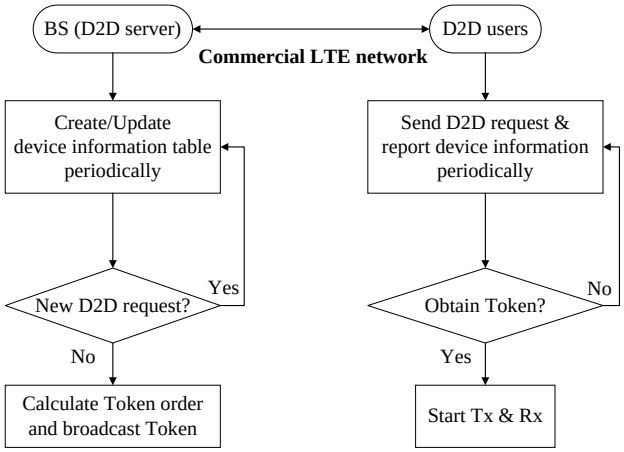

Figure 1: LTE-assisted distributed D2D network setup

2.1 Token Sharing Strategy

In system design, we adopt the concept of Token in ad-hoc networks, to help QoS guarantee. In the initial phase, each user device scans its neighborhood to carry out D2D user discovery, and then send their D2D communication request to D2D server via commercial 4G LTE network. After collecting the D2D communication requirements of related users, a Token will be generated by D2D server, and then broadcasted to all the D2D user devices by 4G LTE network.

The Token sharing strategy is illustrated in Fig. 2. The Token contains the information of user device ID, duration time, timing stamp, and transmission power index. User device ID indicates which user in current D2D network can occupy the wireless channel to communicate with its target users; duration time indicates the time span occupied by a D2D user, which can be adjusted according to different QoS demands; timing stamp indicates the network timing information; transmission power index is to control the power of a D2D transmitter, according to its battery power, and the distance from its destination. Once the corresponding user receives the Token, it will start transmission, and allow other devices to communicate with itself.

Once the duration time is out, D2D server will withdraw the Token, generate the new Token, and distribute it to all the D2D users via LTE BS. During this process, user devices report their information to D2D server in a pre-defined period. Thus, the table in D2D server is dynamically modified, to accommodate the network change.

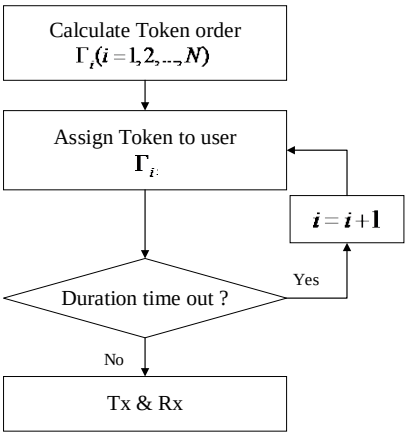

Figure 2: Token sharing process

2.2 Joint Power and Channel Access Control

When D2D server receives the device state information, it will carry out a series of calculation, to determine the distributed D2D network topology, as well as the Token sharing order. In 3GPP, D2D link is specified by the Sidelink protocol, which reuse the same wireless band of cellular networks. Thus, a proper power and channel access control mechanism needs to be designed, in order to reduce the intra-cell interference. In our demo, D2D network is constructed on ISM band, and power control is mainly to reduce the energy consumption of user devices, which is energy-sensitive.

In the initial phase, each user device reports its information to D2D server, as mentioned before. The server then will calculate the Token sharing order according to the following equation:

$$\Gamma = \frac{\alpha}{|L_2 - L_1|} * \frac{\beta}{P_{battery}} * \gamma * Q$$

From above equation, the Token sharing order is proportional to users' SINR condition (γ) and QoS demand (Q), but is inversely proportional to battery power ($P_{battery}$) and distance between source and target D2D user. The parameter α and β are utilized to adjust the significance level of distance and battery power.

In Token sharing phase, the transmission power index is included in the Token, which is categorized into three levels: low, medium, high. It is also determined by battery power, distance of transmission and QoS demand. Thus, a joint control mechanism of channel access and transmission power can be obtained by the device information, to maximize the usage of wireless resources and device power.

3. IMPLEMENTATION

In our demo, we use three Android smartphones to establish a distributed D2D network, as is shown in Fig. 3. All the smartphones are served by CMCC commercial 4G LTE network. We build up a D2D server on a commercial PC, to handle the control and configuration of D2D network. Information of all the devices is maintained in a device information table. The table is updated periodically or when devices join/quit the D2D network.

An Android APP is developed to show the Token information. Because Token is broadcasted in the whole D2D network, so it is possible for each user to know where the Token is. Once the D2D network is set up and D2D user obtains the Token, the data transmission will start as soon as possible.

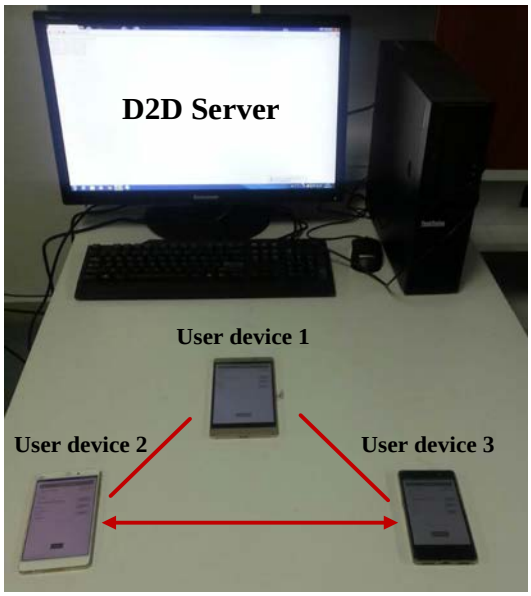

Figure 3: Overview of Demo system

4. ACKNOWLEDGEMENTS

This work was supported by the National 863 Project (No. 2014AA01A701), by the National Natural Science Foundation for Distinguished Young Scholar of China (No. 61325006), by the Shenzhen Science and Technology Project (No. 20150082), and by the Fundamental Research Funds for the Central Universities.

5. REFERENCES

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