Device-to-Device Communication in 5G Cellular Networks: Challenges, Solutions, and Future Directions

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Abstract—In this article we plan to give an overview of a two-tier cellular system, with a macrocell tier (standard BS-to-device communication) and a device tier (device-to-device communications). We will discuss what is different from the conventional cellular architecture and which new technical challenges brings.

Index Terms—D2D, macrocell tier, device tier, device relaying, direct communication, operator controlled, device controlled

1 Introduction

With the increase of hand-held devices and bandwidth-hungry applications and with the prediction of future applications which require data rates that are not achievable with the 4G networks, it means we need some unconventional thinking for the 5G cellular system. This problem can be solved using cooperative communications, in which nodes help each other relaying information.

D2D communication wasn't considered in the previous generations of cellular network mostly because it was envisioned as a tool to reduce the cost of local service, which was insignificant in the past. But this attitude towards D2D has been changing recently with the new trends in the wireless market. D2D can also play a vital role in mobile cloud computing and help effective sharing of resources, and also take some load off the network in local areas such as big malls allowing direct transmission among devices. It could also be useful during natural disasters where D2D could replace damaged BS.

2 Overview

The articles envisions a two tier 5G cellular network, macrocell tier (BS-2-device) wich is the conventional way of cellular network and device tier (D2D). The base station will continue to work and serve devices, but devices will be allowed to communicate which each other creating an ad-hoc mesh network.

There are 4 types of device tier communications:

1) **Device relaying with operator controlled link establishment (DR-OC):** a device can communicate with the BS through relaying its information via other devices, the BS communicates with the relaying devices for partial or full control link establishment;
2) **Direct D2D communication with operator controlled link establishment (DC-OC):** The devices communicate directly with each other but need the BS to establish link;
3) **Device relaying with device controlled link establishment (DR-DC):** The devices communicating are responsible for coordinating communication using relays between each other, BS has no control;
4) **Direct D2D communication with device controlled link establishment (DC-DC):** both devices have direct communication with each other, without any BS control.

A two tier cellular system, if well designed, can bring improvements over the classical cellular system, but it has a couple of technical challenges to overcome.

One of the challenges of D2D communication is security, the users data will be routed through other peoples devices, privacy must be preserved. One possible way to solve this problem would be creating closed access. In closed access, a device has a list of trusted devices. For example, a list of people on the workplace or a list of users that have been authenticated via trusted parties such as an organization, can directly communicate with each other. If the devices are not trusted they would use the macrocell tier.

Other challenge would be interference management. In the first two types, the BS can diminish the interference problems to some extent using centralized methods. On the other hand, the last two types have no centralized entity supervising the resource allocation between devices. The two-tier network needs to be designed with an appropriate interference management strategies and resource allocation schemes.

3 PRINCING

In the actual mobile communication system, it is easy to mobile operators charge the users with the expenses. Since all traffic that users generate necessarily passes through the access points installed by operators, the operators just need to monitor the traffic and associate it with each user and then apply the taxes.

In a network where communication can be made from device to device, control of user activity can be extremely difficult or impossible to do. For example, it may happen a malicious-user do not report his activity to the operator. In this case, operators will have no interest in support such networks.

Therefore, it is necessary to solve these problems by presenting a new plan. On one hand, the operators will have the advantage of not requiring such a large infrastructure to serve the same number of users with even higher quality, but on the another hand, operators will have to give something back to users to make their devices available as replicators of information. Having a device as a replicator is costly, like battery consumption, device storage usage and utilization of available bandwidth.

To solve this problem, operators have to offer some reward to users. For example, get discounts on the fees charged or provision of services.

3.1 Pricing for DC-OR (device relaying-operator controlled)

This type of communication is the most expense for the relaying users because it requires more resources like battery, device storage and bandwidth. The mobile operators should reward them with attractive monetary incentives, otherwise, they will not be interested in participate. As a result, the revenue should be in function of the amount of services provided by the user.

The operator can implement any kind of model to reward the users. But, a good model should increase the operators revenue compared with conventional networks and also should increase users revenue, only in this way is that the system becomes profitable.

3.2 Pricing for DC-OC (D2D communication-operator controlled)

Despite of this type of communication being controlled by the operator, users can just use another kind of communication and get it for free, like free WiFi networks or Bluetooth communication.

To workaround this problem, operators can implement a solution inspired in auction theory and game theory. For example, there are too many users trying to access to the network and there is no free channels for communication. and just some of them will be able to communicate. So, devices that want communicate can submit higher bids in order to have access to the medium and then the operator allocates the available channels to the highest bidders.

The revenue of operators will increase with more devices because the bets will be higher, meanwhile, in a conventional network, the revenue will be constant because the network capacity will be full.

3.3 Pricing for DR-DC and DC-DC (device controlled)

When the operator does not participate in the communication, is expected do not make any profit from it. Users can share information freely over WiFi or Bluetooth, like happens nowadays.

But, devices can ask money to relay information in DR-DC using an approach like in market (law of supply and demand).

4 Conclusion

In this article, we envisioned a 5G network, where devices can communicate with each other. The network is divided in to tiers: macrocell and device tier. Operators have different models that can adopt where the participation of the operator and the devices can be different.

We discussed some technical difficulties in this kind of networks, like security, interference and resource allocation. We also discussed how operators can benefit with this network.

In the end, operators and users can have good benefits in comparison to a conventional network.

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