Multi D2D links sharing the spectrum of one cellular link

Abstract-Recently, a D2D (Device to Device) technique has been proposed, it has many advantages: improved cell capacity; UE power savings, and also improved instantaneous rate. D2D link share the cellular frequency resource, through a direct link to transfer data between each other. Users can control the cellular base station and D2D user resource allocation [2]. With a D2D system in a cellular network, a key question is how to avoid the interference with cellular network, so we can obtain improved system capacity and ensure reliable communication.

This paper discusses how to choose the cellular UE to share spectrum with D2D links, thus ensuring the link quality of both the cellular link and D2D link, not interfering with each other; then propose a D2D link spectrum sharing scheme to Allow multiple D2D links coexist with a cellular UE.

# System Model

We consider D2D use cellular uplink (UL) for communication, so D2D link will cause interference to the base station receiving the signal, the solution is to limit the transmit power, so that our main problem is the interference to D2D users caused by cellular user. Assuming multiple D2D users share link with a cellular UE’s spectrum resources; Our solution to the problem is: define a region generated by D2D link, which makes the selected cellular link is outside of the D2D link thus limiting cellular interference to the D2D users; then we define multiple such regions, since each area id generated by 2D link, all D2D links in different regions can use the same spectrum resources, so we need to consider how to arrange these areas, so that the interference between the D2D links reduced as much as possible; then we proposed sector division scheme.



Figure 1 Multi D2D links sharing the spectrum of one cellular link

Uplink interference is represented in Figure 1, the maximum power of  is strictly limited to avoid interference to cellular network, so the interference of the cellular network can be ignored; however, the D2D user can receive the interference signal from other D2D users; the ith D2D user received signal is expressed as:

 (1)



Where and is the transmitting data of D2D UE and cellular UE respectively. n is sided power spectral density of the AWGN;  is the channel response, subject to an independent Gaussian distribution assumption. represents link distance, and is the transmitting power of D2D UE and cellular UE respectively. Here we use logarithmic attenuation model, defined as , where  is the transmission power,  is the power at the point a; and  is path loss are constant ,  is the path loss exponent;

The signal that the base station receives is :

 (2)

# D2D restrict region

We assume that all base stations received the same CN UE power, So the relation of the transmission power  of cellular UE and the power  BS received is :

 （3）

In addition, we strictly limit the maximum transmit power D2D user to ensure that D2D UE does not cause harmful interference to BS.

Next, assume that there is only one UE D2D sharing spectrum of a cellular UE, and the cellular base station receives the signal requires a minimum SINR defined as, in the case of absence of noise,

 (4)

So that we will limit the transmit power  as:

 (5)

Next, we consider how to generate an area we envision: This area indicates D2D receives the SINR value is less than a threshold, the same frequency cellular UE can not be located in the region, that is

 (6)

And:

 （7）

Put (7) into (6​​), we obtain

 （8）

The position of cellular UE is expressed as , D2D receiver's position is 

 (9)

Let , as D2D link is short, we can easily ensure that the received D2D link power is higher than the base station, so that we can get

 (10)

We can find this area is a circular area, so that our principle is to choose a user located outside the region to share the spectrum. Assuming D2D link received power is a fixed value, so that the value A is constant, then the radius of the circular region on the D2D link has only to do with the distance between the base station and the user receiver’s location.

# D2D link distribution

Next, we consider the interference between D2D links. Suppose there are M D2D links sharing the same frequency, each of equal length and the same transmission power, we can get the same frequency D2D link SINR as



 （11）

Similarly, we assume that the links of D2D must meet certain SINR requirements.

 （12）

To allow multiple D2D links sharing the same spectrum resources, we need a D2D link with the frequency allocation scheme, because D2D link length is not long, and the transmit power is limited. So long as we guarantee that interference D2D link located outside a certain area, it can effectively avoid mutual interference. Here, we have designed a simple strategy: the cell is divided into M sectors, located in the same sector of the D2D link can not use the same spectrum resources. Shown in Figure 2.and because we assume that the transmit power of cellular UE is constant, then it is necessary to set a distance r from base region, where we can not have D2D links.



Figure 2 The sector to divide D2D links

Of course, if the M D2D links randomly fall into M sectors, and to meet the Requirement the cellular UE which share resource with D2D UE is outside of the regions, there may lead to , but the simulation in next part can found that such probability is very low, and in practice we do not always have the same frequency M users communicate simultaneously. In the given limited conditions, The interference caused by D2D UEs in different sectors has no significant increase, the reason is that the same frequency D2D links in different sectors and the cellular UE is in one of the sector, and the cellular UE satisfies the condition of being outside of each D2D link restricted region, and most D2D links is far from cellular users ,so this scheme also reduces uplink transmission interference.

# System Capacity

By equation (1), we can get the SINR at D2D UE is:



 （13）

The SINR of cellular UE is :



 （14）

The total system capacity is:

 （15）

# Simulation

We assume that D2D links with the same length and the same transmit power. The cell radius is 500m, D2D link length is 15m,  equals to 20. in order to ensure that no excessive interference to the base station, in the range from the base station 100m, there is no D2D communication. We assume that the random distribution D2D links within each sector, the cellular UE sharing the spectrum may located in the outside of the circular areas generated by multiple D2D links. We use the Monte Carlo method for simulation.

First, we consider the feasibility of scheme of sectors, defining a outage probability: [3].We can see from Gigure 3,the interference between D2D links in different sector is very low.



Figure 3

Next we consider the cell is divided into three sectors and six sectors.



Figure 4 The capacity of three sectors Figure 5 The capacity of six sectors

From Figure 4 and Figure 5 we can find, D2D links greatly improves the system capacity, even though the D2D transmit power is limited, due to the short D2D link, it can obtain higher spectrum efficiency, the cellular spectral efficiency doesn’t suffer a greater loss. Compared with the six sectors to three sectors, despite the result of mutual interference between the enhancement, the loss of spectral efficiency is not high. Therefore, by sector division of the overall spectrum efficiency can be improved without significantly reducing the spectral efficiency of each single link.

# Conclusion

The introduction of D2D links greatly improves the cell capacity. The establishment of a restricted area generated by D2D program effectively avoid the interference between the link and the cellular link, and to divided sectors used to limit the same frequency D2D link, avoiding mutual D2D interference. Of course, this article uses sectorization way to place the same frequency D2D link is not the most efficient way, but to make the whole system is relatively simplified, and D2D links with the frequency arrangement remains to be further studied.

*Proposal 1 Generate a circular area for each D2D link, The D2D link can’t share resources with the cellular UE within the circle.*

*Proposal 2 Divide the cell into multi sectors, and the D2D links within the same sector can’t share resources.*

# Reference

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