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Research on Interference Coordination and Resource Allocation Algorithm in D2D Communication Systems

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Abstract: D2D in the cellular network (Device-to-Device, Terminal pass through) technology can improve spectrum efficiency of resource utilization, but due to D2D reuse resources of cellular subscribers will cause co-channel interference with D2D user. Reducing interference and improving system performance, a better allocation of resources become the focus of recent studies. In order to suppress this interference, presents a resource allocation scheme based on fairness, using weights value to represent the user's priorities and resource allocation, improve the fairness of the system, aim to improve system throughput. Finally, simulation analysis shows that, the programme can effectively improve the fairness of the system, it also well enhance the throughput of the system.

Key words: D2D, allocation of resources, fairness，throughput;

1 Introduction

With the advent of the Internet age, people began to seek higher rates of mobile data services, the limited spectrum resource has been unable to meet the growing needs of the business, mobile spectrum shortages facing serious challenge, the spectrum of scientific and rational resource allocation scheme has been the focus of the next generation of mobile communication studies. D2D communication technology is a new technology that allows the end user to communicate directly with the shared cell spectrum resources under the control of the cellular system, It can improve the frequency spectrum utilization rate, increase the capacity of communication, reduce the load of the base station, etc.. In addition, D2D communication technology can also reduce the transmit power of the terminal user through power control , thereby ,improving the service life of the battery terminal.

When D2D communication in multiplexed mode, The co-channel frequency interference will be generated between the D2D communication link and the cellular communication link in a cellular cell, how to supress the co-channel frequency interference and improve the system throughput, reasonable resource allocation scheme proposed in D2D communication is particularly important. Literature [1] proposed a power control based on dynamic mechanism to reduce interference and improve the overall performance of cellular systems. Literature [3] have come up with a probability based on interrupt and model selection of combined control algorithm with improve the overall performance of communication systems. Based on the method of Literature [6], the paper proposes a method to select the reuse of cellular users, and proposes a power control scheme based on the distance between the D2D and the base station. Literature [7] set the D2D communication of the SIR threshold, set around the base station to prohibit D2D users communication area. D2D users will not multiplexing communication ban cellular users within the region, otherwise the D2D receiving end of the received signal SIR (signal interference ratio) does not meet the threshold requirements and will not be able to normal communication, so as to improve the performance of the communication system.. Literature [8] allocate the resource to the D2D users at first, and then according the allocation of D2D users in each RB to allocate the resource to the cellular user. First allocate the resource to cellular user, assigning resources to D2D, and then cellular subscribers in proportional fair scheduling timeshare weight value will change, so that the fairness of the system is reduced. Two resource allocation strategies are proposed in the literature [9] ,D2D users fairness policy and cellular user fairness policy to improve the fairness of the system. Although the literature [8-9] improves the system fairness, the throughput of the system is not very high. Considered in the literature are single cell users, this paper will consider multi-cell user scenarios, and combined with the status of current research D2D cellular users, on the basis of literature [8] proposed scheduling fairness based resource allocation scheme. Finally, simulation analysis shows that compared with [8], the proposed algorithm has a great improvement in fairness and throughput.

1 D2D communication model in LTE system model

1.1 System Model

As shown in figure 1 is a seven-cell cellular model, each district is divided into the area of the edge and center regions, and assign different frequency band resources.The central area of allocation bands F1, three edge of the adjacent area allocation band orthogonal F2, F3, F4, thus avoiding the same frequency interference between adjacent neighborhood.

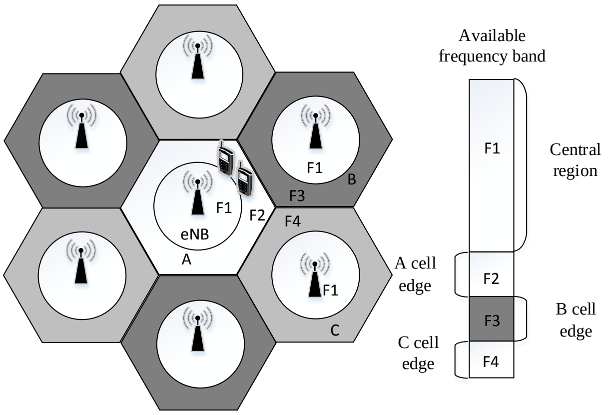

Figure 1 Seven cell model of D2D communication

As shown in figure 2 is a multi-cell environment, Assume cell A as the target user area, In cell A randomly distributed m cellular users and n D2D users, in which the cellular user is set as C={1,2…m},d2d user is set as D={1,2…n}, for the base station, all cellular users of the location coordinates are known. In the figure 1, A circular area with radius r_1 is the base station communication Prohibited Area, A circular area with radius r_2 is the reuse prohibited area for D2D users, A circular area with radius r_3 is the base station traffic prohibited area When d2d other regions when a user is in the base station communication prohibited area where cellular users can reuse the region.

Assume that all fading channel gain exponential distribution and the path loss model:

$$P_r = cP_s d^{-\alpha}$$

Where p_s and p_r respectively means that the transmitter power and transmitter signals received from the transmitter power, c and α respectively on behalf of the path loss constant and the path loss exponent.

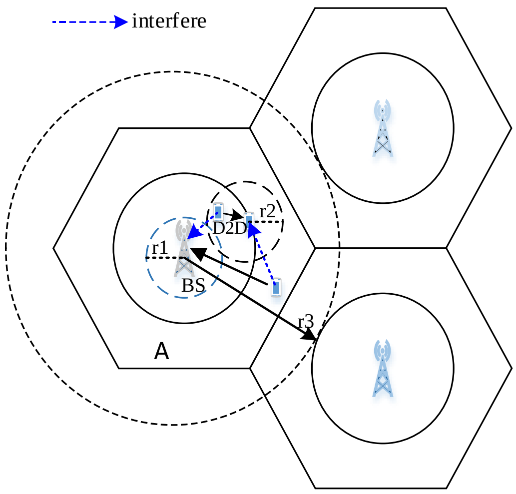

Figure 2 multiple - cell system model

1.2 Problem description

As shown in Figure 2, when a pair of D2D users reuse the cellular user's spectrum resources will inevitably make the same frequency interference with cellular users. At this point, the weight of the cellular system is bound to be affected, so the fairness of the original cellular system will be destroyed by the D2D of the cellular user resources.

In the literature [10], the formula for the weight value of the cellular system scheduling is

$$\omega_i^c = r_i^c / R_i \quad (1.1)$$

Where ω_i^c is the user i in resource block the corresponding weighted value, the higher the weight value, then the user I the larger the priority assigned to the resource.

In (1.1), r_i^c represents the cellular subscribers in an instantaneous data rate in the resource block, The average data rate of R_i to indicate that the user i, The computation of r_i^c the is obtained by the SINR of the user I reference signal on the resource block The programme first assign the resource to cellular users, and then select candidates that meet the criteria for D2D users' cellular users and reuse its resources to weight values it at the same time less impact on the user as a priority in order to ensure the fairness of the system.

1.3 Resource allocation scheme based on Fairness

The proposed scheme is based on the literature [8], which is based on the minimum damage to the cellular user's weight value is a priority, resource allocation for D2D users, specific programs are shown in figure 3:

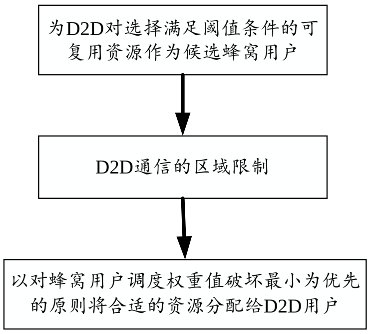

Fig. 3 flow chart of D2D communication resource allocation

Step 1: Choose the celluar users that can meet the conditions of D2D as potential candidate the cellular users

If the cellular user i can be reuse by D2D users j , it must also meet the QoS of cellular user i and D2D users j , that is, meet the following conditions:

$$\gamma_i = \frac{p_i g_{ie}}{p_j g_{je} + N_0} \geq \gamma_{cth} \quad (1.2)$$

$$\gamma_j = \frac{p_j g_j}{p_j g_{ij} + N_0} \geq \gamma_{dth} \quad (1.3)$$

$$p_i \leq p_{c\max} \quad (1.4)$$

$$p_j \leq p_{d\max} \quad (1.5)$$

(1.2) and (1.3) requires a cellular user *i* and D2D users *j* meet the minimum SINR threshold that can make communicate properly, (1.4) and (1.5) provides for maximum transmitting power threshold of their communications, In the above equation, p_i and p_j are respectively represent the transmission power of the celluar user *i* and the D2D users *j*, g_{ie} and g_{je} represent the channel gain between the subscribers of cellular user i and D2D users *j* to the eNB channel gain,respectively. g_{ij} is channel gain between the subscribers of celluar user *i* and D2D users *j* channel gain, g_j is the channel gain of D2D users *j*, r_{cth} And r_{dth} represent the lowest SINR threshold of cellular users and D2D User Communication. Set S_i as the collection of candidate cellular users As shown in figure 4, For the D2D and candidate cellular users matching example.

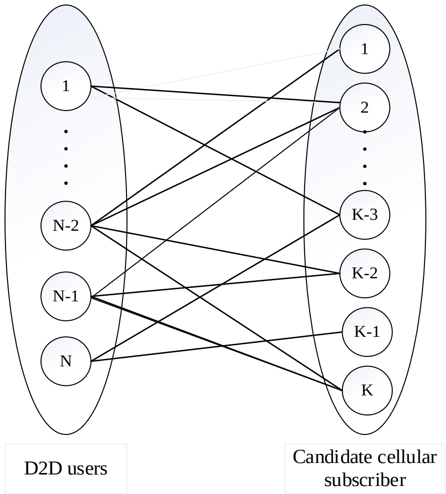

Figure 4 D2D users and candidate cellular users matching examples

Step 2 : D2D limited traffic area

(1) Restrictions on the area of communication for the base station

When the distance between D2D and base station is too close, it will cause greater interference to the base station, in order to ensure the quality of cellular communication links, it should be limited interference of eNB and D2D communication within a certain range. Assume that the noise threshold values for eNB is η_c , there is

$$I_{d,e}/N_0 \leq \eta_c \quad (1.6)$$

Where $I_{d,e}$ is the interference of D2D-Tx to eNB.

$$I_{d,e} = p_d \times g_{je} = p_{d\max} \times c \times (r_1)^{-\alpha_1} \quad (1.7)$$

Take the formula (1.7) into (1.6) will get

$$r_1 = [(p_{d\max} \times c)/(\eta_c \times N_0)]^{-\alpha_1} \quad (1.8)$$

Known by (1.8) that the communications prohibited area of eNB cares that the the largest transmission power of D2D-Tx $p_{d\max}$ and pass loss index α_1.

This communication forbidden area is also called the eNB interference limited area., that is, That is, when the D2D is located in the interference limited area, ENB interference will be greater than the threshold value η_c. If D2D is outside of the interference -limited areas, The interference of D2D to eNB will be below the threshold value, thus ensuring the quality of the cellular communication. Based on the actual situation, eNB's position is fixed, which means that the transmitter should be located in that take the eNB as the center, outside the circle with a radius of r_1.

(2) Restriction of the D2D multiplexing prohibited area

D2D users will be subject to very serious interference if they are reused by D2D users in a relatively close range,in In order to guarantee the communication quality of D2D users, the SIR of D2D-Rx should be limited η_d.

Assuming that D2D-Rx is in the worst case of interference, at this point, all cellular users who use m cellular users of the same uplink resources are located on the circumference of the radius r_2, there is

$$I_{c\max}/N_0 \le \eta_d \quad (1.9)$$

Among them, $I_{c\max}$ refers to Maximum interference of cellular networks to D2D-Rx, Assume that cellular users use maximum transmit power $p_{c\max}$,and there is

$$I_{c\max} = M \times p_{c\max} \times c \times (r_2)^{-\alpha_2} \quad (1.10)$$

Where α_2 is the path loss exponent of cellular subscribers and D2D-Rx. By the formula (1.9) and (1.10) the D2D multiplexing forbidden region range is obtained.

$$r_2 = \left(\frac{\eta_d \times N_0}{M \times P_{c\max} \times c}\right)^{-\alpha_2} \quad (1.11)$$

We can get the D2D multiplexing prohibited area which is a circular area that take D2D-Tx as the center and the radius is r_2, That is, D2D users can only reuse the uplink resources of cellular users located outside the circle, at this time, the D2D-Rx's SIR is lower than the interference threshold value, so as to ensure the quality of D2D communication.

Step 3 : Allocation of resources in order to minimize the priority of scheduling weight values for cellular users

In order to ensure the fairness of the cellular system, resource priority is assigned to the D2D communication which is the minimum of damage to the weight value.

According to the cellular user scheduling weights mentioned above , there are,

For cellular users I, when no d2d users reuse its resources, When there are no D2D users reuse their resources, the scheduling weights is

$$\omega_i = \frac{R_i}{\overline{R_i}}$$

Where R_i is the instantaneous rate at a certain time, $\overline{R_i}$ is average rate.

If the D2D users j reuse the resource of cellular user i ,the scheduling weight value will be changed to

$$\omega_{ij} = \frac{R_{ij}}{\overline{R_i}},$$

Of these, $R_i = \log_2(1+\frac{p_i g_{ie}}{N_0})$

$$R_{ij} = \log_2(1+\frac{p_i g_{ie}}{p_j g_{ie} + N_0})$$

The change of the weight value of the D2D user is

$$\omega_{ij}^* = |\omega_i - \omega_{ij}|$$

$$j' = \arg\min_{i \in S_i} \omega_{ij}^*$$

If the cell contains a number of D2D users, there may be a cellular user exists at the same time in a number of D2D users of the candidate cell collection, at this time based on the fairness of the selection of cellular users algorithm is as follows:

$$\min \sum_{i \in S_i, j \in D} x_{ij} \omega_{ij}^*$$

$$\sum_i x_{ij} \le 1, \forall j \in D$$

$$\sum_j x_{ij} \le 1, \forall i \in S_i$$

$$x_{ij} = \{0,1\}, \forall j \in D, \forall i \in S_i$$

Among them, S_i is a candidate cellular user for D2D users, D is a collection of all D2D pairs, Where x_{ij} is a two-dimensional distribution matrix $H = [x_{ij}]_{M \times N}$, when the D2D users j multiplexing cellular users i ,B is 1, otherwise 0.

Resource allocation of specific steps are as follows :

1. First, according to the formula to calculate the change of each pair of candidate cell weight value, and according to the change of the weight value' s order from small to large set

them into the collection S.

2. Check whether the set s is the empty set, in the case of the empty set, the ending, if not for the empty set, then allocated in the order of elements in the set *s*.

3. If cellular D2D user *i* and j have been assigned, then removes it from the collection *s* cellular subscribers value. If not assigned, the collection *s* cellular user *i* in the order assigned to the D2D *j*, and removes it from the *s*, until the end of the set *s* is the empty set.

4. When the D2D users *j* is assigned to cellular user *i*, separately testing whether the cellular users and D2D users meet their QoS performance , if not satisfied, it won't allow the D2D user *j* multiplexing the resource of cellular user *i*,if meet ,you can reuse.

1.4 Based on D2D user location select reuse area

In the preamble, it calculate the region of the eNB communication prohibit and protection respectively, D2D reuse prohibited area, and according to D2D user's location information to discuss the resource allocation scheme for D2D communication. The radius of the central region of this paper is r_1, which is the central region and the region of eNB prohibit and protection communication overlap.

Determination of the Edge users:

Difference based on RSRP: Assuming the D2D user *i* is located in the edge of a cell A, and adjacent to cell B, according to the feedback of RSRP measurement report from user *i* , The main service area judge whether the difference between the received signal power from the A and B is less than a certain threshold, if the user I receive power to meet

$$|RSRP_A - RSRP_B| < \delta(dB)$$

Then determine the user *i* as the edge users, if not meet the above conditions, then determine the D2D user is not a marginal user.

(1) when D2D the user is located at the edge area, D2D users can reuse within the community except D2D reuse prohibited areas of the region.

(2) When the D2D users in the center zone, adjacent to the cell is as cell cooperation in Regional Center for D2D users provide reusable resources. At the same time, D2D users can reuse region is to base station as the center, the adjacent cells within a circle of radius (except for the district) cellular subscribers to r_3 .

According to the resource allocation scheme in this paper, the mathematical model of the cellular system throughput can be got by the Shannon formula:

$$\max \sum_{i=1}^{M}\sum_{j=1}^{N} x_{ij} \log_2\left(1+\frac{p_i g_{ie}}{p_j g_{ie}+N_0}\right)+\sum_{i=1}^{M}\sum_{j=1}^{N} x_{ij} \log_2\left(1+\frac{p_j g_j}{p_i g_{ij}+N_0}\right)$$

$$\sum_i x_{ij} \le 1, \forall j \in D$$

$$\sum_j x_{ij} \le 1, \forall i \in S_i$$

$$x_{ij} = \{0,1\}, \forall j \in D, \forall i \in S_i$$

2. The simulation results

2.1 Simulation parameters

In order to verify the performance of the proposed resource allocation scheme, taking into account in LTE cellular system with multi-cell scenario, the system simulation using Matlab. Main simulation parameters are set as follows:

Table 1. Main parameters of the simulation

parameter	parameter values
Cell radius	500m
D2D users maximum distance	50m
System bandwidth	20MHz
RB bandwidth	180KHz
Cellular subscriber number	30
D2D users number	10
Maximum transmit power of	23dBm
Maximum transmit power for	10dBm
Noise power density	-174dBm/Hz
Road loss coefficient	10^{-2}
Road loss index	4
Cellular user's minimum SINR	Uniform distribution between
D2D user's minimum SINR	Uniform distribution between

2.2 The simulation results

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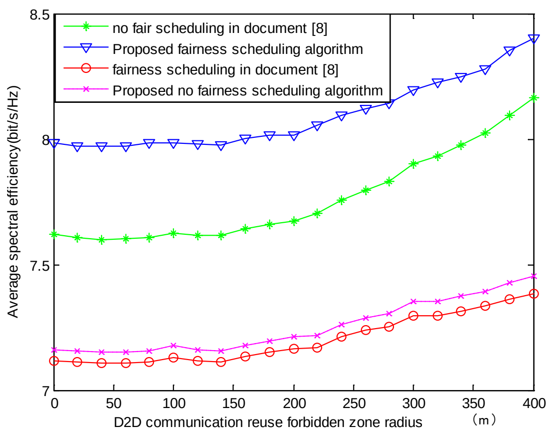

Figure 5 Relationship between D2D forbidden region radius and spectrum efficiency

As is shown in Fig 5 when D2D communication multiplex prohibited zone radius is less than 150 meters, there is no obvious change in the average spectral efficiency of the system, more than this distance, with D2D communication restriction zone radius increases the average spectral efficiency of the system is also increasing. It can be seen that the throughput of the whole communication system is affected by the radius limit of communication multiplexing forbidden region. Therefore, it is beneficial to the D2D communication reuse area restriction in the cellular community. At the same time by Figure 5 can be seen that the proposed algorithm is far superior to the system spectral efficiency of the proposed algorithm in the literature [8].

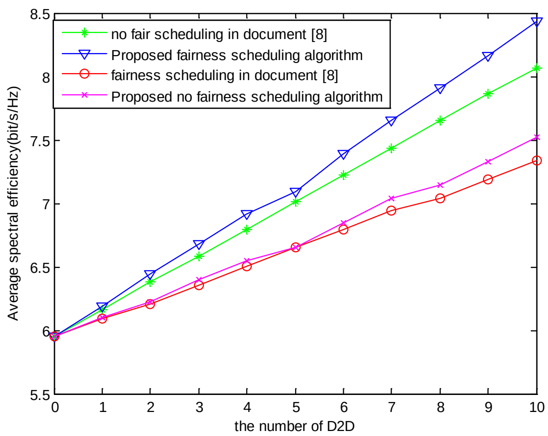

figure 6 the relationship between D2D users and spectral efficiency

From Figure 6 shows, the average spectrum efficiency of the cellular system with D2D users increase almost increasing linearly, similarly, with the increase of D2D users that the proposed scheme is superior to that of the literature [8] scheme, especially in after joining the fair scheduling scheme superiority becomes more significant. As compared to the resource allocation algorithm in the literature [7] that the proposed resource allocation algorithm in block based on fair scheduling based on the multiplexing performance of D2D users better resources for communication, so as to achieve the purpose of improving the performance of the communication

Systems.

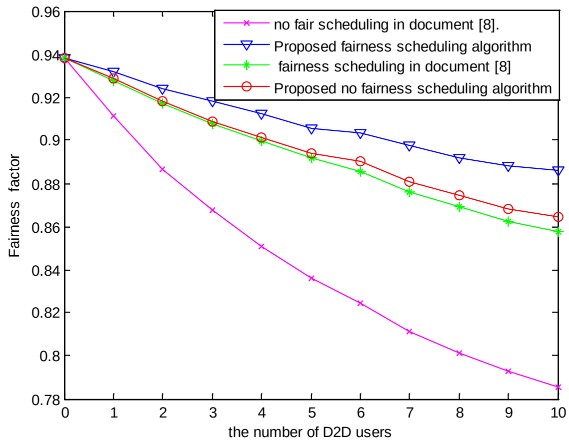

figure 7 The relationship between D2D users and fairness factor

As can be seen from Figure 7, with the increase of D2D, the fairness of the whole cellular system is gradually reduced. This is because the increase in the number of D2D users, D2D users are also increasing the number of celluar users of the reuse, the entire cellular system will be a great change in the weight value, the fair will be reduced. At this time, compared with the proposed scheme, the system fairness of the proposed scheme is significantly improved compared with the literature [8]. This is because the resource allocation algorithm, according to the value of fair scheduling in weight changes in the size for D2D users chose to reuse meet the conditions of cellular subscriber resource block and minimize multiplexing cellular users before and after weight value variation, so as to improve the fairness of the cellular system.

3. Concluding remarks

D2D communication technology introduces LTE cell, which can improve the system throughput and spectrum efficiency, and save spectrum resources. But at the same time, it will bring interference to the cellular system and reduce the system's fairness. In view of this, a resource allocation algorithm is proposed to improve the fairness and spectrum efficiency of the system, which can maximize the system throughput. Simulation results show that the proposed scheme can effectively improve the fairness and efficiency of the system while guaranteeing the D2D of cellular users and QoS users.

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