Joint Power Control and Resource Allocation Algorithm based on Dynamic Grouping

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Abstract

When D2D communication is introduced into cellular system and share cellular wireless resource with cellular users, the interference between these two communication system can't be ignored. Therefore, the interference management of D2D communication is one of the important subjects. In this paper, an algorithm based on dynamic grouping for resource allocation and joint power interference control is proposed. Through the dynamic grouping of D2D users and power control, the resource is allocated to the D2D users these in the same group, which can make the total capacity of system reaches the maximum. Simulation results confirm that our proposed scheme achieves larger throughput and higher acceptance rate of D2D in the system compared with random assignment scheme and fixed grouping scheme.

Keywords

D2D, Interference, Dynamic grouping, Power allocation, Resource allocation.

1. Introduction

D2D communication technology as a key technology of 4G [1], allows two mobile terminals to communicate directly without going through the base station. However, D2D resource reuse inappropriately can bring uncontrolled interference. The power controlling and resource scheduling can reduce this interference caused by D2D. Quite a few work have been proposed to address this interference allocation problem [2-5], based on geographical location, graph theory, game theory and other methods. However, majority of the existing work only focused on some simplified cases for this resource-sharing scenario of cellular and D2D communications.

In order to improve resource utilization, we propose a scheme that a RB can be allocated to multiple D2D users, a D2D user can use multiple RB resources, and adjust the D2D transmit power dynamically.

2. System model

As shown in Fig.1,consider a downlink transmission scenario in a cellular network, in which there exists two types of communications, namely ,cellular user(CUE) and D2D user(DUE).It is assumed that there are M CUE and N DUE,and are randomly distributed in the cell. $A_k\left(k=1,2,\cdots M\right)$ represents the CUE-k, $D_n\left(n=1,2,\cdots N\right)$ represents the DUE-n, $D_{n,t}$ represents the transmitter of the D2D pair, whereas $D_{n,r}$ represents the receiver of the D2D pair. $R=\left\{RB_1,RB_2,\cdots,RB_M\right\}$ represents the available resources. In addition, $C=\left\{1,2,\cdots,M\right\}$ represents all of the CUE, $D=\left\{1,2,\cdots,N\right\}$ represents all of the DUE. The relationship of the number of D2D users and cellular users is arbitrary.

$P_{D_n}^m$ is the transmitting power of $D_{n,t}$ while using RB_m, η_C and η_D are SINR of DUE and CUE respectively. $G_{X,Y}^m$ represents the channel gain between node X and Y when they reuse RB_m .The thermal noise at the terminals follows an independent Gaussian distribution with zero mean and variance δ^2.

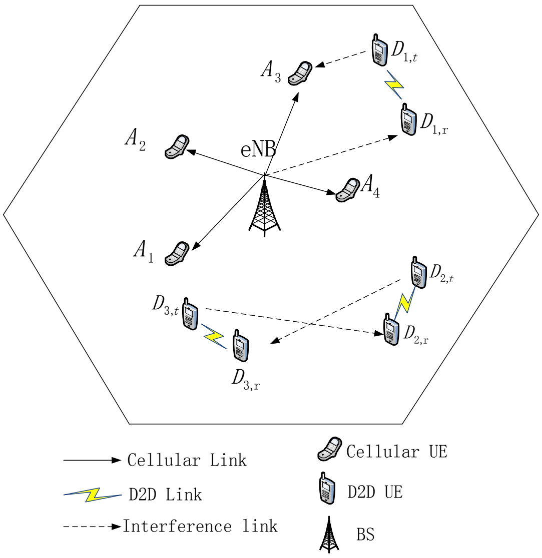

Fig.1 System Model

We take DUE-n reuse the same RB with CUE-k, and CUE-k use RB-m for example, the instantaneous SINR of the cellular link k is expressed as:

$$SINR_{A_k}^{m}=\frac{P_C\cdot G_{A_k,B}^{m}}{\sum\limits_{D_j\in C_m}P_{D_j}^{m}\cdot G_{D_{j,t},A_k}^{m}+\delta^2} \tag{1}$$

Where C_m represents the cluster of the D2D and cellular links that shares RB-m for data transmission. The resource sharing among different CUE is forbidden. The instantaneous SINR of the D2D link n is expressed as:

$$SINR_{D_n}^{m}=\frac{P_{D_n}^{m}\cdot G_{D_{n,t},D_{n,r}}^{m}}{\sum\limits_{A_k\in C_m}P_C\cdot G_{A_k,D_{n,r}}^{m}+\sum\limits_{j\neq n,D_j\in C_m}P_{D_j}^{m}\cdot G_{D_{j,t},D_{n,r}}^{m}+\delta^2} \tag{2}$$

(1) (2) should also be satisfied: $SINR_{A_k}^{m}\geq\eta_C^{'}$, $SINR_{D_n}^{m}\geq\eta_D^{'}$,Let $X\left[\alpha_{n,k}\right]_{N\times M}$ as resource allocation matrix of D2D link, if RB_k is assigned to D_n then $\alpha_{n,k}=1$;otherwise, $\alpha_{n,k}=0$ .Let $P\left[P_{D_n}^{m}\right]_{N\times M}$ as transmit power allocation matrix of D2D link subject to the total power constraint: $\sum\limits_{m=1}^{M}P_{D_n}^{m}\leq P_{D,\max}$ .The goal of our method is to maximize the capacity:

$$\left[X_{opt},P_{opt}\right]=\underset{X,P}{\arg\max}\left[\sum_{n=1}^{N}\log_2\left(1+SINR_{A_k}^{m}\right)+\alpha_{n,k}\cdot\log_2\left(1+SINR_{D_n}^{m}\right)\right] \tag{3}$$

In order to reduce the complexity of the operation, we use graph theory to solve the suboptimal solution by constructing the resource reuse graph and then combining the power allocation.

3. Resource allocation

3.1 Stablish the weighted resource relation graph

Base station constructs the resource reuse relation diagram $G(\nu,\varepsilon)$, as shown in Fig.2, the node set includes CUE and DUE. The solid edge represents the existence of resource sharing between two nodes, otherwise. We use the Resource List $\Gamma(V_i)$, the Optimal Resource Index $\Lambda(V_i)$, the Resource

Allocation Indicator $\mathrm{A}(V_i)$, and the Power Allocation Instruction $\mathrm{P}(V_i)$ to save the four state values of the D2D node. The Resource List $\Gamma(V_i)$ includes RB, where the RB index ordered by the SINR at the receiver, and $\Lambda(V_i)$ is the first element of $\Gamma(V_i)$ .If $V_i \in C_m$, then $a_m(V_i)=1$;otherwise, $a_m(V_i)=0$ .The power allocation indicator the power value of D2D link in each RB.

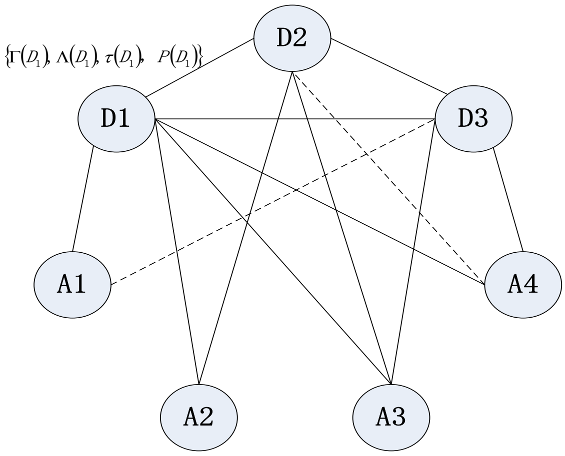

Fig.2 Resource Reuse Diagram

$V_c(C_m)$ represents the sum of the channel capacity for all the communication links belonging to the cluster C_m :$V_c(C_m)=\sum_{V_i \in C_m} \log_2\left(1+SINR_{V_i}^m\right)$ (4),Where $SINR_{V_i}^m$ can be calculated by (1) and (2).Utilizing the node attribute value $\Lambda(V_i)$, we divide D2D nodes into groups and save them in the virtual cluster $C_m^{'}$, specifically: $C_m^{'}=\{V_i \mid m=\Lambda(V_i), V_i \in D\}$ (5), $N_{C_m^{'}}$ represents the number of the virtual cluster $C_m^{'}$: $N_{C_m^{'}}=Length(C_m^{'})$ (6).

3.2 Dynamic packet resource allocation algorithm

Table 1. Algorithm: Dynamic Grouping

Joint power control and resource allocation algorithm based on dynamic grouping:
Begin **Step 1: Cellular Resource Allocation** 1. allocation RB to M cellular users orthogonally by Round Robin algorithm[6]; 2. **for m=1: M do** adjusting the order of RB to meet the RB allocated to A_m is RB_m ;save A_m into C_m ;update $V_c(C_m)$;**end for** **Step 2: Initialization** 1. **for i=1: N do** initialize $\Gamma(V_i)$ and $\Lambda(V_i)$;**end for** 2.**for m=1: M do** Calculate (5) and (6);**end for** **Step 3: Iteration** Goal: $P_{V_i}^{opt}=\arg\max\{V_C(C_m \cup V_i)\}$ (7)

$$= \arg\max\left\{\log_2\left(1+SINR_{V_i}^m\right)+\sum_{V_j\in C_m, j\neq i}\log_2\left(1+SINR_{V_j}^m\right)\right\} \quad (8)$$

Where $\log_2\left(1+SINR_{V_i}^m\right)$ represents the SINR of D2D node V_i when it added into C_m, $\sum_{V_j\in C_m, j\neq i}\log_2\left(1+SINR_{V_j}^m\right)$ represents $V_c\left(C_m\right)$ when D2D node V_i added into C_m .We dynamically adjust the transmit power of this D2D node, so that $V_c\left(C_m\right)$ value can obtain maximum value. When $V_c\left(C_m\right)$ reaches the maximum value, the transmit power is the optimal transmit power of this D2D node.At the same time, the power value of the node on all RB should also meet the power constraints:

$$0\le\sum_{m=1}^{M}P_{V_i}^m\le P_{D,\max} \quad (9)$$

Initialize m=1, then:

1. **for i=1:** $N_{C_m^{'}}$ **do**

Adjust the D2D transmission power according formula, so that satisfies (9)~(13),and those D2D nodes are potential resource allocation nodes:

$\max\left\{V_C\left(C_m\cup V_i\right)\right\}\ge V_C\left(C_m\right)$(10), $SINR_{V_i}^m\ge\eta_D^{'}$(11), $SINR_{V_j}^m\ge\eta_D^{'}$(12), $SINR_{A_k}^m\ge\eta_D^{'}$(13);**end for**

2. **if** the potential resource allocation nodes are not empty **then**

Select the optimal node V^{opt} : $V^{opt}=\arg\max\left\{V_C\left(C_m\cup V_i\right)\right\}, V_i\in C_m^{'}$ (14);Update C_m, $a_m\left(V^{opt}\right)$, $p_m\left(V^{opt}\right)$, $\Gamma\left(V_i\right)$, $C_m^{'}$: $C_m=C_m\cup\left\{V^{opt}\right\}$, $a_m\left(V^{opt}\right)=1$, $p_m\left(V^{opt}\right)=P_{V_i}^{opt}$, $C_m^{'}=C_m^{'}-V^{opt}$;**end if**

3. **for i=1: N do**

According to the latest $\Lambda\left(V_i\right)$,regroup D2D nodes by (10),update $C_m^{'}$ and $N_{C_m^{'}}$;

4. **if** $C_1^{'}\cup C_2^{'}\cup\cdots\cup C_M^{'}\neq\Phi$ **then** m=m+1;Repeat step 3;

else Exit the entire algorithm;**end if**

End

After the execution of the dynamic grouping algorithm, the $\mathrm{A}\left(V_i\right)$ and $\mathrm{P}\left(V_i\right)$ are the results of D2D resource allocation and power control.

4. Simulations and discussion

The simulation model is a single cell model, the base station is located in the center of the cell, cellular users and D2D users are randomly distributed in the cell. We compare three resource allocation schemes, namely fixed grouping scheme, random allocation scheme, and our proposed scheme.

Table 2. Simulation: Parameters

Parameters	Value
Cell Radius/m	500
D2D pair distance/m	60
Number of cellular users	8
Number of D2D users	4-16
SINR threshold $\eta_C^{'},\eta_D^{'}$ /dB	5

Cellular Transmit Power P_C /dBm	24
Channel Bandwidth /MHz	10
Loss model between user and base station	$128.1+37.6\cdot\lg d$
Loss model between D2D and D2D	$38.45+20\lg d$
Noise Power Spectral	-174

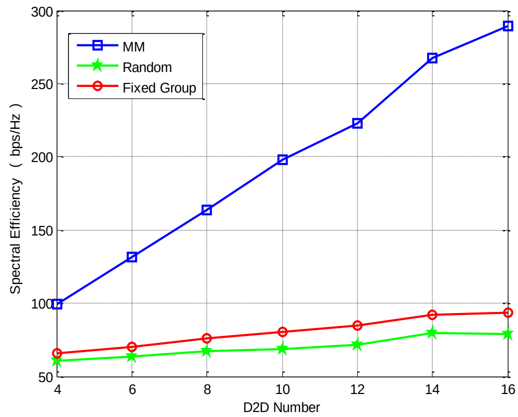

Fig.3 Comparison in terms of network spectral efficiency with different D2D number

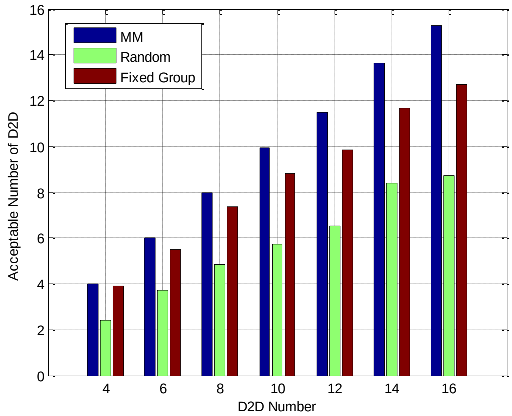

Fig.4 Comparison in terms of acceptable number of D2D with different D2D number

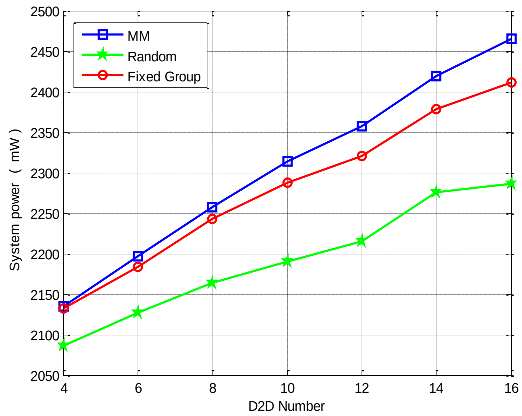

Fig.5 Comparison in terms of system power with different D2D number

In Fig.3, the random assignment algorithm randomly assigns resource to D2D, and does not considered for interference. The fixed group algorithm uses greedy way to allocate resource to D2D that has been divided into groups, and selects resource that can maximize the capacity of the D2D. In this case, the cumulative interference of the D2D to the cellular user is not taken into account, and the fixed transmit power is used. The algorithm proposed in this paper allocates resource to D2D who can maximize the system capacity by dynamically grouping. In other words, if the D2D cannot make system capacity improved, we do not allocate any resource to it, at the same time, through the power control to select the system capacity gain to maximize the D2D allocation of resources. Therefore, the dynamic grouping algorithm performance is clearly optimal.

In Fig.4, we can see the acceptance rate is the lowest by random assignment algorithm. With the increase of D2D number, fixed group lets interference between the D2D in group become larger because of their distance is shorter, so some of D2D fails to join network. Dynamic grouping algorithm takes the interference of D2D between D2D and D2D between cellular UE into account, so it has higher acceptance rate of the system. We have known the acceptance rate of random allocation algorithm is lowest, so the total power consumption is lowest. Dynamic grouping algorithm's acceptance rate is higher than fixed clustering algorithm, through the power control, D2D power spread to more resources, so the system total power consumption is highest.

5. Conclusion

In this paper, an algorithm based on dynamic grouping for resource allocation and joint power interference control is proposed. Simulation results confirm that our proposed scheme achieves larger throughput and higher acceptance rate of D2D in the system compared with random assignment scheme and fixed grouping scheme.

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