Journal of Computers Vol. 31 No. 5, 2020, pp. 176-186
doi:10.3966/199115992020103105013

Joint Optimization Scheme for Mode Selection and Resource Allocation of D2D Communication

Hongliang Tian, Hongle Pan*, Xiaonan Ge

School of Electrical Engineering, Northeast Electric Power University, No. 169, Changchun Road, Jilin, China
hltian@foxmail.com, 839522068@qq.com, gexiaonan1995@163.com

Received 5 May 2019; Revised 10 September 2019; Accepted 21 November 2019

Abstract. D2D communication technology can effectively alleviate congestion in traditional cellular networks. D2D resource allocation is usually carried out simultaneously with mode selection. Effective resource allocation can significantly reduce interference, save power and maximize throughput. In this paper, we propose an improved joint optimization scheme of mode selection and resource allocation. In terms of mode selection, we integrate the exist working mode of user devices, and improve the service quality of user devices by using cooperative relay technology. In terms of resource allocation, we use a heuristic algorithm to allocate channel resources for each user with the goal of maximizing system sum rate. Experimental results show that compared with existing algorithms, the joint optimization scheme proposed in this paper can effectively improve the system sum rate and the service quality of users.

Keywords: D2D, mode selection, power control, resource allocation

1 Introduction

In traditional cellular networks, users usually communicate with each other through the base station. Device-to-Device (D2D) communication in 5G cellular networks is a promising technology, user equipment can communicate with each other directly without data pass through the base station. This technology can reduce power consumption and delay, thereby improving the overall network throughput. The working mode of D2D user equipment can be divided into reuse mode, direct mode and cellular mode. Many works have proposed resource allocation schemes using different methods for D2D user equipment in LTE-A system.

The authors of [1] proposed a general three-dimensional model to investigate the performance of D2D communication. The simulation results verify the accuracy of the proposed model. The authors of [2-3] proposed a general three-dimensional model of heterogeneous networks (HetNets). These three-dimensional models provide a reference for the following research. The authors of [4] introduced mode-mixed D2D communication, which requires little signaling overhead, and has low computational complexity. The D2D mode selection problem for user mobility analyzed theoretically in [5]. The authors of [6] investigated the mode selection of D2D communication in cellular networks for the purpose of energy saving. The authors of [7] proposed a mode selection scheme of D2D communication that consider user mobility. The authors in [8] enhanced the traffic offloading capacity of cellular-assisted D2D communications, considering D2D relay at the same time. The author of [9-10] proposed an algorithm that decomposes resource allocation problems into two sub-problems: mode selection and channel assignment. The simulation results show that the algorithm can effectively improve the transmission rate of D2D users. However, the above model selection schemes are not combined with effective resource allocation schemes, so these schemes need to be improved.

In [11], social and physical properties of D2MD clusters are considered, and a content sharing D2MD scheme for cellular networks was proposed. The authors of [12-14] proposed a dynamic distributed resource sharing scheme. The authors of [15-16] investigated the problem of energy-efficient uplink

* Corresponding Author

resource sharing for D2D communication under cellular networks with multiple potential D2D pairs and cellular users. In [17], a location-based resource allocation scheme was proposed. The resource allocation problem of using LTE-A networks uplink resources in D2D communication were proposed in [18]. The maximum weighted bipartite graph matching method was used to find suitable resources and reuse devices for network users. However, the above resource allocation scheme does not consider the working mode for users, so the system performance is not optimal. The authors of [19] investigated an interference control and resource allocation algorithm for D2D communication in a single-cell cellular system. The proposed algorithm can significantly improve the throughput of the system and the access rate of D2D users. The authors of [20] studied the joint mode selection, resource group (RG) allocation and power allocation of D2D underlay cellular communication system. However, these joint schemes still have some limitations on algorithm and need to be improved.

In summary, the mode selection algorithm in most papers only focuses on the following D2D modes: cellular mode, dedicated mode and reuse mode. Actually, dedicated mode and reuse mode both belong to direct D2D communication mode. That is, the transmitters and receivers of D2D users transmit data directly. However, the direct mode may not make full use of the resources in LTE-A system due to its limited traffic offloading capacity. Sometimes the transmitters and receivers of D2D users may be unable to communicate with each other directly due to some reasons. For example, the distance between them is too far or the link quality is too poor. Consider to fully utilize the traffic offloading capacity of D2D communication in LTE-A systems, relay-assisted D2D transmission should be added to extend the range of D2D communication.

Therefore, after referring to the shortcomings of existing papers. We propose a joint optimization scheme for mode selection and resource allocation, which consider the mobility of user equipment and improve the working mode of user equipment. Unlike other papers, this paper does not consider one aspect of mode selection or resource allocation unilaterally. Our goal in this paper is to improve the link quality of user equipment and expand the communication range. The dedicated mode and reuse mode are combined in the mode selection, and the relay-assisted mode is added by using cooperative relay technology. The working mode of user equipment is divided into three types: direct mode, relay-assisted mode and local routing mode. The resource allocation is carried out with the goal of maximizing the system sum rate, and heuristic algorithm is used to solve the optimization problem.

The rest of the paper is organized as follows: in the second section, the system model is introduced. In the third section, the problem of mode selection is formulated. In the fourth section, the resource allocation plan is introduced. The simulation results are given in section five and the conclusions are given in section six.

2 System Model

We consider a single-cell cellular network scenario, where eNB at the center and all mobile users are randomly distributed. We focus on user equipment moving at a small but different speed for a fixed period of time. In order to make the transmission link orthogonal, the transmission bandwidth is normalized to be one. In addition, the transmission channel model includes path loss, Rayleigh flat fading and power spectral density of additive Gaussian noise. In this case, user equipment uses D2D underlay communication to transfer data. Here, we use a peer-to-peer discovery scheme to identify D2D candidate users. Assume the process of peer-to-peer discovery and device pairing has been implemented in advance. Moreover, the remaining users are regular cellular users. The system model is shown in Fig. 1.

Here, we focus on the underlying D2D communication scenario of uplink resource sharing. There are three modes: direct mode, relay-assisted mode and local routing mode. In direct mode, transmitters and receivers communicate with each other directly. In relay-assisted mode, transmitters and receivers communicate with each other through the relay user equipment. In local routing mode, transmitters and receivers communicate with each other using the eNB as a relay, but data will not pass through the core network. In other words, the eNB in here is used as a relay station. Obviously, the latter two modes should operate under control of eNB. The cellular users are denoted by *M*, the D2D users are denoted by *N* and the channels are denoted by *K*. That is $M \in [m_1, m_2, \cdots m_M]$, $N \in [n_1, n_2, \cdots n_N]$ and $K \in [k_1, k_2, \cdots k_K]$.

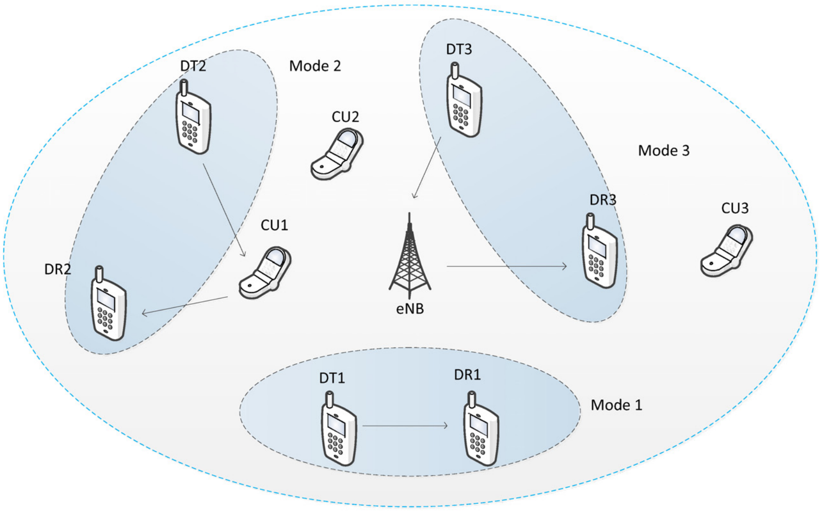


Fig. 1. Network model, in which there is a cellular user with three modes of D2D user

According to the analysis of network model, the SINR of cellular users can be expressed as:

$$\varphi_{m,k}^{c} = \frac{P_m^c g_{m,B}^k}{P_m^d g_{m,B}^k + \sigma^2}, \tag{1}$$

The SINR of D2D users working in direct mode is expressed as:

$$\varphi_{n,k}^{1} = \frac{P_k^1 g_k^1}{\Sigma_{k=1}^{K} P_k^1 g_k^1 + \sigma^2}, \tag{2}$$

The SINR of D2D users working in relay-assisted mode is expressed as:

$$\varphi_{n,k}^{2} = \frac{P_k^2 g_k^2}{\Sigma_{k=1}^{K} P_k^2 g_k^2 + \sigma^2}, \tag{3}$$

The SINR of D2D users working in local routing mode is expressed as:

$$\varphi_{n,k}^{3} = \frac{P_k^3 g_k^3}{\Sigma_{k=1}^{K} P_k^3 g_k^3 + \sigma^2}, \tag{4}$$

Where P_m^c is the transmit power of cellular users, $g_{m,B}^k$ is the link gain from cellular users to the eNB. $P_m^d g_{m,B}^k$ is the interference of cellular users by other users, σ^2 is Gaussian noise. P_k^1, P_k^2 and P_k^3 are the transmit powers of D2D users in three modes, respectively. g_k^1, g_k^2 and g_k^3 are the channel gains of D2D users in three modes, respectively. $\Sigma_{k=1}^{K} P_k^1 g_k^1$, $\Sigma_{k=1}^{K} P_k^2 g_k^2$ and $\Sigma_{k=1}^{K} P_k^3 g_k^3$ are the interference of D2D users in three modes, respectively.

The data rate of cellular users and D2D users in three modes are expressed as follows:

$$r_{m,k}^{c} = B\log_2(1+\varphi_{m,k}^{c}), \tag{5}$$

$$r_{n,k}^{1} = B\log_2(1+\varphi_{n,k}^{1}), \tag{6}$$

$$r_{n,k}^{2} = B\log_2(1+\varphi_{n,k}^{2}), \tag{7}$$

$$r_{n,k}^{3} = B\log_2(1+\varphi_{n,k}^{3}), \tag{8}$$

B represents the channel bandwidth. Therefore, the mathematical expressions of system sum rate and their constraints can be expressed as:

$$\max[\sum_{m=1}^{M} r_{m,k}^{c} + \sum_{n=1}^{N}(\alpha_{n,k} r_{n,k}^{1} + \beta_{n,k} r_{n,k}^{2} + \gamma_{n,k} r_{n,k}^{3})] \quad \textbf{(9)}$$

s.t.

$$\sum_{n=1}^{N} \alpha_{n,k} \le 1, \forall k \in K \quad \textbf{(10a)}$$

$$\sum_{n=1}^{N} \beta_{n,k} \le 1, \forall k \in K \quad \textbf{(10b)}$$

$$\sum_{n=1}^{N} \gamma_{n,k} \le 1, \forall k \in K \quad \textbf{(10c)}$$

$$\sum_{n=1}^{N} \alpha_{n,k} + \beta_{n,k} + \gamma_{n,k} \le 1, \forall k \in K \quad \textbf{(10d)}$$

$$r_{m,k}^{c} \ge r_{\min}^{c}, \quad \textbf{(10e)}$$

$$r_{n,k}^{1} \ge r_{\min}^{1}, \quad \textbf{(10f)}$$

$$r_{n,k}^{2} \ge r_{\min}^{2}, \quad \textbf{(10g)}$$

$$r_{n,k}^{3} \ge r_{\min}^{3}, \quad \textbf{(10h)}$$

Equation (10a), (10b) and (10c) define a mode identifier, which is binary variable. If the D2D users belong to mode one, $\alpha_{n,k} = 1$; otherwise $\alpha_{n,k} = 0$. If the D2D users belong to mode two, $\beta_{n,k} = 1$; otherwise $\beta_{n,k} = 0$. If the D2D users belong to mode three, $\gamma_{n,k} = 1$; otherwise $\gamma_{n,k} = 0$. Equation (10d) limits each D2D user belongs to only one of these modes. Equation (10e), (10f), (10g) and (10h) limit the transmit power of cellular users, and the transmit power of D2D user is greater than its minimum transmit power.

3 Mode Selection Scheme

For mode selection, D2D user equipment can operate in multiple modes, and different modes have different benefits. For example, cellular mode can simplify the procedures of interference management, and the reuse mode can make full use of cellular resources. Therefore, it is important to choose the appropriate mode for each D2D user equipment. According to the mode selection criteria, the exist methods are divided into several categories. For example, minimize energy consumption, minimize power consumption and maximize cellular achievable rates, etc.

In order to improve the D2D communication capability of LTE-A system with the help of relay, three D2D modes are included in this paper. The first is the direct mode, the second is the relay-assisted mode and the third is the local routing mode. As for mobility, we consider the user moving in a fixed period. It has a small but different speed, and network settings can be changed base on current state. For example, add a new user, remove existing users and change channel conditions, etc. Our algorithm has the following characteristics: (1) It will repeat the test periodically as time goes by, enable users to periodically reset their history, and make sure the algorithm adapts to the changing environment. (2) There is a periodic channel state information measurement and reporting procedure between the user and the eNB, users can adjust these changes in a timely manner. (3) Cellular users and D2D pairs are randomly selected to simulate the complexities of the actual scene. Therefore, our algorithm is implemented in a distributed way, and it is robust to dynamic communication environment.

The proposed joint schemes maximized the total end-to-end data rate of all D2D pairs in each subframe. Therefore, each D2D pair selects the D2D mode with the largest end-to-end data rate as the best communication mode. The specific mode selection process can be described as follows: first, based on the channel state information reported, eNB calculates the maximum end-to-end data rate that can be achieved on each channel resource in three D2D modes. The data rate of direct mode is denoted as r_1, the data rate of relay-assisted mode is denoted as r_2 and the data rate of local routing mode is denoted as r_3. After estimating the realizable end-to-end data rates of D2D pairs in three modes, eNB compares the estimated results, and choose D2D mode with the maximum end-to-end data rate as the communication mode. For D2D pairs, if $r_1 = \max\{r_1, r_2, r_3\}$, then select the direct D2D mode; if $r_2 = \max\{r_1, r_2, r_3\}$, then select the relay-assisted D2D mode; if $r_3 = \max\{r_1, r_2, r_3\}$, then select the local routing mode. According to this rule, the eNB can make a mode selection decision for each D2D pair, and it also obtains an estimated end-to-end data rate for each D2D pair. The complete mode selection algorithm is shown in algorithm 1.

Algorithm 1. mode selection

Initialization: CUE $\{m\}$ is a cellular user, D2D $\{n\}$ is a D2D user pair.
for $i = 1 : n$
select the farthest cellular user which is not shared resource as the shared object.
calculate the transmit power P
if $P \le P_{\max}$
shared mode *mode(i)*
else
if $r_1 = \max\{r_1, r_2, r_3\}$
    direct mode=*mode(i)*
else if $r_2 = \max\{r_1, r_2, r_3\}$
    relay-assisted mode=*mode(i)*
else
    local route mode=*mode(i)*
end if
end if
end for

4 Resource Allocation Scheme

In this paper, resources refer specifically to cellular link resources. Realize the intelligent allocation of shared cellular resources, improve the reuse coefficient of the reuse system and combat frequency selective fading are key issues in D2D communication. Technically, these problems can be expressed as mixed integer programming problems or iterative combinatorial competitive problems. Power control is generally regarded as one of the most important interference management techniques. By coordinating the power of potential D2D pairs and cellular users, their QoS performance can be guaranteed and more potential D2D pairs can be allowed to reuse cellular resources. However, most papers only consider optimization of D2D user equipment or cellular user equipment for ease of implementation, and some papers only use fixed power to optimize D2D pairs.

This paper reduces interference through effective resource allocation. Resource allocation shall ensure that the resources allocated to the D2D pair are continuous, and the transmission power of the D2D pair is equally distributed on all resources. The core idea of resource allocation is that D2D pairs with higher end-to-end data rate should have higher priority, and it's more likely to be allocated resources. In order to maximize the total end-to-end data rate of K resources, the resource allocation strategy is divided into two stages. Allocate resources for all D2D pairs in the first stage allocation. If there is still having D2D pairs of direct/relay-assisted mode with no resources allocated in the first stage allocation, then start the second stage of resource allocation. Allocate resources to these D2D pairs of direct/relay-assisted mode.

The first stage of resource allocation begins immediately after the mode selection stage, which is performed based on the expected end-to-end data rate of the D2D pairs. Let R_1, R_2, $\cdots$ R_k denote the data rate of D2D pair, respectively. Let CH_1, CH_2, $\cdots$ CH_k denote the channel resource, respectively. We can describe the first stage of resource allocation as follows.

The eNB first rearranges D2D pairs in descending order of the end-to-end data rate. The order of the D2D pairs after rearrangement is expressed as n_1, n_2, $\cdots$ n_k . The corresponding data rate is $R_1 > R_2 > \cdots > R_k$. Then eNB begins resource allocation and directly assigns CH_1 to the D2D pair n_1. For CH_2, the eNB first estimates the end-to-end data rate of the D2D pair n_1 using the reduced transmit power $P_{\max}/2$, and further determine whether the D2D pair n_1 still having the largest end-to-end data rate among all D2D pairs. If n_1 still has the maximum data rate, then CH_2 is also assigned to the D2D pair n_1. Otherwise, CH_2 is assigned to D2D pair n_2. This allocation process continues until all resources are allocated to all D2D pairs. When considering the allocation of the kth resource, eNB will use the reduced transmission power $P_{\max}/(x+1)$ to estimate the end-to-end data rate for D2D pair n_k. Determine whether the end-to-end data rate of D2D pairs n_k is still greater than the remaining D2D pairs of unallocated resources. If so, the kth resource is assigned to the D2D pair n_k. Otherwise, the eNB will stop allocating resources to the D2D pair n_k, and assign the kth resource to the D2D pair n_{k+1}. This transmission power strategy can achieve power allocation on all resources.

The first stage resource allocation is terminated when all resources are allocated. If resources have been allocated to all D2D pairs in the first stage resource allocation, it means that the entire resource allocation process has been completed. Otherwise, the eNB will confirm whether there is still having a direct/relay-assisted D2D pair of unallocated resources after first stage resource allocation. If so, the eNB starts the second stage of resource allocation. Otherwise, the resource allocation is stopped and the eNB will also stop the scheduling process. The second stage of resource allocation is performed based on the idea of wireless resource sharing. The principle is that D2D pairs of unallocated resources can reuse the resources of direct/relay-assisted D2D pairs. The purpose of resource reuses is to increase the total amount of data transmitted in subframes. The resource allocation process of the second stage is described as follows.

First, the eNB lists all direct/relay-assisted D2D pairs that have been allocated resources during the first stage of resource allocation (that is, reuse candidate D2D pair). List all remaining direct/relate-assisted D2D pair for which no resources have been allocated. Second, search for the best reuse devices between reuse candidate D2D pairs and remaining direct/relate-assisted D2D pairs. Maximize the total end-to-end data rate on all cellular link resources. The key is to select the candidate D2D pairs with the maximum end-to-end data rate for each remaining direct/relay-assisted D2D pair to reuse. When the second stage of the resource allocation process is completed, the entire resource allocation process is completed. The specific process of resource allocation is shown in algorithm 2.

Algorithm 2. resource allocation

1. Initialization: $i, j, l = 1$, and rearrange D2D pairs based on descending order of date rate as n_1, n_2, $\cdots$ n_k .
2. Physical resource blocks (PRB) index: $m = i$, D2D pair index: $k = j$, power changing order: $x = 1$.
3. PRB m is allocated to D2D pair n_k
4. if $k = K$
5. $i = i + 1,\ l = l + 1$
6. if $i > m$
7.   if all direct/relay-assisted mode D2D pair have been assigned PRB
8.   stop resource allocation
9.   else start the second-round PRB allocation by sharing the already assigned PRB
10.   end if
11. else back to 2
12. end if

13. else reduce transmit power of D2D pair n_k to $P_{\max}/(x+1)$ and compute its end-to-end date rate again on a PRB
14. end if
15. if n_k is still with the maximal data rate among the remaining D2D pair
16. back to 5
17. else
18. $i=i+1,\ j=j+1,\ l=1$
19. end if
20. if $i>m$
21. back to 7
22. else
23. back to 2
24. end if

5 Numerical Results

A single-cell networks including cellular users and D2D users is simulated, and the performance of the proposed algorithm is evaluated. The simulation was performed in MATLAB, the experiment was repeated 1000 times, and the results were averaged. Users are distributed in a circular area with a radius of 500m, where the eNB in the center. As previously shown, there are cellular users and D2D users with three modes. That is, direct D2D users, relay-assisted D2D users and local routing D2D users. All these users are randomly distributed in the network, Fig. 2 shows the random distribution of users. There are 50 cellular users and 50 D2D users. Among them, there are 20 D2D users in mode 1, 10 D2D users in mode 2 and 20 D2D users in mode 3.

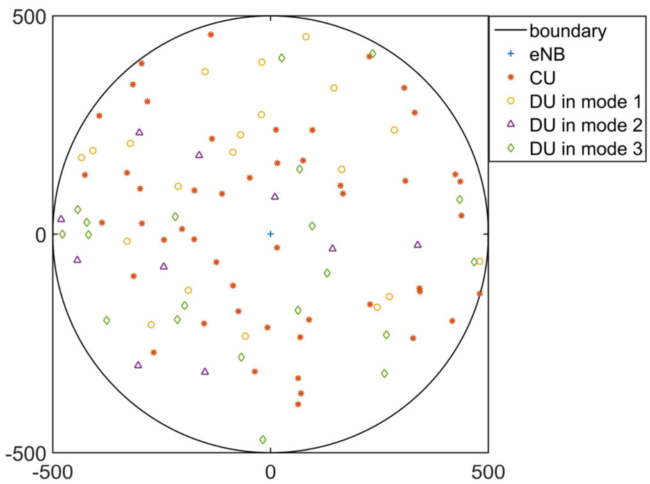


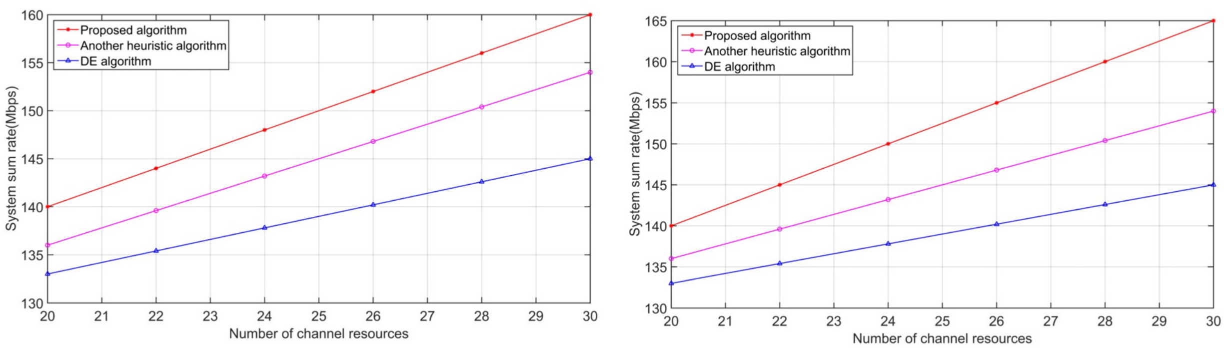
Fig. 2. Example of random distribution of users

In the simulation, the algorithm proposed in this paper is compared with two algorithms in the other papers. In order to ensure the fairness of simulation, the simulation parameters are consistent with the other two papers. In the simulation environment, the path loss of the cellular link is (128.1 + 36.7log(d[km])) dB, and the path loss of the D2D link is (140 + 40log(d[km])) dB. The noise spectral density is -114dBm/Hz, the noise figure of eNB is 5dB and the noise figure of user equipment is 9dB. The antenna gain of the eNB is 14dBi, the antenna gain of the device is 0dBi. The transmission power of the eNB is 46dBm, the transmitting power of the cellular user is 24dBm. The transmit power of the D2D user is 20dBm, the SINR threshold of the two users is 0dBm. The simulation parameters are shown in Table 1.

Table 1. Simulation parameters

parameter name	Numerical value
Cell radius	500m
Path loss of the cellular link	(128.1 + 36.7log(d[km])) dB
Path loss of the D2D link	(140 + 40log(d[km])) dB
Noise spectral density	-114dBm/Hz
Noise figure of eNB	5dB
Noise figure of user	9dB
Antenna gain of the eNB	14dBi
Antenna gain of the device	0dBi
Transmission power of the eNB	46dBm
Transmitting power of the cellular user	24dBm
Transmit power of the D2D user	20dBm
SINR threshold of the two users	0dBm

In order to verify the validity of the proposed resource allocation scheme, this paper selects the algorithms of the other two papers for comparison. One paper uses differential evolution (DE) algorithm [17], another paper also uses heuristic algorithm [21], neither focuses on the mode selection. The resource allocation scheme in this paper is compared with other two resource allocation schemes through simulation. Fig. 3 shows the system sum rate variations of the three schemes under different numbers of channel resources. There are 50 cellular users represented by M, 50 D2D users represented by N. The system sum rate increases as the number of channel resources increases, because more available channel resources directly provide higher data rates. Compare with other resource allocation schemes, this resource allocation scheme combined with D2D mode selection provides optimal data rate performance. Therefore, the effectiveness of the proposed scheme is verified. In order to verify the advantages of the mode selection in this paper. In the simulation of Fig. 3(a), the number of D2D users in the relay-assisted mode is 10. In the simulation of Fig. 3(b), the number of D2D users in the relay-assisted mode is 20. Compare with Fig. 3(a) and Fig. 3(b), it can be found that increase the number of relay user equipment can improve the overall performance of D2D communication.

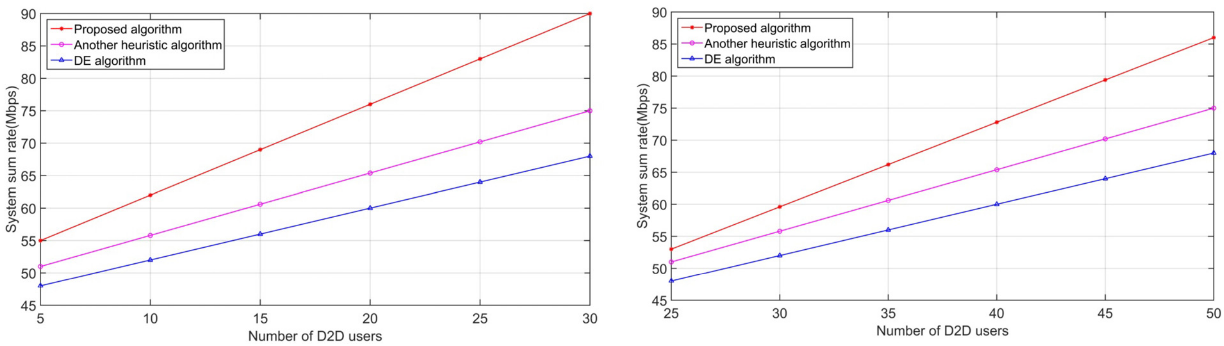


(a) (b)

Fig. 3. The system sum rate increases with the increase of channel resources

Moreover, we simulate the relationship between systems sum rate and the number of users in three algorithms. We will discuss two situations. That is, the cellular users M is larger than the D2D users N, and the cellular users M is smaller than the D2D users N. First simulate the system sum rate when the situation is $M \geq N$. In Fig. 4 (a), the number of M is 30, and the number of N is increased from 5 to 30. As shown in Fig. 4(a), the system sum rate of the proposed algorithm is significantly higher than the other two algorithms. When the number of D2D users is small, the difference between the proposed algorithm and the other two algorithms in system sum rate are small. With the increase of D2D users, the difference between the three algorithms has gradually become larger. Compare with another heuristic algorithm, the system sum rate is improved by 16.7%. Compare with differential evolution algorithm, the system sum rate is improved by 33.3%.

Furthermore, we verify the change of system sum rate when the situation is $M \le N$. In Fig. 4(b), the number of M is 10. In order to keep the fairness of simulation with $M \ge N$, it is necessary to keep the total number of users unchanged. Ensure that the system sum rate changes are not caused by user reduction. So, the number of N increases from 25 to 50. As shown in Fig. 4(b), the system sum rate of the other two schemes does not change, because they do not take into account the user's mode selection. With the total number of system user unchanged, the system sum rate remains unchanged. The proposed scheme still has a considerable improvement, but it can be seen that compared with the situation of $M \ge N$, the system sum rate decreases slightly. This is due to the reduction of cellular users, resulting in a reduction in the number of relay user devices. Consequently, the reuse of resources is reduced, and the gain of system sum rate is reduced.



(a) (b)

Fig. 4. The relationship between the number of D2D users and the system sum rate

Finally, the performance of this scheme will be verified separately. Fix the D2D users to 50, 30 and 10, respectively. Cellular users increased from 0 to 50. As shown in Fig. 5, when $DU = 10$ and $DU = 30$, the slope of the system sum rate will increase as the number of cellular users increases. Because more devices as relays with the increase of cellular users, which increase the gain of resource reuse. When $DU = 50$ and CU changes from 0 to 30, the slope of the system sum rate increases gradually. However, the slope of the system sum rate decreases when $CU = 30$. As the number of system users increases, the interference caused by relay devices to other devices will also increase. Although the system sum rate is still increasing, the slope of the system sum rate is decreasing.

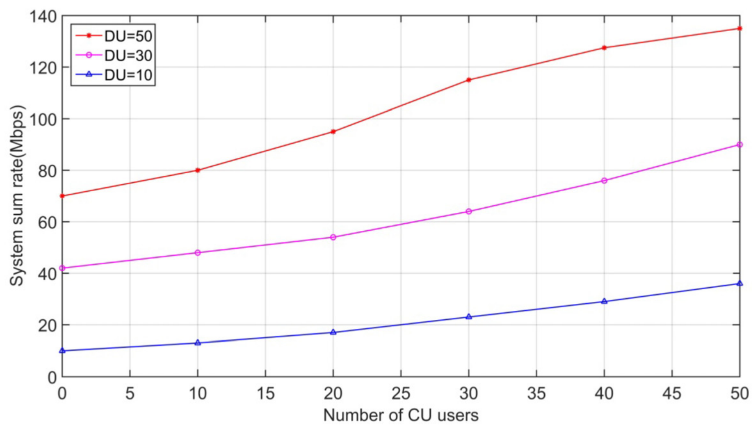


Fig. 5. The relationship between the number of CU users and the system sum rate in proposed scheme

6 Conclusion

In this paper, a joint optimization scheme of mode selection and resource allocation is proposed, which considers the mobility of user devices and improves the working mode of user devices. This scheme optimizes the existing D2D communication scheme from two aspects. In the aspect of mode selection, cooperative relay technology is combined to improve the service quality of user equipment. In the aspect of resource allocation, heuristic algorithm is used to optimize channel resource allocation. Aiming at improving the system sum rate, the throughput of users is greatly improved.

Compared with previous works, the algorithm proposed in this paper has the following advantages: (1) Under the same channel resource condition, higher system sum rate can be obtained. (2) With the same cellular users and D2D users, the throughput and service quality of each device can be improved. (3) In this paper, cooperative relay technology is combined with the existing D2D mode selection technology, and heuristic algorithm is used in resource allocation to greatly reduce the computational complexity. It is not difficult to translate theory into practice.

Based on existing papers and algorithms, this paper proposes a joint resource allocation scheme considering mode selection, which improves system sum rate. Simulation results show that the proposed scheme is effective. In addition, the scheme is designed to improve system sum rate, other problems can also be solved from other perspectives. For example, reduce the power and efficiency of equipment, or improve the efficiency of spectrum. Therefore, control the power of user equipment and improve the spectral efficiency of system is the next research direction for the authors.

References

[1] A. Omri, M.O. Hasna, Modeling and performance analysis of D2D communications with interference management in 3-D HetNets, in: Proc. 2016 IEEE Global Communications Conference, 2016.

[2] X.-Q. Lin, R.K. Ganti, P.J. Fleming, J.G. Andrews, Towards Understanding the fundamentals of mobility in cellular networks, IEEE Transactions on Wireless Communications 12(4)(2013) 1686-1698.

[3] A. Omri, M.O. Hasna, Modeling and performance analysis of 3-D heterogeneous networks with interference management, IEEE Communications Letters 21(8)(2017) 1787-1790.

[4] H. Tang, Z. Ding, Mixed mode transmission and resource allocation for D2D communication, IEEE Transactions on Wireless Communications 15(1)(2016) 162-175.

[5] X.-D. Xu, Y. Zhang, Z. Sun, Y.-T. Hong, X.-F. Tao, Analytical modeling of mode selection for moving D2D-Enabled cellular networks, IEEE Communications Letters 20(6)(2016) 1203-1206.

[6] J. Huang, J.-Y. Zou, C.-C. Xing, Energy-efficient mode selection for D2D communications in cellular networks, IEEE Transactions on Cognitive Communications and Networking 4(4)(2018) 869-882.

[7] A. Omri, M.O. Hasna, A distance-based mode selection scheme for D2D-enabled networks with mobility, IEEE Transactions on Wireless Communications 17(7)(2018) 4326-4340.

[8] R.-F. Ma, N. Xia, H.-H. Chen, C.-Y. Chiu, Mode selection, radio resource allocation, and power coordination in D2D communications, IEEE Wireless Communications 24(3)(2017) 112-121.

[9] Y. Qiu, Z. Ji, Y. Zhu, G. Meng, G. Xie, Joint mode selection and power adaptation for D2D communication with reinforcement learning, in: Proc. 2018 15th International Symposium on Wireless Communication Systems, 2018.

[10] W.-F. Lu, W.-J. Lin, L.-J. Yan, S.-G. Chen, A heuristic D2D communication mode selection algorithm, in: Proc. 2017 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery, 2017.

[11] F. Lei, P. Zhao, F.-Q. Zhou, M.-J. Yin, Resource allocation for 5G D2D multicast content sharing in social-aware cellular networks, IEEE Communications Magazine 56(3)(2018) 112-118.

[12] D. Wu, Y.-M. Cai, Q.-Y. Hu, Y. Qian, Dynamic distributed resource sharing for mobile D2D communications, IEEE Transactions on Wireless Communications 14(10)(2015) 5417-5429.

[13] H.-L. Chen, X.-Y. Deng, M. Gao, L.-N. Yang, L.-H. Guo, M. Chi, Location related communication mode selection and spectrum sharing for D2D communications in cellular networks, in: Proc. 2018 International Conference on Intelligent Transportation, Big Data & Smart City, 2018.

[14] Y. Qiu, Z. Ji, Y. Zhu, G. Meng, G. Xie, Joint mode selection and power adaptation for D2D communication with reinforcement learning, in: Proc. 2018 15th International Symposium on Wireless Communication Systems, 2018.

[15] D. Wu, J.-L. Wang, Q.-Y. Hu, Y.-M. Cai, L. Zhou, Energy-efficient resource sharing for mobile device-to-device multimedia communications, IEEE Transactions on Vehicular Technology 63(5)(2014) 2093-2103.

[16] S. Krishnan, H. S. Dhillon, Effect of user mobility on the performance of device-to-device networks with distributed caching, IEEE Wireless Communications Letters 6(2)(2017) 194-197.

[17] X.-Y. Liu, X.-K. Li, C.-S. Liu, Position-based mode selection and resource allocation for D2D communications underlaying cellular networks, in: Proc. 2017 9th International Conference on Wireless Communications and Signal Processing, 2017.

[18] Z.-H. Qian, S.-Y. Yan, C.-S. Tian, X. Wang, Research on resource allocation algorithm for D2D communications underlaying LTE- a networks, Journal of electronics & Information technology 40(10)(2018) 2287-2293.

[19] K.-K. Fan, Y. Dong, Z.-H. Qian, X. Wang, Research on the interference control and resource allocation in D2D communication, Journal on communications 39(11)(2018) 198-206.

[20] T.-D. Hoang, L.-B. Le, T. Le-Ngoc, Joint mode selection and resource allocation for relay-based D2D communications, IEEE Communications Letters 21(2)(2017) 398-401.

[21] R. Balakrishnan, B. Canberk, Traffic-aware QoS provisioning and admission control in OFDMA hybrid small cells, IEEE Transactions on Vehicular Technology 63(2)(2014) 802-810.