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D2D Communication Mode Selection and Resource Optimization Algorithm With Optimal Throughput in 5G Network

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ABSTRACT Aiming at the problem of device-to-device (D2D) communication mode selection and resource optimization under the joint resource allocation mode in the 5G communication network, a probabilistic integrated resource allocation strategy and a quasi-convex optimization algorithm based on channel probability statistical characteristics are proposed. This strategy and algorithm guarantee D2D. Communication maximizes total system throughput while maximizing access. The analysis results show that this algorithm can significantly optimize the total throughput of the system and reduce the communication interference between the users, which proves the rationality and efficiency of the communication model. The research results obtained in Muwen can provide a theoretical basis for analyzing more complex D2D communication systems and provide a numerical basis for designing heuristic algorithms.

INDEX TERMS 5G, D2D communication, resource allocation, resource optimization.

I. INTRODUCTION

Due to the high-speed and high-efficiency information transmission requirements of the wireless system, the D2D (Device-to-Device) technology, which is one of the key technologies of 5G communication, was born. The terminal direct communication technology allows the terminal to skip the forwarding process of the base station. Direct point-to-point information transmission is directly performed by multiplexing channel resources of the cellular network. Compared with the existing LTE and IMT-A technology features, D2D has advantages in spectrum efficiency, system capacity, and transmission rate. In the current research trend, communication mechanisms, mode selection, resource allocation, and D2D relay technology research have made considerable progress.

Since the D2D system is mainly dedicated to reducing the base station forwarding pressure, it is important to improve the point-to-point transmission speed and optimize the system throughput. It is proposed in [1] that in cellular communication, the power control effect is limited and affected due to the fact that some users with poor link quality need higher transmission power at the cell edge. Literature [2] proposes interference avoidance measures aimed at maximizing the overall capacity of the network. Literature [3] proposed a dynamic power control strategy optimization method. The literature [4] broadcasts the information of the D2D user's allocated resources on the CCCH, so that the user can detect whether there are D2D users around and report to the BS in time, thus avoiding the interference of the two communication modes. The above power control strategies are centralized control of the base station, requiring D2D to periodically report interference, which greatly increases the signaling overhead [5]–[7]. The resource allocation and optimization problem is a hot issue in D2D communication. The literature [8] uses the Lagrangian mathematical theorem to give the theoretical optimal solution under various modes. Literature [9] selects the appropriate resource utilization mode for each pair of D2D users based on the transmission power of the user equipment. Literature [10]–[12] proposed a joint optimization model to improve the spectrum utilization of the system. Literature [13]–[15] aims at signal-to-noise ratio and combines mode selection and power control.

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However, none of the above documents considers the channel difference of users in different scheduling periods, and allocates all RB (Resource Block) probability to users who need to be scheduled. In practical applications, due to the fading phenomenon of the wireless channel, the quality of the channel observed by one end user on different channels (resource blocks) is different. If a good quality channel is assigned to the user, a higher data rate can be obtained. It can be seen that if the system considers the difference in channel quality caused by location and channel fading of each user when allocating resource blocks, the resource allocation scheme can be optimized to further increase the capacity of the network. Therefore, the main contribution of this paper is based on channel quality, and proposes a mode selection and resource optimization algorithm in D2D communication.

This paper first describes the problem that needs to be solved, then mathematically models the problem to maximize the system throughput. The communication mode selection and resource optimization algorithm in 5G network mode is proposed. All of them consider the channel quality difference of each user, dynamically select the user's communication mode in each scheduling period, and allocate appropriate resource blocks to maximize the capacity of the system while ensuring the user's fair experience.

II. SYSTEM MODEL

A. 5G INTERNET

In China, the cellular system has experienced various stages of ''1G, 2G tracking, 3G break through, 4G synchronization'', and there are a large number of technical reserves. At present, I hope to achieve catch-up in 5G and lead the development of the world communication industry. In early 2013, the Ministry of Industry and Information Technology, the Ministry of Science and Technology and the National Development and Reform Commission led the establishment of a 5G research alliance covering major Chinese telecom carriers, manufacturers, universities and research institutions, and formulated 5G standards with China's independent intellectual property rights.

Core performance indicators of 5G network:

(1) The user experience rate reaches 0.1-1Gbps to meet the needs of services such as high definition video, mobile cloud, virtual reality, 3D games, etc., to provide users with fiber-like access speed.

(2) Access equipment with a density of millions of square meters per square kilometer to meet the communication needs in densely populated scenes such as dense residential areas, large commercial centers, stadiums, and open air gatherings, as well as smart home, smart meter reading, and industrial monitoring. Such as the rapid development of the Internet of Things business, the huge amount of device access requests, to achieve the Internet of Everything.

(3) The end-to-end delay reaches the millisecond level to meet the needs of emerging applications such as real-time mobile control, auto-driving, augmented reality, and cloud desktops, giving users a zero-delay-like service experience.

5G network design requirements indicators:

(1) The spectral efficiency is 5-15 times higher than that of 4G. At present, network traffic is exponentially growing, while spectrum resources are scarce and expensive. Therefore, it is necessary to greatly increase the spatial multiplexing rate of spectrum resources, and to flexibly and efficiently utilize various types of spectrum, including symmetric and asymmetric frequency bands, low frequency bands and high frequency bands, and licensed and unlicensed frequency bands.

(2) The energy efficiency is increased by more than 100 times with respect to 4G. The ever-increasing huge bill of electricity bills has always been a big burden for operators. At the same time, battery life is also a major bottleneck for smart terminals such as the iPhone, which seriously restricts the development of high-energy-consuming services such as video. Therefore, while 5G greatly increases the system traffic density, it is imperative to improve energy efficiency.

(3) Cost efficiency is increased by more than 100 times compared with 4G. The industry can continue to develop, and it is necessary to reduce the complexity and cost of network deployment in order to cope with the rapid growth of data traffic and provide users with affordable services.

The design requirements of 5G communication systems are high spectral efficiency, high energy efficiency and high cost efficiency, and D2D communication can just improve these requirements. First, channel gain, hop count gain, and multiplexing gain all contribute to improved spectral efficiency. Second, channel gain and hop count gain help reduce user energy consumption, and D2D communication can assist in the intelligence of microcells and cells. Sleep, thereby improving the energy efficiency of the system; finally, the channel gain can improve the user service experience, while the hop gain and multiplexing gain help to increase the number of user access, so D2D communication can reduce the deployment of small base stations in future UDN networks. Density, thereby increasing the cost is efficiency of the system.

D2D communication has the unique advantage that the carrier is authorized to use the spectrum, and the communication process is controlled by the base station, and the quality of service of the user can be guaranteed. Moreover, the user's access pairing and resource allocation such as power and channel can be uniformly completed by the base station, and the user access is safer, faster, and more efficient, and the interference can be effectively controlled, and thus is widely supported by the operator.

B. COMMUNICATION MODE

In this paper, a single wireless cell is considered, and the base station performs centralized control on users of the cell. The base station acquires the channel quality between each user and the base station through a certain mechanism, and the channel quality between each user pair (the transmitting terminal and the receiving terminal). In each scheduling period, the base station uses this information to make decisions about the communication mode of each pair of users while allocating channel resources to each pair of users. The mode decision and channel allocation information is communicated to the user before the start of each scheduling period by a corresponding control mechanism.

In each scheduling period, the base station selects one of the following two communication modes for each user pair: (1) dedicated mode: the sender and the receiver do not directly communicate via the BS (Base Station); (2)the cellular mode: the sender Through the BS transfer, the BS and the receiver communicate. This type of communication is similar to traditional cellular user communications.

Figure 1 specifically depicts two modes of communication for the user, with solid lines indicating the cellular mode and dashed lines indicating the dedicated mode. It is not difficult to see that the channel quality of different communication methods depends largely on the transmission power and the spatial distance between the terminals. Therefore, the performance of the whole system should be effectively improved by appropriate mode selection and resource allocation algorithms.

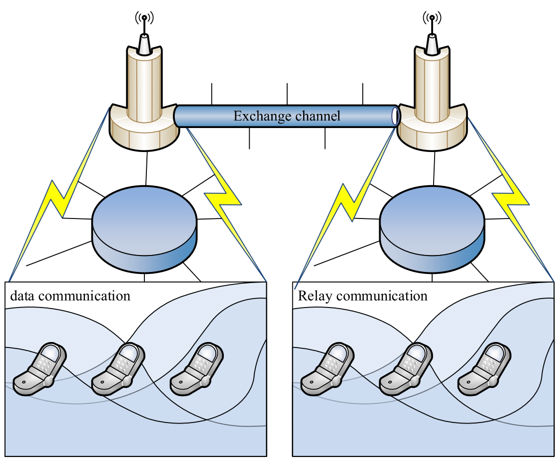

FIGURE 1. D2D communication and traditional base station relay communication.

As shown in the figure above, in order to highlight the role of D2D communication, this chapter considers a full-load cellular network scenario, that is, N CU users have occupied N mutually orthogonal channels in the network, and the BS has no additional spectrum resources that can be distributed to D2D user. The D2D user needs to access it only by multiplexing the channel of the CU user in the network. In addition, in order to ensure the user's QoS requirements, this chapter also assumes that each D2D user and CU user has its own minimum SINR requirement, while considering that the BS has perfect channel information of all relevant channels for coordinating resource allocation of D2D users and CU users.

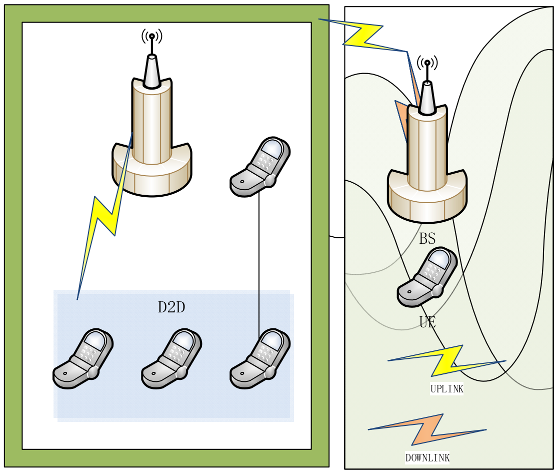

FIGURE 2. D2D communication mode.

C. D2D USER ACCESS CONTROL AND RESOURCE ALLOCATION

To solve the problem of maximizing the overall throughput of CU users and D2D users defined in the optimization objective function, the scope of the set S is first determined, that is, which D2D users can be accessed into the network and their QoS requirements are guaranteed.

When no D2D user multiplexes the channel of CU user i, the lowest transmit power that satisfies its SINR requirement can be expressed as:

$$P^{c}_{\min} = \frac{\xi^{c}_{\min}\sigma_N^2}{g_{i,B}} \tag{1}$$

Similarly, when there is no interference from the CU user, that is, when the D2D user exclusively enjoys the channel of the CU user, the minimum transmit power that satisfies the SINR requirement can be expressed as:

$$P^{c}_{j\min} = \frac{\xi^{c}_{j\min}\sigma_N^2}{g_j} \tag{2}$$

The minimum SINR limit and the maximum transmit power limit of both users must be met. Therefore, the condition that D2D user J can access the network by multiplexing the channel of CU user i can be expressed as:

$$\xi_i = \frac{P^c_i g_{i,n}}{\sigma_N^2 + P_j^2 h^{in}_{j,n}} \geq \xi_{\min} \tag{3}$$

For scenarios of multiple pairs of D2D users in the network, since different D2D users may have the same optimal CU multiplexing partner, the D2D user's access control and CU multiplexing partner selection become more complicated. Nguyen *et al.* [16] propose a heuristic algorithm based on user distance and user channel state information to pair D2D users and CU multiplexing partners. Although these two algorithms are simple, they are not theoretically optimal.

A pair of D2D users can multiplex the channel of one CU user at most, and the channel of one CU user can be reused by a pair of D2D users at most. At this time, the optimal CU multiplexing partner selection problem of the D2D user can be converted into the weighted two parts in the graph theory. The mathematical matching of the graph's maximum matching problem is as follows:

$$\begin{aligned} \max \quad & \sum_{i\in C, j\in S} p_{i,j} T_{i,j}^{a} \\ s.t. \quad & \sum_{i} p_{i,j} \leq 1, \forall i \in C \\ & \sum_{j} p_{i,j} \leq 1, \forall j \in S \end{aligned} \tag{4}$$

The above formula is the maximum matching problem of the weighted bipartite graph of the constraint condition, wherein the set of all D2D users and the set of all CU multiplexing partners respectively represent two sets of internally disjoint vertex sets in the figure. If CU user i is a potential multiplexing partner of D2D user i, there is a connection between CU user i and D2D user j, and the weight on this line is the channel band of D2D user J multiplexing CU user i The throughput gain coming.

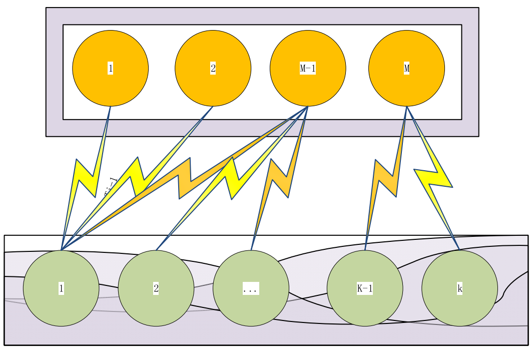

FIGURE 3. Multiplexing partner based on the maximum match of the weighted bipartite graph.

The following will give the channel fading, the communication radius of the D2D user, the location of the D2D user in the cell, the cell radius, the maximum transmit power limit of the D2D user, the number of CU users in the network, and the number of D2D users. The impact and analyze the reasons. In the following figures, the algorithm based on cross-layer optimization design proposed in this chapter is represented by "Proposed".

As the D2D user cluster radius is changes. It can be seen that the D2D user's access rate and whether there is fading or no fading The throughput gain decreases as the radius of the D2D user cluster increases. The reason is that as the D2D user cluster radius increases, the D2D user's pass-through link gain becomes smaller, so higher transmit power is needed to satisfy its SINR requirement, resulting in more interference to the CU multiplex user. As a result, fewer CU users can meet the channel multiplexing requirements, so the overall performance of the network is degraded.

TABLE 1. Perfect channel cross-layer optimization resource allocation algorithm.

Algorithm Cross-layer optimization resource allocation algorithm
Step 1 D2D user access control
For all j $\in$ D, and i $\in$ C do
Calculate $L_{ij}^{\min}$
If $L_{ij} > L_{ij}^{\min}$ then
$i \in R_j$
End if
If R_{ij} =0 then
D=D-j
End if
End for
Step 2 D2D user optimal power matching
For all j $\in$ D, and i $\in$ R_j do
Calculate (P_i^C , P_J^D)
End for
Step 3 D2D user channel multiplexing selection
If |D|=1 then
i= arg max T_{ij}^{C}
else
get i
end if

Often, the performance of the system will decrease due to fading. However, for D2D communication, fading leads to more channel diversity, such as enhancing the power gain of the useful channel and reducing the power gain of the interfering channel, thereby increasing the access probability of the D2D user and increasing the system throughput. That is, in a wireless network with limited interference, fading can improve the QoS of the user.

III. DISTRIBUTION AND OPTIMIZATION OF COMMUNICATION RESOURCES UNDER 5G NETWORK

It is studied that when the BS has no perfect channel information for the CU-D link, multiple pairs of D2D users and multiple CU users share the access control and resource allocation problem of the D2D users in the resource network scenario. Consider a fully loaded network scenario and ensure QoS requirements for access network users. The difference is that when the base station does not have perfect channel information of the CU-D link, the minimum SINR of the D2D user is not guaranteed, so the outage probability is used to ensure the quality of service of the D2D user. The uncertainty of channel information will be handled by two different approaches: a probabilistic resource allocation strategy based on channel probability statistics and a limited feedback mechanism based on user selection. One method is that the base station transmits a downlink pilot sequence, and the mobile station recovers the sparse channel by using

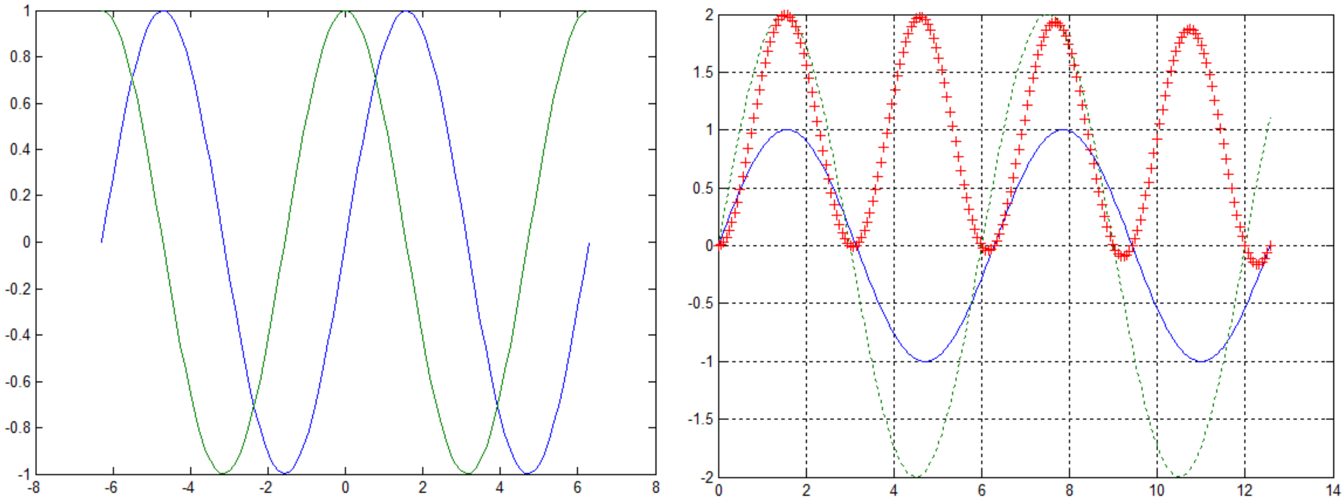

FIGURE 4. **Throughput performance.**

a conventional compressed sensing recovery algorithm, and feeds the quantized information to the base station through the uplink. Another method is that the base station transmits a downlink pilot sequence, and the mobile station only performs local channel observation, and the pilot sequence is equivalent to the observation matrix, and the observation value is quantized, and then fed back to the uplink base station.

A. HYBRID RESOURCE ALLOCATION OPTIMIZATION ALGORITHM BASED ON CHANNEL PROBABILITY AND STATISTICS

According to the channel statistics characteristics, a resource allocation scheme based on the D2D user outage probability threshold is proposed to solve the uncertainty caused by channel fading of the CU-D link. First, a user access control criterion based on a minimum access distance compensation factor under a fading channel is proposed. Then, a method similar to user power allocation and channel allocation under perfect channel is adopted to obtain a resource allocation scheme for guaranteeing user QoS requirements under imperfect channel information.

To solve the problem of maximizing the average throughput of the system in the optimization goal, first determine the scope of the set S, that is, know which D2D users can access the QoS requirements. In a fully loaded network, D2D users can access the network only by multiplexing the channels of the CU users. Therefore, for D2D user J, if the channel of CU user i is to be multiplexed, the constraints in the optimization problem must be met, namely:

$$\begin{cases} \dfrac{P_i^C g_{i,n}}{\sigma_N^2 + P_j^D h_{j.n}^{\theta}} \geq \xi_{i\,\min} \\ P_r \dfrac{P_j^d g_j^c}{\sigma_N^2 + P_{\mathrm{i}}^C h_{ij}} \leq \xi_{j\,\min}^d \leq \varsigma \end{cases} \tag{5}$$

Under perfect channel information, determining whether a D2D user can access the network can use the shortest access distance criterion that satisfies all access conditions of the D2D user. According to this criterion, the BS can find all CU users that can be multiplexed for a D2D user and judge whether the D2D user can access the network. Obviously, this shortest access distance does not satisfy the access conditions defined by the imperfect channel information. Nevertheless, the following two inferences can be obtained.

$$\gamma_{i+j+N} = \frac{G_{iN} P_i}{N_d} \tag{6}$$

$$C_{h+N} = B \log_2(1 + \gamma_{c+N}) \tag{7}$$

The channel capacity in equation (2) is the main basis of the existing channel resource allocation method, and its value mainly depends on the channel bandwidth B, the transmission power and the distance between the transceiver terminals. However, we believe that due to the existence of channel fading, the quality of the channel observed by a user on different channels is different. If this factor is taken into account during channel allocation, the channel allocation can be optimized to further increase the capacity of the system. In order to maximize system throughput, two resource allocation algorithms are proposed by solving nonlinear models. The optimal resource algorithm can obtain the theoretical global optimal solution, and the sub-optimal resource allocation algorithm can be used as a supplement to the former. When the system structure is too complicated, it can be used to reduce costs and improve efficiency. Therefore, this paper uses the Rayleigh distribution to describe the user's quality changes on different channels. The variable is used to represent C, that is, the capacity of the user when communicating with the selected channel i, and the probability density function is:

$$f(x, \sigma) = \frac{x}{\sigma^2} e^{-x^2/2\sigma^2}, \quad x \geq 0 \tag{8}$$

TABLE 2. Simulation parameters.

parameter name	Parameter value
Cell radius	1500m
Cell uplink bandwidth	5Mhz
Noise power	-174dBm/Hz
Channel loss index	4
Channel loss constant	10^{-2}
CU user maximum transmit power	24 dBm
D2D user maximum transmit power	24 dBm
Fixed power factor	10 dB
Minimum SINR requirement for CU users	Uniform distribution over [0,25] dB
Minimum SINR requirement for D2D users	Uniform distribution over [0,25] dB
D2D cluster radius	20,30,40…100m
D2D cluster position	Uniform distribution within a circle of radius R
Number of CU users	20,40
Number of D2D users	105,20%,,,100% number of CU users
Multipath fading	index distribution
Shadow fading	Lognormal distribution

In the cellular mode, there are an uplink channel from the transmitting end to the base station and a downlink channel from the base station to the receiving side. Assume that the sender is user J and the receiver is user j+N.

After obtaining the average throughput gain of the D2D user, the KM algorithm based on the weighted bipartite graph maximum matching problem can be used to obtain the optimal channel pairing of the D2D user and the CU multiplexing partner.

At this point, a resource allocation scheme based on channel probability statistical characteristics under imperfect channel information can be obtained: the first step is D2D user access control, which finds all D2D users based on the improved minimum access distance criterion between CU users and D2D users. The CU multiplexing partner for the multiplexed channel; the second step is the power allocation of the D2D user and the CU multiplexing partner, and the D2D user feasible access area is provided to provide the user with a fast power allocation scheme; the third step is the channel of the D2D user. Allocation, based on the weighted bipartite graph maximum matching algorithm in graph theory, selects the appropriate CU multiplexing partner for the D2D user to maximize the overall average throughput of the system. The specific process is shown in the algorithm in Table 3.

In the foregoing hybrid policy resource allocation scheme, the KMDR algorithm is first executed to find K optimal CU feedback users, and the CU-D link channel information of the feedback user and the D2D user receiver is measured and reported to the BS according to the accurate channel information. Select the multiplexing partner of the D2D user. Then, for all CU users that are not selected as feedback users, an access criterion based on the guaranteed D2D user outage probability requirement is performed to determine whether it is a D2D user's multiplexing partner. In this way, on the one hand, the KMDR mechanism helps to improve the accuracy of CU multiplexing partner selection in the resource allocation scheme based on channel probability statistics, and on the other hand, the resource allocation scheme based on channel probability statistics helps to increase the CU multiplexing partner. Select a range to increase the probability of D2D users accessing the network. After performing the multiplexing partner selection, the BS performs an optimal power allocation scheme and a heuristic power allocation scheme proposed in this chapter for the CU multiplexing

TABLE 3. Hybrid resource allocation algorithm based on channel probability statistical characteristics under imperfect channel information.

Algorithm Hybrid resource allocation algorithm based on channel probability and statistics

Step 1 D2D user access control with guaranteed outage probability
For all j ∈ D and i ∈ C do
    Calculate $L_{ii}^{\min}$ with given c
  If $L_{ii} \geq L_{ii}^{\min}$ then
      $i \in R_i$
  End if
  If R_i=0 then
      D=D-j
    End if
End for
Step 2 Power allocation multiplexed by D2D users and potential CU users
For all j ∈ D and i ∈ C do
  (P_i^C, P_i^D) =arg max $L(P_i^C, P_i^D)$
End for
Step 3 Optimal channel selection for D2D users
If |D|=1 then
    $i^* = \arg\max L_{ii}^G$
  End if

TABLE 4. Spectrum efficiency optimal resource allocation algorithm based on dichotomy.

Algorithm dichotomy

Initialize
Given range
$\tau = \frac{l+\gamma}{2}$
Solving convex feasibility problem
$\sigma_i(a) \geq 0$
If The above solution then
  τ=r
else
  $\gamma = r$
End if

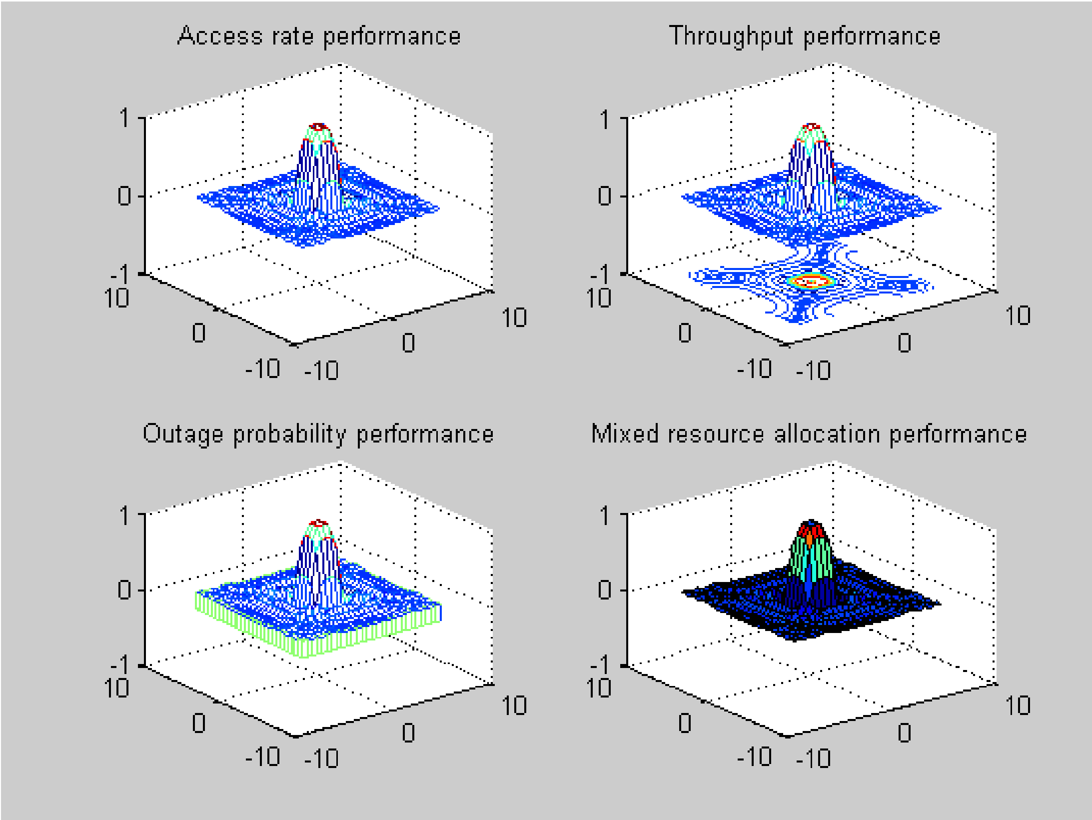

FIGURE 5. Hybrid resource allocation algorithm performance.

partner selected based on the KMDR mechanism and the channel probability statistical characteristic.

B. D2D COMMUNICATION MODE SELECTION IN 5G NETWORK

The previous section describes how to increase user access rate and throughput in a network through D2D communication in a fully loaded cellular network. Because the network is fully loaded, D2D users can only access the network by multiplexing the resources of the CU users. In a more general network scenario, the BS may also allocate resources orthogonal to other users to the D2D users or allow the D2D users to return to the network based on the traditional communication mode of the BS relay. This article refers to these types of communication transmission modes: Reusing Mode, Dedicated Mode, and Cellular Mode.

More transmission modes mean more freedom of communication. Reasonable communication mode conversion is to further improve network performance, so DZD communication transmission mode selection has received extensive attention. Therefore, considering user service priority and QoS requirements and transmission power limitation, jointly optimize frequency and power resource allocation, and design an optimal mode selection algorithm aiming at maximizing network spectrum efficiency. For each transmission mode of D2D communication, according to the convex optimization theory, the optimal resource allocation algorithm is obtained. Among them, in the orthogonal mode and the base station relay mode, it is proved that the optimization problem is the quasi-convex optimization problem, and the dichotomy method is used to obtain the optimal solution.

In the multiplexing mode, the D2D user and the CU user use the entire spectrum at the same time, and the user spectrum resource division is not involved in the resource allocation, but there is interference between the D2D user and the CU user, which complicates the user power allocation. The spectrum efficiency optimization problem in this mode can be expressed as:

$$\max SE_n = \frac{\omega_c R_c + \omega_d R_d}{W} \tag{9}$$

In the base station relay mode, as in the orthogonal mode, the D2D user and the CU user communicate using mutually orthogonal spectrum resources, and there is no interference between users. The difference is that in the base station relay mode, data transmission between D2D users is through the BS relay, and needs to go through two stages of uplink and downlink. Therefore, its spectrum resources are also divided into upper and lower parts. The data transmission rate of the D2D client end-to-end can be expressed as:

$$\max SE_c = \frac{\omega_c R_c + \omega_d R_d}{(\sigma_c + \sigma_d)W} \tag{10}$$

TABLE 5. Simulation parameters.

parameter name	Parameter value
Cell radius	600m
Cell uplink bandwidth	6Mhz
Noise power	-180dBm/Hz
Channel loss index	4
Channel loss constant	10^{-2}
CU user maximum transmit power	48 dBm
D2D user maximum transmit power	48 dBm
Fixed power factor	20 dB
Minimum SINR requirement for CU users	Uniform distribution over [0,50] dB
Minimum SINR requirement for D2D users	Uniform distribution over [0,50] dB
D2D cluster radius	20,30,40…100m
D2D cluster position	Uniform distribution within a circle of radius R
Number of CU users	20,40
Number of D2D users	105,20%,,,100% number of CU users
Multipath fading	index distribution
Shadow fading	Lognormal distribution
Fading parameters in k-distribution	Corresponding to parameters in radius and shadow fading

In the base station relay mode, the D2D user spectrum resources are divided into two parts: the uplink and the downlink. Therefore, it is necessary to optimize the proportion of uplink and downlink spectrum resources. However, in an actual cellular network, uplink and downlink resource allocation is performed separately. To optimize, the downlink transmit power PB needs to be determined, and the total transmit power of the base station is limited, so the transmit power of a single user is also affected by the transmit power of other downlink users in the network.

Let the BS coordinate the user's transmit power. Therefore, the problem in the optimization goal can be simplified to the following form:

$$\max \frac{\omega_c R_c + \omega_d R_d}{(\sigma_c + \sigma_d)W} \tag{11}$$

The above problem has the same form as the problem in the orthogonal mode in the optimization target, so the optimal power and optimal spectrum resource division can be obtained by the dichotomy.

IV. PERFORMANCE ANALYSIS

A. PERFORMANCE ANALYSIS OF RESOURCE ALLOCATION OPTIMIZATION ALGORITHM

This section will give the hybrid resource allocation algorithm based on channel probability and statistics, the resource allocation algorithm based on user-selected limited feedback mechanism, and the performance of hybrid resource allocation algorithm based on the two, and the cross-layer optimization based on perfect channel information. The designed resource allocation algorithm is compared.

In the resource allocation algorithm based on channel probability statistical characteristics and the hybrid strategy resource allocation algorithm, the transmission interruption phenomenon of D2D users is inevitable. Therefore, in addition to the D2D user access rate and D2D user throughput gain, the two main performance indicators of D2D communication, this chapter also uses D2D user outage probability to evaluate the two algorithms, which is defined as the occurrence of transmission interruption in the access network. The ratio of the number of D2D users is to the total number of D2D users accessing the network. In addition, in order to compare the algorithms fairly, the D2D user access rate and D2D throughput gain in this chapter are respectively defined as the ratio of the number of D2D users in the access network without the transmission interruption to the total number of D2Ds in the network and the access network does not appear. The throughput gain from the transmission is of the interrupted D2D user.

The following figure compares the mixed strategy resource allocation (Comb) algorithm, the Prob algorithm and the KMDR algorithm in the Rayleigh fading channel model, the D2D user access rate, the D2D user throughput gain, and the D2D access user outage probability with the D2D user cluster radius: Changes.

As seen from the above figure, in this algorithm, the D2D user first performs a limited feedback mechanism, selects the most valuable CU user to measure and feedback the interference channel to reduce the D2D user interruption probability; and then performs the CU user that is not selected. A resource allocation strategy based on channel probability statistics to increase the number of channels that D2D users can multiplex and reduce signaling overhead. The simulation results show that the resource allocation algorithm based on channel probability and statistics has an optimal outage probability threshold, which makes the D2D user access rate and D2D user throughput gain the largest. Based on the user-selected limited feedback algorithm, the user feedback overhead can be significantly reduced. It is not sensitive to channel fading model changes and D2D communication distance changes; hybrid strategy resource allocation algorithm can combine the advantages of channel probability statistics based on user-selected limited feedback mechanism resource allocation algorithm, in the same D2D user access rate and D2D throughput Under the amount gain level, the D2D user outage probability and feedback signaling overhead can be further reduced.

B. PERFORMANCE ANALYSIS OF D2D COMMUNICATION MODE SELECTION IN 5G NETWORK

Considering that the CU users are evenly distributed in the cell, the D2D users are evenly distributed in the clusters with the radius: the different clusters are independent of each other. The specific simulation parameters are shown in Table 6.

TABLE 6. Simulation parameters.

parameter name	Parameter value
Cell radius	1500m
Cell uplink bandwidth	1.25Mhz
Noise power	-180dBm/Hz
Channel loss index	4
Channel loss constant	10^{-2}
CU user maximum transmit power	250 mW
D2D user maximum transmit power	250 mW
CU user minimum rate	[0,10]M bit
D2D user minimum rate	[0,10]M bit
D2D user rate weighting factor	1
Multipath fading	index distribution
Shadow fading	Lognormal distribution

The figure below shows the proportion of the three transmission modes of D2D communication in the optimal transmission mode selection, as the D2D user cluster radius: changes. As can be seen from the figure, the orthogonal mode is selected as the highest ratio of the optimal transmission mode, the multiplexing mode is second, the relay mode is hardly selected; the difference between the orthogonal mode and the multiplexing mode follows the D2D user cluster. Radius: Increases and increases.

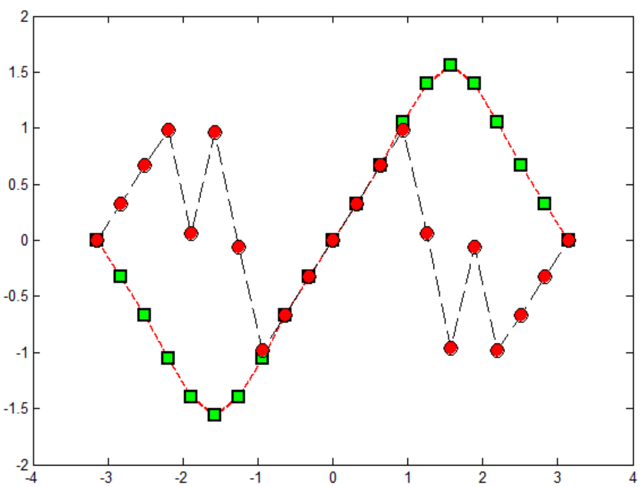

FIGURE 6. D2D communication optimal transmission mode efficiency performance.

As can be seen from the above figure: (1) In the orthogonal mode, there is no interference between the D2D user and the CU user, and both the D2D user and the CU user always use the maximum transmit power, so the system has the highest spectral efficiency; C2) in the multiplexing mode. As the D2D user cluster radius increases, the D2D user's pass-through link gain decreases, and higher transmit power needs to be used to meet its own QoS requirements, which may cause more interference to the CU reuse user. Therefore, the gap between it and the orthogonal mode is further expanded. (3) In the base station relay mode, the spectrum of the D2D user is divided into two parts, the upper and lower parts, so the spectrum efficiency is the lowest, which is also the original intention of D2D communication, namely: between users. Direct communication is performed to avoid base station relay transmission.

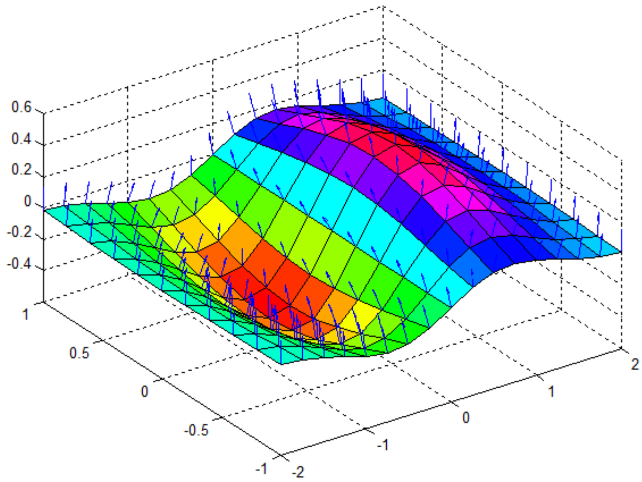

FIGURE 7. D2D user weighting factor and transmit power impact on algorithm performance.

The figure above shows the effect of the weighting factor and transmit power of the D2D user on the performance of the mode selection algorithm. It can be seen from the figure that under the same D2D user maximum transmit power limit, the spectral efficiency of the system decreases as the D2D user weighting factor decreases. This is because the distance of the D2D straight-through link is short, the channel quality is usually better than that of the CU user, and the transmission rate that can be achieved is also high, so the impact on the overall spectrum efficiency performance of the network is also greater. In addition, it can also be seen from FIG. 7 that increasing the maximum transmission of the D2D user increases the spectral efficiency performance of the system at the same D2D weighting factor. The reason is that increasing the maximum transmit power limit of the D2D user expands the feasible domain of the spectrum optimization problem, thus bringing performance improvement.

To further analyze throughput, the interference gate is limited to a 150dBm, and the cumulative distribution function (CDF) plot of throughput per pair of D2D communications is as follows. From the figure, the joint allocation scheme can improve performance for the independent allocation scheme. When the interference threshold of the base station is 155dBm, the throughput/per-pair user and the allowable D2D user logarithm are affected by the maximum distance between D2D users.

It can be clearly seen that the maximum distance between the D2D communication pairs and the quasi-connected D2D

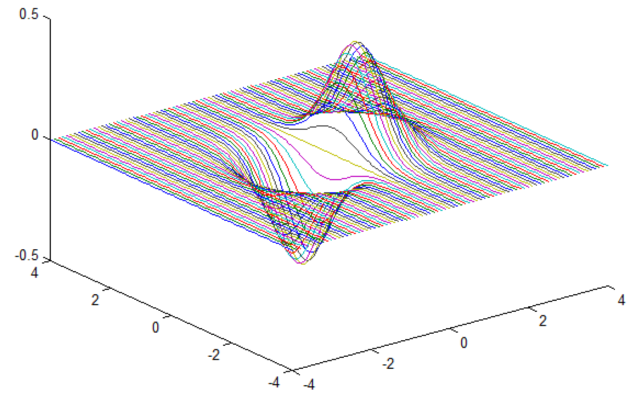

FIGURE 8. **Logarithmic relationship between the maximum distance between D2D communication pairs and the admission D2D communication.**

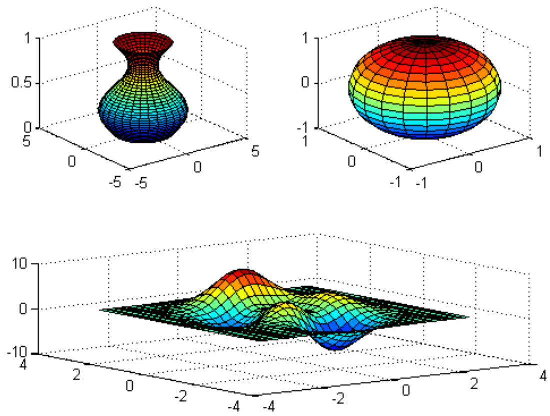

FIGURE 9. **Relationship between maximum distance and throughput between D2D communication pairs.**

communication are inversely proportional to the logarithm λ. This is because the relative distance of the D2D user is reduced, and the interference generated to the cellular base station is smaller and the access is easier. At the same time, the reduction in the distance between D2D users results in a decrease in transmission power and an increase in the average throughput generated by the user. The figure also shows that the performance of joint allocation is significantly higher than the independent allocation method.

D2D communication multiple transmission modes bring more communication freedom to users, and reasonable communication mode conversion helps to further improve network performance. Therefore, the spectral efficiency priority transmission mode selection problem in D2D communication is studied to improve the system spectrum efficiency. Firstly, the spectrum and power resource allocation problem based on spectral efficiency is optimized in D2D communication in the multiplexing mode, orthogonal mode and base station relay mode. Then the corresponding optimal algorithm is proposed for each problem. In the orthogonal mode and the base station relay mode, the spectral efficiency optimization problem is proved to be a quasi-convex optimization problem, and the dichotomy method is used to obtain the optimal solution. In the reuse mode, the original optimization problem is first transformed into a DC optimization problem through function recombination. Then, the CCCP process is used to transform the DC optimization problem into a series of convex optimization problems. Finally, the optimal solution of the convex optimization problem is obtained by the interior point method, and the KKT condition that the solution obtained by the CCCP process satisfies the original optimization problem is proved. Finally, the highest spectral efficiency that can be achieved by selecting three transmission modes is the optimal transmission mode. The simulation results show that D2D communication based on optimal mode selection can significantly improve the spectral efficiency of the system. In addition, the simulation results also show that in the three modes, the probability that the orthogonal mode is selected is the largest, the multiplexing mode is second, the relay mode is hardly selected; and as the D2D user cluster radius: increases, the orthogonal mode The advantages of the relative reuse model are expanding.

V. CONCLUSION

As an emerging technology in the G network, D2D communication will be more developed in the future, which will bring more convenience to traditional cellular users. This paper discusses the user's mode selection during D2D communication, and proposes an optimal resource allocation algorithm and the sub-optimal resource allocation algorithm. When the number of users is too large and the system model is extremely complicated, in order to save costs and improve efficiency, the sub-optimal the allocation algorithm is a good alternative. The simulation results show that the method of this paper can greatly improve the system throughput and give users a better experience. With the increasing number of users in the future, channel resources are becoming more and more tighter, and multiplexing cellular network resources is an inevitable choice. However, multiplexing resources will cause interference between users and reduce user experience. In addition, in a multi-cell environment, allowed multiple D2D pairs to multiplex the same resource block makes the system model more complex and computationally time consuming. How to maintain the balance between user experience and channel resource utilization in the hybrid network is the next step. Allowing multiple D2D pairs to reuse the same resource block makes the system model more complex and computationally time consuming. How to maintain the balance between user experience and channel resource utilization in the hybrid network is the next step of research.

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