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D2D communication channel allocation and resource optimization in 5G network based on game theory

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ABSTRACT

With the rapid development of intelligent hardware and the Internet of Things, the bandwidth and resource utilization efficiency of related networks need to be improved. At the same time, the corresponding communication spectrum is becoming more and more scarce. At present, cognitive D2D communication technology in 5G network can establish communication link directly through communication equipment, so that two established communication equipment can realize direct communication, so as to make full use of communication resources and finally meet the explosive growth of traffic demand. How to manage communication resources and select communication links is the main research direction of D2D communication technology in 5G technology. Based on the knowledge of game theory, this paper proposes a communication channel allocation scheme and resource optimization scheme based on spectrum clustering and non cooperative game to maximize the operation efficiency of D2D communication equipment. The actual efficiency can reach about 1.5 times of the original communication efficiency. Finally, the optimization method proposed in this paper is compared with the traditional communication method. The experimental results show that this method has higher advantages.

1. Introduction

With the development of mobile communication technology and the development of Internet technology, the number of mobile intelligent terminals is increasing in recent years, while the communication spectrum resources are becoming increasingly scarce. This series of problems are a challenge to the global mobile communication technology. The arrival of 5G technology has brought great significance to the research of improving the capacity of communication system, optimizing the spectrum efficiency of the system and optimizing the resource allocation [1–3]. The D2D communication technology in 5G technology makes use of the short-range characteristics of both sides of the communication, improves the spatial multiplexing of the spectrum by reusing the wireless resources, which has become the research hotspot and focus in recent years. In practical applications, reasonable utilization and distribution of D2D users' multiplexing resources and transmission of their corresponding transmission power can guarantee a certain quality of service, thus improving the corresponding spectral efficiency [4–6]. However, the traditional D2D communication technology still has problems related to allocation efficiency and interference coordination in homogeneous networks [7]. Therefore, how to use the new algorithm to realize the resource optimization and channel allocation of D2D communication technology is very important and practical.

For the current allocation and optimization of related resources of D2D communication technology in 5G communication technology the research algorithm of channel allocation and resource optimization in 5G communication technology, the mainstream research institutions and corresponding researchers mainly focus on the research of D2D communication technology. At the mode selection level of D2D communication technology in 5G, tsiropoulou et al. [8] have proposed three modes for D2D users to share specific wireless resources, which are respectively informal mode, separation mode and cellular mode. The application of these three modes in reality is mainly reflected in multiplexing mode, dedicated mode and cellular mode. Parsaefar et al. [9] have proposed three modes The mode selection method for power optimization and D2D mode selection method based on joint game, which uses channel occupation and D2D user transmission power as cost function to find stable alliance as the corresponding mode selection method. In the power control of the corresponding D2D communication technology, Zhang et al. [10] control the D2D users to send power through the fixed enhancement factor and the corresponding backoff factor, so as to ensure the QoS of the cellular users; Rose et al. [11] discuss the greedy power control technology and the speed maximum power control technology for a pair of corresponding D2D users, the effect of which is to improve the corresponding Zappone et al. [12] analyzed the D2D performance of D2D users under

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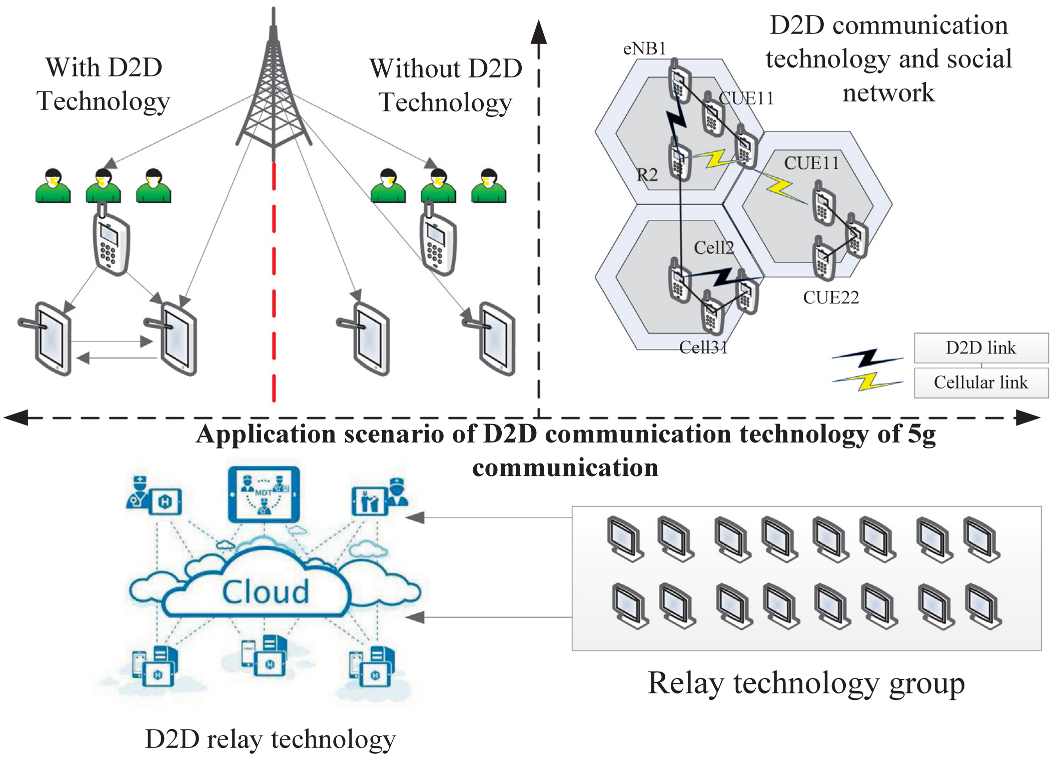

Fig. 1. Application scenario of D2D communication technology of 5G communication.

the control of fixed transmit power, fixed SNR threshold and open-loop fractional power by simulation. In the specific channel allocation, the mainstream research methods mainly include channel allocation planning simulation method, distributed algorithm, precise position based algorithm and time-oriented channel algorithm [13–16], among which the corresponding distributed algorithm is more typical, which is mainly based on the relevant game theory as the basic theory of D2D channel allocation, and the corresponding channel problems are corresponding Modeling and analysis, but there are some problems in the distributed algorithm, which needs iterative calculation constantly. The corresponding convergence and operation time of the algorithm are the difficulties [17].

Combined with the above research status, this paper proposes a communication channel allocation scheme and resource optimization scheme based on game theory [18,19]. The core algorithm of the scheme is mainly to focus on the actual spectrum allocation of clustering and non cooperative games, so as to solve the communication resource allocation problem and maximize the D2D communication operation efficiency of signal equipment [20,21]. The experimental results show that the proposed algorithm has obvious advantages in efficiency and energy consumption.

The main structure of this paper is as follows: in the second section of this paper, the application principle of game theory in D2D communication technology is analyzed in detail, and the non cooperative game theory model is proposed based on the theory of clustering and non cooperative game theory, so as to realize the optimization of channel allocation and communication resources; in the third section of this paper, the simulation comparison between the algorithm in this paper and the traditional communication algorithm is carried out, so as to be specific Analyze the corresponding results, and finally verify the superiority and practicality of this algorithm.

2. Application and analysis of game theory in 5G communication D2D communication technology

This section mainly discusses the application and analysis of game theory in 5G communication D2D communication technology, as shown in Fig. 1 is the application scenario of the corresponding whole 5G communication D2D communication technology, and also gives the corresponding position of the corresponding game theory in the whole system. It can be seen from Fig. 1 that in the whole 5G communication system, each user node can send and receive signals in the distributed network composed of D2D communication users, and has the function of automatic routing (message forwarding). Network participants share part of their hardware resources, including information processing, storage and network connectivity. These shared resources provide services and resources to the network, and can be directly accessed by other users without passing through intermediate entities. At the same time, the relevant information can be stored in cloud.

2.1. Application principle of game theory in D2D communication technology

As the core theory of D2D communication technology improvement in this paper, game theory mainly includes seven elements: characters in the system, information system, strategy, action, income, sequence and corresponding equilibrium. Among these seven elements, characters, strategy and income in the corresponding system are the most important three elements in the game theory system. The game theory is mainly divided into three theories, the specific contents are as follows:

A. Dynamic game and static game: they are mainly classified according to the time sequence. In the dynamic game, the corresponding characters make decisions in a certain order. At the same time, the corresponding post decision makers can know the implementation scheme of the decision made by the first decision maker, while the corresponding static game is that all the characters in the whole decision cannot know the decision content. So in the practical communication application, it is mainly the decision of information flow.

B. Non cooperative game and cooperative game: the main difference between these games is whether there is a mandatory binding force between people in the game system. In the non cooperative game theory, there is no restriction between the action of the corresponding

Table 1
Application cases of game theory in 5G communication D2D communication technology.

Algorithm	Algorithm details	Advantage	Malpractice
Game theory spectrum allocation algorithm	Analysis and distribution of spectrum based on Game Theory	It has obvious advantages over the average distribution	No time
Resource allocation algorithm of Stackelberg game	Main application of Nash equilibrium rules	Finally, convergence can be achieved	Complex, high power consumption
Hybrid algorithm of Stackelberg game	Taking the service provider of wireless network as the leader, Nash equilibrium can be realized finally	To optimize performance	Prone to non convergence
Vehicle algorithm based on Cooperative Game	Based on the cooperation between roadside units to coordinate the distribution of data types	This algorithm can improve the performance of the whole system	Too complex structure

person and the independent decision-making, while in the corresponding cooperative game theory, there is a binding agreement between people.

C. Game of complete information and incomplete information: it is mainly classified according to the degree of information equivalence in the whole game system. The fully corresponding information game is that each person or module in the whole system has a certain understanding of the characteristics, strategies and corresponding benefits of other people. The corresponding incomplete information game is that the player does not fully understand other players Information about things. The main application of this paper is the theory of non cooperative game.

In the field of 5G communication, there are serious conflicts in resource scheduling between base stations and corresponding users, which lead to a large number of channel conflicts and interference in resource allocation, thus affecting the efficiency and performance of the whole communication system. The key to the application of game theory in 5G communication is to establish a proper game theory model, according to the corresponding Shannon formula, we can actually design the corresponding utility function, and then design the corresponding call function and selection strategy to achieve the corresponding goal optimization. The main cases and advantages in practical application cases are shown in Table 1:

2.2. Theoretical research and analysis of 5G communication channel allocation and resource optimization based on clustering and non cooperative game

Based on the relevant game theory in Section 2.1 above, this paper proposes a channel resource allocation and optimization solution based on clustering and correlation equalization for D2D in 5G communication. First, the corresponding system model is established, and the corresponding system model is shown in Fig. 2. The corresponding network model is a small cellular network, including n small cells, and the corresponding overall macro base station is located in the center of the whole macro cell. In the figure, the corresponding base station is mainly spherical and overall circular. The coverage radius of the corresponding small cell base station is r, and the corresponding macro base station is deployed and maintained by the operator. Finally, it will be directly connected to the core network.

The calculation formula of the transmission rate corresponding to the macro user in the system model is shown in Formula (1), and the corresponding mathematical symbols are expressed as follows: n represents the corresponding Gaussian noise parameter, a1 corresponds to the interference index of the cell base station received by the macro user, a2 corresponds to the interference index of the cell base station received by the cell user, and the corresponding channel gain is defined as *b1* and *b2*.

$$C = w\log_2\left(1 + \frac{a_1 b_1}{\sum_{j=1}^{k} a_1 g_1 + {b_2}^2}\right) \tag{1}$$

The calculation formula of the corresponding small cell transmission rate is shown in formula (2), where the corresponding w is the transmission broadband of the whole macro base station.

$$C = w\log_2\left(1 + \frac{a_1 b_2}{\sum_{i=1,j=1}^{n} a_1 g_1 + a_2 g_2 + {b_2}^2}\right) \tag{2}$$

Based on this, the corresponding non cooperative game model between clusters can be summarized as shown in formula (3). The corresponding s represents the strategy set of any cluster, and the corresponding U represents the revenue.

$$G = |\{C|C = 1,2,3,4,\dots,N\},\{\prod_{c=1}^{N} S_c\},\{U_c(f_m)\}|. \tag{3}$$

The corresponding small cell system of the base station system based on this paper is shown in Fig. 3, in which the corresponding system interference scenario is also given.

Based on the above models, firstly, the spectrum of 5G communication system is allocated. The main algorithm is clustering algorithm, and its theoretical core is non cooperative game theory. In the actual clustering algorithm, it is assumed that the corresponding *k* small cells in the system model are randomly distributed within the coverage range of the macro base station, and the distribution formula of the barycenter of all the corresponding small cell base stations is shown in Eq. (4), and the corresponding *(ma, na)* is the barycenter coordinate of the small base station.

$$\begin{cases} m_a = \dfrac{\sum_{i=1}^{k} m_i}{k} \\ n_a = \dfrac{\sum_{i=1}^{k} n_i}{k} \end{cases} \tag{4}$$

The calculation formula of Euclidean distance between small cell base station and other small cell base stations is shown in formula (5):

$$d_{i,d} = \sqrt{(m_a - m_b)^2 + (n_a - n_b)^2} \tag{5}$$

In specific clustering, the corresponding links mainly include absorption links and splitting links. The corresponding absorption process steps are as follows:

Step 1: calculate the geographical coordinates of all the small cell base stations in the system, and calculate the average distance between the two base stations at the same time.

Step 2: calculate the center of gravity of the unclusted base station based on Formula (3), and define the nearest small cell as the absorption source and the corresponding absorption distance.

Step 3: for the small cell satisfying the corresponding distance, the corresponding cluster shall be included nearby and marked.

Step 4: recheck all the small cells, repeat the above steps, and calculate the new absorption source and the corresponding absorption distance until all the small cell base stations in the whole system are clustered.

The main operation process of the corresponding split link is as follows:

Step 1: check all base stations, and check any corresponding cluster. If the number of corresponding members exceeds the number of traffic, the corresponding small cell needs to be re clustered.

Step 2: repeat step 1 until all clusters meet the requirements of corresponding traffic and system members.

After the completion of intra cluster allocation, intra cluster coordination is needed to solve the corresponding channel allocation problem.

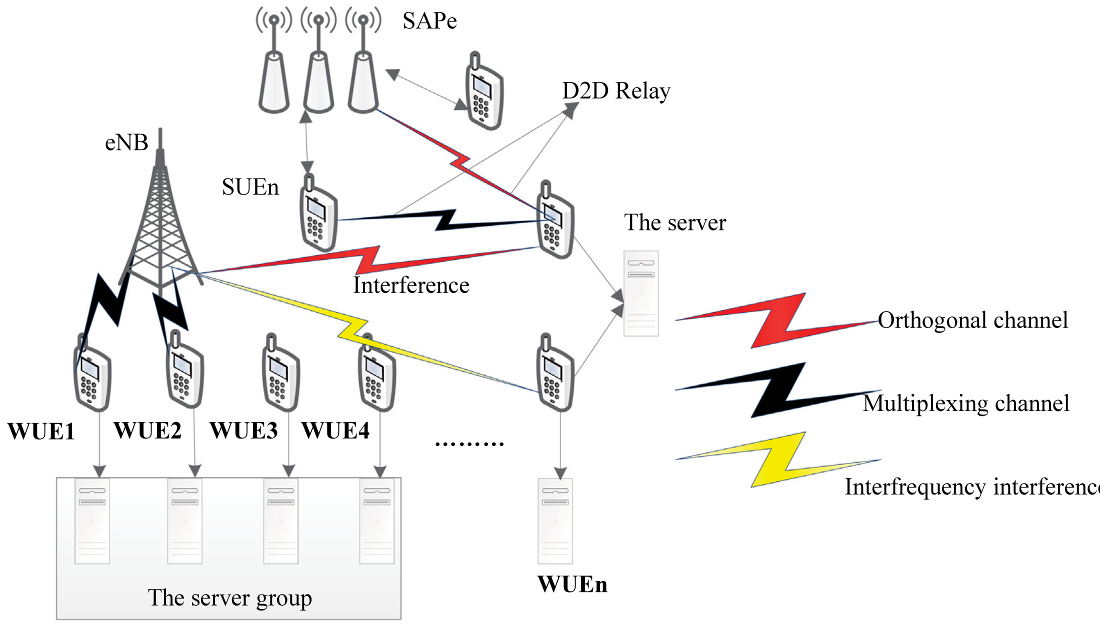

Fig. 2. System model.

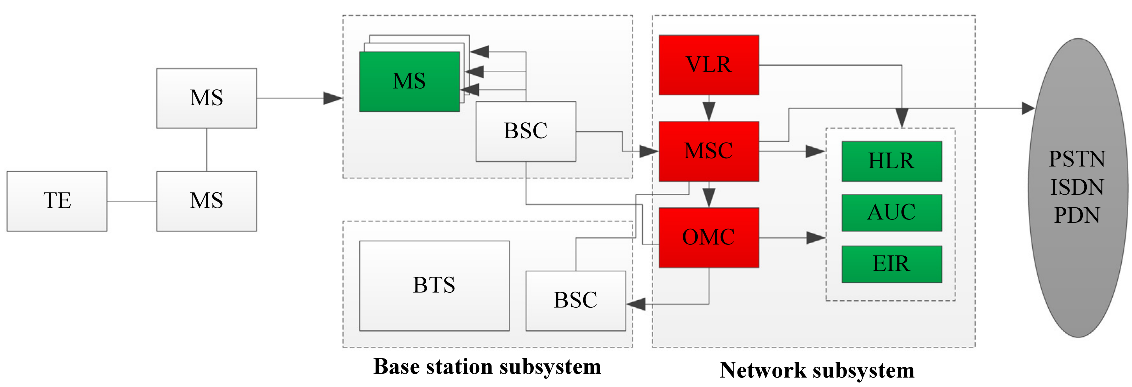

Fig. 3. Small cell architecture system and corresponding system interference scenario.

The corresponding allocation multiplexing diagram is shown in Fig. 4. In order to reduce the interference between clusters, it needs to meet the different edge spectrum of adjacent members and the different edge spectrum of corresponding cluster head and common members.

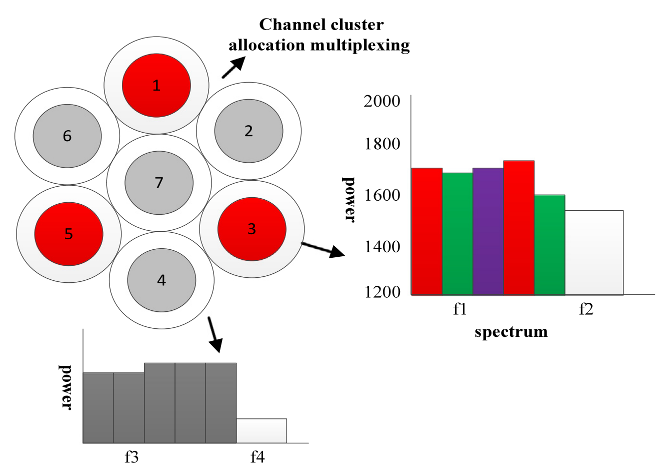

Fig. 4. Channel cluster allocation multiplexing diagram.

3. Experimental results and data analysis

Based on the algorithm proposed in this paper, the 5G communication network is simulated in a certain coverage range. The typical parameters related to the experimental environment are as follows: the corresponding macro cell parameters are set to 1000 m, in which the corresponding micro unit parameters are designed to be 200 m; the corresponding channel loss model is designed to be 122.1 + 33.6 log10 (d [km]) db; the shadow fading variance is designed to be 10 dB; the corresponding channel loss model is designed as follows; The corresponding channel noise spectrum density is — 173 dbm/Hz; the user bandwidth is set to 2 MHz; the corresponding SNR threshold is set to 5dBi; the system macro base station transmission power is set to 46 dbm; the carrier frequency is set to 3 GHz; and the transmission power of the experimental cell base station is set to 15 dbi. The corresponding test platform and corresponding experimental preparation are corresponding to the corresponding Table 2:

On the basis of controlling the same experimental environment, two experimental situations are considered in this paper. One is to use the algorithm proposed in this paper to allocate channel resources when the cell is full load, and the other is to use the traditional algorithm to allocate resources and channels in 5G communication system when

Table 2
Main simulation parameters.

Serial number	Parameter	Corresponding value
1	Macro cell, small cell radius parameter	1000 m, 200 m
2	Corresponding road loss model	122.1+33.6log10 (d[km]) dB
3	Shadow fading variance	10 dB
4	Noise spectral density	−173 dBm/Hz
5	User broadband	2 MHz
6	SINR threshold	10 dB
7	Antenna gain of small cell base station	5 dBi
8	Transmitting power of Hongji station	46 dBm
9	Carrier frequency	3 GHz
10	Transmitting power of small cell base station	15 dBi
11	User broadband 2	3 MHz
12	SINR threshold 2	9 dB
13	Antenna gain of small cell base station 2	9 dBi
14	Noise spectral density 2	−1553 dBm/Hz

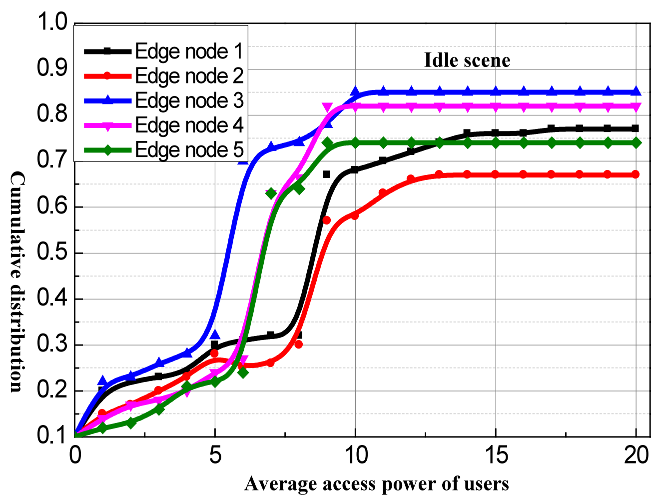

Fig. 5. Scene power dissipation curve corresponding to idle channel resources in the whole communication system.

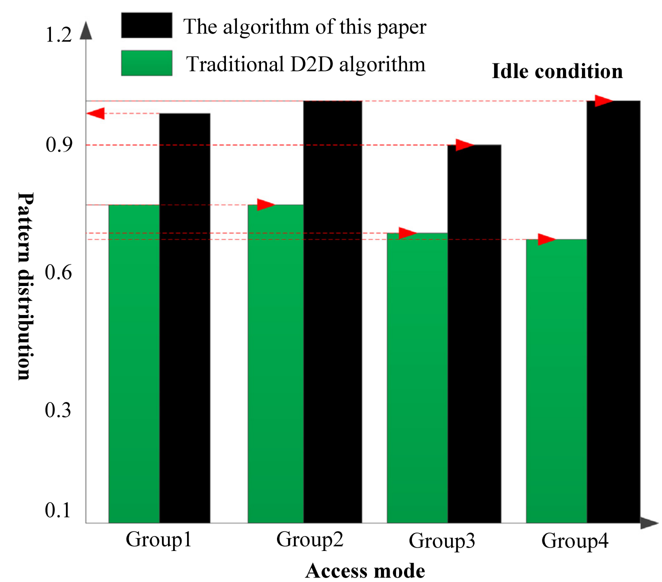

Fig. 6. Four corresponding experimental groups (user access analysis diagram) when the channel is idle.

the cell is full load. The corresponding experimental results are shown in Fig. 5. On the whole, when the channel resources of the whole communication system in the cell are idle, the corresponding idle channel parameter K 'is the largest. At the same time, it can be seen from Fig. 5 that the traditional D2D communication technology can save the corresponding user power, but the corresponding channel state detection is insufficient, and the corresponding channel consumption is still worse than the algorithm proposed in this paper. The corresponding Fig. 6 shows two different algorithms of four groups of corresponding experimental groups in the case of idle channel and the distribution of end-user access mode. As can be seen from the figure, in this case, nearly 60% of wues in the algorithm are connected to 5G communication network, while the corresponding traditional scheme only has 40% access at most. Experiments show that the algorithm used in this paper has obvious advantages.

In the whole 5G communication system, when the channel is in saturation state, the corresponding average power access distribution is shown in Fig. 7. It can be seen from the figure that the corresponding power consumption under the traditional D2D communication technology is very huge, and the corresponding channel state detection is lack, and the corresponding channel consumption is still worse than the algorithm proposed in this paper. The corresponding Fig. 8 is the experimental group corresponding to four groups in the case of relatively saturated channel. It can be seen from the figure that the traditional scheme cannot allocate the resource channel in this case, while the corresponding scheme proposed in this paper can still realize the access of some users and realize the channel allocation of the whole communication system.

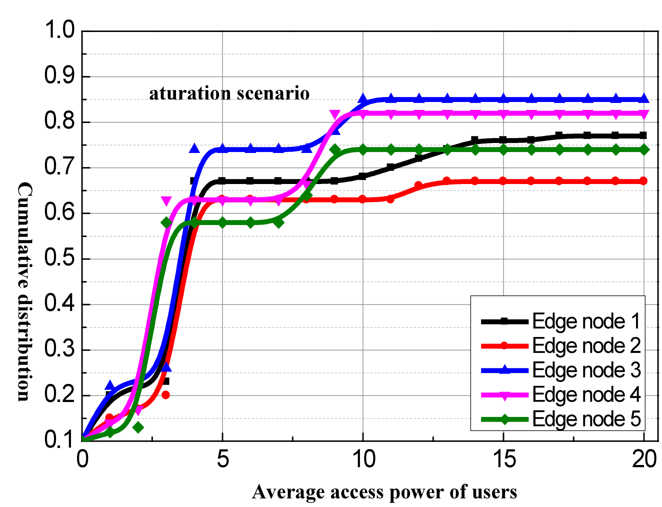

Fig. 7. Scene power dissipation curve corresponding to channel resource saturation in the whole communication system.

In order to verify the performance of intra cluster coordination of the whole 5G communication system based on the algorithm proposed in this paper, Figs. 9–11 show the change of the overall income of the

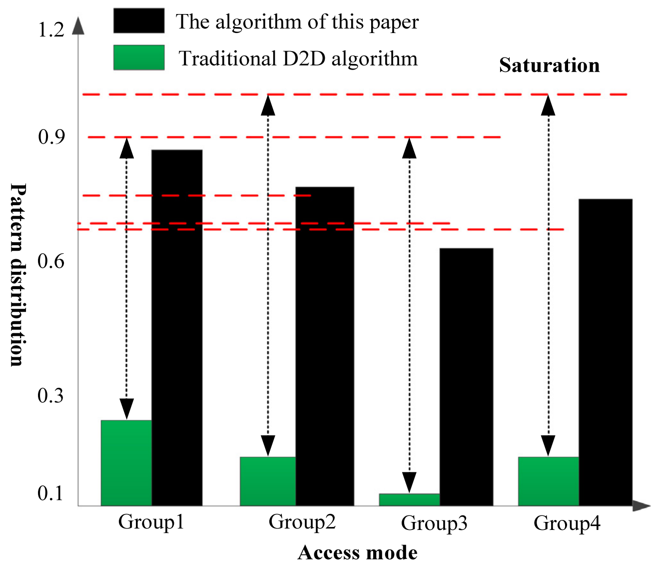

Fig. 8. Four corresponding experimental groups (user access analysis diagram) in case of relatively saturated channel.

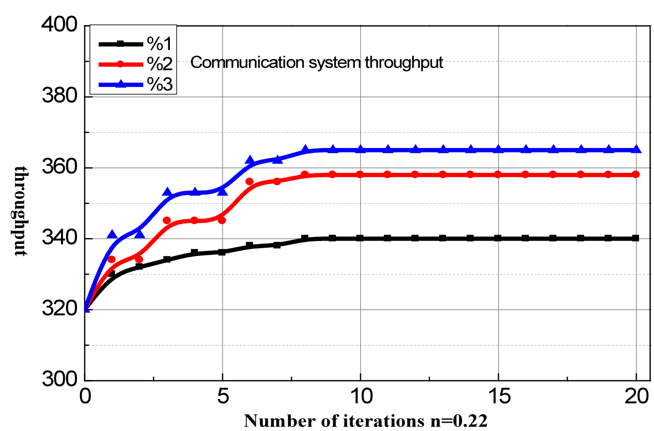

Fig. 9. Change curve of total revenue of corresponding communication system under different number of small cells (n=0.22).

corresponding communication system under different number of small cells. From the figure, it can be seen that the whole 5G communication system will accelerate the convergence speed with the increase of the small cell scale, and the corresponding clusters will execute in parallel, so the stability speed of the whole system will be very fast.

4. Conclusion

This paper mainly discusses the existing problems of 5G communication and the corresponding research status. At the same time, the principle of channel allocation and resource optimization in D2D communication technology is analyzed and studied. Finally, the following conclusions are drawn: in the first generation 5G network, D2D communication technology can establish communication link directly through communication equipment, so that both can establish good communication equipment, but there are some problems in D2D communication technology, which need to continue iterative calculation. The corresponding convergence and operation time of the algorithm are difficult. On this basis, based on game theory, a communication channel allocation scheme and resource optimization scheme are proposed to maximize the operation efficiency of D2D communication equipment. Finally, the optimization method proposed in this paper is compared

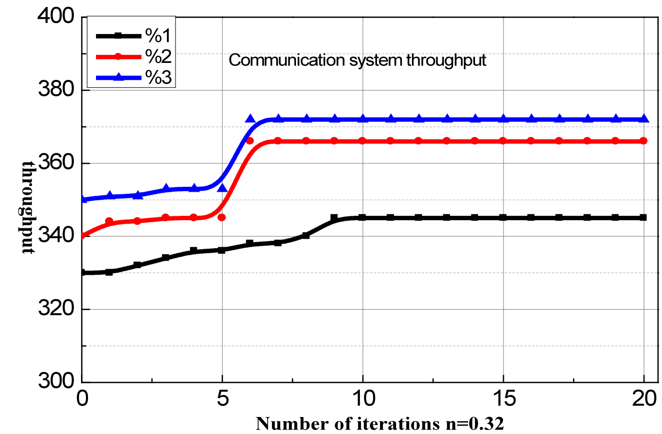

Fig. 10. Change curve of total revenue of corresponding communication system under different number of small cells (n=0.32).

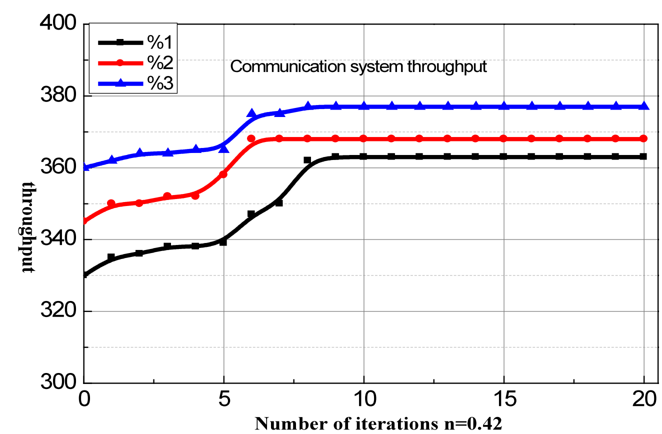

Fig. 11. Change curve of total revenue of corresponding communication system under different number of small cells (n=0.42).

with the traditional communication method. The experimental results show that this method has higher advantages. In the follow-up research, we will focus on the energy consumption of the corresponding algorithm. At the same time, we will carry out practical verification for large-scale applications, and continuously reduce the corresponding cost.

CRediT authorship contribution statement

Shasha Zhao: Data curation. **Yingying Feng:** Formal analysis. **Gan Yu:** Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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