

Resource Allocation Algorithm Based on Multi-objective Optimization in D2D Communication

Xueying Han and Yi Sun*

School of Software Engineering, 2. State Key Laboratory of Networking and Switching Technology Beijing University of Posts and Telecommunications, Beijing 100876, China

*Corresponding author

Abstract—At present, the algorithm for solving the problem of resource sharing in D2D communication and cellular communication in cellular networks is mostly optimized for a single target. This paper proposes a general resource allocation algorithm based on multi-objective optimization, which optimizes system throughput and total system energy efficiency while ensuring QoS (Quality of Service). In this paper, the non-inferior solution of D2D user transmit power is obtained by combining objective function and constraint with Particle Swarm Optimization. In addition, the algorithm allows different requirements to be set according to different business needs and sub-goal preferences to obtain different solutions. The simulation shows that the algorithm can optimize the system performance by optimizing the system throughput and total energy efficiency of the cellular network.

Keywords—D2D communication; resource allocation; multi-objective optimization; equilibrium

I. INTRODUCTION

In recent years, due to the widespread popularization of mobile intelligent terminals, D2D communication has begun to be applied to cellular networks, and various resource allocation schemes have been proposed to improve the spectrum efficiency of the system and reduce the load of the base station. However, the system model established by these resource allocation schemes is ideal. In addition, most of the resource allocation schemes are single-objective optimization schemes. In the system, each optimization target is mutually constrained. When considering the optimality of a sub-goal, it is bound to undermine the interests of other sub-goals.

In summary, this paper establishes a more complex system model that is closer to reality and proposes a resource allocation algorithm based on particle swarm optimization (A multi-objective optimization algorithm). On the basis of single-objective optimized resource allocation algorithm, the multi-objective optimized algorithm in this paper can optimize the overall performance of the system with the goal of balancing the optimization of system throughput and total energy efficiency under the premise of ensuring QoS.

II. SYSTEM MODEL

In this paper, a single-cell cellular network link is considered, including one base station B, N cellular users CU, the nth cellular user is recorded as C_n , and M D2D user pairs, the mth user pair is recorded as DD_m , which includes one receiving end D_m and

one sending end T_m . The base station uniformly allocates radio resources for cellular users to communicate. The total bandwidth of the system is divided into N sub-bands, which are occupied by N activated cellular users, so that there is no mutual interference between the CUs. In order to improve spectrum efficiency, the D2D user selects the multiplexing mode to share the same resources with the CU to communicate. For ease of analysis, it is assumed that CU resources are at most multiplexed by one D2D user. In addition, considering that the network state changes during different time periods, it is assumed that each channel keeps a constant independent block fading channel in each transmission time block, and the channel changes in the time block units.

III. DESCRIPTION OF THE PROBLEM

In the resource allocation schema of optimizing a single goal, the proposer establishes the objective function and constraints according to the actual needs. The optimization targets are mostly system throughput, system capacity, system energy efficiency, and interference between users. This paper considers two aspects: system throughput and total system energy efficiency. So the resource allocation scheme should consider the following objectives: 1) maximize system throughput; 2) maximize system total energy efficiency; 3) planning simultaneously for two goals, so that both parties can achieve the best possible at the same time; 4) to ensure the quality of communication of users.

IV. MULTI-OBJECTIVE OPTIMIZATION MODEL

The goal of resource allocation includes ensuring user service quality, maximizing system total energy efficiency, and maximizing system total throughput. The multiple objectives and constraints of resource allocation are as follows.

Taking the transmit power of the D2D user as an independent variable, the optimization function aiming at maximizing the throughput of the system [1] is

$$\max_{P_{d_i}} R = E \left\{ \sum_{(i,j)} \left(\text{lb} \left(1 + \xi_j^k \right) + \text{lb} \left(1 + \eta_i^k \right) \right) \right\}$$

$$i=1,2,3,k. \quad (1)$$

Subject to

$$\beta_i^k = \frac{P_{d_i} h_{si,B}^k}{N_0} \leq \beta_{\max}, \quad (2)$$

$$\eta_i^k \geq \eta \quad (3)$$

$$1 \leq i \leq M, \quad (4)$$

$$1 \leq j \leq N \quad (5)$$

Where K is the total number of transmission time blocks considered ; The SNR (signal to noise ratio) received by the base station in time block k is $\xi_j^k = \frac{P_{c_j} h_{c_j,B}^k}{P_{d_i} h_{si,B}^k + N_0}$; The SNR of D2D users

is $\eta_j^k = \frac{P_{d_i} h_{di}^k}{P_{c_j} h_{c_j,di}^k + N_0}$; Since the problem considered is more complicated, it is assumed that the transmit power of the D2D user and the transmit power of the cellular user do not change with time; P_{d_i} is the transmit power of the D2D user; $h_{sj,B}^k$ is the channel gain between the D2D user and the base station at time block k ; N_0 is NEP(Noise Equivalent Power); β_i^k is the D2D user pair Cellular user interference; η is the target SNR of the D2D user; P_{C_j} is the transmit power of the cellular user; $h_{c_j,B}^k$ is the channel gain between the cellular user and the base station at time block k ; $h_{d_i}^k$ is the channel gain of the D2D link at time block k ; $h_{c_j,di}^k$ is the channel gain at time block k between the cellular user and the D2D user; $E\{\cdot\}$ for the averaging operation.

The energy efficiency of a D2D user pair is defined as the ratio of the data bits transmitted per unit time to the energy consumption per unit time, ie the number of bits per joule. Taking the transmit power of the D2D user as an independent variable, the optimization function aiming at maximizing the total energy efficiency of D2D user [2] is

$$\max_{P_{d_i} \rho_{i,j}} EE = E \left\{ \sum_{(i,j)} \frac{\rho_{i,j} W \log \left(1 + \frac{P_{d_i} h_{d_i}^k}{P_{C_j} h_{c_j,di}^k + N_0} \right)}{P_{d_i} P_{CE}} \right\} \quad i=1,2,3,\dots,k \quad (6)$$

Subject to.

$$0 \leq P_{d_i} \leq P_{d_{\max}} \quad (7)$$

$$\sum_i \rho_{i,j} \leq 1, \rho_{i,j} \in \{0,1\} \quad (8)$$

Where P_{CE} is the circuit power of the D2D user pair; $\rho_{i,j}$ is the indication factor, $\rho_{i,j}=1$ when the D2D user multiplexes the channel of the cellular user j , otherwise $\rho_{i,j} = 0$; $P_{d_{\max}}$ is the maximum transmit power of the D2D user.

When the cellular network works, to ensure the communication quality of the cellular users and the real-time transmission of the cellular network users are not terminated by some extreme conditions, [3] respectively add the long-term statistical average SINR constraint and the minimum SINR constraint of the cellular link, as follows

$$E \left\{ \frac{P_{t_i} h_{di,B}^k}{1 + P_{d_i} h_{c_j,B}^k} \right\} \geq \text{SINR}_{\text{op}} \quad i=1,2,\dots,k, \quad (9)$$

$$\frac{P_{t_i} h_{di,B}^k}{1 + P_{d_i} h_{c_j,B}^k} \geq \text{SINR}_{\text{min}} \quad \forall i \quad (10)$$

Wherein, SINR_{op} is the average SINR threshold of the cellular user set in advance to ensure the communication quality of the cellular user; SINR_{min} is the minimum SINR threshold that the cellular user must guarantee within each transmission time block.

V. ALGORITHM IMPLEMENTATION

In Sending at a fixed power in traditional D2D communication, and resource selection is performed on this basis, which results in low resource utilization.

This article uses dynamic power control. In the initial state, both the cellular user and the D2D user transmit with random values. Considering all the pairing methods, compare the received interference power of the D2D user in each of the assigned N pairs, and select the N -to-D2D user receiving in all the allocations. The pairing mode with the smallest maximum value of interference power is the best pairing, and then the particle swarm optimization algorithm is used to search the non-inferior optimal solution set of D2D user transmit power.

Particle swarm optimization (PSO) has the advantages of easy implementation, high precision and fast convergence, and is more and more applied in practice. This paper uses the improved particle swarm optimization algorithm in literature [4] to obtain a non-inferior solution. Since the particle swarm optimization algorithm solves the optimal solution for the minimum value, take the formula (1)(6) negative respectively. Let the D2D user's transmit power be the variable x , construct two objective functions, denoted as "f" _ "1" ("x") and "f" _ "2" ("x").

The detailed process is as follows:

Step 1: Set the group size to the number of D2D users N , and randomly assign the transmit power of each D2D user.

Step 2: Calculate the fitness value of each particle using two objective functions, which are a negative system throughput expression and a system total energy efficiency expression.

Step 3: Use two objective functions to find the individual extremum and global extremum of the particle.

Step 4: Calculate the mean and distance of the two global vectors found in step 3.

Step 5: Calculate the distance of each particle from the position of the extremum based on the different objective function on the plane.

Step 6: Calculate the speed and position required for each particle's next iteration.

Step 7: If the position of the particle, that is, the transmit power of the D2D user does not satisfy the constraint that the communication quality needs to be guaranteed, stop the iteration.

Step 8: Update the position and speed of each particle.

Step 9: If the iteration satisfies the termination condition set according to the actual demand and the preference for the sub-object, stop the iteration; otherwise, return to step 2.

The flow chart is as figure 1.

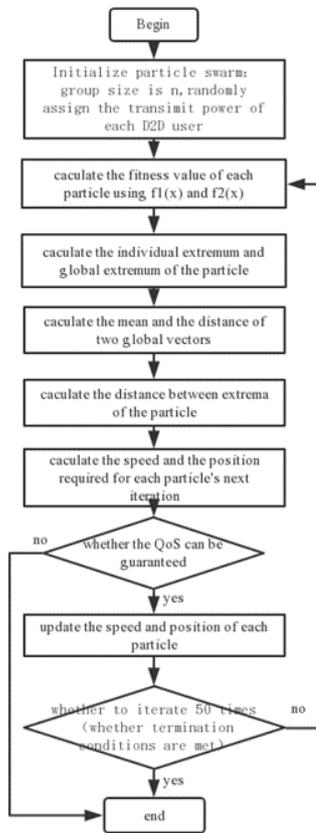


FIGURE 1. FLOW CHART

VI. SIMULATION IMPLEMENTATION

The pseudocode is implemented as:

Step 1 initialize x_i, v_i ;

for $i=1$ to N

fitness1[i]= $f_1[x_i]$;

fitness2[i]= $f_2[x_i]$;

Step 2 for $i=1$ to N

$pb[1,i]=f_1(x)$'s individual minimum;

$pb[2,i]=f_2(x)$'s individual minimum;

Step 3 $gb[1]=f_1(x)$'s global minimum;

$gb[2]=f_2(x)$'s global minimum;

Step 4 $gbest=Average(gb[1],gb[2])$;

Step 5 $dgbest=Distance(gb[1],gb[2])$;

Step 6 for $i=1$ to N

$dpb=Distance(pb[1,i],pb[2,i])$;

Step 7 for $i=1$ to N

if $dpb[i]<dgbest$

$pb[i]=RandSelect(pb[1,i],pb[2,i])$

else

$pb[i]=Average(pb[1,i],pb[2,i])$;

Step 8 if x_i and v_i isn't accord with constraint

go to end;

Step 9 update x_i, v_i ;

Step 10 if the number of iterations<50

go to Step 2

Where fitness is the fitness value; pb is the individual extremum; $gb[.]$ is the global extremum; gb is the mean; dgb is the distance between the two global vectors; $dpb[i]$ is the interaction between each particle pb under the two objective functions distance. The algorithm finally needs to satisfy the termination condition before jumping out of the iteration. This paper considers one of the most common cases in which the number of iterations is used as the termination condition. In addition, the decision-maker can set different termination conditions according to different business requirements and preferences of the sub-goals, thus getting different resource allocation schemes and improving the applicability of the network.

VII. CONCLUSION

This paper establishes a more realistic system model, based on the received interference power to achieve pairing, and introduces the particle swarm algorithm to obtain the optimal transmit power of D2D users. In a way, it optimizes overall performance by optimizing one target while considering the other objective, and solves the limitation of single optimization. In addition, the decision-makers can set different termination conditions according to different business needs and the preference of sub-targets, thus obtaining different resource allocation schemes and improving the applicability of the network.

The algorithm effectively improves the performance of the system, but it only takes two optimization targets into consideration at the same time. Next, we need to further consider the situation with more optimization goals. In addition, setting the termination condition requires some practical experience.

ACKNOWLEDGMENT

This research was financially supported by the 2018 Double-class notch talent competition Project.

REFERENCES

- [1] Wei-wei GAO, Hui-yue YI, Yan-jun HU, Hong-lin HU, Resource allocation algorithm based on SNR equalization(2012)
- [2] Yan-ping LIU, Xu-ming FANG, Research on resource reuse strategy in energy efficient D2D communication system(2016)
- [3] Chun-yan HAN, Power allocation scheme based on ensuring communication quality of cellular users in D2D communication(2015)

- [4] Li-Biao ZHANG, Chun-guang ZHOU, Ming MA, Xiao-hua LIU, Solving multi-objective optimization problems based on particle swarm optimization(2004)
- [5] Hao-xiang FANG, Wu ZHENG, Chen LIU, Design and implementation of terminal matching based on optimal energy efficiency(2017)
- [6] Doppler K, Yu Chia-Hao, Ribeiro C. Mode Selection for Device-to-Device Communication Underlying an LTE-Advanced(2010)