A D2D Resource Scheduling Algorithm Based on Position Relation in Cellular Network

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Abstract. With the development of 5G, device-to-device (D2D) and other technologies have emerged one after another, making the communication services faster and wider in coverage. Aiming at the problem of high computational complexity of traditional resource allocation algorithms, by studying the D2D communication network model and the spatial location relationship of users, ignoring parameters that have little impact on the calculation, a D2D resource scheduling algorithm based on location relationship is proposed and optimized system performance. Simulation results show that, compared with traditional algorithms, the proposed resource scheduling algorithm has greatly reduced algorithm complexity, and has good data transfer rate and high system capacity.

Keywords: D2D · Resource scheduling · Location relationship

1 Introduction

Terminal pass-through D2D technology refers to data transmission between two terminals with relatively close geographical locations using a direct link without forwarding through the base station [1]. This method can offload traffic from the core network, and has extremely high flexibility, which can greatly improve system capacity and spectrum efficiency, and reduce energy consumption. It is listed as one of the key technologies in the 5G mobile communication system [2].

D2D technology in cellular mobile networks can improve spectrum utilization and system throughput. The contradiction between numerous user equipment and limited spectrum resources cannot be ignored, and it is easy to cause co-channel interference (CCI). Common solutions include precoding algorithms and resource management algorithms. The precoding algorithm calculates the appropriate coding method by estimating the channel information, thereby facilitating the smooth recovery of the signal at the receiver [3]. Resource management algorithms are often combined with other technologies [4], to study frequency selection and power control issues of D2D [5].

The rest of this paper is organized as follows. Section 2 will analyze the research model of this paper. Section 3 will analyze the theory of the proposed algorithm in detail from the perspective of positional relationship and give the framework of the proposed method. Section 4 will provide the implementation and performance analysis. The conclusion will be drawn in Sect. 5.

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2 System Model

The D2D channel in the cellular network is different from the channel of the cellular users, because the antennas of the transmitter and receiver of the D2D user are very low (compared to the base station) and will interact with a large number of scatterers. Therefore, in most literatures, the channel model is set to large-scale path loss and Rayleigh fading channels. Considering the above model, the power received by the base station (BS) from the Cellular transmitter (CT) is $P_{BS} = P_{CT}|h|^2 d^{-\alpha}$. Where h represents the channel fading coefficient, obeys CN(0,1) distribution, α represents the path loss index, and d represents the distance between CT and BS. Similarly, the power of any transmitter in the network can be expressed similarly.

In the downlink, the base station's transmit power is much greater than the mobile user's transmit power, which means that the DR will be subject to stronger CCI. In the uplink, the base station acts as the receiver and does not interfere with other users. So, this paper studies the issue of multiplexing resources for D2D users in the uplink.

Consider the situation shown in Fig. 1.

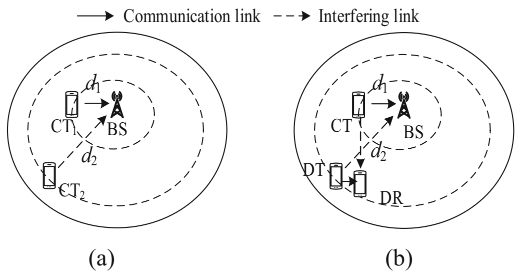

Fig. 1. Two users' CCI under a single antenna

When the same antenna of two cellular users CT_1 and CT_2 is received at the same BS, their signal-to-interference and noise ratios $SINR_1$ and $SINR_2$ are respectively:

$$SINR_1 \cdot SINR_2 = \frac{P_1 d_1^{-\alpha}|h_1|^2}{P_2 d_2^{-\alpha}|h_2|^2 + \sigma^2} \cdot \frac{P_2 d_2^{-\alpha}|h_2|^2}{P_1 d_1^{-\alpha}|h_1|^2 + \sigma^2} < 1 \quad (1)$$

Where P_1 and P_2 are the transmission power of CT_1 and CT_2 respectively, d_1 and d_2 are the distances from CT_1 and CT_2 to the BS, h_1 and h_2 are the channel attenuation coefficients of CT_1 and CT_2 to the BS, and α represents the path loss index.

Assuming that the minimum SINR for the user to guarantee the communication quality QoS is γ_0. Usually, $\gamma_0(\text{dB}) > 0$, so it is impossible to guarantee the communication quality of two CTs at the same time. Therefore, there can only be one CT user on the same frequency under a single antenna. Assuming $P_1 = P_2$, $h_1 = h_2 = 1$, then for CT, the $SINR_1 \geq \gamma_0$ is derived to $d_1 < \gamma_0^{\frac{-1}{\alpha}} d_2 < d_2$. It can be seen that the distance from the DT to the BS needs to be greater than the distance from the CT to the BS.

3 The Proposed Method

3.1 Analysis of Positional Relationship

There are two quantities that have little effect on the algorithm. One is the transmission power. Since most users in the cellular network are smartphones, there is an approximate relationship of $P_1 = P_2$. Other is the channel attenuation coefficient, because h follows the distribution CN(0,1), then the magnitude of $|h|^2$ is around 10°, having little effect on $P \cdot d^{-\alpha}$, so it is approximately regarded as the case of no attenuation $h_1 = h_2 = 1$.

Analyze the situation of DR being disturbed. Assuming that the minimum distance between the transmitting user in the same frequency band and the DR is d_{min}, and the distance d between the same pair of DT and DR is much smaller than d_{min}, neglecting small amounts, then the transmitting user in the same frequency band and DR are equivalent, and the case of maximum interference will be As shown in Fig. 2.

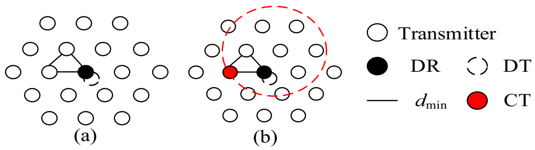

Fig. 2. Position relationship in the same frequency band

The positional relationship of the equilateral triangle is extended outward, and the distance between each pair is d_{min}. If the layer is extended outward, the radius of the occupied area increases by d_{min}. Then the SINR of DR is:

$$SINR = \frac{P_0|h_0|^2 d^{-\alpha}}{\sum P_i|h_i|^2 d_i^{-\alpha} + \sigma^2} \tag{2}$$

Where b is the distance factor, $b = \sum d_i^{-\alpha}/d_{min}^{-\alpha}$, which is determined by the location of the transmitting user in the same frequency band. Assuming $P_1 = P_2$, $h_1 = h_2 = 1$, then the constraint condition can be obtained from (2):

$$d_{min} = \left(\frac{\gamma_0 b P_0}{P_0 d^{-\alpha} - \gamma_0 \sigma^2}\right)^{\frac{1}{\alpha}} \tag{3}$$

To further discuss the situation in Fig. 2(b), suppose that there are n DTs equidistantly arranged on a circle with a radius of R_2 at a distance of d_{min}, in order to simulate the CCI situation of CT and estimate R_1 and R_2 relationship.

$$b = n = \left\lceil \frac{2\pi R_2}{d_{min}} \right\rceil \tag{4}$$

$$R_1 < \left(b\gamma_0 R_2^{-\alpha} + \frac{\gamma_0\sigma^2}{P}\right)^{\frac{-1}{\alpha}} \tag{5}$$

3.2 Resource Scheduling Algorithm

Through the study of the positional relationship, it is found that when the user interval of the same frequency band is large and the number is small, the CCI is small. So consider the quantity (variance) that can measure the degree of dispersion of points as a system indicator.

Let $\omega_{m,k}$ indicate whether the m^{th} mobile user uses the k^{th} frequency band. Assuming the user's position is represented by (x, y). Also, a D2D user pair occupies only one frequency band, $\sum_{l=1}^{K} \omega_{m,l} = 1$. The average position of all mobile users in the k^{th} band is expressed as $(\overline{x_i}, \overline{y_i})$. The objective function is the maximum sum of variance of all points in the K frequency bands, that is:

$$\max \quad \sum_{l=1}^{K} \frac{\sum_{j=1}^{M} \left(\omega_{j,k}x_j - \overline{x_k}\right)^2 + \sum_{j=1}^{M} \left(\omega_{j,k}y_j - \overline{y_k}\right)^2}{\sum_{j=1}^{M} \omega_{j,k}} \tag{6}$$

Based on the above theoretical basis, a resource scheduling algorithm based on position relationship is proposed. The specific process is as follows.

Step 1: If CT, go to **Step 2**; otherwise, go to **Step 6**.
Step 2: If there is an unused frequency band, access & end; otherwise, go to **Step 3**.
Step 3: If CT exists in any frequency band, go to **Step 7**; otherwise, go to **Step 4**.
Step 4: Iterate through the frequency bands used only by DT, select the frequency band with the least DTs that cannot work after access. If there are no DTs that cannot work, end; otherwise, use these DTs as the object of new access, go to **Step 5**.
Step 5: If there is an unused frequency band, access & end; otherwise go to **Step 6**.
Step 6: Try to access each frequency band, on the premise of not affecting the communication of the original user, select the frequency band with the largest sum of variance to access, end; otherwise, go to **Step 7**.
Step 7: Unable to connect to the network, end.

4 Simulation and Analysis

With the base station as the center and the coverage area of radius R, the distribution of cellular users and D2D users are subject to the uniform Poisson Point Process (PPP). Other simulation parameters of cellular networks are shown in Table 1.

Table 1. Simulation parameter settings

Parameter	Value
Cell radius	500 m
Transmit power	0.1 W
D2D maximum spacing	50 m
Number of frequency bands	40
Path loss index α	4
SINR threshold	16 dB
AGWN power spectrum	−174 dBm/Hz

Based on the model in Fig. 2, the cell theoretically needs to accommodate at least two densely arranged transmitting users in the same frequency band.

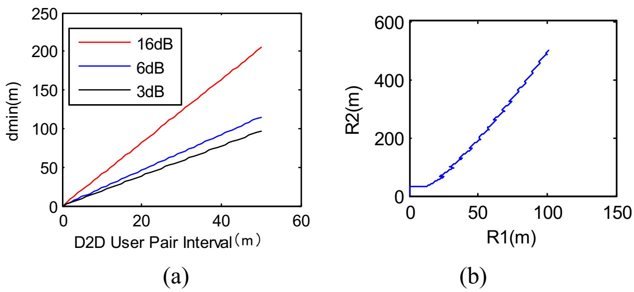

Fig. 3. Mathematical relationship of parameters

Changing the spacing d of D2D user pairs, the minimum interval $d_{\min}$ changes as shown in Fig. 3(a). When $d = 50$ m and $\gamma_0 = 16\,\text{dB}$, $d_{\min}$ is about 204 m, and the cell radius is between $2d_{\min}$–$3d_{\min}$. That is, the two-layer dense arrangement is suitable as the analysis condition. The curve in Fig. 3(b) is the critical value of R_1 and R_2. The feasible region is the area above the curve while satisfying $R_1 > 0, R_2 < 500$.The vertices are (0, 32), (101.1, 500), (0, 500) (unit m). It means that the DT is at least 32 m away from the BS. When the distance between the CT and the BS is greater than 101.1 m, the cell will not be able to accommodate D2D communication in the same frequency band.

Then simulate and analyze the resource scheduling algorithm based on the maximum sum of variance (Algorithm 1). The algorithms used for comparison are the resource scheduling algorithm based on the maximum data transfer rate (Algorithm 2). The results of the simulation are shown in Fig. 4.

It can be seen when the frequency resources are sufficient, Algorithm 1 and Algorithm 2 have little difference in the total data transfer rate and system capacity. When the total number of users increases, Algorithm 2 has a higher data transmission rate, but Algorithm 1 has a larger system capacity. In this simulation, the system capacity of Algorithm 1 is 65, and the system capacity of Algorithm 2 is 55.

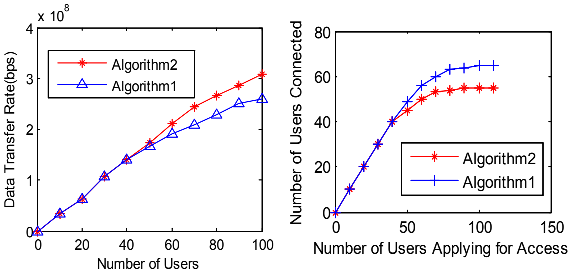

Fig. 4. Algorithm performance comparison

5 Conclusion

In order to reduce the computational complexity of traditional algorithms and make full use of the location relationship of users in cellular networks, this paper proposes a D2D resource scheduling algorithm based on location relationship. The algorithm uses the sum of variance as the performance index, pursues the dispersion in the user space to reduce CCI, and determines the constraints by the positional relationship between the D2D user and the cellular user to ensure the user's communication quality. Experimental results show that the algorithm proposed in this paper maintains a good data transfer rate, and has lower computational complexity and higher system capacity. The next step of research can be in-depth in the direction of improving system throughput.

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