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Power Control Performance Evaluation for Efficiency in D2D Cellular Network

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Abstract

Over the past decade, the demand for mobile broadband traffic and fast data transmission has been increasing rapidly, and D2D communication is attracting attention for solving this problem. D2D communication reduce the amount of traffic that the base station should directly process and improve the performance of the network. In this paper, we will analyze whether there is a need to control the power allocation in the resource allocation algorithm when the power is controlled to satisfy the minimum SINR value in uplink cellular network environment. The resource allocation algorithm selects available resources among all the cellular network resources using the location information, and then selects the resource with the maximum throughput. In order to maximize D2D performance, we compare the simulation results with the case where the power control is performed and the case where the power control is not performed.

Keywords: Uplink, D2D, Location Information, Resource Allocation, Cellular Networks, Power Control

INTRODUCTION

Over the past decade, the amount of mobile broadband traffic has increased and users are increasingly demanding fast data transmission. Recently, as smart UEs equipped with various application services are rapidly spreading, the data traffic in the mobile communication network is also rapidly increasing. In addition, as the interest in the Internet-of-things (IoT) field is rapidly increasing, it is expected that the traffic transmitted to the base station will increase sharply when the wireless communication technology between objects is continuously developed and expanded. In order to prevent the rapid increase of traffic, it is necessary to use a technology that can efficiently use limited frequency resources. D2D communication has been attracting attention as a solution to use efficiently with limited frequency resources [1] [2].

D2D communication can reduce the traffic load of the base station and reduce power consumption of the UE, but there is a disadvantage that D2D communication link can interfere with other D2D link or existing Cellular UE [3]. This interference exists in three kinds of interference in the uplink. There is interference between the Cellular UE and the D2D link, the interference caused by the D2D link to the eNB, and the interference between the D2D link using the same resources. Therefore, it is necessary to efficiently use the resources when sharing and use the cellular frequency resources. Further, if the power is controlled to reduce the interference to the surroundings, more efficiency can be obtained.

In D2D communication, there are many cases where efficiency is lowered due to interference. Therefore, methods of allocating resources and controlling power have been continuously studied in order to prevent efficiency degradation. A technique has been proposed to guarantee performance by simultaneously performing SINR and power control to reduce interference to the surroundings. If the minimum SINR is not satisfied through the SINR calculation, the resource can’t be allocated or the SINR is considered in the multicast environment and the power value is derived accordingly [4][5]. There are also papers on power control by analyzing SNR with resource allocation based on area based method [6]. It is based on the information that it is possible to obtain a higher efficiency when power control is performed when allocating resources, and a method using the location information and the SINR information is used to search for resources, allocate optimized resources, we want to make sure that the search has higher efficiency.

In this paper, the D2D link in the Cellular network allocates the cell resources after calculating the maximum data rate using SINR and location information. In this case, the number of resources and CUEs in the Cellular network are the same, and it is assumed that the eNB knows the location information of all the terminals through GPS. There are two processes to allocate resources. First, the location information is used to create a resource group to be used by the D2D link. Second, after selecting the resource with the maximum transfer rate among the selected resource groups, the resource is selected. At this time, it is assumed that if the selected resource does not satisfy a specific SINR value, transmission is not performed. The power is controlled to satisfy a specific SINR value. We will see the advantage that the resource allocation algorithm used by performing power control can have higher efficiency.

MATERIALS AND METHODS

System Model

Cellular UE and D2D link consider single cell scenario environment sharing the resources of Cellular network in uplink. The number of Cellular resources is equal to the number of Cellular UEs, and the resources used by one D2D link use only one Cellular resource. The Celluar UE and the D2D link using the same resource perform the algorithm to maximize the data rate. The number of resources existing in the Celluar network is N. Since the number of Cellular UEs is the same as the number of Cellular UEs, the number of Cellular UEs is N, but the number of Cellular UEs is C for classification and N is C. The number of D2D links is D. In order to distinguish each UE from the eNB, the Cellular terminal uses C = {1, ..., c}, and D2D link is D = {1, ..., d}.

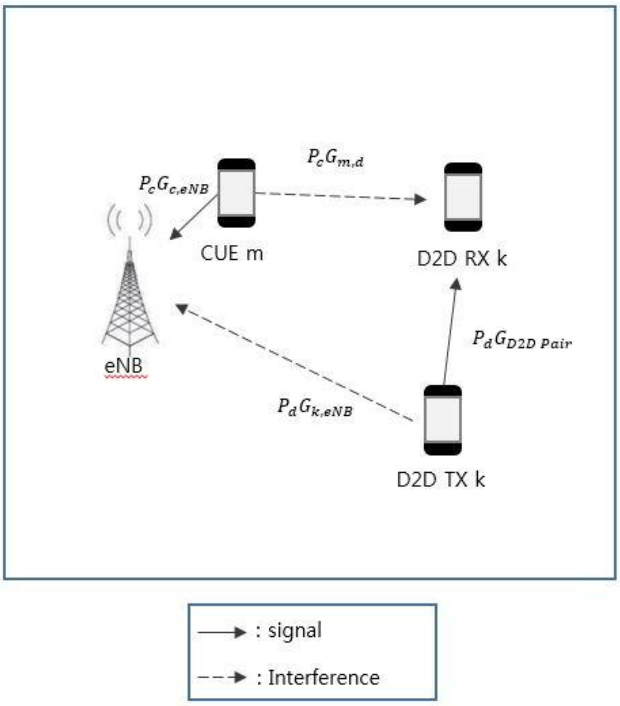

Figure 1. Resource allocation scenarios in cellular network(uplink)

It uses the symbol of $y_{c,d}$ to indicate the interference. In the case of $y_{m,k}$=1, it means that D2D link k share the resource of the CUE m. And in the case of $y_{m,k}$=0, it means that they do not share the resource.

SINR of CUE is thus defined as

$$SINR_{Cellular} = \frac{P_{Cellular} G_{m,eNB}}{P_{noise} + \sum_{i-1}^{d} y_{m,k} P_{D2D} G_{k,eNB}} \quad (1)$$

where $P_{Cellular}$ is the transmission power of the CUE, $G_{m,eNB}$ is the channel gain between CUE m and eNB and P_{noise} is noise power. SINR of D2D link is thus defined as

$$SINR_{D2D} = \frac{P_{D2D} G_{D2D\ Pair}}{P_{noise} + \sum_{m=1}^{c} y_{m,k} P_{Cellular} G_{m,k}} \quad (2)$$

where P_{D2D} is the transmission power of the D2D link.. $G_{D2D\ Pair}$ is the channel gain between D2D link d TX and D2D link d RX and $G_{m,k}$ is the channel gain between CUE m and D2D link k.

In this case, the SINR of the D2D link and the SINR of the Cellular UE need to satisfy a certain SINR value.

The SINR of the cellular UE and the SINR of the D2D link can be expressed as follows.

$$\mathrm{SINR}_{\mathrm{Cellular}} = \frac{P_{\mathrm{Cellular}} G_{m,eNB}}{P_{noise} + \sum_{i-1}^{d} y_{m,k} P_{D2D} G_{k,eNB}} \quad (3)$$

$$\mathrm{SINR}_{\mathrm{D2D}} = \frac{P_{D2D} G_{D2D\ Pair}}{P_{noise} + \sum_{m=1}^{c} y_{m,k} P_{Cellular} G_{m,k}} \quad (4)$$

If the SINR information of each UE is known, the D2D link and the cellular UE need to satisfy a certain SINR value. A SINR value to be satisfied by the cellular UE is denoted by r_{cellular}, and a SINR value to be satisfied by the D2D link is denoted by r_{D2D}. The equation for satisfying the SINR value is as follows.

$$r_{\mathrm{cellular}} < \mathrm{SINR}_{\mathrm{Cellular}} \quad (5)$$

$$r_{\mathrm{D2D}} < \mathrm{SINR}_{\mathrm{D2D}} \quad (6)$$

It is assumed that the transmission is successful only when the SINR value is satisfied.

Finally, we need to find the transmission rate to find the value that maximizes the overall rate.

$$R_{\mathrm{Cellular}} = \log_2(1 + \mathrm{SINR}_{\mathrm{Cellular}}) \quad (7)$$

$$R_{\mathrm{D2D}} = \log_2(1 + \mathrm{SINR}_{\mathrm{D2D}}) \quad (8)$$

It finds and shares resources that maximize the sum of the transmission rates of the cellular UE and the D2D link.

Resource Allocation scheme

Location based resource allocation [7], which uses only the location information through GPS, determine resources to be shared with D2D link out of total available resources. The used algorithm is designed to avoid interference by using location information and SINR information [8][9].

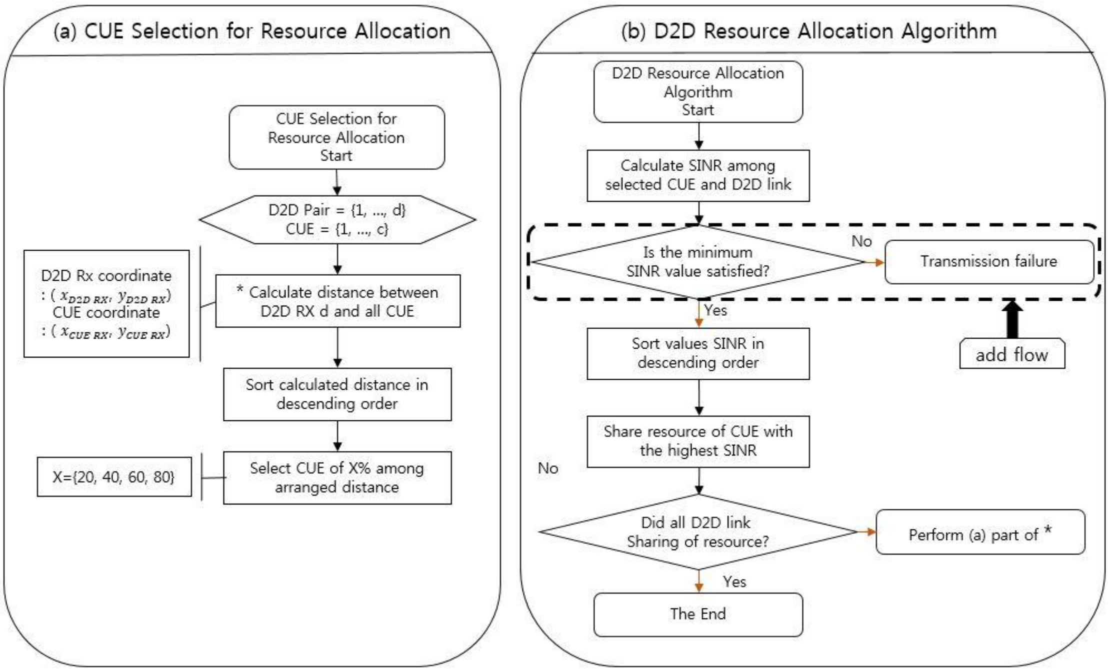

Figure 2. Flow chart of the resource allocation scheme

The resource allocation algorithm is divided into a CUE selection algorithm for resource allocation and a D2D resource allocation algorithm.

CUE selection algorithm for resource allocation

When eNB knows the positions of all UEs, all the distances between CUE and D2D link can be calculated from these informations. When we know the locations of each UEs and eNB, the distance between CUE and one of D2D link, $R_{D2D\ RX,CUE}$, can be determined by

$$R_{D2D\ RX,CUE} = \sqrt{(x_{D2D\ RX} - x_{CUE})^2 + (y_{D2D\ RX} - y_{CUE})^2} \tag{9}$$

where the coordinate of CUE and D2D are referred to as (x_{CUE}, y_{CUE}) $(x_{D2D\ RX}, y_{D2D\ RX})$, respectively. From (9), eNB calculates the values of distance between one D2D link and all the CUEs. Then, eNB sorts the calculated distances between CUE and D2D link in descending order. We select some part of resources from the sorted CUE list since they means the shorter distance between D2D link and CUE uplink and it also indicate that the less interference between them even if they share the resources in the cell.

D2D resource allocation algorithm

After performing the process in Section 2.2.1, each D2D link can obtain the available lists of CUE resource to be shared. SINR for D2D link is required to consider the interference from CUE as well as the interference from other D2D links which use the same resource with them. The $SINR_{D2D}$ can be determined by

$$SINR_{D2D} = \frac{P_{D2D} G_{D2D\ Pair}}{P_{noise} + \sum_{m=1}^{c} y_{m,k} (P_{Cellular} G_{m,k} + \sum_{i=1}^{d} y_{m,i} P_{D2D} G_{k,i})} \tag{10}$$

where $G_{k,i}$ is channel gain between D2D link to calculate SINR and other D2D to use same resource. After calculating SINR of CUE and D2D link from (1) and (10), the maximum throughput rate of CUE and D2D link can be determined by using the equation (7), (8). The maximum throughput is finally shown as

$$Max(\sum_{k=1}^{d} R_k^{D2D} + \sum_{m=1}^{c} R_m^{Cellular}) \tag{11}$$

After calculating the maximum throughput rate, D2D link shares the CUE resource as the throughput rate reached the maximum value in (11).

Power Control

The power control scheme aims to increase or decrease the power when the minimum SINR value is not satisfied.Only the D2D link controls the power and the power of the Cellular UE is fixed at 23dBm. The method of controlling the power is shown in Fig. 3.

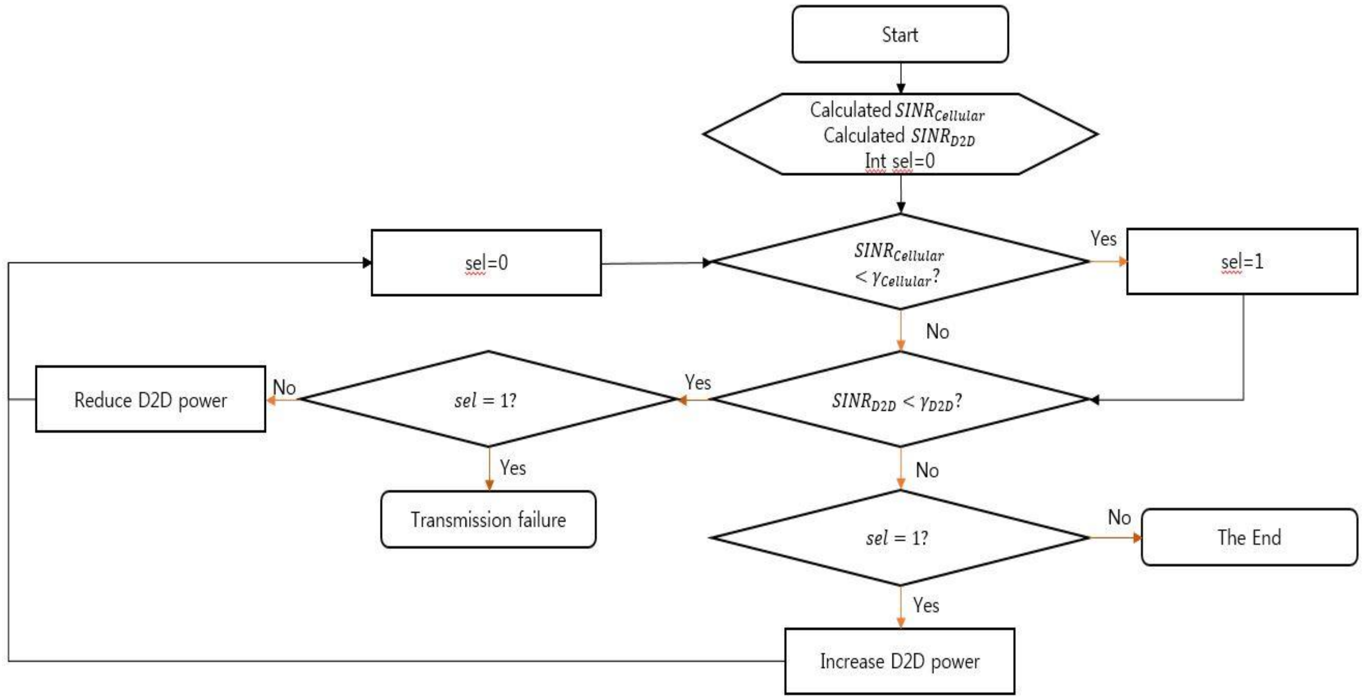

Figure 2. Flow chart of Power Control

In Fig. 3, Int sel is a measure of whether the Cellular UE and the D2D link satisfy minimum SINR or not. The power control is simply configured, and transmission failure is set in the situation that the SINR of the D2D and the SINR of the cellular UE are not all satisfied. In addition, when the SINR of the D2D link or the SINR of the Cellular UE is not satisfied, the D2D power is increased or decreased until the two SINRs are satisfied.

PERFORMANCE EVALUATION

In this section, we evaluate the performance of a resource allocation algorithm that includes power control through simulations in a single cell.

Table 1. Simulation Environment

Parameter	Value
Cell radius	500m
Maximum distance between D2D links in a pair	50m
Minimum SINR of D2D link (Max.)	40dB
Minimum SINR of D2D link (Min.)	0dB
Minimum SINR of Cellular UE	0dB
Maximum Transmission Power of D2D users	13dBm
Transmission Power of Cellular users	23dBm
P_{noise}	-114dBm
Number of Cellular UE	10
Number of D2D link	7
pathloss	128,1+37,6*log(d/1000)

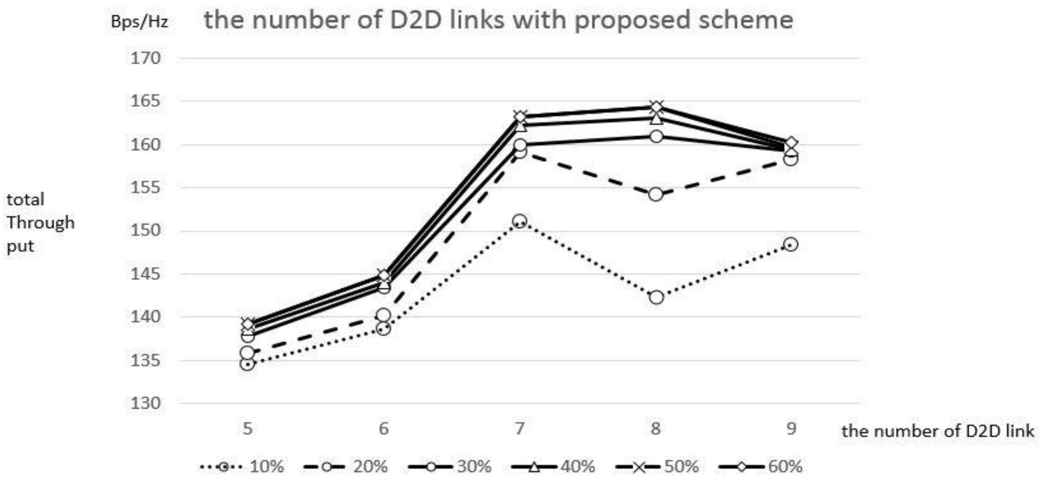

Figure 4. Comparison of total throughput according to the number of D2D links

The simulation environment is shown in Table 1 and the simulation is designed using C ++. First, a simulation of an algorithm that does not include power control is tested to compare an algorithm that includes power control and an algorithm that does not include power control. The algorithm that does not include power control assumes that the D2D link and the Cellular UE use the maximum power of each UE, and the target SINR value to satisfy the QoS is set to 0dB for both the D2D link and the cellular UE. In addition, the number of D2D links was changed from 5 to 9, and the change of the overall data rate was confirmed.

Fig. 4 shows that the D2D link preferentially selects X% of the cellular resources to allocate the resources. The ratio of the resource selection is 10% to 60% at 10% interval. Fig. 4 shows that the throughput increases as the number of selected resources increases. When the total throughput is changed according to the change of D2D links, 10% and 20% decrease rapidly when there are 8 D2D links. In case of 9 D2D links, performance is worse than that of 7 UEs. The reason why performance is lowered when 8 and 9 D2D link is that the increased D2D link increases the interference to the Cellular UE. The interference is larger than when the size of the interference is 7, which causes a large decrease in the data rate of the cellular UE. As a result, the total throughput is lowered. Therefore, there are seven D2D links where the interference is small and the throughput is high. In Table 1, we simulated the algorithm that includes power control based on the presence of seven D2D links.

The following procedure confirmed the simulation of the algorithm including power control. The simulation environment at this time is shown in Table 1.

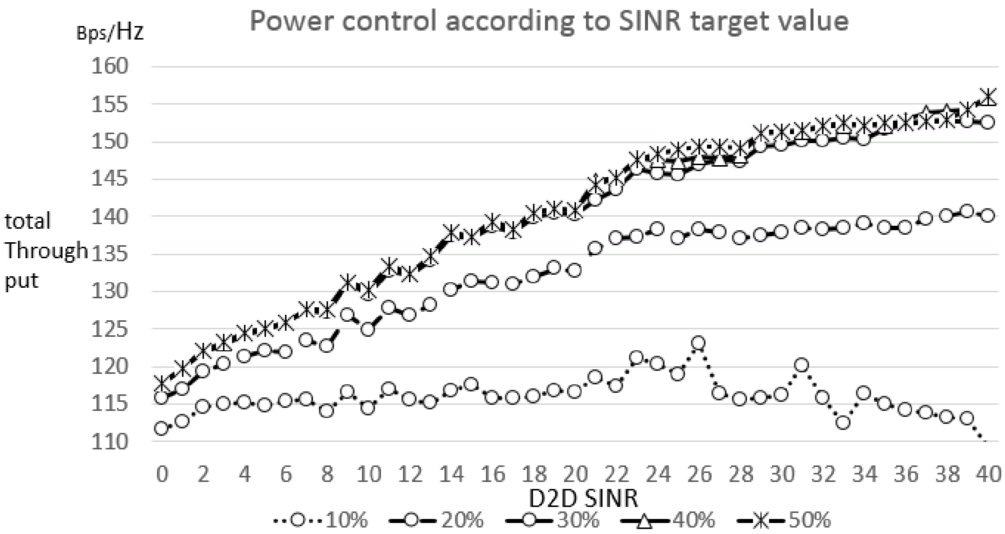

Figure 5. Power control according to SINR target value (total throughput)

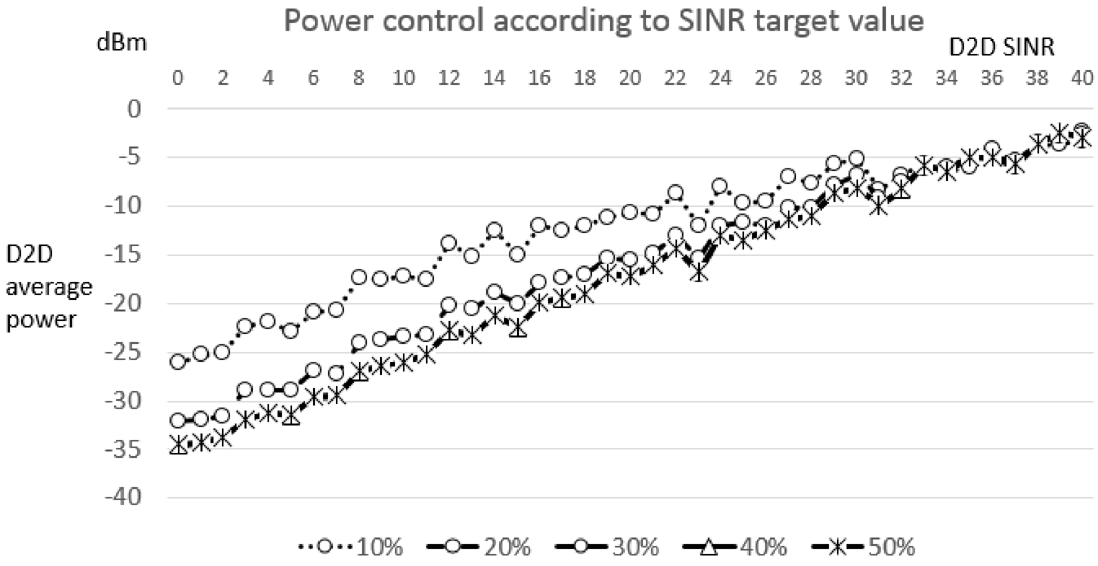

Figure 5. Power control according to SINR target value (D2D Avg. Power)

Fig. 5 shows that as the minimum D2D SINR increases, the total throughput also increases. As the minimum SINR increases, the power value increases and the SINR value of the D2D link increases on the average, and the total throughput increases. Also, the gap between 30% and 50% of throughput is drastically reduced because interference is reduced by power control, and throughput is transmitted stably.

By comparing Fig. 4 and Fig. 5 through Fig. 6, the necessity of power control can be confirmed. Based on the resource selection of 30 ~ 50%, it can be seen that it increases from -35dBm to -17dBm in Fig. 6. At this time, in Fig. 5, it is seen that it increases from 117 to 8 bps/Hz to 160 bps/Hz. In Fig. 4, the total throughput is 165bps/Hz, assuming that there are 7 D2D links. At this time, The D2D power is 13dBm. The total throughput is about 20bps / Hz, but the power efficiency shows a difference of about 20dBm. It can be seen that it is more important to obtain high efficiency by keeping the power appropriately rather than increasing the total throughput by using a lot of power.

CONCLUSION

In this paper, we have added a power control function to satisfy the minimum SINR value in a resource allocation algorithm that combines existing SINR and location information in a single cell network environment. It has been found that it is more important to maintain the power appropriately and improve the efficiency rather than to increase the total throughput by using the power control function by performing the power control function. It is necessary to test the measures to maintain efficiency by adding concrete power control methods in the future. In addition, it is necessary to confirm not only a single cell network but also an operation process in a multi-cell network and a UDN environment.

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