Spectrum Allocation with Power Control in LBS based D2D Cellular Mobile Networks

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Abstract² Over the past decade, the demand for mobile internet traffic has been rapidly increasing as the huge increase of the smart phone and mobile devices. D2D (Device to Device) is known that it reduce the traffic load of the base station and also improves the reliability of the network performance. However, D2D communication may share the same spectrum, which means that it shares the resource with cellular networks. Although D2D reduce the load on the base station through direct communication, it also results in the increase of interference due to the sharing of the cellular spectrum. It may occur the decrease of the network throughput as the mutual interference is increased. In this paper, we propose a spectrum allocation scheme to use the resources efficiently when the D2D link share the resources of the cellular network in the uplink. D2D communication utilizes the location information for allocating resources when the eNB know the location of all devices. The proposed scheme not only ensures the performance of the D2D communication but also decrease the computational complexity We applied the power control in order to attain the maximum throughput in the D2D underlay network. We also analyze several schemes to control the power of Cellular UE and D2D user in order to satisfy the minimum SINR value in uplink cellular network environment. Simulation results show that the proposed scheme provides the maximum throughput with the 30 % of computational complexity. In order to maximize total throughput, we compare the simulation results in case of controlling only the cellular UE or D2D user and both simultaneously. It is observed that power control is effective to achieve comparable throughput with a reduced complexity for spectrum allocation.

Index Terms² D2D, spectrum allocation, power control, LBS, cellular networks

I. INTRODUCTION

D2D communication is one of the short-range communication technologies available today. As the number of devices is increasing, communication between devices has become increasingly important in indoor and outdoor locations. As such, the need for D2D communication technology has increased in order to efficiently allocate frequency resources to the growing number of devices. Device-to-device communication (D2D) has been announced as a key technology in LTE-Advance networks [1]. The advantages of D2D communication over traditional cellular transmission include not only the proximity gain in terms of improved link budget, but also the so-called reuse and hop gains [2].

D2D communication is a service for the direct communication between devices without passing through the eNB. It is possible to reduce the data traffic and to use limited frequency resource efficiently because D2D communication shares resources of cellular network.

The transmission efficiency of the communication network can be further improved by combining these similar contents shared among groups of UEs with the same social interests

D2D communication technology in cellular networks was proceeded for standardization as entitled ProSe (Proximity Services) in 3GPP (3rd Generation Partnership Project) Release 12 since 2011. 3GPP Release 13 is currently proceeding for standardization called eProSe (Enhancements to ProSe) that contain relay technology of D2D device [3], [4]. Many researches on D2D communication has been focused on allocating resources in order to prevent the degradation of efficiency that occurs due to the interference. There is a fixed dividing scheme for the available resource for cellular communication and for D2D communication. But, if there are relatively fewer D2D Pairs, it has the possibility to waste resources for full utilization [5]. Besides, there are also schemes that ensure performance by reducing the interference on the surrounding through power control [6], [7]. However, those schemes require the higher computational complexity and also consider the more parameter values to be implemented.

In this paper, we investigate the spectrum allocation scheme when the D2D link share the resources of the cellular network in the uplink. It is assumed that the base station knows the location information of all devices through GPS. The proposed scheme utilizes the location information in order to allocate the resources for D2D communication.

It is very desirable to use the location information to reduce the computational complexity for resource allocation.

Spectrum allocation is done in two steps. First, the location information is used to create a resource group, to be used by the D2D link as the available resources among the cellular resources. Second, the D2D link selects and

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allocates resources using the SINR so that the maximum data rate is selected among the selected resource groups. Power control is performed with a simple algorithm, which results in either a power up or a power down, in order to satisfy the minimum SINR target value.

The proposed scheme attains the comparable throughput with much reduced computational complexity when the location information is utilized. The addition of power control can attain stable and maximum throughput with a reduced complexity for spectrum allocation

In section 2, the system model is described. In section 3, we propose the spectrum allocation with LBS and power control to increase the throughput for D2D based cellular network. In section 4, simulation results are provided to evaluate the performance of spectrum allocation and power control for CUE and D2D link. Finally, conclusion are made in Section 5.

II. System Model

Fig. 1 shows that Cellular UE and D2D link consider single cell scenario environment sharing the resources of Cellular network in uplink. We assume that there are *N* resources in the cellular network. The number of cellular resources is equal to the number of Cellular UEs and the resources of one D2D link use only one cellular resource. The number of Cellular UEs is *N*, but the number of Cellular UEs is *C* for classification and *N* is equal to *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 uses D = {1, ..., d}.

If typical CUE and D2D link have the same resource, there may exists interference between CUE and D2D link. The symbol, $y_{i,j}$ indicates the interference between CUE i and D2D j. For example, $y_{m,k} = 1$ means that D2D link k share the resource of the CUE m. SINR (Signal-to-Interference-plus-Noise Ratio) of CUE is thus defined as

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

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

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

The D2D link and the cellular device need to satisfy a certain SINR value. The SINR value to be satisfied by the cellular device is indicated as '$r_{cellular}$' and the SINR value to be satisfied by the D2D link is indicated as 'r_{D2D}'. The SINR equation to be satisfied is as follows ():

$$r_{cellular} < SINR_{Cellular}, \quad (3)$$

$$r_{D2D} < SINR_{D2D}, \quad (4)$$

If the SINR value is not satisfied, it is assumed that the transmission has failed. Conversely, if the SINR value is satisfied, it is assumed that the transmission is successful. Finally, the throughput $R_{Cellular}$ and R_{D2D} , for CUE and D2D link are thus defined as

$$R_{Cellular} = log_2(1 + SINR_{Cellular}) \quad (5)$$

$$R_{D2D} = log_2(1 + SINR_{D2D}) \quad (6)$$

where '$R_{Cellular}$' is the throughput of the cellular device and 'R_{D2D}' is the throughput of the D2D link.

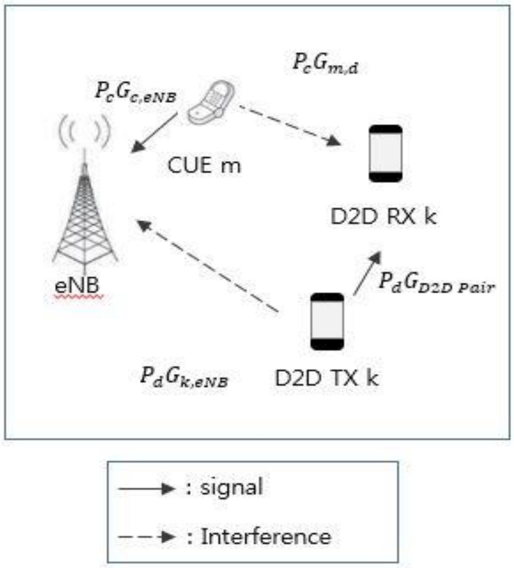

Fig. 1. Interference scenario in D2D Uplink cellular network

III. Proposed Spectrum Allocation

A. *Spectrum Allocation Scheme*

Location Based Resource Allocation [8], which uses only the location information through GPS, determines resources to be shared with D2D link out of total available resources. In order to overcome the disadvantages caused by interference when using only location information, we propose the spectrum allocation algorithm in which both the interference avoidance rate and the efficiency are increased through using both SINR and location information. In this paper, power control is employed to improve a spectrum allocation algorithm that utilizes both location and SINR information. The resource allocation algorithm comprises of only two simple steps: division into a cellular device selection algorithm for resource allocation, and a spectrum allocation algorithm for each D2D link.

1) CUE selection for resource allocation

The selection of cellular UE is shown in Fig. 2. Assuming that the base station knows the location of all devices, the distance between the cellular device and the D2D link can be calculated through the location information of the device. With the coordinates of the cellular device denoted by '(x_{CUE}, y_{CUE})' and the coordinates of the D2D link denoted by '$(x_{D2D\,RX}, y_{D2D\,RX})$', the distance between the cellular device and the D2D link is calculated as follows:

$$R_{D2D\,RX,CUE} = \sqrt{(x_{D2D\,RX} - x_{CUE})^2 + (y_{D2D\,RX} - y_{CUE})^2}. \quad (7)$$

The base station calculates the distance to all cellular devices for one D2D link. The reason for this is that calculating the distance to the cellular device is the same as comparing the interference magnitudes of the resources, as the cellular device has assumed that each of the cellular devices has different resources in order to find the resources to be used by the D2D link. In the next step, we show how the base station aligns the distance between the D2D link and the cellular devices. As the interference between the D2D link and the cellular device is small as the distance increases, a resource that can be shared at only a certain rate among the distant resources is selected.

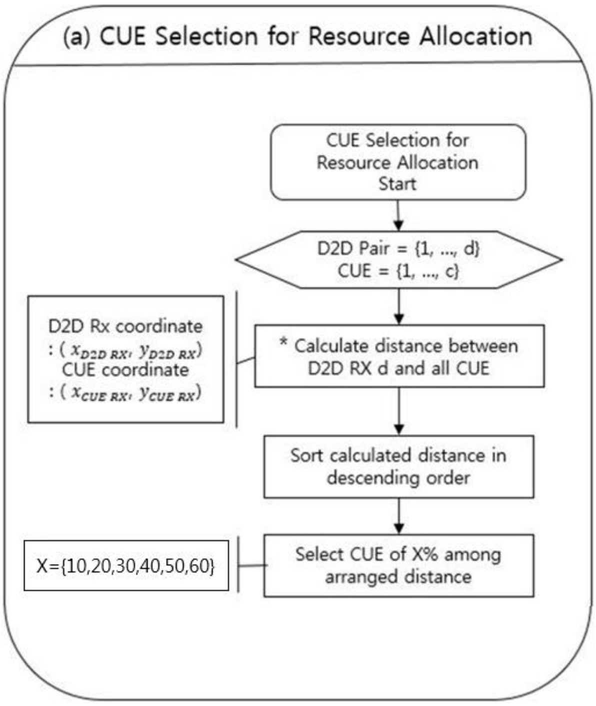

Fig. 2. The procedure for cellular UE selection

2) Spectrum allocation for each D2D link

After performing the cellular device selection algorithm for resource allocation process, each D2D link must find a cellular resource to share. Fig. 3 describes the procedure for D2D spectrum allocation. In the case of resource allocation using only location information, interference between D2D links that occur when selecting the same resource is not considered. Therefore, it is necessary to calculate the SINR value in order to improve the interference. Hence, it is necessary to calculate the SINR value in order to improve the performance. Considering a D2D link using the same resource, $SINR_{D2D}$, which is SINR value of D2D UE, can be expressed by the following equation.

$$SINR_{D2D} = \frac{P_{D2D} G_{D2D\,Pair}}{P_{noise} + \sum_{m=1}^{c} y_{m,k} (P_{Cellular} G_{m,k} + \sum_{i=1}^{d} y_{m,i} P_{D2D} G_{k,i})}, \quad (8)$$

where $G_{k,i}$ is the channel gain between other D2D links using the same resource and the current D2D link.

After calculating SINR of CUE and D2D link for all the possible combination, the maximum throughput of the sum of the throughput of CUE and D2D link can be determined by using (5), (6) and the relative comparison of all the possible values of sum throughput.

The maximum throughput is finally shown as

$$Max(\sum_{k=1}^{d} R_k^{D2D} + \sum_{m=1}^{c} R_m^{Cellular}) \quad (9)$$

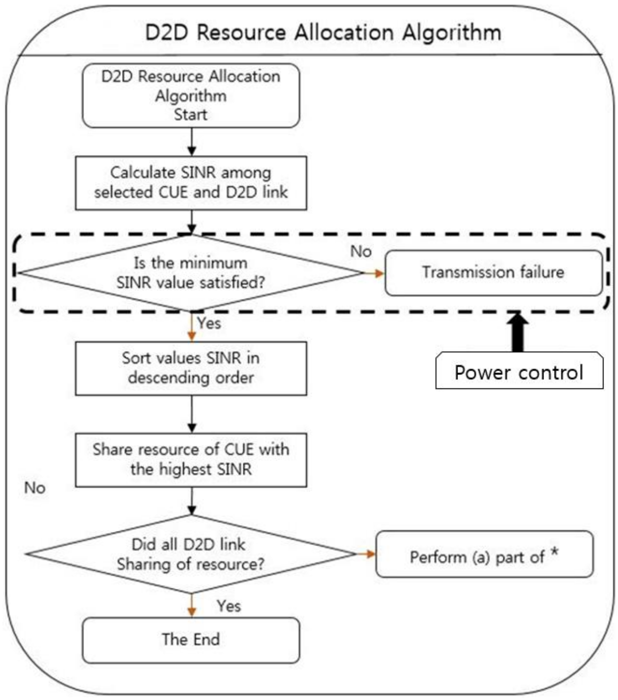

Fig. 3. The procedure for D2D spectrum allocation

B. Power Control

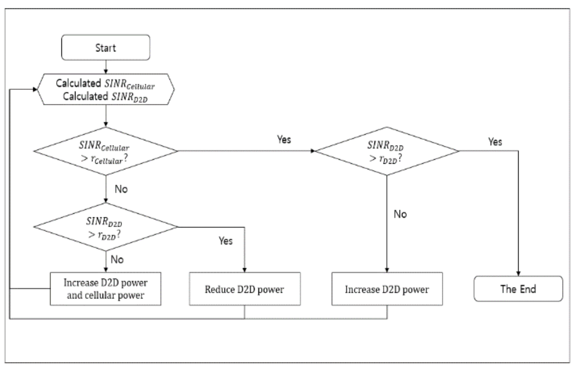

Fig. 4. Power control for D2D cellular networks

The power control scheme is shown in Fig. 4. Main function is that the power of the D2D link is either increased or decreased in order to satisfy the minimum SINR value for CUE and D2D.

First, if both SINR of CUE and D2D are not satisfied, the power of CUE and D2D are increased at the same time. Second, if only CUE SINR is not satisfied, the power of D2D is decreased to reduce the interference to CUE. Third, if only D2D SINR is not satisfied, the power of D2D is increased to achieve the minimum target SINR value.

Since there is a limitation of the maximum power for CUE (23 dBm) and D2D link (13 dBm), if both power reach to the maximum power, the transmission is considered as failed process and it is not added to the calculation of sum of total throughput.

IV. Simulation Results

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

The simulation environment is shown in Table I and the simulation is designed using C ++. First, simulation without power control is carried out to investigate the effect of power control in the proposed scheme.

In the case of simulation without power control, the D2D link and the Cellular UE use the maximum power of Table I since power control is not performed. The target SINR value to satisfy the QoS is set to 0dB for both the D2D link and the cellular UE. The number of D2D links is changed from 5 to 9 in order to examine if there is some point for the performance variation.

TABLE I. Simulation Parameters

Parameter	Value
Cell radius	500m
Maximum distance between D2D links in a pair	50m
Maximum SINR of D2D link (Max. D2D)	5dB
Minimum SINR of D2D link (Min. D2D)	-5dB
Maximum SINR of Cellular UE (Max. Cellular)	5dB
Minimum SINR of Cellular UE (Min. Cellular)	-5dB
Maximum Transmission Power of D2D users	13dBm
Maximum Transmission Power of Cellular users	23dBm
Maximum Throughput	2.5bps/Hz
P_0	-84dBm
P_{noise}	-144dBm
Number of Cellular UE	10
Pathloss	128.1+37.6*log(d/1000)
Number of D2D link	7
BW of an RB	180KHz

A. *Performance Without Power Control*

Fig. 5 shows that the total throughput according to the increase of D2D links without power control. D2D link preferentially selects X % of the cellular resources to allocate the resources as mentioned in Fig. 2.

The ratio of the selection varies from 10% to 60% with 10 % interval. It shows that the throughput linearly increases as the ratio of selected resources is gradually increased until D2D link is less than 7.

When the D2D link more than 8, total throughput is rather decreased. In case of 9 D2D links, throughput is lower than that of 7 D2D links. The reason why throughput is reduced when D2D link is more than 8 is that the increased D2D link results in the increase of the interference to the Cellular UE.

Therefore, it is observed that 7 D2D links can attain the best performance with interference is not big and the throughput is higher than other cases. It also describes the 30 % of CUE selection is best to achieve maximum throughput since there is no further increase of throughput when we compare with that of the higher ratio of CUE selection, which rather results in the higher complexity as shown in Fig. 2.

B. *Performance with D2D Power Control*

The power control in this section means that only the D2D power is changed compared with target SINR value when the power of CUE is fixed as 23 dBm.

Fig. 6 shows the total throughputs when power control of D2D link is applied.

It is shown that total throughput for all cases shows an increase as D2D SINR is gradually increased. The increase of minimum D2D SINR can increase the average D2D power and the total throughput.

Also, the throughputs when the CUE selection is between 30% and 50% attain nearly same since power control reduces the mutual interference and results in stable user performance.

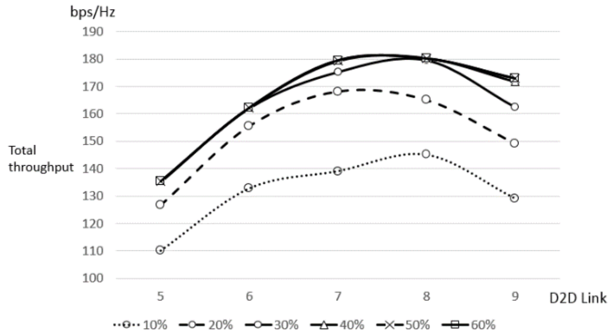

Fig. 5. Comparison of total throughput according to the number of D2D links

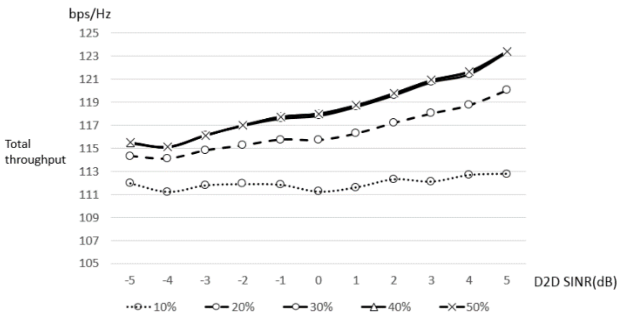

Fig. 6. Total Throughput according to D2D SINR

Fig. 7 shows the D2D power is increased when the minimum SINR value of the D2D link is increased. It is shown that the average D2D power can be reduced to achieve the same desired SINR value when we apply the proposed scheme with more than 30 % of CUE selection.

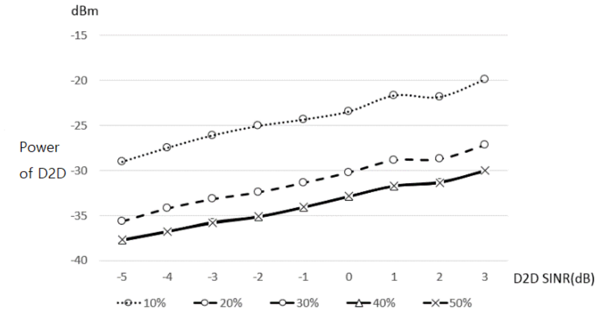

Fig. 7. D2D average power according to D2D SINR target value

C. *Performance with CUE and D2D Power Control*

The power control in this section means that both D2D power and CUE power are changed compared with target SINR value at the same time.

Fig. 8 shows the total throughputs when power control of both D2D and CUE are applied.

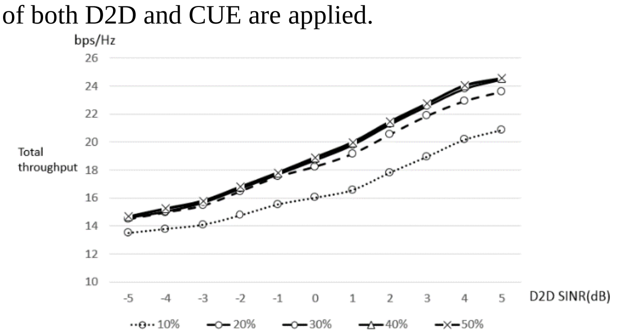

Fig. 8. Total throughput according to D2D SINR

It is shown that total throughput for all cases shows an increase as D2D SINR is gradually increased. It also provide that throughputs when the CUE selection is between 20% and 50% attain nearly same while it appears same performance from 30 % in Fig. 6. It means that the power control of CUE can be effective to achieve the stable performance and to reduce the complexity for resource selection.

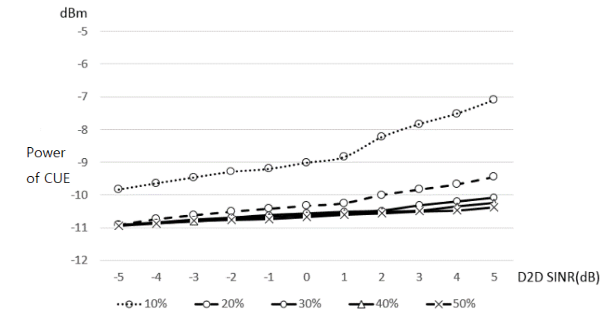

Fig. 9. Average CUE power according to D2D SINR

Fig. 9 and Fig. 10 represent the average power of CUE and D2D according to the increase of D2D SINR, respectively

The reason why D2D power has more variation than that of CUE power is that we set the priority for satisfying CUE power, hence D2D power is controlled more frequently than that of CUE power.

Fig. 11 shows the total throughputs according to the increase of CUE target SINR value. It shows that total throughput increases as CUE SINR is gradually increased.

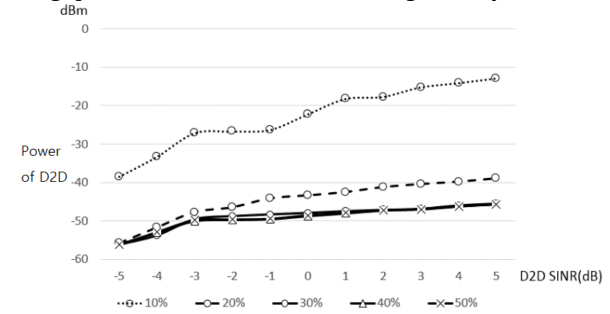

Fig. 10. Average D2D power according to D2D SINR

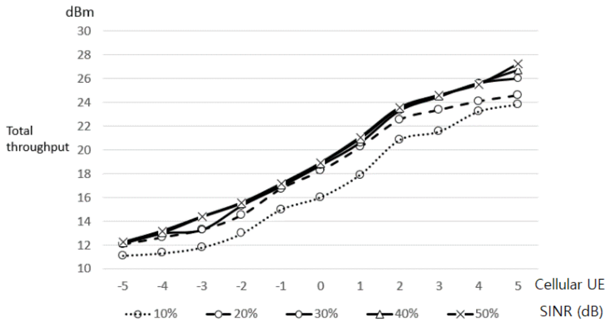

Fig. 11. Total throughput according to CUE SINR

Also, the throughputs when the CUE selection is between 20% and 50% attain nearly same as we already mentioned in Fig. 8.

Fig. 12 represents the average CUE power according to the increase of CUE target SINR. The reason why CUE power has more variation than that of Fig. 9 is that CUE power is controlled with larger range since we set the CUE SINR is the criteria for power control.

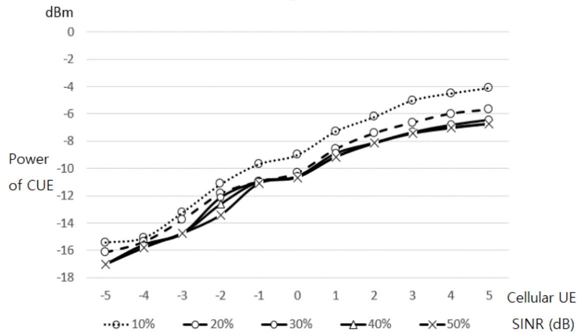

Fig. 12. Average CUE power according to CUE SINR

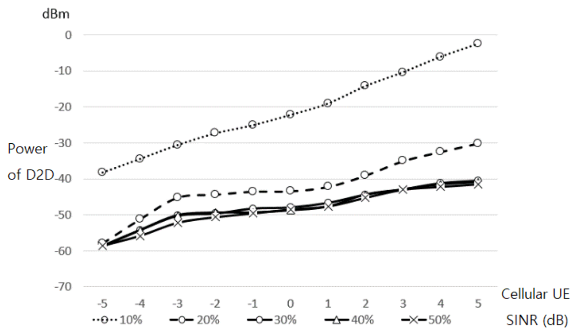

Fig. 13. Average D2D power according to CUE SINR

Fig. 13 illustrates the average D2D power according to the increase of CUE target SINR. The reason why D2D power has more variation than that of Fig. 10 is that D2D power is controlled with larger range to avoid the interference due to the increase of CUE SINR value.

IV. Conclusion

In this paper, we investigated the spectrum allocation schemes that combines existing SINR and location information in a single cell network environment. We also added a power control function to satisfy the minimum SINR value to improve the stable performance and higher total throughput. We have identified the benefits of adding power control to the D2D resource allocation scheme. It has been found that it is more important to maintain the power appropriately by performing the power control for D2D and CUE in view of achieving higher throughput and reducing the complexity for selecting the resource candidates.

In addition, it is necessary to study not only a single cell network but also an operation process in a multi-cell network and a UDN environment

Conflict of Interest

The authors declare no conflict of interest

Author Contributions

Jeong Gon Kim and Soo Hyeong Kang conducted the research; Soo Hyeong Kang analyzed the data; Jeong Gon Kim wrote the paper; all authors had approved the final version.

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