LBS Based Resource Allocation in Ultra-Dense Network with Joint COMP Scenarios

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Abstract—In 5G mobile communication, technologies are being studied today to provide higher data rates. Among them, UDN(Ultra Dense Network) can be considered as a key technology of 5G because it can improve system capacity and spectral efficiency by making the number of BS(Base Stations) more than or equal to the number of UE(User Equipment). However, in the case of UDN, since the number of BSs is large, the UE at the edge of the cell receives signals from more than one BS, causing interference. Therefore, in this paper, we can improve the total data rate of the system by converting the interference signal of the cell edge UE into a useful signal through inter-cell coordination using Joint CoMP (Coordinated Multi Point) technique. After that, we propose a GCD (Graph Coloring based on Distance) algorithm that adds the concept of distance between UEs when sub-carriers are distributed. Simulation results show that the proposed scheme increases the data rate of each cell edge UE, resulting in a higher total data rate than the result of using the CLA-CoMP(Cell Load Aware-CoMP) technique without considering subcarrier allocation.

Index Terms—UDN, 5G, CoMP, Graph Coloring, CLA-CoMP, subcarrier allocation

I. Introduction

In 5G mobile communication, with the development of the IoT(Internet of Things) technology, the number of mobile devices is rapidly increasing, and at the same time, the amount of data used by the mobile devices is also rapidly increasing. In order to solve this problem, high density deployment and miniaturization of SBS (Small cell Base Station) is considered, and this is defined as UDN (Ultra Dense Network). UDN is considered one of the key technologies to improve system capacity and spectral efficiency in future 5G mobile networks [1]. UDN is also considered one of the best ways to meet QoS(quality of service) requirements of users and support future wireless network deployments [2]. However, the high density deployment of SBS using existing approaches will increase the cost of maintaining and managing complex networks and interference between SBS will be inefficient [3]. In addition, the high density deployment of SBS in UDN causes the problem of overlapping cell coverage [4]. In this case, a UE(User Equipment) located at an edge of the SBS region receives a signal from not only a serviced SBS but also two or more other SBSs. This causes great interference to the edge UE. As such, inter-cell interference is one of the important problems to be solved in UDN. The higher the density of SBS, the closer the cell-to-cell distance becomes, and thus, the cell coverage overlaps frequently. Therefore, [5] proposes channel state and interference aware power allocation scheme to reduce the effect of interference on the UE located at the edge of the cell. Interference-aware power allocation scheme is a method of adjusting the transmit power strength of the SBS so as not to give a large interference to the UE located at the edge of the cell. However, this scheme does not consider cooperative communication between SBS, so there is a limit to obtaining a large data rate.

In addition, in [6], the interference weighting based advanced heuristic clustering technique, which divides SBS by introducing the concept of interference weight, is used to mitigate interference and then perform subchannel allocation research. The subchannels allocate the same channel within each cluster and different channels between the clusters to minimize inter-cluster interference. However, there is still interference in the cluster.

In [7], we studied the method of mitigating interference using the existing graph coloring method. Conventional graph coloring scheme sets base stations with overlapping or close range of cells as neighbors. The base station determined as the neighbor is allocated a different resource to each other to reduce the interference. However, this method only considers the neighbor relationship of the base station and does not consider the neighbor between UEs. Therefore, an interference problem occurs in which the distance between UEs is close but the same resources are allocated.

This problem can be solved by using CoMP(Coordinated Multi Point) technique, which is a cooperative communication between cells. In [8], SBSs transmit the same data using the same frequency to the UE located at the edge of the cell through the Joint CoMP technique. As a result, the previously interfering signal is changed into a useful signal, providing a higher data rate for the cell edge UE. In addition, using the CLA-CoMP(Cell Load Aware-CoMP) technique in consideration of the cell load, the SBS serves the UE by the number of available sub-carriers to balance the cell

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load. However, since the subcarrier allocation scheme is not considered, interference with the same subcarrier occurs. Therefore, this paper uses Joint CoMP in UDN environment and additionally studies on subcarrier allocation scheme.

In this paper, we use the well-known graph coloring scheme as a representative subcarrier allocation method. The graph coloring scheme is a method for allocating sub-carriers. When applied to a general UDN environment, when cell coverage overlaps in each SBS, two cells are determined to be adjacent nodes. Next, all UEs in the corresponding SBS region are connected and defined as neighboring UEs [9]. However, this scheme causes two problems because it only considers the SBS and not the distance between UEs. The first is a case where the distance between the UEs is far away but the SBS is adjacent to use another sub-carrier, and the second is a case where the distance between the UEs is adjacent but the area of the SBS is not overlapped to use the same sub-carrier. In the former case, the same subcarrier may be used because the distance between UEs is long, but different subcarriers may be used, resulting in a lower frequency reuse rate and, as a result, a lower system efficiency. In the latter case, since the same subcarrier is allocated in a situation where the distance between the UEs is close, the interference becomes severe, and as a result, a problem arises in that not only the data rate of the UE but also the total rate of the entire system is lowered.

Therefore, in this paper, we study the subcarrier allocation using the graph coloring scheme considering the distance between UEs in the UDN environment using the Joint CoMP technique. In Section II, describes the system model of signal transmission. Section III introduces the power allocation scheme used in this paper. In Section IV, we propose a GCD algorithm that performs graph coloring based on distance. Section V compares the performance of the existing CLA-CoMP with the proposed GCD algorithm through simulation. And concludes with the conclusion of this paper in Section VI.

II. System Model

This paper considers the UDN environment, and the SBS and the UE are randomly located within the system area. The number of SBSs also has a number greater than or equal to the number of UEs. In this area, each SBS forms a service cell, but due to the high density arrangement, cell edges can overlap other cells. Therefore, the signal received by the UE located at the cell edge may be from two or more SBS. Using the Joint CoMP technique at the cell edge, the UE transforms the interference signal into a useful signal to improve the data rate and total sum data rate in the system. SBS provides services to UEs according to channel state information (CSI) of the UE within cell range. After all BSs select a UE to serve, a subcarrier is allocated by suggesting a distance-based graph coloring scheme based on the distance between UEs. The system model is shown in Fig. 1.

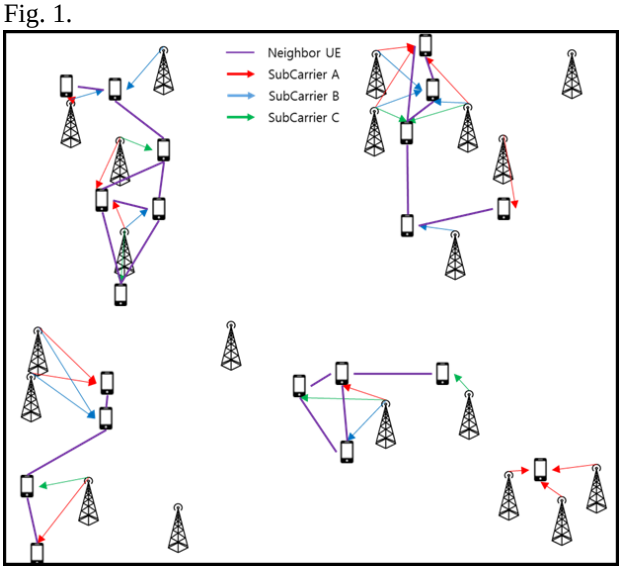

Fig. 1. Joint CoMP communication system using graph coloring based distance.

In this paper, only downlink transmission is considered. The system is assumed to be based on OFDM with frequency reuse factor 1. In SBS, the available bandwidth is divided into S orthogonal sub-carriers. SBS b is represented by 1 to B, UE u is represented by 1 to U. The set of SBS and UE is represented by b = {1,2, ..., B} and u = {1,2, ..., U}, respectively. Therefore, the signal received by the UE u may be defined as in Equation (1).

$$y_u = \sum_{b\in B_u} \sqrt{p_u^b h_u^b}\, s_u + \sum_{i\in B-B_u} \sqrt{p^i h_u^i}\, s_{u'} + n_u \quad (1)$$

Here, $\boldsymbol{b_u}$ represents SBSs serving the UE u, and $\boldsymbol{p_u^b}$ and $\boldsymbol{p^i}$ are transmit power of the cooperative transmitter and the transmit power of the interfering transmitter, respectively. $\boldsymbol{h_u^b}$ and $\boldsymbol{h_u^i}$ are channel gains. This paper considers both large scale fading and small scale fading. $\boldsymbol{H^{U\times B}}$ is a channel gain matrix between the SBS and the UE, and $\boldsymbol{h_u^b} = \boldsymbol{H^{U\times B}}$, $\boldsymbol{h_u^i} = \boldsymbol{H^{U\times B}}$, and can be represented by Equation (2). $\boldsymbol{n_u}$ is a adaptive white Gaussian noise with a distribution. Thus, the right side of Equation (1) is a useful signal, an interference signal, and a noise signal in order. As a result, the SINR of UE u is defined as in Equation (3).

$$H_b = \begin{bmatrix} h_1^1 & \cdots & h_1^b & \cdots & h_1^B \\ \vdots & & \vdots & & \vdots \\ h_u^1 & \cdots & h_u^b & \cdots & h_u^B \\ \vdots & & \vdots & & \vdots \\ h_U^1 & \cdots & h_U^b & \cdots & h_U^B \end{bmatrix}_{U\times B} \quad (2)$$

$$SINR_u = \frac{\sum_{b\in B_u} \sqrt{p_u^b h_u^b}}{\sum_{i\in B-B_u} \sqrt{p^i h_u^i} + \sigma^2} \quad (3)$$

Equation (3) defines the data rate of UE u and the total data rate R of the system as Equations (4) and (5), where the bandwidth value of the subcarrier is set to 1.

$$r_u = \log_2(1 + SINR_u) \quad (4)$$

$$R = \sum_{u=1}^{U} r_u \quad (5)$$

In this paper, we object to increase the overall data rate achievable using the proposed scheme.

III. Power Allocation Algorithm

This section describes the power allocation scheme for each subcarrier used in this paper. The method is an average power allocation scheme and a power allocation scheme based on channel state. The simulation results are then used to compare the differences between the two power allocation schemes.

A. Average Power Allocation

The first scheme is the average power allocation scheme. This scheme is a scheme of equally allocating the maximum power allocated to SBS i to UEs served by the SBS. The equation below represents power allocated to UE u receiving service from SBS i.

$$P_{UE}^{i} = \frac{P_{max}^{i}}{N_{UE}^{i}} \quad (6)$$

In the above formula, P_{max}^{i} represents the maximum power allocated to SBS i. N_{UE}^{i} represents the number of UEs currently receiving service from SBS i.

This scheme also allocates power to UEs that are currently in poor channel state. Therefore, even a UE with poor channel state can communicate. Also, as can be seen from the equation, the calculation complexity is very low because it does not require additional calculation. However, this scheme has a disadvantage in that energy efficiency is inferior because power is allocated to UEs having a very poor channel state.

B. Power Allocation based on Channel State(PA-CS)

The second scheme is a power allocation scheme based on channel state. This scheme allocates more power to UEs with good channel state and less power to UEs with poor channel state. The brief sequence is as follows. First, SBS i calculates the sum of channel gain values of respective UEs that it serves. Then, the channel gains of each UE are divided by the sum of channel gains. The divided value is defined as the power allocation coefficient, and can be expressed by the following equation.

$$\gamma_{UE}^{i} = \frac{h_{UE}^{i}}{\sum_{u \in U_i} h_u^i} \quad (7)$$

h_{UE}^{i} in the above equation is the channel gain of the UE to obtain the power allocation factor. U_i is a set of UEs that receive service from SBS i. h_u^i is the channel gain of UE u receiving service from SBS i.

Next, the power allocation coefficient obtained from the above equation is multiplied by the maximum power allocated to SBS i. The multiplied value is the power to be allocated to the actual UE.

$$P_{UE}^{i} = \gamma_{UE}^{i} P_{max}^{i} \quad (8)$$

As mentioned above, P_{UE}^{i} is actually allocated to the UE by multiplying the maximum power P_{max}^{i} allocated to SBS i by the power allocation factor γ_{UE}^{i} obtained from the above equation.

The flowchart of the above method is illustrated in detail in Fig. 2 for better understanding.

Power allocation based on channel state allocates large power to UEs with high channel gains. Conversely, a small power is allocated to a UE having a small channel gain. This scheme is similar to the existing water filling power allocation scheme, but has a much simpler calculation. In case of using channel gain-based power allocation scheme, the maximum sum data rate can be achieved by allocating more power to UE with high channel gain. In addition, the UE is low in the channel gain can be assigned a low power to reduce the interference caused. Based on this, higher data rates can be obtained.

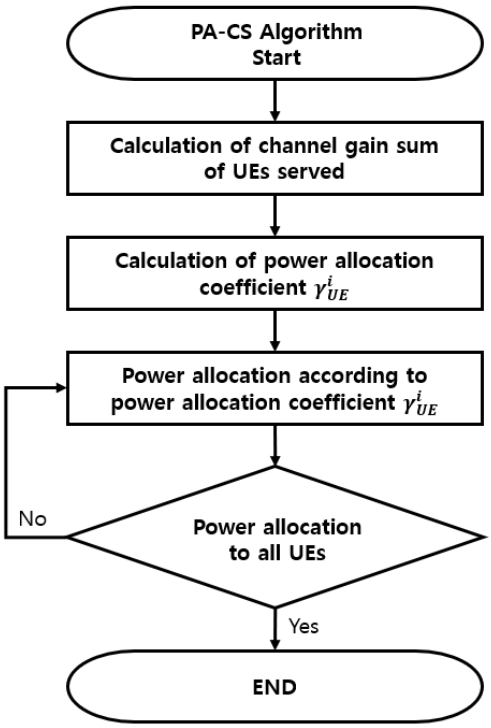

Fig. 2. Power allocation based on channel state flowchart

IV. Graph Coloring Based on Distance Algorithm

This section describes the graph coloring technique that is the basis of the proposed scheme and the GCD technique proposed in this paper.

A. Graph Coloring Scheme

The graph coloring scheme is one of the well known methods for solving the interference problem by allocating different resources to neighboring UEs. For the system description, we assume three colors red, yellow, and green, and the colors represent subcarriers. Fig. 3 shows a UE set up as a neighbor.

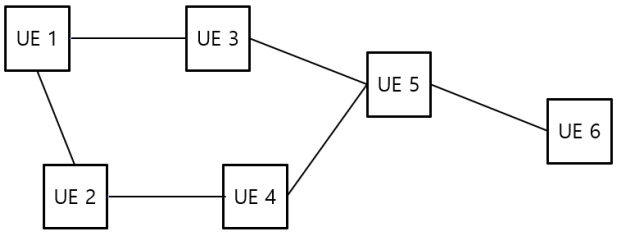

Fig. 3. UE set up as neighbor

Here's how to assign colors:

Step 1. Firstly, UE 1 is randomly assigned one of three colors.

Step 2. UE 2 determines whether there is a neighboring UE and uses one of two colors except for the color used by the neighboring UE.

Step 3. Repeat the process step 2 according to the number of the UE.

Step 4. If the color has been assigned to all UEs, the process ends.

Fig. 4 shows the final color assignment to all UEs.

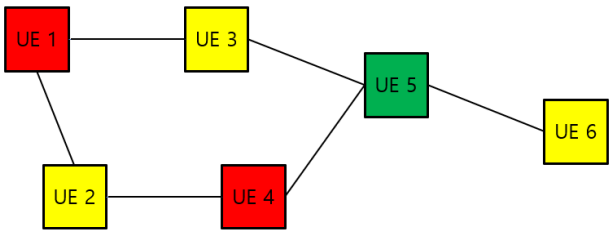

Fig. 4. UE after completion of graph coloring process

However, since the existing graph coloring scheme does not consider neighbors between UEs, interference will occur in the case of UE2 and UE3. To solve this problem, this paper proposes a GCD algorithm that adds the concept of distance between UEs.

B. GCD Algorithm

The GCD algorithm additionally considers the distance between UEs, which is not considered in the traditional graph coloring scheme. Therefore, different subcarriers are allocated to UEs located in adjacent distances, and the same subcarriers are allocated to UEs located at far distances. Therefore, the frequency reuse rate of the entire system can be improved and the data rate of the UE located at the edge of the cell can be increased by minimizing the interference between the same sub-carriers. In addition, as the data rate of the cell edge UE is improved, the overall total sum data rate of the system can be improved.

Details of the GCD algorithm are as follows. First, all SBSs arranged in the system are known to know CSI (Channel State Information) with each UE and CLI(Cell Load Information), which is the number of UEs they serve. Therefore, the SBS forms a service link to the UE based on the CSI. However, because of the UDN environment, the UE can receive services from more than one SBS. In this case, the CoMP scheme may be used to improve the data rate of the UE located at the cell edge. In this paper, however, since each SBS uses a total of three orthogonal subcarriers, all SBSs are limited to serving up to three UEs based on the CLI. In order to increase the data rate of the system, the SBS preferentially provides a service to the UE having the best channel gain. Then, the distance between all UEs in the system is measured and a distance matrix

$D^{U\times U}$ between UEs is generated as shown in Equation (9). This is used when calculating the proximity between UEs later using the actual distance values between UEs.

$$D = \begin{bmatrix} d_1^1 & \cdots & d_1^u & \cdots & d_1^U \\ \vdots & & \vdots & & \vdots \\ d_u^1 & \cdots & d_u^u & \cdots & d_u^U \\ \vdots & & \vdots & & \vdots \\ d_U^1 & \cdots & d_U^u & \cdots & d_U^U \end{bmatrix}_{U\times U} \tag{9}$$

Next, the neighboring UE matrix $E^{U\times U}$ indicating the proximity between the UEs may be created based on the value of the distance between UEs matrix obtained in Equation (9). The neighboring UE matrix has a value of 1 when the distance value of the distance matrix is small, that is, when the distance between UEs is close. On the other hand, when the distance value is large, that is, when the distance between UEs increases, the matrix has a value of 0. Therefore, the neighbor UE matrix may be represented as shown in Equation (10).

$$E = \begin{bmatrix} e_1^1 & \cdots & e_1^u & \cdots & e_1^U \\ \vdots & & \vdots & & \vdots \\ e_u^1 & \cdots & e_u^u & \cdots & e_u^U \\ \vdots & & \vdots & & \vdots \\ e_U^1 & \cdots & e_U^u & \cdots & e_U^U \end{bmatrix}_{U\times U} \tag{10}$$

Subcarrier allocation is discussed after completing the preparation of the neighbor UE matrix of Equation (10). Subcarrier allocation allocates different subcarriers between neighboring UEs and the same subcarrier to distant UEs in consideration of the neighbor UE matrix obtained in Equation (10). Once all subcarrier assignments have been made, power is allocated to each connected link. The Power allocation is based on the method mentioned in Section II. A detailed flowchart of the algorithm is shown in Algorithm 1.

Algorithm 1 Graph Coloring based on Distance

Initialization:

1: Based on CSI and CLI, SBS decides which UE to service (Each SBS can only serve up to 3 UEs considering the CLI)

2: Create distance matrix $D^{U\times U}$ after measuring distance between UEs

3: Create neighbor matrix $E^{U\times U}$ based on $D^{U\times U}$ (1 if UE is neighboring, 0 is assigned when not neighboring)

4: Assign subcarrier not used by neighboring UE to UE based on $E^{U\times U}$

5: SBS distributes fixed power values according to equations (7) and (8)

6: Terminate algorithm when all SBS have allocated power

end

V. Simulation Results and Analysis

In this paper, the simulation environment is based on the $100X100m^2$ area. SBS and UE are uniformly and randomly arranged in this area. The channel uses a randomly generated unitary Rayleigh fading channel. The bandwidth of each subcarrier is set to 1. The main parameters of the simulation are summarized in Table I.

TABLE I: Simulation Parameter

Parameter	Value
Number of UE	1 : 20
Number of SBS	20
Number of sub-carrier	3
Bandwidth of sub-carrier	1
Path-loss exponent factor (u)	3.5
AWGN distribution (σ)	0.1
Max power of SBS (dBm)	10
Frequency reuse factor	1

Fig. 5 compares the total transmission rates of Pure Random (when not considering CLA-CoMP), conventional CLA-CoMP, and GCD, which is proposed in this paper, when the average power allocation is used in an increasing number of UEs. As shown in Fig.5 the total data rate does not show a big difference in a situation where there are few UEs. However, when the number of UEs increases, the GCD algorithm is superior to the CLA-CoMP technique and the pure random data rate because there is a limitation of the number of available subcarriers.

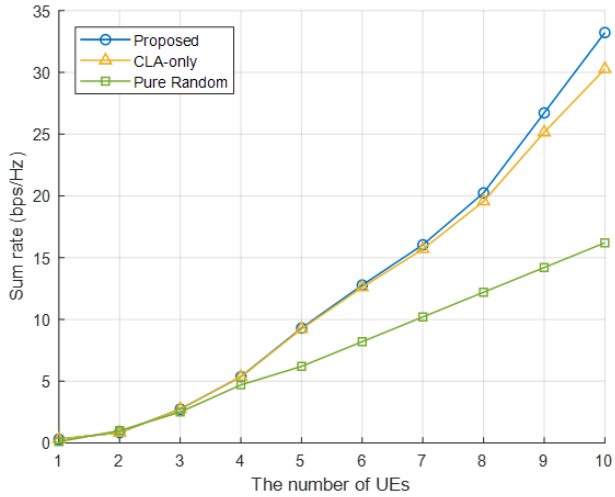

Fig. 5. Overall system data rate comparison of proposed, CLA-Only, pure random using average power allocation

Because Pure Random serves more UEs than the maximum number of subcarriers available in one SBS, interference occurs within the cell. In addition, since CLA-CoMP does not consider a subcarrier allocation method, the same subcarriers are allocated to adjacent distances. Therefore, a problem arises in that interference is increased for the UE located at the edge of the cell. However, the core idea of the GCD scheme is to set the neighbor UE matrix by considering the distance between UEs. Then, by allocating different subcarriers between adjacent UEs to minimize interference, it can be seen that the edge UE of each cell provides a better data rate. As a result, it can be seen that as the data rate of UEs located at the edge of the cell is improved, the total rate of the entire system is also improved.

Fig. 6 compares the data rates of the entire system for each power allocation and resource allocation scheme. When power is allocated to each subcarrier using an average power allocation scheme, CLA-only, which randomly assigns a subcarrier to a user using CoMP, has the lowest data rate. However, it can be seen that the GCD scheme presented in this paper can achieve higher data rates than the CLA-only scheme as the number of UEs increases. The following is the result of using the PA-CS technique. As mentioned earlier, in the case of PA-CS, higher data rates can be obtained by allocating more power to UEs with good channel state. Therefore, as can be seen in the result graph, it can be seen that the result of using PA-CS can achieve higher data rate than the result of average power allocation. In addition, it can be seen that the data rate increase of the GCD scheme is larger than that of the average CLA-only allocation. When the PA-CS is used simultaneously when using the proposed scheme, the effect of interference is reduced by allocating more power when the SBS and the UE are adjacent to each other. In addition, since neighboring UEs use different subcarriers, no interference occurs. On the contrary, when the SBS and the UE are far apart, they allocate small power, thereby achieving a higher data rate than the traditional scheme.

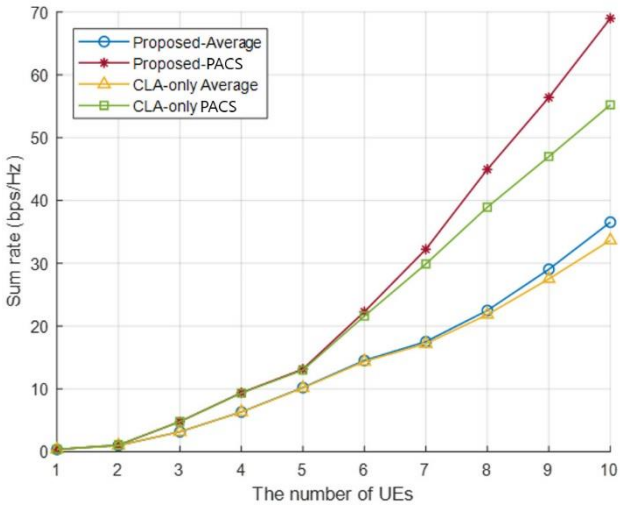

Fig. 6. Overall data rate comparison by power and resource allocation

VI. Conclusion

The purpose of this paper is to reduce the interference and improve the data rate by using Joint CoMP technique and proposed GCD algorithm for UE located at the edge of cell in UDN environment. In view of the constraints of the resources available in the system, the SBS coordinates to service as many UEs as there are available sub-carriers. Since the traditional CLA-CoMP scheme randomly allocates sub-carriers, interference between neighboring UEs has been severe. In order to solve this interference

problem, this paper proposes a distance-based graph coloring technique. Through simulation result, we compare the performance of the traditional CLA-CoMP scheme with the proposed GCD algorithm. As a result, we can see that the performance of the proposed algorithm is superior to the traditional scheme.

CONFLICT OF INTEREST

The authors declare no conflict of interest

AUTHOR CONTRIBUTIONS

Ho Kyung Yu, Sung Hyun Oh and Jeong Gon Kim conducted the research; Ho Kyung Yu, Sung Hyun Oh and Jeong Gon Kim analyzed the data; Ho Kyung Yu wrote the paper; all authors had approved the final version.

REFERENCES

[1] Y. Liu, X. Li, H. Ji, K. Wang, H. Zhang, "Joint APs selection and resource allocation for self-healing in Ultra dense network," presented at the IEEE Computer, Information and Telecommunication Systems, 2016.

[2] Y. Sui, I. Guvenct, and T. Svensson, "On the deployment of moving networks in ultra-dense urban scenarios," in *Proc. IEEE International Conference on 5G for Ubiquitous Connectivity*, 2014, pp. 240-245.

[3] W. Yu, H. Xu, H. Zhang, D. Griffith and N. Golmie, "Ultra-Dense networks: Survey of state of the art and future directions," *IEEE Computer Communication and Networks*, Sep. 2016.

[4] X. Zhu, C. Xiao, J. Zeng, X. Su, and L. Huang, "Virtual cell interference alignment in Ultra dense network," presented at the IEEE/CIC International Conference on Communications in China, 2016.

[5] G. Yuehong, C. Lei, Z. Xin, Z. Yajun, and Z. Yunfei, "Enhanced power allocation scheme in ultra-dense small cell network," *IEEE China Communications*, February 2016.

[6] W. Yao, J. Li, B. Tan, and S. Hao, "Interference management scheme of Ultra dense network based on clustering," presented at the IEEE 2nd Information Technology, Networking, Electronic and Automation Control Conference, 2017.

[7] H. W. Tseng, Y. J. Yu, B. S. Wu, C. F. Kuo, and P. S. Chen, "A resource allocation scheme for device-to-device communication over ultra-dense 5G cellular networks," presented at the International Conference on Applied System Innovation, 2017.

[8] J. Wu, J. Zeng, X. Su, X. Xu and L. Xiao, "Joint CoMP and power allocation in Ultra dense networks," presented at the Wireless Telecommunications Symposium, 2017.

[9] J. A. Kwon, B. G. Kim, J. W. Lee, J. W. Lim, and B. H. Kim, "A subchannel allocation algorithm for femtocells in OFDMA cellular systems," *The Journal of the Korean Institute of Communication Sciences*, vol. 35, no. 4, pp. 350-359, 2010.

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