Dynamic Cooperating Set Planning for Coordinated Multi-Point (CoMP) in LTE/LTE-Advanced Systems

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***Abstract*—Coordinated Multi-Point (CoMP) is considered as one of the most important technique in 3GPP LTE/LTE-Advanced. In CoMP, several base stations can be grouped together to form the cooperating set, where the cooperating set is used to improve the system throughput as well as the throughput of cell edge users. Most of the studies discuss static cooperating set, i.e., the size of the cooperating set is fixed, such as 3 or 7. However, when big activities occur with gathered crowds, such as gala parades and New Year's Eve, the amount of wireless communication demands in such areas is over the capacity of serving base stations. In this case, the static cooperating set can bring only limited help and fails to adapt to the actual conditions. Moreover, additional communication overhead among cells is introduced but futile. In this paper, we propose the dynamic cooperating set to solve the problem. The proposed method takes the actual traffic requirement and geographical area into consideration to form dynamic cooperating set to offload the wireless communication demand. Dynamic cooperating set can not only enhance the system and cell edge throughput but also utilize the radio resource in an efficient way. The latter avoids unlimited expansion of the cooperating set. Simulation results show that the throughput of our method is 1.23 and 1.36 times of the static CoMP scheme and no CoMP scheme, respectively.**

Keywords—CoMP, LTE, SFR (Soft Frequency Reuse), resource management, OFDMA, DCS (Dynamic Cell Selection)

I. INTRODUCTION

With the appearance of smart devices, various kinds of popular applications are developed, such as cloud computing, Machine-to-Machine (M2M), communication, smart meter, Vehicular Network and smart home. All smart devices are unable to be supported simultaneously in current 3G networks. The demand for high-speed access and broad bandwidth accelerates the arrival of 4G networks to provide these smart devices wireless Internet access at any time and any place. To support large number of devices to access wireless networks at the same time, Long-Term Evolution (LTE)/LTE-Advanced (LTE-A) 4G networks [2] develop a variety of new technologies, such as Coordinated Multi-Point (CoMP) [2][3], relay networks, femtocells with collocation of 4G networks. With these techniques, LTE/LTE-A can effectively increase the system throughput and satisfy user's QoS (Quality of Service). This paper thus focuses on CoMP in the 4G LTE-A. CoMP can be used to enhance the throughput of the cell both in cell average and the cell edge.

CoMP is considered as one of the most important technique in 3GPP LTE/LTE-A. CoMP is classified into two categories. The first is Coordinated Scheduling and/or Beamforming (CS/CB), in which the data destined to each user is saved only in his/her serving cell and the schedule of resource and beamforming is co-decided by the Cooperating Set. The second is Joint Processing (JP), in which the data destined to each user is saved in every cell of the cooperating set and the resource schedule is co-decided by the cooperating set. In terms of the transmission mode, JP can be further assorted into two types: Joint Transmission (JT) [5] and dynamic cell selection (DCS) [6]. The former delivers the data of a mobile equipment by scheduling a couple of base stations (BSs) to transmit at the same time, which can improve the transmitting BS from the member cells of the set for each the users receiving signal quality. The latter allows the cooperating set to dynamically select user, but the BS doesn't have to be the user's serving cell. In the paper, we focus on the dynamic cell selection, which as mentioned above can dynamically assign the transmitting BSs for users. The cooperating set can thus share free resource of member cells with the overloaded cells. Exploiting this feature, we propose the concept of the dynamic cooperating set. When cells have to serve gathered crowds in the big activities, such as gala parades, the demands of wireless communication in such areas is always over the capacity of serving base stations. Many users are unable to communicate through their mobile devices. At this moment, the system, can dynamically through organize the BSs around the overloaded base stations to compose cooperating set to meet the people's necessities and enhance system efficiency and throughput.

There are several researches discussing the dynamic cell selection and cooperating set. In [7], the LDA-SFR (Load Distribution Aware-Soft Frequency Reuse) scheme is proposed, which partitions the cells into groups and each group comprises seven base stations. For each group the center of each base station uses the same frequency and transmit with less power, while the cell edges of the seven cells use different frequencies and transmit with larger power than the center. Though LDA-SFR can avoid Inter channel Interference (ICI), the frequency reuse of the cell edge is only 1/7. Reference [8] assumes each BS has 3 sectors and only considers static cooperating set. Each cooperating set are comprised by the dynamically selected sectors.

When big activities occur with gathered crowds, the amount of wireless communication demands in such areas are always over the capacity of serving BSs. In this case, the static cooperating set can bring only limited help and fail to adapt to the actual conditions. Moreover, additional communication overhead among cells is introduced but futile. In this paper, compared to the static cooperating set aforementioned, we propose the dynamic cooperating set to solve above problem. When the overloaded BS appears in the system, the overloaded base station as the center of a cooperating set invites adjacent cells (one-hop neighbors) with free resource to join and form the cooperating set, so as to mitigate the load of the overloaded BS and meet the QoS requirements of the users. If all adjacent cells have joined the cooperating set but still cannot solve the overload problem, the system will continue to invite the neighbor cells of the cooperating set (two-hop neighbors) of the overload cell to join the cooperating set. Considering the fact that the size of the cooperating set will affect the complexity of resource allocation and scheduling and the BSs which are farther from the center of the cooperating set can improve limited efficiency and throughput, our method will give priorities to the neighbor cells as a reference when selecting them to join the cooperating set. Also we will set a stop point. When the condition of the stop is formed, the invitation to the cooperating set will cease. This can avoid excessive growth of the system complexity by adding helpless BSs to the cooperating set.

The remainder of this article is as follows. Section II describes our system model and formulates the problem. In Section III, we present our proposed dynamic cooperating set planning algorithm. Simulation results are shown in Section IV. Finally, we conclude the paper in Sector V.

II. SYSTEM MODEL AND PROBLEM FORMULATION

LTE-A uses Orthogonal Frequency Division Multiple Access (OFDMA) technology in downlink. OFDMA is a combination of frequency and time division multiple access techniques to use spectrum resource, which uses a large number of orthogonal narrow-band subcarriers to load data against multipath effect. Schedulers can exploit multi-user diversity and choose suitable subchannels for users to enhance spectral efficiency and throughput.

LTE-A Frequency Division Duplexing (FDD) frame structure is as shown in Figure 1. The spectrum is divided into frames. Each frame is comprised of 10 subframes. One subframe is 1ms. In LTE-A, the minimum transmission unit is a Physical Resource Block (PRB). A subframe is composed of 2 PRBs in the time domain. A PRB includes 7 symbols in the time domain and 12 subcarriers in the frequency domain, so the PRB has 84 symbols in total. In LTE-A, the minimum resource assignment unit is a Transmission Time Interval (TTI), where a TTI is comprised of 2 successive PRBs, with 168 symbols. The Modulation and Coding Scheme (MCS) decides the capacity of each symbol, i.e., one symbol can carry 4 and 6 bits by employing 16QAM and 64QAM, respectively. In this paper, we assume the bandwidth is 10MHz, thus each subframe has 50 PRBs in the frequency domain and can provide 50 TTIs for resource assignment.

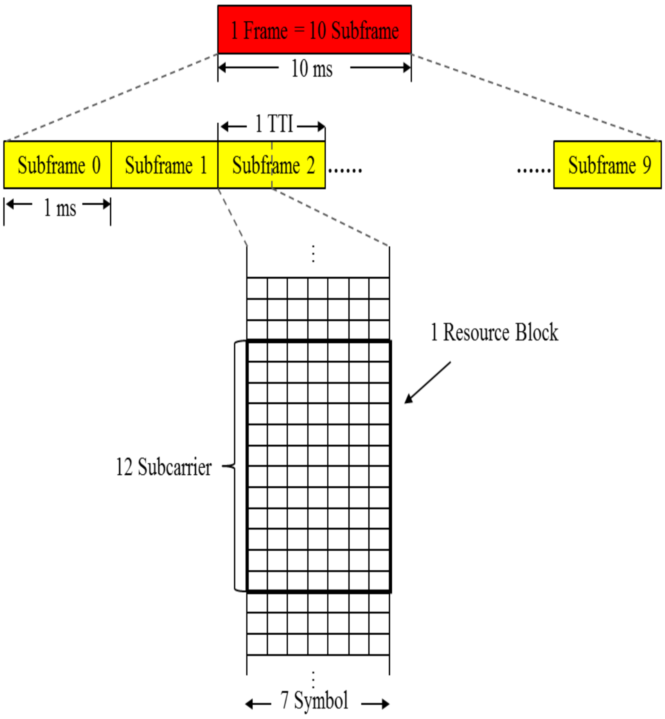

Figure 1. FDD frame structure of LTE-A OFDMA

In OFDMA systems, User Equipment (UEs) simultaneous data transmission activities will interfere with each other if they adopt the same frequency. To avoid this, we adopt traditional SFR model [9][10][11][12] to mitigate interference and ICI and enhance frequency efficiency. SFR model is as shown in Figure 2, we can see that 3 cells consist of a frequency reuse unit. Each cell contains center and edge areas. Frequency band is partitioned into 3 subbands, F_1, F_2 and F_3, where each cell edge in a frequency reuse unit allocates different frequency subband, F_1, F_2 or F_3, as shown in Figure 2, while the center of each cell uses the frequency subbands other than that of its cell edge, i.e., in Figure 2, the edge area of cell 1 allocates subband F3 while the center area allocates F_1 and F_2. To effectively reduce the ICI, subbands of centers are allocated low power while the subband of edges is allocated high power. So the system can mitigate interference problem by SFR model. Other spectrum allocation schemes can also be combined with our proposed method (not limited to SFR), but this is not within the scope of this article.

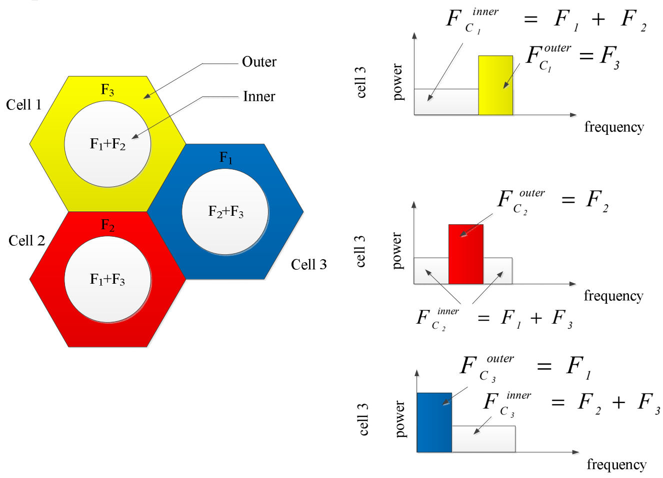

Figure 2. SFR Model

The cell edge area is covered by multiple cells. When the resource of a cell is not enough, transferring some UEs in the cell edge to other adjacent cells by DCS can achieve the goal of offload. Previous work usually use a fixed cooperating set [7] [8]. Although these schemes work and are simple, they are inflexible and cannot fit the cooperating set to the actual traffic situation, which is actually changed time to time. This motivate us to propose the concept of dynamic cooperating set combined with DCS. According to the actual traffic situation, a dynamic cooperating set based scheme can dynamically invite proper adjacent cells to organize cooperating set, such that more users can be served and the system resource can be efficiently utilized.

In this paper, We are to solve the following problem. Each cell in the system uses omni directional antenna, and the cell edge share the 1/3 area of the total area. Initially, each cell is responsible only for the users within its coverage area (for the users covered by several cells, they choose the closest one as the serving cell). If a cell or several adjacent cell overload, these cells will become cluster head (or head of the cooperating set) and start to invite adjacent cells with free resource to join the cluster (cooperating set). The size of the cooperating set is not fixed. Based on the actual traffic situation, the cooperating set is dynamically regulated. Here we are to find suitable cells to join the cooperating set. For a larger size cooperating set, the overall resource can be more effectively used, but the computing overhead is high, too. Our observation also shows that in some cases, we can add more cells into the cluster to alleviate the overload problem and satisfy more users but the overload problem cannot be always solved.

TABLE I. THE MCS WITH THE REQUIRED RECEIVED SINR

Modulation	**Code rate**	**SINR(dB)**
16QAM	1/2	7.9
	2/3	11.3
	3/4	12.2
	4/5	12.8
64QAM	2/3	15.3
	3/4	17.5
	4/5	18.6

To evaluate the channel quality, we use the Signal to Interference plus Noise Ratio (SINR) model. Based on the received SINR, the system selects a suitable MCS for a UE. TABLE I shows the MCS and its required received SINR. If the SINR value of a UE is high (resp., low), it can use high (resp., low) level MCS. Assume the transmission power of sender i is P_i, the receiving power $\widetilde{P}(i, j)$ of receiver j can be derived as

$$\widetilde{P}(i,j)=\frac{G_i \cdot G_j \cdot P_i}{L(i,j)}, \qquad (1)$$

where G_i and G_j are the antenna gains at transmitter i and receiver j, L(i,j) is the path loss between i and j. The SINR of j is as below:

$$SINR=10\log_{10}\left(\frac{(G_i \cdot G_j \cdot P_i)/L(i,j)}{B \cdot N_0 + I(i,j)}\right), \qquad (2)$$

where B is the effective frequency band, N_0 is the thermal noise level and I(i,j) is the interference from other transmitter, which can be evaluated by:

$$I(i,j)=\sum_{l \neq i}\widetilde{P}(l,j) \qquad (3)$$

III. OUR PROPOSED ALGORITHM

In this section, we present how the proposed algorithm dynamically organizes the cooperating set (or cluster) to offload the traffic. First, we assume that every BS, in the very beginning, operates independently, i.e., initially, every BS itself is a cooperating set of size 1. Considering that somewhere (or some BS) in the system may have a big activity or event with gathered crowds, so traffic demand increases. This induces much people cannot communicate to the network. To solve this problem, we propose to dynamically organize the cooperating set by inviting the BSs around the overload area based on the actual traffic distribution and the status of the neighbor BSs. Then the cooperating set effectively disperses the overloading traffic demand to the BSs with free resource via DCS, thus enhancing the spectrum efficiency. Our method is composed of two parts: In the first part, we consider the direct adjacent BSs to the overload BS (C_h), i.e., one-hop neighbors of C_h, denoted by $\Psi^1{}_{Ch}=\{N^1{}_i, i=1..6\}$, $N^1{}_i$ is the i_{th} direct adjacent cell of C_h. To alleviate the load of C_h, the users, which are originally serviced by C_h and are also covered by any neighbor BS in $\Psi^1{}_{Ch}$, are dynamically scheduled to use the free resource of cells in $\Psi^1{}_{Ch}$ via DCS, i.e., transferring part of the edge users from C_h to neighbor BSs, $N^1{}_i$, i = 1..6. If overload still exists after all $N^1{}_i \in \Psi^1{}_{Ch}$, i=1..6, joining the cooperating set, our method will continue the second part. In the second part, the BSs which are adjacent to the cooperating set are considered; note that they are not directly adjacent BSs of C_h but two-hop neighbors of C_h. Then, we continue select suitable BSs to join the cooperating set. These BSs can *relay* their resource to $N^1{}_i$, i = 1..6, by serving $N^1{}_i$'s edge users, thus increasing the free resource of $N^1{}_i$ which can be used to offload more users in C_h. In TABLE II, we summarize all notations used in the paper.

TABLE II. SUMMARY OF NOTATIONS

Notation	**Meaning**
C_h	Overload cell or cluster head
ψ^1_{Ch}	The set of one-hop neighbor BSs of C_h, i.e., $\psi^1_{Ch}=\{N^1_i$, i=1..6}
ψ^2_{Ch}	The set of two-hop neighbor BSs of C_h, i.e., $\psi^2_{Ch}=\{N^2_j$, j=1..12}
T	The capacity of a BS in one subframe (in PRB)
π	The Total amount of overload traffic demand of C_h per subframe
$\alpha_{m,n}$	The amount of demand which is served by cell m and is also covered by cell n
$\beta_{u,v}$	The amount of free resource in the cell edge of cell v which can be provided to cell u
G	The set of member cells in the cluster (or cooperating set)
S	The set of candidate cells for the cluster
W_m	Weight of cell m

A. Selecting One-hop Neighbors

This part selects suitable directly adjacent BS for the cooperating set (in the rest of the article, we use cluster instead of cooperating set, denoted by G). We select BSs to join cluster G by considering the following three parameters, $\alpha_{m,n}$, $\beta_{u,v}$ and $F(N^1_i, G)$, where $\alpha_{m,n}$ is the amount of traffic demand which is served by BS m and is also covered by BS n, $\beta_{u,v}$ is the amount of free resource in the cell edge of BS v which can be provided to BS u and $F(N^1_i, G)$ is to calculate the number of adjacent edges between BS N^1_i and G. For each directly adjacent BS i of G, we calculate its weight W_i according to the three parameters. The BSs with the greater W_i are preferred to join cluster G. W_i are defined as follows:

$$W_i = X\times\alpha_{Ch,i} + Y\times\beta_{Ch,i} + (1-X-Y)\times F(N^1_i,G). \quad (4)$$

Larger $\alpha_{Ch,i}$ represents that C_h has more potential to transfer its cell edge demand to BS N^1_i, while larger $\beta_{Ch,i}$ means that BS N^1_i has more free resource in the cell edge. $F(N^1_i, G)$ measures the overlapping area between BS N^1_i and cluster G. The greater the overlapping area is the more potential resource can be borrowed to cluster G. Carefully observing the relationship between $\alpha_{Ch,i}$, $\beta_{Ch,i}$ and π (π is the total amount of overload traffic demand of C_h), three characteristics as below can be found. I. When $\pi < \alpha_{Ch,i}$ and $\beta_{Ch,i}$, it means that N^1_i has enough resource ($\beta_{Ch,i}$) to solve the overload condition of C_h and C_h has sufficient demand ($\alpha_{Ch,i}$) in the overlapping area between C_h and N^1_i. Transferring part of the demand in $\alpha_{Ch,i}$ can solve the overload problem. II. When $\beta_{Ch,i} < \alpha_{Ch,i}$ and π, it represents that N^1_i does not have enough free resource to solve the overload condition, but it is still possible for N^1_i to relay resources of N^2_j to increase $\beta_{Ch,i}$ to help offload the traffic of C_h. III. When $\alpha_{Ch,i} < \beta_{Ch,i}$ and π, it means that, C_h does not have enough demand ($\alpha_{Ch,i}$) in the overlapping area, so it is impossible for N^1_i to help to solve the overload problem even $\beta_{Ch,i} \geq \pi$ or relaying more resource from N^2_j. In the following, we illustrate how we select cells in set Ψ^1_{Ch} to join G.

Step1. If some cell C_h overloads, our scheme starts executing.

Step2. $G=\{C_h\}$, $A=\emptyset$ and $S=\emptyset$ and calculate π, consider to add directly adjacent cells of C_h into G first, i.e., $S=\{N^1_i, i=1..6\}$, and calculate $\alpha_{Ch,i}$, $\beta_{Ch,i}$ and W_i for each $N^1_i \in S$.

Step3. Select the cell N^1_{i*} in S with the greatest W_{i*} to join cluster G. Update $G=G+\{N^1_{i*}\}$ and $S=S-\{N^1_{i*}\}$.

Step4. If the relationship of π, $\alpha_{Ch,i*}$ and $\beta_{Ch,i*}$ conforms condition I, terminate the scheme and stop organizing the cooperating set. G is the final cooperating set; otherwise, go to next step.

Step5. If the relationship of π, $\alpha_{Ch,i*}$ and $\beta_{Ch,i*}$ conforms characteristic II, means that N^1_{i*} can provide only limited PRBs, but N^1_{i*} still has the possibility to relay free resource from the outer BSs (C_h's two-hop neighbors) to increase $\beta_{Ch,i*}$ to solve the overload problem. Update $A=A+\{N^1_{i*}\}$ (which will be used in the 2nd part of the proposed method and which is illustrated in Sec. 3.B). If the relationship of π, $\alpha_{Ch,i*}$ and $\beta_{Ch,i*}$ conforms characteristic III, this means that N^1_{i*} cannot solve the overload problem even relay free resource from the outer BSs, so do not add N^1_{i*} into A.

Step6. For each $N^1_{i*} \in S$, update $\alpha_{Ch,i}$, $\beta_{Ch,i}$ and W_i. Update π, too.

Step7. If S is empty, go to Step 8; otherwise, go back to Step3.

Step8. If $\pi \neq 0$ and $A \neq \emptyset$, enter the procedure of relaying external resources of two-hop neighbors in Sec. 3.B. The procedure continues inviting the two-hop neighbors of cluster head C_h to solve the overload problem. Otherwise, the algorithm is over. G is the final cooperating set.

B. Relaying External Resource of Two-hop Neighbors

In this part, we consider to invite the two-hop neighbors of C_h to join cluster G. Two-hop neighbors are not directly adjacent to C_h, so they cannot serve the demand of C_h directly. But they can serve the demand of C_h's one-hop neighbors, thus increasing $\beta_{Ch,i}$ of $N^1_i \in \Psi^1_{Ch}$. This is what we call "relay external resource". By this way, we can increase $\beta_{Ch,i}$ such that BS N^1_i is able to offload more C_h's overload demand. Note that the amount of resource a BS $N^2_j \in \Psi^2_{Ch}$ can transfer is limited to $\min\{\alpha_{i,j}, \beta_{i,j}\}$. Also, for N^1_i, the amount of demand it can offload from C_h is limited to $\alpha_{Ch,i}$. In the following, we illustrate how we add two-hop neighbors of C_h to G.

Step1. For set A, we select the $N^1_{i*} \in A$ which has the greatest $\alpha_{Ch,i*}$. Considering the adjacent BSs of N^1_{i*} and they need to be the two-hop neighbors of C_h, i.e., $N^2_j \in (\Psi^2_{Ch} \cap \Psi^1_{i*})$, $j=1..|\Psi^2_{Ch} \cap \Psi^1_{i*}|$, update $S=\{N^2_j | N^2_j \in (\Psi^2_{Ch} \cap \Psi^1_{i*})\}$ and $A=A-\{N^1_{i*}\}$. For each $N^2_j \in S$, calculate $\alpha_{i*,j}$, $\beta_{i*,j}$ and W_j, where W_j is defined as:

$$W_j = X\times\alpha_{i*,j} + Y\times\beta_{i*,j} + (1-X-Y)\times F(N^2_j,G). \quad (5)$$

Step2. Calculate π. Select the N^2_{j*} in S with the greatest weight W_{j*} to join G, i.e., $G=G+\{N^2_{j*}\}$ and update $S=S-\{N^2_{j*}\}$.

Step3. If $\pi \leq \alpha_{i*,j*}$ and $\beta_{i*,j*}$ (otherwise go to Step4), it means that N^2_{j*} has enough free resource which can be relayed to N^1_{i*} to alleviate the overload problem. In this way, if $\pi \leq \alpha_{Ch,i*}$, set $\pi=0$ and $G=G \cup \{N^2_j\}$. The algorithm is over. G is the final cooperating set; otherwise ($\pi > \alpha_{Ch,i*}$), update $\pi = \pi-\alpha_{Ch,i*}$ and $S=\emptyset$ and go back to Step1 if $A \neq \emptyset$ or else terminate the algorithm and return G if $A=\emptyset$.

Step4. $\beta_{i*,j*} < \alpha_{i*,j*}$ and π (otherwise, go to Step5), N^2_{j*} only have limited free resource to relay to N^1_{i*}. In this case, if $\beta_{i*,j*} \geq \alpha_{Ch,i*}$, update $\pi=\pi-\alpha_{Ch,i*}$ and $S=\emptyset$. If $A \neq \emptyset$, go back to Step1. If $A=\emptyset$, our algorithm is over and return G. Otherwise, if $\beta_{i*,j*} < \alpha_{Ch,i*}$, update $\pi=\pi-\beta_{i*,j*}$ and $S=S-\{N^2_{j*}\}$, renew $\alpha_{i*,j'}$, $\beta_{i*,j'}$, $W_{j'}$ and $\alpha_{Ch,i*}$ for each $N^2_{j'} \in S$. If $S \neq \emptyset$, go back to Step2. If $S=\emptyset$ and $A \neq \emptyset$, go back to Step1. If $S=\emptyset$ and $A=\emptyset$, return G and terminate the scheme.

Step5. If $\alpha_{i*,j*} < \beta_{i*,j*}$ and π and $\alpha_{i*,j*} \geq \alpha_{Ch,i*}$, update $\pi=\pi-\alpha_{Ch,i*}$ and $S=\emptyset$. If $A \neq \emptyset$, go back to Step1. If $A=\emptyset$, our algorithm is over and return G. On the other hand, if $\alpha_{i*,j*} < \beta_{i*,j*}$ and π and $\alpha_{i*,j*} < \alpha_{Ch,i*}$, update $\pi=\pi-\alpha_{i*,j*}$, $S=S-\{N^2_{j*}\}$, $\alpha_{i*,j*}$ and $\alpha_{Ch,i*}$ and renew $\alpha_{i*,j'}$, $\beta_{i*,j'}$, $W_{j'}$ for each $N^2_{j'} \in S$. If $S \neq \emptyset$, go back to Step2. If $S=\emptyset$ and $A \neq \emptyset$, go back to Step1. If $S=\emptyset$ and $A=\emptyset$, our method is over and return G as the final cooperating set.

IV. SIMULATION RESULTS

In this section, we evaluate the performance of the proposed Dynamic Cooperating Set Planning (DCSP) method in LTE/LTE-A networks. In the network, we consider 19 cells. The bandwidth of the system is 10 MHz. The transmission power of a BS and a UE are 46dBm and 23dBm. The inner area of each cell occupies 2/3 of the total area. The data rate of each user is 500kbps. The amount of TTI in a subframe is 50. 2 TTIs are for control signaling, while 48 TTIs are for data transmission. To alleviate the interference problem, we adopt SFR model. The bandwidth is partitioned into three equal subbands. Two subbands, 32 TTIs, are used in inner area and one subband, 16 TTIs, is used in outer area. No adjacent cells use the same subband for the outer area. The transmission power of outer area is twice that of inner area. The system parameters are summarized in TABLE III.

TABLE III. SYSTEM PARAMETERS

Parameters	Values
Carrier frequency	2GHz
Bandwidth	10MHz
Cell radius	500m
UE distribution	Uniform random distribution
eNode B/UE Tx power	46 dBm/23 dBm
eNode B/UE Tx gain	14 dBi/0 dBi
Distance-dependent distance	$128.1+37.6\log_{10}d(\text{dB})$，d in km
Thermal noise	-174 dBm/Hz
Number of users in the system	190
Number of users in C_h	300

We compare our DCSP scheme with SCSP (Static Cooperating Set Planning) and single (no CoMP). Every 3 BSs form a cooperating set in SCSP, while our DCSP dynamically organize cells into the cooperating set depending on the actual traffic situation.

Our simulation analyzes the effects of following four parameters: number of users in the overload cell (N_{Ch}), number of users in the system (N), cell radius (R) and the distance between cells. We observer the effects of these four parameters on the system throughput, number of dropped users and cluster size. All users are uniformly distributed in the system unless otherwise started.

A. Effect of N_{Ch}

In this experiment, we uniformly distribute 190 users over the network. Then, N_{Ch} is gradually increased to see its effect on the system throughput, number of drooped users and cluster size. As we can see in Figure 3(a) As N_{Ch} increase, the system throughput increases for all schemes. Our DCSP scheme outperforms SCSP and single. This is because DCSP will dynamically invite ambient cells to join the cluster to help offload the overloading traffic according to the actual situation. SCSP is better than single because the other two cells in the cooperating set that C_h resides can help offload C_h's traffic. When N_{Ch} is more than 240, Figure 3(a) shows that the system throughput of DCSP converges. This is mainly because the amount of free resource in the outer area of cells other than C_h is limited, i.e., $\beta_{u,v}$ limits the system throughput. Figure 3(b) shows the effect of N_{Ch} on the number of dropped users. As N_{Ch} increases, number of dropped users increases. In

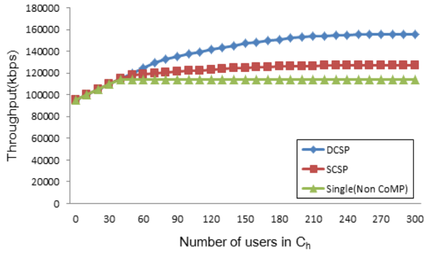

Figure 3(a). Throughput vs. number of users in C_h

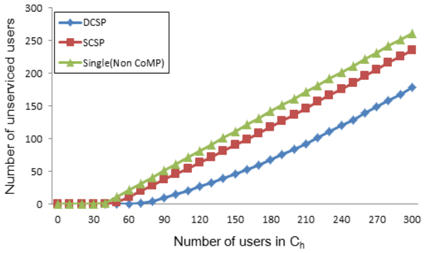

Figure 3(b). Number of dropped users vs. number of users in C_h

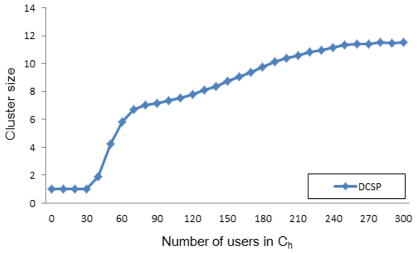

Figure 3(c). Cluster size vs. number of users in C_h

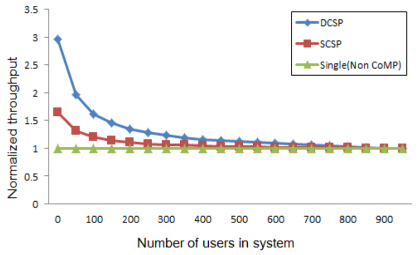

Figure 4(a). Throughput vs. number of users in the system

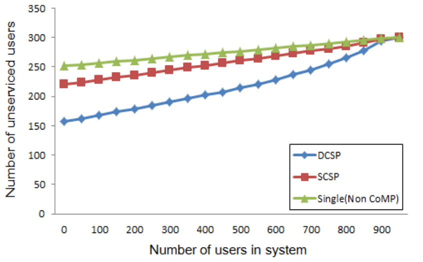

Figure 4(b). Number of dropped users vs. number of users in the system

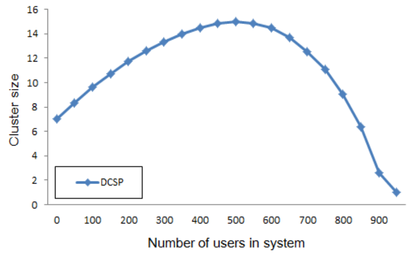

Figure 4(c). Cluster size vs. number of users in the system

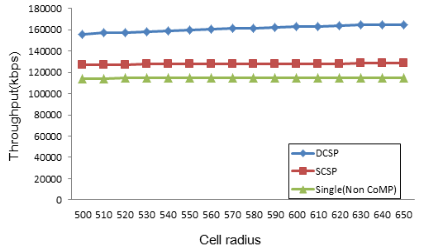

Figure 5(a). Throughput vs. cell radius

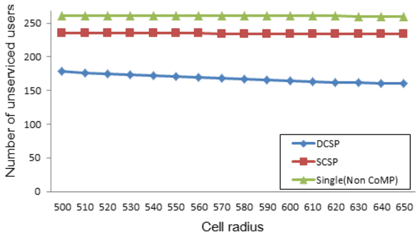

Figure 5(b). Number of dropped users vs. cell radius

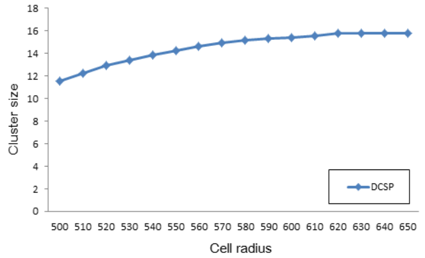

Figure 5(c). Cluster size vs. cell radius all three schemes, DCSP performs the best, SCSP the second and single the third. In DCSP, when N_{Ch} comes to 70, the system starts to drop users. This is because N_{Ch} users are uniformly distributed in cell C_h. For those users in the inner area, they are dropped once the inner runs out of all the resource because they are not in the overlapping area of cells. Figure 3(c) shows the effect of N_{Ch} on the cluster size. We can see that DCSP adds surrounding BSs to the cluster according to the actual traffic situation. Initially, DCSP invites only the one-hop neighbors to help to offload traffic. As N_{Ch} overs a point, two-hop neighbors start to join the cluster. The cluster size converges at 12 cells because not all two-hop neighbors help. If there no users located in the overlapping area between C_h's one-hop and two-hop neighbors ($\alpha_{i,j}$), it is impossible for a two-hop neighbor of C_h to relay resource to the one-hop neighbor of C_h.

B. *Effect of N*

In this subsection, we gradually increase the number of users in the system (N) to see the changes of normalized throughput number of dropped users and cluster size. As we can see from Figure 4(a), normalized throughput decreases when N increases. This is because $\beta_{u,v}$ decreases as the number of users in the system increases, i.e., the amount of free resource in the cell edge decreases as N rises such that the surrounding cells of C_h can offload limited traffic for C_h. Figure 4(b) illustrates the number of dropped users over different N. Overall, DCSP schemes outperforms SCSP and single. Figure 4(c) shows the impact of N on the cluster size. Initially, cluster size increases as N increases. This is because the $\beta_{u,v}$ decreases as N increases, then C_h has to invite more cells to join the cluster to offload its overloading traffic. When N is over 500, the cluster size starts decrease because more and more cells run out of their resource and cannot join the cluster to help to offload C_h's traffic.

C. *Effects of R*

In this subsection, we increase the cell radius to observe its impact. Actually, fixing the locations of cells, increasing R will increase the overlapping area between cells. This can increase $\alpha_{m,n}$ which limits the amount of demand being able to transfer to neighbor cell. As we can see from Figure 5(a), the system throughput of DCSP and SCSP increases as R increases Figure 5(b) shows that for both DCSP and SCSP, number of dropped user degrades when R rises. In both Figure 5(a) and 5(b), our DCSP performs the best and enhances the most when R increases. Figure 5(c) shows that as R increases, the cluster size increases, too. This is because a larger R increases $\alpha_{m,n}$ such that more transferable demand exists in the overlapping area between cells.

V. CONCLUSIONS

In this paper, we study how to form dynamic cooperating set of CoMP in LTE/LTE-A networks. Combined with CoMP, our proposed DCSP scheme can effectively alleviate the overloading condition in the system and improve the overall system throughput. Compared to the previous schemes, DCSP's system throughput is 1.36 and 1.23 times that of single and SCSP schemes, respectively DCSP forms cooperating set in a dynamic and efficient way, i.e., it always finds the least number of surrounding cells to organize the co-operating set. This prevents the excessive growth of the system complexity. Simulation results show that the performance can be further improved by increasing the radius of cells or reducing the distance between cells. This is because more users or demand will be located in the overlapping area such that the number of transferable users or demand increases. In the future work, we will study how to adjust the cell radius of BSs to enhance the system performance.

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