Time Detection Based Hybrid Clustering Strategy for JP-CoMP in LTE-A

Fengfei Song(✉), Liqiang Zhao, Kai Liang, and Cheng Guo

State Key Laboratory of Integrated Service Networks, Xidian University, Xidian 710071, Shaanxi, China
Song.fengfei@hotmail.com

Abstract. Coordinated multipoint (CoMP) has been applied as a key technology to enhance the coverage of cell and mitigate the intercell interference (ICI) in LTE-A. Traditional fundamental research of cell clustering for CoMP concentrates on both static and dynamic clustering. However, in the high data demands and heavy ICI scenario, both the static and dynamic clustering cannot ensure good Quality of Service (QoS) for User Equipments (UEs). Hence, in this paper, we formulate the problem to maximize cell-edge throughput and analysis the system complexity, and the time detection based hybrid clustering strategy for JP (Joint Processing)-CoMP is proposed to solve this problem. Based on LTE system level platform, simulation results show that the proposed scheme has better performance than static clustering even gets close to dynamic clustering with less complexity.

Keywords: JP-CoMP · Hybrid clustering · Time detection · ICI · LTE-A

1 Introduction

Demands for mobile communications services and high data rates are increasing rapidly, which require better performance of wireless mobile communication service. Frequency reuse is an effective solution to meet the high data rate. The long-term evolution-advanced (LTE-A) system adopts Orthogonal Frequency Division Multiple Access (OFDMA), which can enhance the spectral efficiency as far as possible. Meanwhile, OFDMA can better eliminate the intra-cell interference with the cost of greater ICI. To mitigate the ICI, the 3rd Generation Partnership Project (3GPP) proposed CoMP and Inter-Cell Interference Coordination (ICIC) in LTE-A. Fundamental research has proved that CoMP is an advanced wireless mechanism to mitigate ICI, enhance the spectral efficiency and cell edge data rates [1].

The most basic principle of CoMP is to utilize multiple transmit and receive antennas from several different Transport Points (TPs). By making use of co-channel interference among different coordinated cells in coordinated downlink transmission, CoMP can effectively improve the interference environment to

J.-H. Lee and S. Pack (Eds.): QShine 2016, LNICST 199, pp. 365–373, 2017.
DOI: 10.1007/978-3-319-60717-7_36

enhance the signal quality as well as to improve spectrum efficiency and increase the coverage area [2]. During the evaluation of CoMP, in Release 11, different kind of CoMP schemes have been put forward under a tight backhaul between eNBs, such as Coordinated Scheduling and Coordinated Beamforming (CS/CB) and JP [3]. The latter promises larger throughput and spectral efficiency than CS/CB by changing the interference signal into useful signal.

CoMP may require additional signal overhead on the air interface and backhaul. Therefore, only a limited number of TPs can participate in cooperation to meet the limited capacity backhaul demands. User selection should be done to indicate which TPs should form cooperation clusters [4]. Multi-trans points form a cluster which jointly serves a group of UEs in CoMP, the key of clustering for JP-CoMP is designing proper scheduling scheme to suppress the ICI.

In general, clustering can be categorized into static and dynamic clustering. Static clustering is designed based on geographical criteria as the position of TPs and the surrounding of cells, and the cooperative TPs will keep constant over time [4,5]. Therefore, it requires little signal overhead and less complexity. In addition, there are many strengths of static cluster such as fairly simple clustering algorithms, low complexity and relatively stable system. However, due to the irregular movement of UEs and the fast change of the interference environment, it cannot provide best serving performance to each UE in actual application. In the case of dynamic clustering, the system continuously adapts the clustering strategy to meet the fast change of UE locations and radio frequency (RF) conditions [4–6]. Because of its stronger sensitivity and adaptability to channel changes, dynamic clustering can guarantee the system performance keeps in the optimal state. But with the fast change of cluster structure, leading to high information sharing and heavily backhaul delay among cooperative TPs [7], meanwhile, the complexity of the system increased comparing to the static clustering.

In this paper, we propose a time detection based hybrid clustering strategy, for the purpose of maximizing the throughput of cell edge and minimizing the system complexity. Basing on the LTE system level platform, the performance gain is evaluated in terms of cell-edge and average throughput, system complexity and spectral efficiency.

The rest of the paper is organized as follows. In Sect. 2, we state a centralized cluster with JP-CoMP model for time detection based hybrid clustering, and the detail description of proposed scheme is given in Sect. 3. The simulation results and discussion are provided in Sect. 4 and followed by conclusions in Sect. 5.

2 System Model

To illustrate the system models for CoMP in downlink transmission, a centralized cluster with JP-CoMP model [4,7] is considered in this paper, as show in Fig. 1. A central unit (CU) performs all preprocessing for a cluster of cooperating cells. In other words, the CU collects the UEs' CSI firstly. Secondly the clustering strategy and coordinated scheduling to optimize network performance in coordination area are processed. Finally, those signal will be quantized and transmitted to each TP.

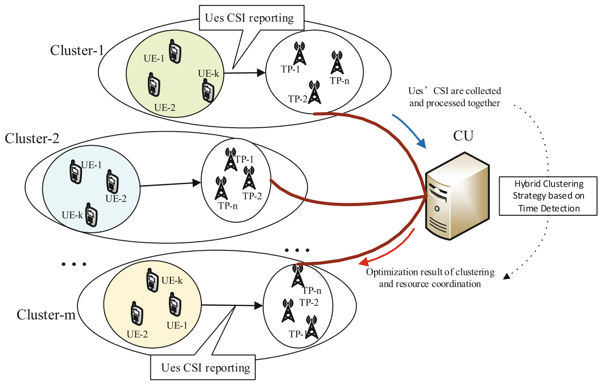

Fig. 1. System model

Each eNB serves three hexagonal cells through three high transmission power Remote Radio Heads (RRHs) that each cover one cell area. Following 3GPP standards, we considered the homogeneous network consisting of 7 eNBs that each one has three sectors, thereby making a total number of 21 sectors. The path loss between UEs and TPs is given by [5].

$$PL = 130.5 + 37.6\lg(\frac{d}{km})[dB] \tag{1}$$

The antenna loss is affected by many factors, such as the antenna azimuth of TPs and UE, maximum attenuation. We consider the 20 dB as the maximum attenuation, and the antenna model is:

$$AL(\theta) = \min(12|\frac{\theta}{65}|^2, 20)[dB] \tag{2}$$

Assume that there are M UEs and N cells. The signal to interference plus noise ratio (SINR) of the mth UE in the Kth cluster [5] can be expressed as:

$$SINR_m^K = \frac{P \cdot \sum\limits_{k \in K} \lambda_m^k}{P \cdot \sum\limits_{k \in \{N \setminus K\}} \lambda_m^k + \sigma^2}[dB] \tag{3}$$

where λ_m^k represents the path gain of the UE m served from the coordinated cell k. P is the transmission power of the RRH and σ^2 is the noise power the UE m has received.

The received power of UE m^k is given by:

$$Pr_m^k = P - PL_m^k - AL(\theta_m^k)[dB] \tag{4}$$

In addition, the throughput of the mth UE in the Kth cluster can be expressed as:

$$TP_m^K = B \cdot \log(1 + SINR_m^K)[bps] \tag{5}$$

3 Time Detection Based Hybrid Clustering Strategy

As mentioned in previous sections, the mechanism of static clustering cannot provide best serving performance for UEs. In the meanwhile, the dynamic clustering may cause heavy backhaul delay and high complexity. Therefore, we aim at maximizing the cell edge throughput and minimizing the system complexity and the time detection based hybrid clustering strategy is proposed in this paper.

3.1 Basic Idea

Time detection means in every major cycle, and for those base stations (BSs), whose channel state have no significant change, and the coordinated cluster of those BSs will not change obviously. In other words, their coordinated cluster will appear repeatedly or with high probability in one period. Therefore in next major cycle, those clusters appearing repeatedly or with high probability will use static clustering, and dynamic clustering will be used to those variable structure clusters. This is mentioned as hybrid clustering and specific introduction will be given in the next section.

3.2 The Proposed Solution

We consider a major cycle L consists of nT (T represent one Transmit Time Interval (TTI)), and set a experienced threshold value $SINR_{th}$ to distinguish the edge and center UEs.

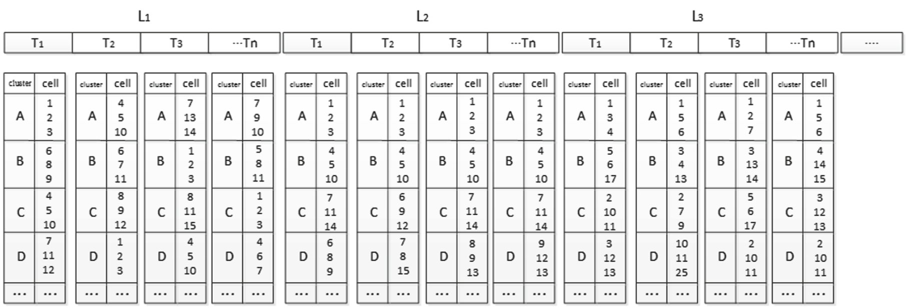

Fig. 2. Cluster structure instructions for time detection based hybrid clustering strategy

Figure 2 is an example for the time detection based hybrid clustering, and the proposed scheme works as following steps:

- *step*1. Dividing the edge and center UEs:
  - if $SINR_m^K < SINR_{th}$, the UE m is considered as cell edge user;
  - else if $SINR_m^K \geq SINR_{th}$, the UE m is considered as center user.
- *step*2. Dynamic clustering for cycle L_1. And storage the clustering information $C_1 = \{C_{11}, C_{12}, C_{13}, \ldots, C_{1i}\}$[1].
- *step*3. Divide cluster information C_1 into three types[2]:
  - fixed structure cluster $F_1 = \{F_{11}, F_{12}, F_{13}, \ldots, F_{1i}\}$
  - high frequency cluster $H_1 = \{H_{11}, H_{12}, H_{13}, \ldots, H_{1j}\}$
  - variable structure cluster $V_1 = \{V_{11}, V_{12}, V_{13}, \ldots, V_{1k}\}$.
- *step*4. Clustering in cycle L_2.
  - if $F_1 \neq \emptyset$ or $H_1 \neq \emptyset$, using hybrid clustering. Static clustering[3] for those cells of F_1 and H_1, dynamic clustering for the rest cells of V_1.
  - else if using dynamic clustering for all cells.
- *step*5. Loop *step*2 to get clustering information C_2 and classified to get the results of F_2, H_2 ,V_2.
- *step*6. Simplified dynamic clustering of L_3.
  - the member cells of F_2 and H_2 give priority to the members of the same cluster when doing dynamic clustering in cycle L_3
- *step*7. End.

3.3 Analyzation and Discussion

First in each cycle L_n, each UE reports its CSI to the serving eNB in every TTI. Then CU can make the best resource allocation scheme and optimizing clustering strategy for coordinated cells according to CSI. In addition, in *step*4, static cluster is used to those cells belonging to F_i and H_j to reduce the cost of computation, and dynamic clustering is used to adapt the fast changing of wireless channel from BS to UEs. Moreover, the structure of F_i and H_j may have changed through serval cycle because of the change of wireless channel environment due to UEs random motion. So every few cycles one global dynamic clustering operation is necessary. In our scheme, the operation of dynamic clustering is used every three cycles. Finally, the *step*6 can not only reduce the complexity for the dynamic clustering in our architecture, but also balance the changes of wireless environment.

Taking advantages of dynamic clustering and static clustering, the proposed strategy makes clustering decision aiming at optimizing the system performance and minimizing the system complexity based on channel conditions in the previous and current slots.

---

[1] Such as clusters of (1,2,3), (4,5,10),. . . ,(7,11,12) constitute C_{1i} in Fig. 2.

[2] As shown in Fig. 2, the fixed structure such as cell 1, 2, 3 is integrated a cluster (1,2,3) in each TTI of cycle L_1. The cluster (4,5,10) which appears frequently in most of TTI of cycle L_1 represents the high frequency cluster. Moreover the cluster structure changes obviously refers to variable structure cluster, such as clusters (6,8,9), (7,11,12) and (6,7,11).

[3] On the basis of the fixed structure of F_1 and H_1, (1,2,3) and (4,5,10) is processed as static cluster, and the cells of V_1 clustering in the mechanism of dynamic clustering for cycle L_2 in Fig. 2.

4 Simulation Results

According to Release 11 [8], some simulation parameters are used in the LTE system level simulator. First, we simulate 7 eNBs with 21 sectors using 2.14 GHz as the LTE frequency and 20 MHz as the bandwidth, the inter site distance (ISD) is considered as 500 m in the urban area. Besides, there are 20 UEs randomly distributed in one cell, the total of UE is 420, and they irregularly moving with the rate of 5 km/h. The full buffer traffic model is considered in our simulation. Some simulation parameters are listed in Table 1. Figure 3 shows SINR and the assignment of eNBs.

Table 1. Model parameters

Parameters	Value
Cell layout	7 eNBs/21 sectors (cells)
UE number	20 UEs/cell, total 420 UEs
ISD	500 m
Carrier frequency	2.14 GHz
Bandwidth	20 MHz
UEs rate	5/3.6 m/s
Resource block	100 RBs/cell
Scheduler	Round-robin
Traffic model	Full buffer
Channel model	ITU Pedestrian B channel
Simulation time	50 TTI

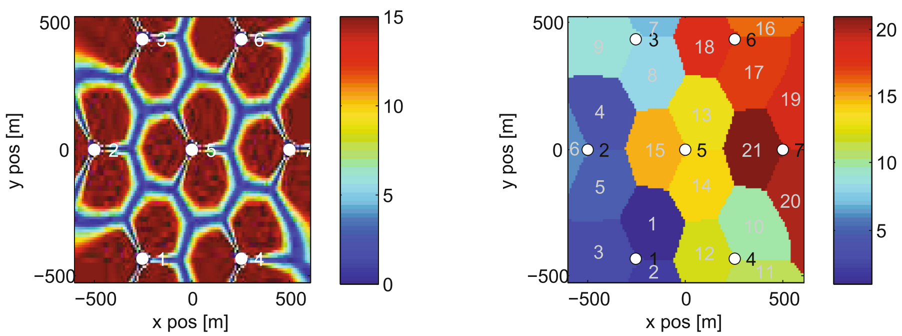

Fig. 3. SINR for different area, the assignment of eNBs and sectors

To verify the performance of the proposed scheme, we simulate Non-CoMP, Static-cluster and Dynamic clustering with different optimization criteria for comparison.

Figure 4 shows the evaluation of UEs throughput, and the cumulative density functions (CDF) is plotted in the Fig. 5. The corresponding simulation value of mean throughput, cell-edge throughput and peak throughput for four schemes are listed in Table 2. As shown in Fig. 4, the throughput of cell-edge UEs sharply increase after taking the operation of JP-CoMP. In addition, the mean and peak throughput also get improvement. What's more, the cell-edge throughput of hybrid clustering is better than static clustering and close to dynamic clustering.

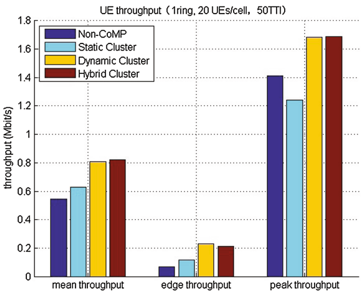

Fig. 4. UEs throughput

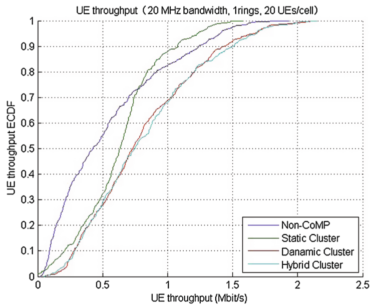

Fig. 5. UEs throughput CDF

Table 2. The UEs throughput (Mbit/s)

Throughput	Non-CoMP	Static	Dynamic	Hybrid
Edge	0.07(0)	0.12(↑71.4%)	0.23(↑228.6%)	0.21(↑200.0%)
Mean	0.54(0)	0.63(↑16.7%)	0.81(↑50.0%)	0.82(↑51.9%)
Peak	1.41(0)	1.24(↓12.1%)	1.68(↑19.1%)	1.69(↑19.9%)

In the previous introduction, we expect to reduce the complexity to cut the system overhead. By recording the simulation runtime and normalized processing, the evaluation of normalized complexity compared to dynamic cluster is shown in the Fig. 6. We can easily know that the complexity of our scheme is slightly higher than static clustering, but slightly lower than dynamic clustering. The algorithm complexity of hybrid clustering is between static clustering and dynamic clustering. Hence, the proposed clustering algorithm can not only enhance the cell-edge throughput but also reduce the complexity. It can be a very practical scheme for limited overhead JP-CoMP system.

The Figs. 7 and 8 show the average coordinated cell throughput and the average spectral efficiency of Non-CoMP, static clustering, dynamic clustering and hybrid clustering. And the simulation values of cell throughput are 10.88, 12.61, 16.17, 16.38 (Mb/s), compared with Non-CoMP, increasing by 15.9%, 48.6% and 50.5%. In addition, the spectral efficiency are 0.67, 1.05, 1.13, 1.14

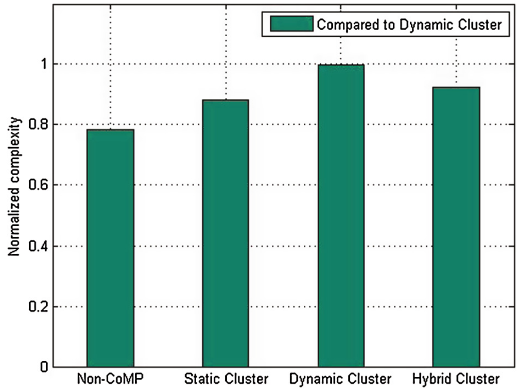

Fig. 6. Normalized complexity.

(bit/cu), and increasing by nearly 49.2%, 68.6% and 70.1% matching to Non-CoMP, respectively. In short, it clearly shows that the proposed hybrid clustering strategy performs as good as dynamic cluster in improving the throughput for UEs.

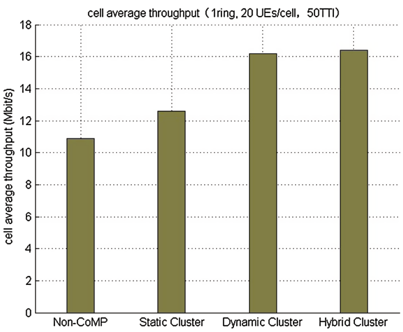

Fig. 7. Cell average throughput

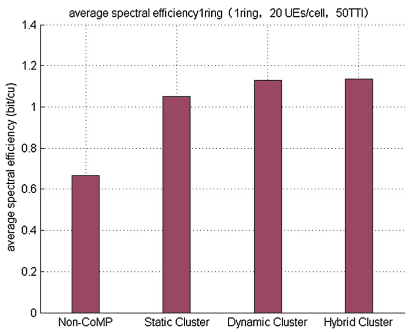

Fig. 8. Average spectral efficiency

5 Conclusion

In this paper, we investigate the homogeneous network CoMP architecture, and propose a time detection based hybrid clustering strategy for JP-CoMP. The simulation results show that our scheme can not only enhance the cell-edge throughput and spectral efficiency but also reduce the system complexity compared to non-CoMP, static and dynamic clustering based on LTE system level simulator. Hence, it can be more suitable to the limited overhead CoMP system.

Acknowledgement. This work was supported in part by National Natural Science Foundation of China (61372070), Natural Science Basic Research Plan in Shaanxi Province of China (2015JM6324), Ningbo Natural Science Foundation (2015A610117), National Science and Technology Major Project of the Ministry of Science and Technology of China (2015zx03002006-003), and the 111 Project (B08038).

References

1. Muqaibel, A.H., Jadallah, A.N.: Practical performance evaluation of coordinated multi-point (CoMP) networks. In: Proceedings of the 8th IEEE GCC Conference and Exhibition (GCCCE), Muscat, pp. 1–6. IEEE Press (2015)
2. Ali, M.S., Synthia, M.: Performance analysis of JT-CoMP transmission in heterogeneous network over unreliable backhaul. In: International Conference on Electrical Engineering and Information Communication Technology (ICEEICT), Dhaka, pp. 1–5. IEEE Press (2015)
3. Cui, Q., Wang, H., Hu, P., Tao, X., Zhang, P., Hamalainen, J., Xia, L.: Evolution of limited-feedback CoMP systems from 4G to 5G: CoMP features and limited-feedback approaches. IEEE Veh. Technol. Mag. **9**(3), 94–103 (2014). IEEE Press
4. Weber, R., Garavaglia, A., Schulist, M., Brueck, S., Dekorsy, A.: Self-organizing adaptive clustering for cooperative multipoint transmission. In: 73rd Vehicular Technology Conference (VTC Spring), Yokohama, pp. 1–5. IEEE Press (2011)
5. Marsch, P., Fettweis, G.: Static clustering for cooperative multi-point (CoMP) in mobile communications. In: 2011 IEEE International Conference on Communications (ICC), Kyoto, pp. 1–6. IEEE Press (2011)
6. Irmer, R., et al.: Coordinated multipoint: concepts, performance, and field trial results. IEEE Commun. Mag. **49**(2), 102–111 (2011)
7. Lee, H.J., Won, S.H., Kim, Y., Lee, J.: Centralized resource coordination scheme for Inter-enB CoMP with non-ideal backhaul. In: Globecom Workshops (GC Wkshps), Austin, TX, pp. 827–832. IEEE Press (2014)
8. 3GPP TR 36.819: Coordinated multi-point operation for LTE physical layer aspects (2011)