Research on Grouping Methods in CoMP Networks

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Abstract. Coordinated multi-point (CoMP) networks are inter-cell cooperation mechanisms specifically proposed to enhance transmission of users at cell edge. Therefore, selection appropriate group of cells to provide better transmission service is an important research topic in CoMP networks. In this paper, we proposed two grouping methods in CoMP networks including: (1) the arriving user accesses the same empty channels of his best and second best link quality cells and (2) if there are no same empty channels from his best and second best link quality cells, allow the arriving user to access one of the empty channels from his best or second best link quality cells. Simulation Results show that the proposed model can effectively evaluate influences of system performance of these two grouping methods.

Introduction

Cooperative techniques are proposed to exploit the spatial diversity gain via cells instead of using multiple antennas. Extensive research on cooperative techniques has been conducted in many communication domains [1-4]. By separating the communication link into two or more links, cooperative cells can provide effective solutions for mitigating the signal decay due to path loss and shadowing effects rather than increasing the transmission power. Research on using a group of cells instead of single cell techniques has been conducted.

Coordinated multi-point systems are using cooperative techniques and specified in 3rd Generation Partnership Project (3GPP) [5]. In traditional network communication, users can access only one cell. However, a CoMP-enabled user can communicate with more than one cell. One of the CoMP types is called “joint transmission” (JT) in downlink. By implementing JT, multiple cells can transmit the same data concurrently by using the same radio resources and improve the users’ reception performance. In the other hand, in order to minimize interference among cell-edge users, coordinated beamforming (CB) CoMP is used for selecting one of the cooperating cells as a transmission cell, and the cell can use beamforming technique to communicate with users. CB allocates different spatial resources (beam patterns) to users at cell edge by using smart antenna technology in downlink.

In this paper, we proposed two grouping methods, method 1 and method 2, which are appropriate for applying in JT and CB CoMP networks. First, we assume that each cell will broadcast a pilot signal on physical broadcast channel (PBCH). After receiving the pilot signals from the cells, the user equipment detects the pilot signal and can determine which $q$ best-quality links to be attached ($q$ is assumed to be 2 in this paper). In the proposed grouping method 1, the CoMP system will randomly assign one of the same empty channels from user’s best and second best link quality cells, called channel pair. The radio resource management of JT is one of the implementation case for our proposed grouping method 1. In the proposed grouping method 2, the CoMP system will first assign the empty channel pairs from user’s best and second best link quality cells if they exist. If there is no channel pair from user’s best and second best link quality cells, the CoMP system will allocate one of the single empty channels from user’s best or second best cells. The proposed grouping method 2 can be applied in JP/CB CoMP network. If the empty channel pairs within users’ best and second best cells exist, the JP mechanism will be used to enhance reception quality. If there are only single empty
channels within users’ best or second best cells, CB mechanism will be used to eliminate the cochannel interference and to provide services to different users at the same time.

The remainder of this paper is organized as follows. In section 2, the proposed network model for the CoMP networks are introduced. The proposed grouping method 1 and method 2 are presented in section 3. Finally, the summary is presented in section 4.

**Network Model**

The deployment of cells is assumed to be a checkerboard-like pattern. The network infrastructure is illustrated in Figure 1. The new user arrival rate in each square is assumed to be the Poisson distribution with mean $\lambda_T$. The user service time is assumed to be an exponential distribution with mean $\mu_e^{-1}$. The service area for each cell is assume to be a square illustrated in Figure 1 (Real cells). However, the service areas of edge cells and vertex cells are different from the service areas of centers. In order to evaluate the performance of whole networks which are composed of cells that have the same service area, the extra cells, named virtue cells, are added at the top and leftmost positions of the networks. The deployment of the network model extends the original $M \times M$ cell matrix to the $(M + 1) \times (M + 1)$ matrix. In Figure 1, the virtue cells, numbered 18, 19, and 20, are mirroring the real cells, numbered 14, 15, and 16, respectively. The virtue cells numbered 22, 23, and 24 are mirroring the real cells numbered 1, 5, and 9, respectively. The virtue cells numbered 17, 21, and 25 are only mirroring one real cell, numbered 13. The proposed infrastructure solves the problem of service area for every cell even if the positions of the cells are different. Therefore, the number of users arriving to the service area for every cell is statistically identical if the arriving users are assumed to be uniformly distributed in the network.

![Figure 1. The simulation model for the cooperative networks.](image)

**Grouping Methods**

The two proposed grouping methods are shown as follows.

Initialization for both Method 1 and Method 2:

(a.1) Let the network comprise $(M \times M)$ cells (including $(M - 1) \times (M - 1)$ real cells and $[M^2 - (M - 1)^2]$ virtue cells), and the number of channels in each cell is $N$. The cells are deployed uniformly in the checkerboard-like cell network at positions $(i, j)$, where $i, j = 0, 1, 2, \ldots, (M - 1)$.

(a.2) The channels in each cell are initially set as empty.
(a.3) The total number of users arrived is $K$. The users arrive one by one. Each user arrives to the network randomly and uniformly.
(a.4) The arrival time for user $k$ is $T^a_k$, where $k = 1, 2, \ldots, K$. The user arrival rate is assumed to be Poisson distribution with mean $\lambda_\tau$ for each square area; therefore, the mean user arrival interval time is $1/\lambda_\tau$. The initial value of $k$ is 1.
(a.5) The service time for each user $k$ is $T^s_k$, which is assumed to be exponential distribution with mean $\mu_\tau^{-1}$; therefore, the mean user service time is $\mu_\tau$.
(a.6) The time indexes for the next departure event, $T_d^\tau$, for the differential time from the previous event to the current event, $\Delta T^\tau$, and for the current timer, $T_c^\tau$, are initialized to be 0.
(a.7) The number of grouping success users, $k_g^\tau$, and the number of accessing success users, $k_a^\tau$, are initialized to be 0.
(a.8) The temp index for the channel utilization, $C^\tau$, is initialized to be 0.

**Method 1 Main Process**

(b.1) If $T_c^\tau \leq T^a_k$, go to step (b.2). Else, go to step (b.12).
(b.2) If $T^s_k \leq T_d^\tau$, go to step (b.3). Else, go to step (b.9).
(b.3) Calculate the channel utilization:
(b.3.1) $\Delta T^p = T^s_k - T_c^\tau$.
(b.3.2) $C = C + \text{(number of used channels/numbers of total channels of all cells)} \times \Delta T^p$.
(b.4) Randomly assign the coordinate $(x_k, y_k)$ for the arriving user $k$, where $x_k \in [0, 1, \ldots, (M-1)]$ and $y_k \in [0, 1, \ldots, (M-1)]$.
(b.5) Find the best and second best cells for user $k$ based on the shortest and second shortest distances from user $k$ to the cells. If the best or second best cell belongs to the virtue cells, use the mirroring method proposed in section 2 to map the virtue cell to the real cell.
(b.6) If the number of channel pair is more than 1, go to step (b.7). Else, go to step (b.6.1)
(b.6.1) $T_c^\tau = T^a_k$, $T^s_k = T^s_{k+1}$, and $k = k + 1$.
(b.6.2) Return to step (b.1).
(b.7) Randomly assign one of the empty channel pairs within the best and second cells.
(b.8) Update the grouping and time indexes:
(b.8.1) $k_g^\tau = k_g^\tau + 1$, $k_a^\tau = k_a^\tau + 1$, $T_c^\tau = T^s_k$ and $T^s_k = T^s_{k+1}$.
(b.8.2) $k = k + 1$.
(b.8.3) If $((T^s_k > (T_c^\tau + T^s_{k+1})) \land T^a_k = 0)$, then $T_d^\tau = T_c^\tau + T^s_k$.
(b.8.4) Return to step (b.1).
(b.9) Calculate the channel utilization:
(b.9.1) $\Delta T^p = T_d^\tau - T_c^\tau$.
(b.9.2) $C = C + \text{(number of used channels / numbers of total channels of all cells)} \times \Delta T^p$.
(b.10) If the number of accessing users is larger than 0, go to step (b.11). Else, let $T_d^\tau = 0$ and return to step (b.2).
(b.11) Execute the user departure process and update the time indexes.
(b.11.1) The user who departs earliest ends his service and releases the channels of his best and second best cells.
(b.11.2) $T_c^\tau = T_d^\tau$.
(b.11.3) If the number of residual accessing users is not larger than 0, let $T_d^\tau = 0$ and return to step (b.2). Else, go to step (b.11.4).
(b.11.4) Find the minimum departure time, $\bar{T_d}^\tau$, from the residual accessing users and update the time, $T_d^\tau$, for the next departure event. $T^\tau_a = \bar{T_d}^\tau$.
(b.11.5) Return to step (b.2).
(b.12) Calculate the grouping success probability, $P_{\text{GroupingSuccess}} (k_g^\tau / K)$, accessing success probability, $P_{\text{AccessingSuccess}} (k_a^\tau / K)$, and channel utilization $(C/T^a_K)$.
(b.13) End

**Method 2 Main Process**
(b.1) If \( T_c \leq T_{d}^a \), go to step (b.2). Else, go to step (b.12).
(b.2) If \( T_d^a \leq T^d \), go to step (b.3). Else, go to step (b.9).
(b.3) Calculate the channel utilization:
(b.3.1) \( \Delta T_p = T_K^a - T_c \).
(b.3.2) \( C = C + (\text{number of used channels} / \text{numbers of total channels of all cells}) \times \Delta T_p \).
(b.4) Randomly assign the coordinate \((x_k, y_k)\) for the arriving user \( k \), where \( x_k \in [0, 1, \ldots, (M - 1)] \) and \( y_k \in [0, 1, \ldots, (M - 1)] \).
(b.5) Find the best and second best cells for user \( k \) based on the shortest and second shortest distances from user \( k \) to the cells. If the best or second best cell belongs to the virtue cells, use the mirroring method proposed in section 2 to map the virtue cell to the real cell.
(b.6) If there is no empty channel pair, go to step (b.6.1). Else, go to step (b.7).
(b.6.1) If there exists any empty channel, randomly assign one of the empty channels from his best or second best relay and go to step (b.6.2). Else, go to step (b.6.6).
(b.6.2) \( k_g = k_a + 1, T_c = T_k^a, \) and \( T_k^a = T_k^{a+1} \).
(b.6.3) \( k = k + 1 \).
(b.6.4) If \((T_d > (T_c + T_k^a)) \) \( \parallel T_d = 0 \), then \( T_d = T_c + T_k^a \).
(b.6.5) Return to step (b.1).
(b.6.6) \( T_c = T_k^a \) and \( T_k^a = T_k^{a+1} \).
(b.6.7) \( k = k + 1 \).
(b.6.8) Return to step (b.1).
(b.7) Randomly assign one of the empty channel pairs within the best and second cells.
(b.8) Update the grouping and time indexes:
(b.8.1) \( k_g = k_g + 1, k_a = k_a + 1, T_c = T_k^a, \) and \( T_k^a = T_k^{a+1} \).
(b.8.2) \( k = k + 1 \).
(b.8.3) If \((T_d > (T_c + T_k^a)) \) \( \parallel T_d = 0 \), then \( T_d = T_c + T_k^a \).
(b.8.4) Return to step (b.1).
(b.9) Calculate the channel utilization:
(b.9.1) \( \Delta T_p = T_d - T_c \).
(b.9.2) \( C = C + (\text{number of used channels} / \text{numbers of total channels of all cells}) \times \Delta T_p \).
(b.10) If the number of accessing users is larger than 0, go to step (b.11). Else, let \( T_d = 0 \) and return to step (b.2).
(b.11) Execute the user departure process and update the time indexes.
(b.11.1) The user who departs earliest ends his service and releases the channel/channels from his best or/and second best relays.
(b.11.2) \( T_c = T_d \).
(b.11.3) If the number of residual accessing users is not larger than 0, let \( T_d = 0 \) and return to step (b.2). Else, go to step (b.11.4).
(b.11.4) Find the minimum departure time, \( T_d \), from the residual accessing users and update the time, \( T_d \), for the next departure event. \( T_d = T_d \).
(b.11.5) Return to step (b.2).
(b.12) Calculate the grouping success probability, \( P_{\text{GroupingSuccess}} (k_g / K) \), accessing success probability, \( P_{\text{AccessingSuccess}} (k_a / K) \), and channel utilization \((C / T_K^a)\).
(b.13) End

In the simulation of both method 1 and 2, there is a \((5 \times 5)\) cells deployment (including 16 real cells and 9 virtue cells), and the number of sample points (total arrival users) is 45000. In Figures 2-4, we compare the results obtained by using method 1 and 2 under the condition that the number of channels in each cell, \( N \), is 5. Figure 2 shows that the grouping success probability in method 1 is better than that of method 2. Owing to the strategy of grouping with single access, the users can access a single empty channel. Therefore, the grouping probability for the users who want to access an empty channel pair in method 2 is lower than that for the users who want to access an empty channel pair in method
1. Figure 3 shows that the accessing success probability in method 2 is much better than that in method 1. In Figure 4, the channel utilization in method 2 is better than in method 1. These results confirm that the grouping strategy in method 2 improves the channel utilization and user accessing situation.

**Figure 2.** The grouping success probability ($\mu_c = 5$).

**Figure 3.** The accessing success probability ($\mu_c = 5$).

**Figure 4.** The channel utilization ($\mu_c = 5$).

**Summary**

The grouping strategy for cooperative networks can enhance the system performance and reduce unnecessary transmission. In this paper, two methods for CoMP networks are proposed and can be
effectively evaluated the influences of system performance. Furthermore, the radio resource management of JT is one of the implementation case for our proposed grouping method in method 1 and the proposed grouping strategy in method 2 can be applied in JP/CB CoMP networks. Two grouping methods can also be implemented in other application fields such as the cooperative networks using visible light communication in parking garage or indoor environments.

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