Radial Velocity Based CoMP Handover Algorithm in LTE-A System

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Abstract. In the Long Term Evolution-Advanced (LTE-A) systems, coordinated Multi-Point (CoMP) transmission/reception technology is widely used to improve cell-edge throughput and system throughput. With the introduction of CoMP technology, handover scenes have changed and traditional handover algorithms are no longer able to meet the requirements of current handover scenes. Different from traditional CoMP handover trigger mechanism, we adopt the event based handover trigger mechanism to update the CoMP coordinating set (CCS) and transmission points (CTP). Furthermore, under the constraints of the reference signal received power (RSRP) and the load of the base stations (BSs), we propose the cycle selection algorithm to choose CCS and CTP based on the radial velocity and SINR. Simulation results show that the proposed handover algorithm can effectively reduce the total number of handover, system delay and signaling overhead in the practical CoMP system.

Keywords: CoMP · Handover algorithm · Event trigger mechanism · Cycle selection

1 Introduction

In cellular network system, handover mechanism aims at providing seamless service for users during the moving process. Hence, handover is considered as a key issue of mobility management and an important indicator of cellular network performance.

Meanwhile, CoMP technology has been widely applied in the LTE-A network. As a key technique, CoMP technology reduce inter-cell interference and improve cell-edge throughput as well as system throughput effectively by applying cooperation between independent and decentralized transmission points geographically [1]. There are two kinds of CoMP techniques considered in LTE-A systems, i.e., joint processing (JP) and coordinated scheduling/beamforming (CS/CB). JP supports multiple connections between cooperated BSs and a typical UE while CS/CB only supports a single connection between the serving BS and a typical UE using the scheduling/beamforming parameters decided by the coordination among the cooperated BSs [2]. In the case of JP, if multiple BSs transmit data to a UE on the same frequency resource at the same time and turn interference signal into useful signal, it's known as Joint Transmission

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(JT). And if only one BS transmit data to UE at a time, it's known as Dynamic Cell Selection (DCS).

However, handover scenes have changed a lot when CoMP-JT technology is introduced and the traditional handover algorithms can't meet the requirements of current handover scenes any more. On this basis, there are some relevant researches about CoMP handover algorithms. A detailed analysis of information exchange and signaling transmission among multi-cells or between multi-cells and UE is introduced in [3] according to the existing non-CoMP handover mechanism. [4] proposes a RSRP limited CoMP handover algorithm that considers Physical Resource Block (PRB) utilization, system throughput and system delay. In [5] and [6], the authors propose the handover algorithms based on capacity assessment and capacity performance respectively. Although those algorithms improve system throughput, a minimum number of handover can not be guaranteed because they all ignore the necessity of handover. In [7], a handover scheme based on static coordinating set to reduce the number of unnecessary handovers is proposed, but it is only applicable to the environment with fixed BS density. Therefore, we propose a new CoMP handover algorithm based on dynamic coordinating set that considers of the handover overhead and the necessity of handover.

The rest of this paper is organized as follows. In Sect. 2, the system model using CoMP-JT is introduced in detail. In Sect. 3, radial velocity based CoMP handover algorithm in LTE-A system is proposed. Performance evaluation of the simulation results are presented and analyzed in Sect. 4. Finally, we conclude this study in Sect. 5.

2 System Model

In this paper, there are four units involved in CoMP-JT handover algorithm: measurement set, CCS, CTP and serving cell. Among them, serving cell takes the responsibility of making handover decision and each UE can only attach to one serving cell at each time instant. Measurement set is a cluster of cells whose channel state information (CSI) can be received and reported by UE, and then, UE gives serving cell the feedback. CCS is a set of cells selected from the measurement set by serving cell which participates in data transmission to UE directly or indirectly. A CTP is a set of cells chosen from the CCS by serving cell which directly and simultaneously participate in data transmission to UE. Figure 1 demonstrates an example of CoMP system model in LTE-A system. Where, the serving cell of UE is assumed as cell 1, the measurement set is $\chi_i = \{1, 2, 3, 4, 10, 11, 12\}$, the CCS is $C_i = \{1, 2, 3, 4\}$. Moreover, CTP is a subset of CCS with $\psi_i = \{4, 5\}$.

There are two variables involved in CoMP-JT handover algorithm: handover margin (HOM) and time to trigger (TTT). HOM is a constant variable which represents the threshold for the difference of RSRP between the serving BS and the target BS. HOM ensures the target BS is the most appropriate BS which UE switches its connection to. A handover can only be executed after TTT is met on the time. A combination of TTT and HOM can prevent unnecessary handovers, which is also called Ping Pong effect.

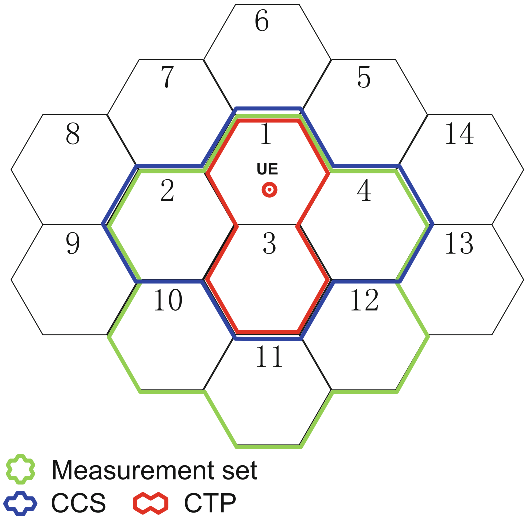

Fig. 1. An illustration of CoMP system model

In CoMP-JT systems, backward compatibility is an important criteria. It means that the emerging handover algorithm can not only be applicable to CoMP handover but also support traditional non-CoMP handover. Based on backward compatibility, this paper no longer distinguishes CoMP UE and non-CoMP UE. Especially, when the size of CTP is one, the UE is represented as non-CoMP UE.

In this paper, we have the following assumptions. The transmit power of each BS is assumed identical and fixed which is expressed by P_0. The channel gains between BS j to UE i can be denoted as $h_{i,j} \cdot r_{i,j}^{-\beta}$ $r_{i,j}^{-\beta}$ is the large-scale fading between BS j and UE i, with, where $r_{i,j}$ denotes the distance and β is the path loss exponent. And $h_{i,j}$ represents the small-scale fading. When the channels follow independent flat Rayleigh fading, the channel power gains are exponentially distributed, i.e., $h_{i,j}$ follows exponential distribution with mean 1. Therefore, the RSRP form BS j to UE i can then be expressed as

$$RSRP_{i,j} = P_0 \cdot h_{i,j} \cdot r_{i,j}^{-\beta} \tag{1}$$

Then the received signal-to-interference and noise ratio (SINR) of UE i in CoMP-JT systems can be given by

$$SINR_i = \frac{\sum_{j \in \psi_i} P_0 \cdot h_{i,j} \cdot r_{i,j}^{-\beta}}{\sum_{m \in \chi, m \notin \psi_i} P_0 \cdot h_{i,m} \cdot r_{i,m}^{-\beta} + \sigma^2} \tag{2}$$

where the noise is additive white Gaussian noise (AWGN) with zero mean and variance σ^2. Therefore, the date rate of UE i is given by

$$R_i = B \cdot \log_2(1 + \frac{\sum_{j \in \psi_i} P_0 \cdot h_{i,j} \cdot r_{i,j}^{-\beta}}{\sum_{m \in \chi, m \notin \psi_i} P_0 \cdot h_{i,m} \cdot r_{i,m}^{-\beta} + \sigma^2}) \tag{3}$$

where, B represents the channel bandwidth allocation from each BS of the CTP to UE i.

2.1 User Mobility Prediction

In this section, we propose a user mobility prediction method to improve handover performance. By assessing the relative change in radius from neighboring BSs per unit time which is known as radial velocity [8], the UE selects suitable cooperative cells as CTP set. Figure 2 shows the calculation principle of radial velocity v_r form BS j to UE i.

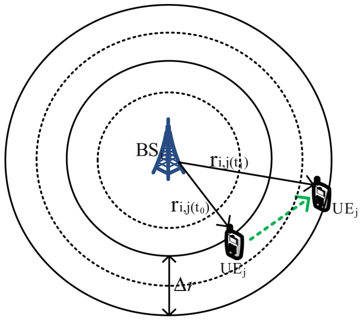

Fig. 2. Calculation principle of radial velocity

Suppose that v_r is constant during the time interval between t_0 and t_1, it can be simply represented by

$$v_r = \frac{r_{i,j}(t_1) - r_{i,j}(t_0)}{t_1 - t_0} \tag{4}$$

From Eq. (4), we can get that UE is moving away from the BS when v_r is positive, and the larger v_r is, the faster UE leaving the BS. UE is closing to the BS when v_r is negative, and the smaller v_r is, and the faster UE closing to the BS.

If we substitute Eq. (1) into Eq. (4), v_r becomes

$$v_r = \frac{1}{P_0^{\beta}(t_1 - t_0)} \left[\left(\frac{RSRP_{i,j}(t_1)}{h_{i,j}(t_1)} \right)^{\beta} - \left(\frac{RSRP_{i,j}(t_0)}{h_{i,j}(t_0)} \right)^{\beta} \right] \tag{5}$$

For the sake of simplicity, $h_{i,j}$ can be considered as a constant variable for the time interval $t_1 - t_0$. We use the mean of $h_{i,j}(t)$, which is represented as $E(h)$, instead of $h_{i,j}(t_1)$ and $h_{i,j}(t_0)$. Then $E(h)$ can be given by

$$E(h) = \int_{t_0}^{t_1} e^{-t} dt = e^{-t_0} - e^{-t_1} \tag{6}$$

Substituting Eq. (6) into Eq. (5), we can get

$$v_r = \frac{RSRP_{i,j}^{\beta}(t_1) - RSRP_{i,j}^{\beta}(t_0)}{P_0^{\beta}(e^{-t_0} - e^{-t_1})^{\beta}(t_1 - t_0)} \tag{7}$$

When choosing the CCS and CTP, UE gives radial velocity a higher priority under the promise of RSRP. During the movement, if the UE has a tendency toward the BS j, i.e., the radial velocity from BS j to the UE is smaller, we give priority to BS j as a candidate BS of CTP. By choosing such a cell as candidate cell, UE can stay connected with that cell for a longer time, which reduces the number of handovers during a call connection.

2.2 Average of RSRP

Caused by the influence of various environmental factors, instantaneous RSRP may cause fluctuation. In this paper, we use the average RSRP to eliminate the influence for convenience. The time interval between t_0 and t_1 is equally divided into N sub-intervals with the length T_m. The average of RSRP form BS j to UE i, which is represented as $E[RSRP_{i,j}]$ and can be obtained as

$$E[RSRP_{i,j}] = \frac{1}{t_1 - t_0} \sum_{n=0}^{N-1} (RSRP_{i,j}(t_1 - n \cdot T_m)) \tag{8}$$

3 CoMP Handover Algorithm

In the mobile terminal, a handover decision process is triggered when the RSRP received from the current network falls below a given threshold or the QoS provided by the networks under a desired threshold of UE [8, 9]. CoMP Handover in LTE-A systems includes not only handover between cells, but also handover of CCS, CTP and the serving cell.

Generally, handover trigger mechanism can be divided into time trigger mechanism and event trigger mechanism. In the existing CoMP handover algorithms, UE gathers measurement reports from the measurement set and feeds the reports back to the serving cell based on time trigger mechanism. Then the serving cell selects a set of cells as CCS from measurement set and selects a set of cells to be CTP from CCS periodically. This allows UE to maintain optimal system throughput but results in a large number of handover and high signaling overhead because handover necessity is not considered.

In this paper, handover process of CCS and CTP is driven by the UE's instantaneous SINR. If the SINR from the current CTP to UE drops below the handover threshold for entire TTT, the election or re-selection of CCS and CTP is executed. The proposed cycle selection algorithm of the CTP set based on radial velocity of UE is shown in Algorithm 1. Where, A PRB is the smallest transmission unit in the downlink LTE-A systems which is the resource of 12 consecutive subcarriers in the frequency-domain and a slot of 0.5 ms in the time-domain. Since handover process is implemented by the serving cell, it sends a cancellation message to the source CTP and interrupts the connection between UE and all cells in the source CTP. Then a new connection is established between UE and the target CTP.

In theory, the more cells participate in cooperating, the better CoMP performance. But in fact, when the number of cooperation cells is large, the throughput gain of CoMP-JT is not necessarily higher as expected after taking the complexity and the overhead into consideration [10]. Therefore, it is not necessary to add cooperation cells when the current cooperation cells is able to meet the QoS requirement of the UE [11]. Specifically, We generally select the size of CTP not larger than four [12].

Algorithm 1

v_j^i : represents radial velocity from BS j to UE i ;
PRB_j : represents RB utilization of BS;
N : represents the maximum size of CTP;
$\gamma_i^{E[RSRP]}, \gamma_i^{RSRP}, \gamma_i^{PRB}$: represent the threshold of $E[RSRP], RSRP, PRB$
1: Input: $RSRP_{i,j}, PRB_j, \gamma_i^{E[RSRP]}, \gamma_i^{RSRP}, \gamma_i^{PRB}$;
2: Output: ψ_i ;
3: measurement set selection of UE i :
$\chi_i = \{j \mid E[RSRP_{i,j}] < \gamma_i^{E[RSRP]}\}$;
4: CCS selection of UE i : $C_i = \left\{ j \middle| RSRP_{i,j} > \gamma_i^{RSRP} and\ PRB_j < \gamma_i^{PRB} \right\}, j \in \chi$;
5: Calculating the relative radial velocity v_j^i ;
6: Sorting the BSs of the C_i in ascending order
according to v_r , labeled as $M_i = \{1, 2, \cdots, n\}$, namely,
n responds to BS with the largest radial velocity.
7: for $k = 1 : n, k \le N$
8: if $\frac{\sum_{j=1}^{k} P_0 \cdot h_{i,j} \cdot r_{i,j}^{-\beta}}{\sum_{j \in \chi} P_0 \cdot h_{i,j} \cdot r_{i,j}^{-\beta} - \sum_{j=1}^{k} P_0 \cdot h_{i,j} \cdot r_{i,j}^{-\beta} + \sigma^2} > \gamma_i^{SINR}$ then
9: $\psi_i = \{1 : k\}$;
10: break;
11: else
12: CCS and CTP will not change.
13: end if
14: end

After the election or re-selection of CCS and CTP, we need to determine whether the serving cell need to handover. A serving cell handover will be triggered when the triggering condition (9) is satisfied during the entire TTT duration.

$$RSRR_{CTP} > RSRP_S + HOM \tag{9}$$

where $RSRR_{CTP}$ and $RSRP_S$ are the $RSRP$ received by an UE from the target cell with the maximum RSRP in CTP and the serving cell respectively. Once a handover is triggered, a handover command is sent by the serving cell to instruct the UE to handover to the next serving cell. Otherwise, the current CTP starts transmitting data to the UE and waits for the next measurement period expires.

4 Simulation Results

In this paper, we evaluate the performance of CoMP handover algorithm based on three metrics: total number of handover, handover failure (HOF) rate, and system throughput. In the following part, some numerical results are shown to illustrate the impact of different system characteristics. We assume that UE's direction is randomly between 0 to 2π and stays constant in each time slot. The user's speed is 36 km/h and keeps constant. Other simulation parameters are shown in Table 1.

Table 1. Simulation Parameters

Simulation parameters	Values
Radius	1000 m
System bandwidth	10 MHz
Path loss	k*r^(−4)
BS's position	PPP($\lambda = 1e - 5$)
UE's position	Random distribution
Total number of users	20,30,40,50,60,70 and 80
Simulation time	5000 ms
Measurement period	50 ms
TTT	5 ms
System bandwidth	10(Mhz)
The number of subcarriers	600
Size of CCS	no more than 5
Size of CTP	no more than 3

Figure 3 shows the comparison of the total number of handover between the proposed CoMP handover algorithm and capacity based CoMP handover algorithm in LTE-A. As is depicted in Fig. 4, our proposed algorithm has less total number of handover as 20, 51, 81 and 110 times than capacity based CoMP handover algorithm as 38, 85, 129 and 172 times, respectively. That is, the proposed CoMP handover algorithm has a 47.37%, 40%, 37.21% and 36.05% decrease in total number of handover

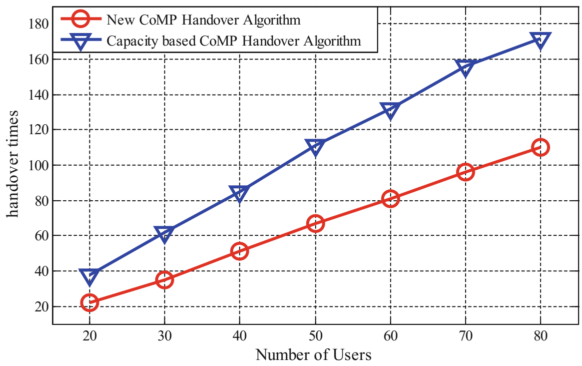

Fig. 3. Total Number of Handover with the change of the number of UE

than existing CoMP handover algorithm in 20, 40, 60 and 80 UE respectively. In conclude, the total number of handovers of the proposed scheme is smaller than that of the existing scheme by analyzing the necessity of handover. this is because the current CTP can meet the service requirements of the UE and the handover of CCS and CTP is not required in the proposed algorithm.

Figure 4 compares the system throughput of new CoMP handover algorithm and capacity based CoMP handover algorithm. We can see that the system throughput is improved with the increase of number of UE. The proposed CoMP handover algorithm provides lower system throughput as 21.60Mbps, 42.08Mbps, 63.25Mbps and 84.29 Mbps, and brings about 8.32%, 6.16%, 6.95% and 6.12% system throughput increase than capacity based CoMP handover algorithm in each scenario of 20, 40, 60 and 80 UE respectively. It is shown that capacity based CoMP handover algorithm has a better throughput because it firstly considers the cells with the best performance to switch periodically, while the proposed algorithm perform doesn't choose the CTP with largest SINR when the current CTP can meet the requirement of UE.

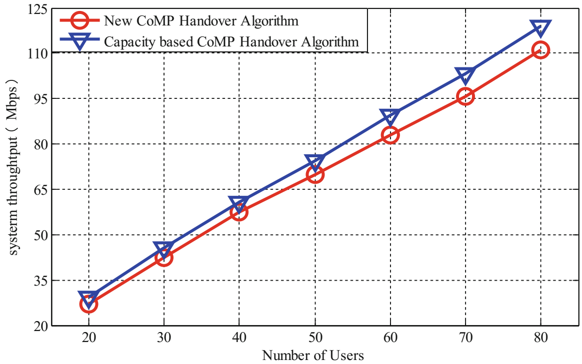

Fig. 4. System throughput with the change of the number of UE

Figure 5 shows the handover fail (HoF) rate comparison between the new CoMP handover algorithm and capacity based CoMP handover algorithm. It is observed that the HoF rate increases as velocity of UE increases, and the increase trend of capacity based CoMP handover algorithm is faster than the new CoMP handover algorithm. In contrast, the new CoMP handover algorithm have less HoF rates, which can be explained that the new CoMP handover algorithm can provide better handover performance, especially in the case of high velocity.

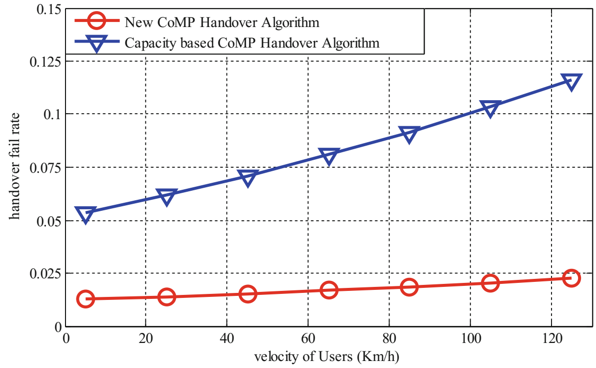

Fig. 5. HoF rates with the change of the velocity of UE

Figure 6 illustrates the comparison of system delay of our proposed CoMP handover algorithm and capacity based CoMP handover algorithm. We can see that the system delay of the proposed algorithm is smaller than that of capacity based CoMP handover algorithm. When number of users is changed from 20 to 80, the proposed handover algorithm results in 9.84%, 8.52%, 10.98%, 9.90%, 9.28%, 7.67% and 8.17% decrease of system delay than capacity based CoMP handover algorithm. This is because we consider a lower loaded cell firstly when making a handover decision.

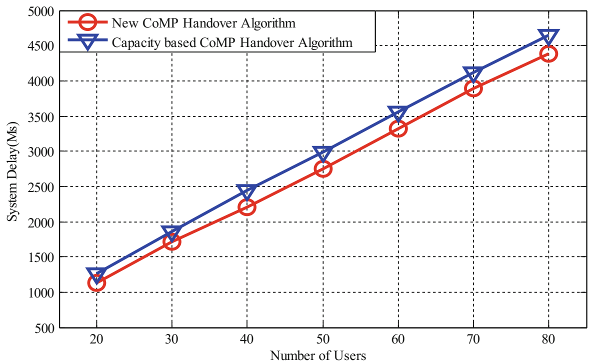

Fig. 6. System Delay with the change of the number of UE

5 Conclusions

In this paper, we propose a radial velocity based CoMP handover algorithm in LTE-A considering the handover necessity and the handover trigger mechanism and the cycle selection of the set of CTP. Simulation results illustrate that radial velocity based CoMP handover algorithm can effectively reduce the total number of handover, the probability of handover failure and the impact of system delay on system performance. Therefore, the proposed mechanism is useful for the practical CoMP-JT system.

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