Handover Methods Considering Channel Conditions of Multiple Aggregated Carriers

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Abstract— **Carrier aggregation was introduced to Long Term Evolution Advanced in order to improve the performance especially in terms of a higher peak data rate. When employed, sets of user equipment will have a set of serving cells, which includes a Primary cell (PCell) and Secondary cells (SCells). For inter evolved Node B (eNB) handover, target eNB is selected only consider the channel condition of the PCell. Thus, a suitable set of serving cells cannot be selected. In order to address this problem, this paper proposes three handover methods considering channel conditions for multiple cells. Methods 1 and 2 adjust the handover margin according to the difference in channel conditions between the PCell and SCells for the serving eNB. Method 3 decides handover based on equivalent channel conditions for the PCell and SCells in both the serving eNB and neighboring eNBs. Simulation results show that the proposed methods provide higher cell-edge throughput and a much smoother handover at the cost of a slightly increased number of handovers.**

Keywords- carrier aggregation; equivalent channel condition; handover; PCell; SCell.

I. INTRODUCTION

Support of a wider bandwidth is an important enhancement for Long Term Evolution Advanced (LTE-A). Carrier aggregation (CA) was incorporated in order to support higher peak data rates to sets of LTE-A User Equipment (UEs). There are five CA deployment scenarios described in TS 36.300 [1][2]. For one eNB, there are multiple component carriers. In scenario 1, one cell with Frequency 1 (F1 cell) and one with Frequency 2 (F2 cell) are co-located and provide the same coverage area. In scenario 2, the F1 cell and F2 cell are co-located but provide different coverage areas because of different path losses. In scenario 3, the F1 cell and F2 cell are co-located but their antennas are set in different directions. In scenario 4, the F1 cell provides macro coverage area, while the F2 cell employs Remote Radio Heads. Scenario 5 is similar to scenario 2, but frequency selective repeaters are deployed in the F2 cell. In all these scenarios, it is expected that the F1 cell and F2 cell of the same eNB can be aggregated where the coverage areas overlap.

When CA is employed, a UE only has one Radio Resource Control (RRC) connection to the network [3]. At RRC connection establishment/re-establishment, one serving cell provides the security input and the non-access stratum mobility information, which is similar to the case in Rel. 8/9. This cell is referred to as the PCell. Depending on the UE capabilities, SCells in the same eNB can be configured to form together with the PCell as a set of serving cells. In this case there is more than one serving cell for users when CA is employed (hereafter CA users).

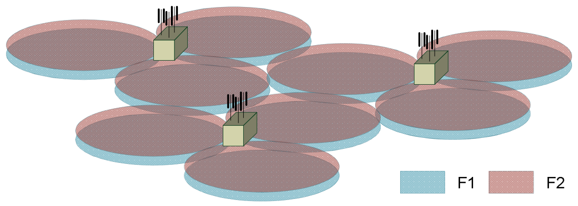
Handover is a key technology that maintains the UE connection to the best serving cell in a wireless communication system. As is well known, in the conventional handover method, handovers are performed when a neighboring cell becomes better than the serving cell [4][5][6]. In LTE-A, CA users may have multiple serving cells, and the conventional handover method that considers the channel condition of only one serving cell is not sufficient to support the handover of CA users.

PCell based handover method was proposed in [7] for CA users. During the handover decision process, the PCell plays the role of a reference cell. The PCell can be a fixed cell, or the cell that is selected as the best cell. In the conventional PCell based handover method, a target PCell is selected first, thus the target eNB can be decided. Then a SCell in the target eNB is configured. This method selects the best target eNB for a UE in scenario 1 and scenario 2. Since in scenario 1, the F1 cell and F2 cell are co-located and provide the same coverage area, this means that the F1 cell and F2 cell experience consistent channel conditions. If the best F1 cell is served by eNB 1, the best F2 cell must be served by eNB 1. In this case, either the F1 cell or F2 cell can be the PCell. In scenario 2, the F1 cell has a larger coverage area than the F2 cell. Similar to scenario 1, if the best F1 cell is served by eNB 1, the best F2 cell must be served by eNB 1. In this case, the F1 cell can be the PCell. However, in scenarios 3, 4, and 5, it is possible that the best F1 cell is served by eNB 1 but the best F2 cell is served by eNB 2. Thus, conventional PCell based handover method, which only considers the channel conditions of the PCell cannot select the best target eNB and best set of serving cells.

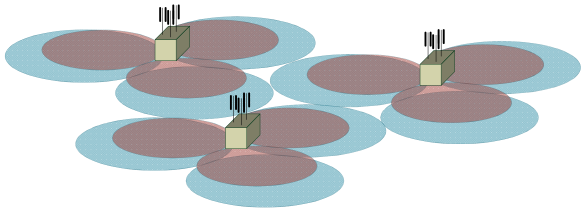
In order to address this problem, three new handover methods are proposed that consider all the channel conditions for multiple serving cells. Methods 1 and 2 adjust the handover margin according to the difference in the channel conditions between the PCell and SCell in the serving eNB. Method 3 selects the target eNB based on the equivalent channel conditions for the PCell and SCell in both the serving eNB and target eNB. Simulation results in scenario

3 show that these three methods improve the cell-edge throughput and provide a smoother handover.

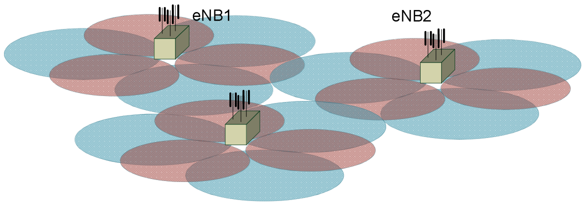
The rest of the paper is organized as follows. In Section II, the conventional methods and the problems are reviewed. Section III describes the principles behind the proposed methods. Performance evaluations are shown in Section IV, followed by our conclusions in Section V.



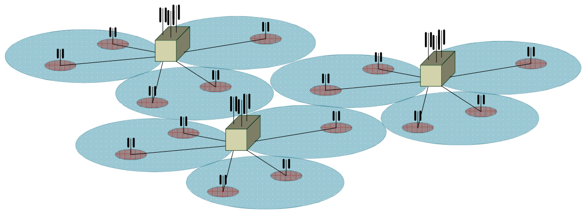
Scenario 1 Identical coverage



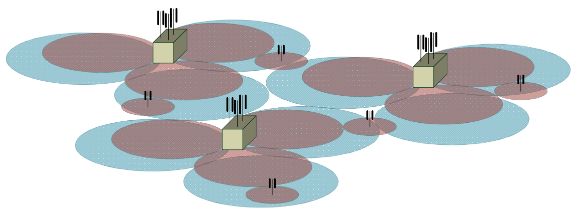
Scenario 2 Diverse coverage



Scenario 3 Main beam directed at sector boundaries



Scenario 4 Use of remote radio head



Scenario 5 Use of relay

Figure 1. CA deployment scenarios

II. PCELL BASED HANDOVER METHODS

Here we assume that there are two component carriers, F1 and F2 in each eNB and each UE has two serving cells, i.e., a PCell and a SCell. As noted earlier, PCell based handover method was proposed in Rel. 10. When a neighboring cell in a neighboring eNB has a better channel condition than the PCell by an offset, a UE will handover to that target eNB. PCell based handover method can be divided into two conventional methods. Conventional method 1 is fixed PCell based handover method and conventional method 2 is best PCell based handover method. In the former case, the PCell is a fixed cell, i.e., it can only be the best F1 cell. While in the latter case, the PCell can be adaptively changed to the best cell among all F1 and F2 cells.

This paper focuses on inter-eNB handover, which means that conventional methods 1 and 2 will be used for selecting the best target eNB. While intra-eNB handover is performed independently on each frequency while a UE moves within one eNB. This means that the UE can independently select the best F1 cell as serving cell 1 and select the best F2 cell as serving cell 2 in the same eNB. For conventional method 1, the PCell is the best F1 cell. For conventional method 2, If the best F1 cell is better than the best F2 cell, the F1 cell is the PCell; otherwise, the F2 cell is the PCell.

In order to clarify details regarding the problems with conventional methods, we present some simulation results based on parameters in Table I [8]. The simulation scenario is scenario 3, in which F1 is 2 GHz and F2 is 3.5 GHz. F2 antennas are directed to the cell boundaries of F1. The inter-site distance (ISD) of the cells is 500 meters.

TABLE I. SIMULATION PARAMETERS

Parameter		Assumption
Number of scenario		3
Cellular layout		Hexagonal grid, 19 cell sites, 3 sectors per cell site
Transmitter antenna pattern of base station (Antenna gain)		3-sector antenna pattern, 70 degree sector beam (14 dB)
Carrier frequency		2 GHz, 3.5 GHz
Inter-site distance (ISD)		500 m
Distance-dependent path loss		L=58.7 + 37.6log10(R) + 21log10(fc), R in km, fc (MHz)
Penetration loss		20 dB
Shadowing standard deviation		8 dB
Transmission power of base station		46 dBm
Terminal noise density		-174 dBm
Shadowing correlation	Between cells	0.5
	Between sectors	1.0
Minimum distance between UE and eNB		>=35 meters
UE moving speed		3 km/h
UE moving direction		Random and does not change
Measurement period		200 ms
Initial eNB selection		Based on 2 GHz
Handover margin		3 dB

The active UEs are uniformly distributed over the cells. Each UE is given a uniform random direction in the range of [0 ◦, 360◦) and the UE moves in the same direction at the constant speed of 3 km/h during the entire simulation. In order to avoid the drawback of a limited network area, the wrap-around technique is employed.

The channel model includes path loss, log-normal shadowing, and fast fading. The log-normal shadowing samples are spatially correlated using a negative exponential function (Gudmundson's model) [9]. Fast fading is modeled using the Typical Urban (TU) power delay profile with 20 paths [10].

Figs. 2 and 3 show the simulation results. In both figures, the difference in the Reference Signal Received Power (RSRP) of serving cell 1 to that for serving cell 2 is represented on the X axis. In Fig. 2, the equivalent Signal to Noise Ratio (SNR) of the serving eNB and that for the target eNB for users that are handed over (hereafter handover users) based on conventional method 1 is represented on the Y axis. In Fig. 3, the equivalent SNR of the serving eNB and that for the target eNB for handover users based on conventional method 2 is represented on the Y axis. Here, the equivalent SNR for an eNB can be calculated from two serving cells, e.g., for F1, there is serving cell 1 and for F2, there is serving cell 2. Thus the SNR of the serving eNB can be calculated as shown in (1).

$$SNR\_serv = (1+SNR\_cell\ 1)(1+SNR\_cell\ 2) - 1 \qquad (1)$$

From Figs. 2 and 3, we can establish a rule. When the difference in the RSRP is less than 2 dB, the equivalent SNR of the serving eNB is higher than that for the target eNB; otherwise, the equivalent SNR of the serving eNB is lower than that for the target eNB. In addition, when the difference in the RSRP is greater than 4 dB, the equivalent SNR of the target eNB is much higher than that for the serving eNB. This means that, sometimes conventional methods 1 and 2 perform early handovers, and sometimes they perform late handovers. Simply, they cannot provide a suitable time for handover.

In order to address this problem, we propose handover methods based on the channel conditions of two cells in serving eNB and target eNB.

III. PROPOSED HANDOVER METHODS

Based on analysis of Figs. 2 and 3, the conventional methods 1 and 2 cannot find a suitable time for handover. Thus this paper proposes handover methods that can find a more suitable time for handover.

Methods 1 and 2: Adjusting handover margin based on difference in RSRP between PCell and SCell in serving eNB

From Figs. 2 and 3, we find that conventional methods 1 and 2 sometimes perform early and late handovers. What is vital is that we know under what conditions early and late handovers will be performed. Thus proposed methods 1 and 2 will adjust the handover margin according to the difference in RSRP of serving cell 1 and serving cell 2. The principle is described in detail hereafter.

Define V_serv = RSRP_cell 1 –RSRP_cell 2;

-If V_serv < threshold 1, a larger value for the handover margin will be used;

-If V_serv > threshold 2, a smaller value for the handover margin will be used.

-Else, we use the default value for the handover margin.

For example, if V_serv < 2 dB (threshold 1), handover margin 1 = 5 dB; if V_serv > 4 dB (threshold 2), handover margin 2 = 1 dB; else, handover margin = 3 dB.

Fig. 4 is a flow chart for proposed methods 1 and 2. With an adaptive handover margin, methods 1 and 2 can delay the early handovers and advance the late handovers in the conventional methods 1 and 2 respectively.

The difference of proposed methods 1 and 2 is that: method 1 employs the adaptive handover margin for the fixed PCell based handover method and method 2 employs the adaptive handover margin for the best PCell based handover method. These two methods respectively improve the two conventional PCell based handover methods.

In fact, proposed methods 1 and 2 only adjust the value of the handover margin to adjust the handover time of the PCell

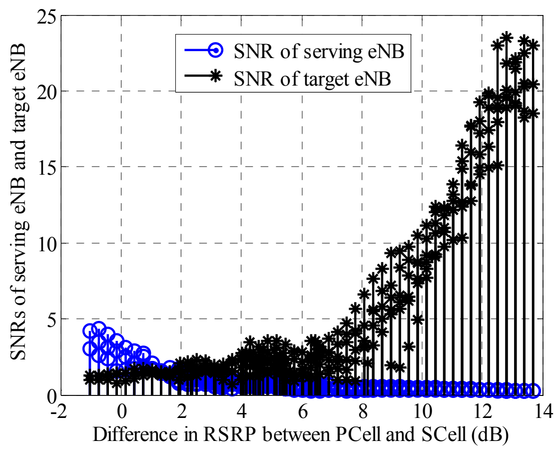


Figure 2. Equivalent SNR of fixed PCell based handover method

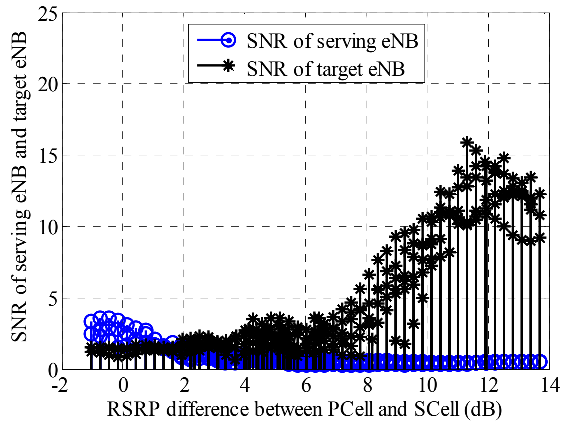


Figure 3. Equivalent SNR of best PCell based handover method

based handover method based on the channel conditions of the two serving cells in the serving eNB. It does not consider the channel conditions for two cells in a neighboring eNB. We should know that the metric used for deciding early or late handover is the difference in the equivalent SNR for the serving and target eNBs. Thus, it will be much better to use the equivalent SNR of both the serving and target eNBs for handover decision.

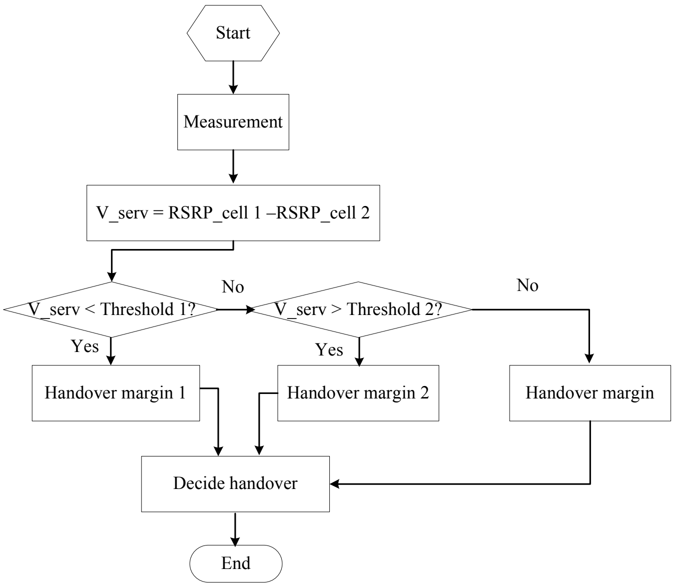


Figure 4. Flow chart for proposed methods 1 and 2

Method 3: New handover method based on equivalent SNR

Method 3 is a handover method that considers the equivalent SNR in both the serving and target eNBs. In this method, when the equivalent SNR of the target eNB becomes better than that of the serving eNB based on the handover margin, the UE is handed over. The handover criteria can be expressed as (2).

$$\text{SNR\_target} > \text{SNR\_serv} + \text{handover\_margin} \qquad (2)$$

Here the SNR_target can be obtained in a manner similar to SNR_serv using (1). I.e., SNR_target equals to the equivalent SNR of the best F1 cell and the best F2 cell in the target eNB.

Method 3 can select a target eNB that can provide the highest equivalent SNR, i.e., highest capacity. Thus, it can find a more suitable time for handover to improve the UE throughput and provide a smoother handover. However, method 3 has a problem on the measurement configuration. Currently, the measurement report can be triggered by the measurement result of a single cell, e.g., a neighboring cell becomes better than the serving cell by an offset. While method 3 needs to trigger the measurement report based on combined measurement results of more than one neighboring cells and more than one serving cells. Thus it needs a new measurement configuration and the UE should be indicated which two neighboring cells belong to a same neighboring eNB.

IV. Performance Analysis

The performance of the proposed handover methods and conventional methods are evaluated in Scenario 3 based on the simulation parameters in Table I and Table II, which give the handover parameters. There are five handover methods being evaluated. The two conventional methods are: conventional method 1 and conventional method 2. The three proposed methods are: proposed method 1, proposed method 2 and proposed method 3.

In Table II, the handover margin is used in the two conventional methods and the proposed method 3. Threshold 1, threshold 2, handover margin 1, and handover margin 2 are used for proposed methods 1 and 2. The performance metrics include the difference in the SNR of the serving and target eNBs for handover users, the cumulative distribution function (CDF) of the SNR for cell-edge users, and the number of handovers per hour, which are shown in Figs. 5, 6, and 7 respectively.

TABLE II. Handover Parameters for Proposed Method

Parameter	Assumption
Handover margin	3 dB
Threshold 1	2 dB
Handover margin 1	5 dB
Threshold 2	4 dB
Handover margin 2	1 dB

Fig. 5 shows the difference in SNRs for the serving eNB and target eNB for handover users. Along the X axis where the difference in SNR is less than zero indicates that the SNR of the serving eNB is higher than that for the target eNB, i.e., early handovers. Where the difference in SNR is higher than zero indicates that the SNR of the serving eNB is lower than that for the target eNB, i.e., it is time to handover. However, if the difference in SNRs is very large, e.g., larger than 3dB, this means that the handover is performed too late. Fig. 5 shows that proposed methods 1 and 2 can delay a part of the early handovers and advance a part of late handovers compared to conventional methods 1 and 2 respectively. While proposed method 3 can further delay the early handovers and advance the late handovers, compared to proposed methods 1 and 2. Proposed method 3 provides the most suitable time for handover.

Fig. 6 gives the CDF of the SNR for the cell-edge users. Proposed methods 1 and 2 improve the cell-edge user SNR by approximately 30% compared to conventional methods 1 and 2 respectively. While proposed method 3 provides the highest cell-edge user SNR by approximately 50% even compared to conventional method 2. That is because that the proposed methods provide a more suitable time for handover. Before UEs are subjected to a worse SNR, the proposed handover methods find a better target eNB that improves the SNR for the UE.

Fig. 7 shows the number of handovers per hour. Compared to conventional methods 1 and 2, the number of handovers for

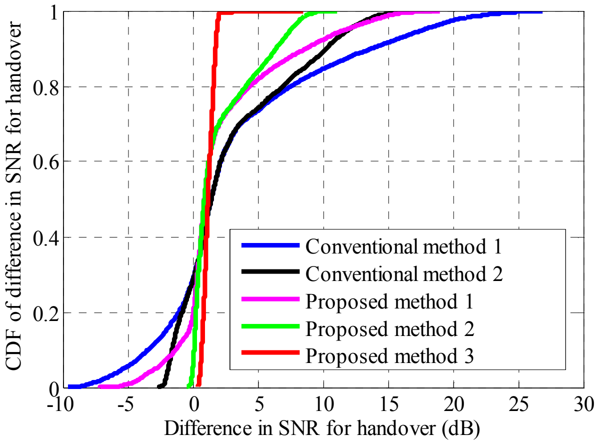


Figure 5. Difference in SNR between serving eNB and target eNB for handover

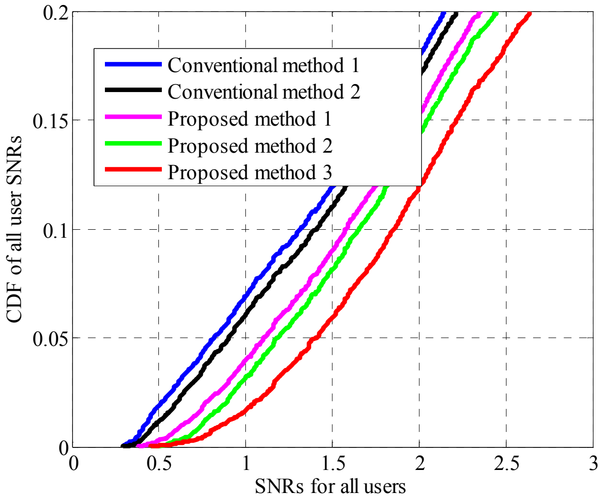


Figure 6. CDF of SNRs for cell-edge users

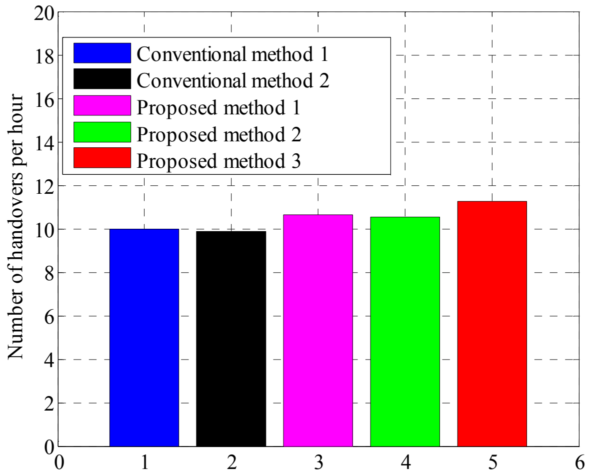


Figure 7. Number of handovers per hour

proposed methods 1 and 2 is increased by only approximately 6%. The number of handovers for proposed method 3 is the highest. Compared to conventional method 1, the number of handovers is increased by approximately 10%. However, this method improves the cell- edge user SNR by more than 50% compared to conventional method 1.

Based on the above analysis, we find that the proposed handover methods that take into consideration the channel conditions of two cells provide higher cell-edge user SNRs and smoother handovers at the sacrifice of a slightly increased number of handovers.

V. CONCLUSION

This paper proposes three handover methods that consider the channel conditions of not only the PCell but also the SCells. In the first two methods, the handover time is adjusted based on the difference in RSRP of the PCell and SCell in the serving eNB. In the third method, the handover time can be adjusted based on the equivalent SNRs of the serving and target eNBs. In this case, some early handovers and late handovers caused by the conventional PCell based handover method will be delayed and advanced, respectively. Thus, the cell-edge throughput can be improved significantly and smoother handovers can be achieved at the cost a few more handovers. In conclusion, the proposed handover methods that consider the channel conditions of multiple cells improve the handover performance for users when CA in LTE-A is employed.

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