A Proposal of Cell Selection Algorithm for LTE Handover Optimization

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Abstract— **A large number of cells will be deployed to provide high speed services in any places using the Long-Term Evolution (LTE) system. The management of such a large number of cells increases the operating expenditure (OPEX). Self-organizing networks (SON) attracted interest as an effective way to reduce OPEX. One of the main targets in SON is the self-optimization of handover (HO) that realizes mobility robustness. HO optimization algorithms adjust HO parameters between the serving and the reconnected cells based on the HO failure logs and cell selection, which is the procedure used to select a suitable reconnected cell, is very important for HO optimization algorithms. In this paper, we propose a cell selection scheme to enhance the performance of HO optimization. In the proposed scheme, both the uplink and downlink channel quality is considered when selecting a suitable reconnected cell. Through the computer simulation, we can see that the proposed scheme reduces the HO failure rate and the number of HO failures by 3 percentage points and 38%, respectively, compared to the conventional scheme based solely on downlink channel quality.**

Keywords-component; SON; LTE; Cell Selection; Handover; Self-Optimization

I. INTRODUCTION

The recent dramatic growth in mobile traffic requires new wireless communication systems that increase network capacity. Long-Term Evolution (LTE), which has been developed in the 3rd Generation Partnership Project (3GPP) is a wireless communication system that increases network capacity with high spectral efficiency [1]. Even if the LTE system is newly introduced, it is better to deploy a large number of cells to accommodate such a large volume of traffic. However, as the number of cells becomes larger Operating Expenditure (OPEX), which is the cost spent continuously for network operation and maintenance, increases enormously. Therefore, it is necessary to develop new schemes which operate cellular systems automatically. In 3GPP, Self-Organizing Networks (SON) have been specified for that purpose [2]. One of the main targets in SON is the self-optimization of handover (HO).

Several studies have discussed the optimal setting of HO parameters [3-8], considering not only the HO failure rate, but also the ping-pong HO rate, which is defined as the rate of HOs from the neighbor cell to the original serving cell within a certain period of time after the HO from the original serving cell to the neighbor cell. Legg et al. [5] showed that there is a tradeoff between the HO failure rate and the ping-pong HO rate especially for highly mobile user equipments (UEs). In order to realize mobility robustness, an optimization algorithm was proposed [9]. The algorithm takes into account the cause of HO failures, which directly reflects the change in UE mobility, and realizes tracking capability for any change in UE mobility without requiring additional functions for estimation of UE mobility.

The algorithm adjusts the handover parameters between the serving and the reconnected cells based on the HO failure logs and the cell selection, which is the procedure used to select a suitable reconnected cell, is very important for the HO optimization algorithms. If the reconnected cell determined by cell selection is unsuitable, HO parameter adjustment by the HO optimization algorithm may decrease HO performance. In LTE systems, the cell selection procedure after HO failure is performed based on the downlink channel quality. In other words, the cell selection procedure cannot assure uplink performance and it is not always true that the reconnected cell is suitable. Therefore, by introducing a new cell selection parameter optimization scheme that assures both the uplink and downlink channel quality, we can expect to achieve further improvements in HO performance.

In this paper, we propose a cell selection parameter optimization scheme for HO optimization and evaluate HO performance with the proposed scheme from the viewpoint of the HO failure rate and ping-pong HO rate. And, in order to verify the advantages of the proposed scheme, we evaluate HO performance in terms of the change in interference on uplink.

The rest of the paper is organized as follows. In section II, we introduce the HO procedure and the cell selection procedure in LTE. Section III explains the HO optimization scheme. Section IV explains the proposed cell selection scheme. Simulation conditions and results are presented in section V. Finally, we conclude this paper in section VI.

II. HANDOVER AND CELL SELECTION IN LTE

A. Handover Procedure

The HO procedure within 3GPP LTE is illustrated in Figure 1. The procedure starts with the measurement configuration message by the source cell (serving cell) to UE. Then the UE can know the configuration for measurement, such as the measurement interval, the threshold for measurement report (MR) transmission, and so on. The UE periodically performs downlink channel measurements based on the cell-specific reference signals. If any conditions for measurement report transmission are satisfied, the UE sends the corresponding measurement report indicating the triggered event. Based on the measurement report, the serving cell starts to negotiate with the target cell. The communication interface between the serving and the target cell is called X2. Then, the source cell sends the HO command message to the UE. The connection between UE and the serving cell will be released. Next, the UE attempts to synchronize and access the target cell by using the random access (RA) channel. Upon successful synchronization at the target cell, the UE transmits the HO complete message to the target cell. When the measurement report, the HO command message, the random access preamble, the random access response, or the HO complete message is received incorrectly, HO fails. Therefore, in order to successfully complete the HO process, it is necessary to correctly receive all messages on both downlink and uplink. When HO failure is detected within the HO procedure, a Radio Resource Control (RRC) connection re-establishment procedure is performed. The re-establishment procedure consists of cell selection procedure and contention based random access procedure. In the following subsection, we explain the cell selection procedure in LTE systems.

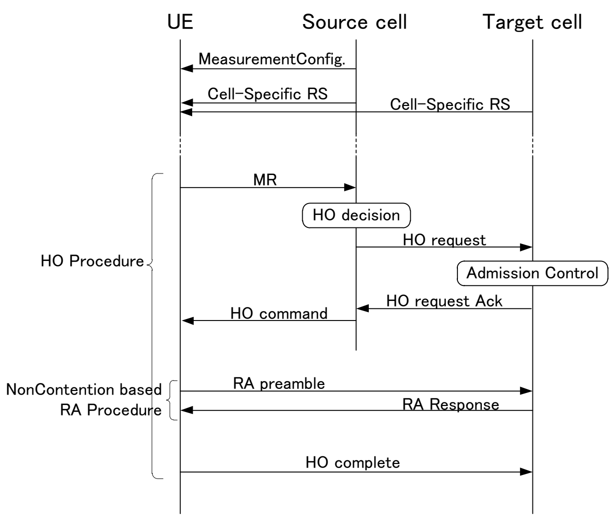

Figure 1. LTE Handover procedure.

B. Cell Selection Procedure

The UE performs measurements for cell selection when a HO failure occurs. In the cell selection procedure, the UE selects a cell which fulfills the following [10]

$$Srxlev>0 \text{ AND } Squal>0, \quad (1)$$

where

$$Srxlev = Qrxlevmeans - Qrxlevmin, \quad (2)$$

$$Squal = Qqualmeans - Qqualmin. \quad (3)$$

Here, *Qrxlevmeans* is the measured cell RX level value, i.e. the Reference Signal Received Power (RSRP) as defined in [11]. *Qqualmeans* is the measured cell quality value, i.e. the Reference Signal Received Quality (RSRQ). *Qrxlevmin* is the minimum required RX level in the cell, given in dBm. *Qqualmin* is the minimum required quality level in the cell, given in dB. The values *Qrxlevmin* and *Qqualmin* are broadcasted as the system information at every cell. In this way, the cell selection procedure in LTE is based on the downlink channel.

III. Handover Optimization Scheme

A. HO failures

When the message in the HO procedure is not received correctly or the radio link failure (RLF) is detected in the UE, it becomes HO failure. Then, the UE selects the cell to reconnect following the cell selection procedure. When the reconnection is completed, the eNodeB (eNB) outputs the HO failure log which shows the cause for HO failure. In LTE, the HO failure logs are classified in to the following three types [1].

- Too Early HO
  Too early HO trigger timing leads to a low RSRP level of the target cell. In this case, the message transaction between the UE and the target cell fails, and the UE changes the state to radio link failure (RLF). After detecting the RLF in the UE, the UE reconnects to the serving cell again using the cell selection procedure.
- Too Late HO
  Too late HO trigger timing leads to a low RSRP level of the serving cell. The message transaction failures between the UE and the serving cell during the HO procedure, or before HO is triggered, are classified as too late HO. After the RLF is detected in the UE, the UE reconnects to the target cell using the cell selection procedure.
- HO to Wrong Cell
  HO to a wrong cell is a failure event involving three cells: the serving cell, the target cell, and the reconnected cell using the cell selection procedure. HO to a target cell providing unstable received power leads to HO failure. If there is another suitable cell for the UE to reconnect to after the RLF, the UE reconnects to the cell that is neither the serving cell nor the target cell by the cell selection procedure.

Since the HO procedure is radio-resource consuming, in addition to the above HO failure cases, it is necessary to minimize the number of ping-pong HOs, in which the UE returns to the original serving cell within a certain period of time (e.g. 2 seconds) after a HO from the original serving cell to a neighbor cell.

B. Handover Optimization Scheme

The HO optimization algorithm adjusts the HO timing between the serving and the reconnected cells based on the

HO failure logs and cell selection, which is the procedure used to select a suitable reconnected cell. The HO timing is controlled by *Ocn* in a condition of measurement report transmission. Table I shows the direction of *Ocn* adjustment for reducing HO failures. Here, *i* is the serving cell, *j* is the target cell in the HO procedure, and *k* is the reconnected cell using the cell selection procedure. As shown in Table I, the parameter adjustments for a reduction in HO failures are different in some kinds of HO failure logs. Hence, the adjustment of the *Ocn*, which is cell individual offset for measurement configuration, should be performed taking the occurrence of each kind of HO failure into consideration. At the same time, since the HO procedure is radio-resource consuming, it is desirable for the parameter adjustment for reduction of HO failures to be executed with the minimum occurrence of ping-pong HOs.

TABLE I. OCN ADJUSTMENT DIRECTION FOR REDUCTION OF EACH KIND OF HO FAILURE

HO Failure Log	Direction of *Ocn* Adjustment
Too Late HO	Increase *Ocn(i,j)*
Too Early HO	Decrease *Ocn(i,j)*
HO to Wrong Cell	Decrease *Ocn(i,j)* and increase *Ocn(i,k)*
Ping-Pong HO	Decrease *Ocn(i,j)*

Cell *i* is the serving cell, cell *j* is the target cell, and cell *k* is the reconnected cell.

C. Problem of Handover Optimization

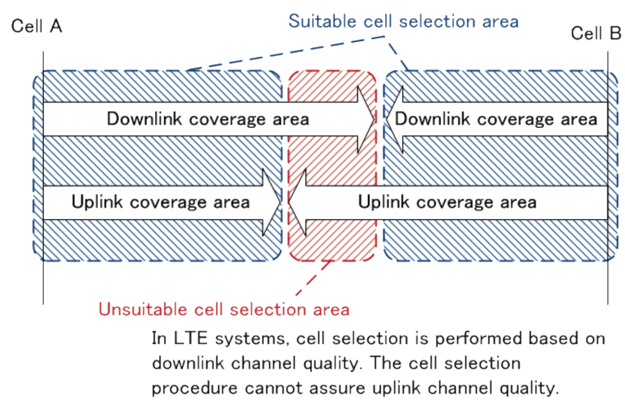

Figure 2. Cell selection area.

The HO optimization algorithm adjusts the handover parameters between the serving cell and the reconnected cell to ensure successful HO to the reconnected cell. However, it is not always true that the reconnected cell is suitable. In LTE, the cell selection procedure after HO failure is performed based on the downlink channel quality. In other words, the cell selection procedure cannot assure uplink channel quality. As shown in Figure 2, when the uplink coverage area does not overlap with the area that is selected by the cell selection scheme based on the downlink channel quality, this situation occurs. The downlink coverage area is almost static and can be estimated by the surrounding environment, radio propagation model, and so on. On the other hand, the uplink coverage area changes dynamically due to the uplink interference level which depends on offered traffic and the location of UEs. If the uplink interference level is high, the reconnected cell may be an unsuitable cell which cannot achieve the required uplink quality. The difference in the uplink and downlink coverage areas is caused by the difference in transmission power between eNB and UE. It occurs at the cell at the edge of the frequency band which has no interference from the neighbor cell of another frequency band. In these cases, the HO parameter adjustment by the HO optimization algorithm may decrease the HO performance. We need a cell selection scheme taking account of both uplink and downlink qualities to solve this problem. Therefore, by connecting to a suitable cell which assures uplink quality, we can expect to achieve further improvement of HO performance.

IV. PROPOSED CELL SELECTION OPTIMIZATION SCHEME

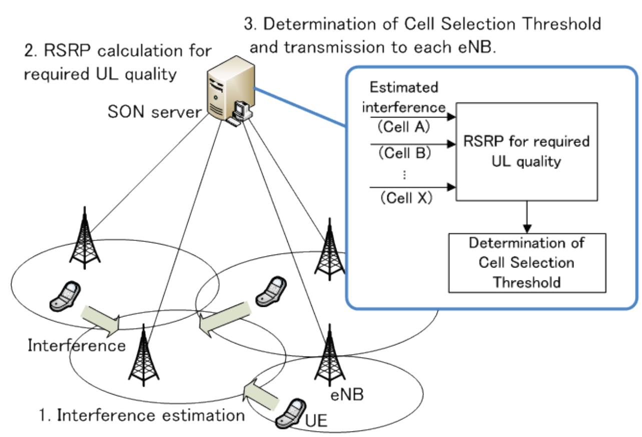

Figure 3. Proposed cell selection optimization system.

Figure 3 shows the proposed scheme for the determination of cell selection threshold. First, the eNB measures the interference level on the uplink data channel using a demodulated reference signal and the measured interference level is sent to the SON server. The SON server obtains the interference level not only of the target cell for cell selection optimization, but also of the neighbor cell. Second, the SON server estimates the required RSRP which fulfills required SINR on uplink. The required RSRP is estimated using the current interference levels and uplink required SINR. Third, the SON server sets the required RSRP to *Qrxlevmin* at each cell. Finally the proposed scheme can select a suitable cell with the required uplink quality.

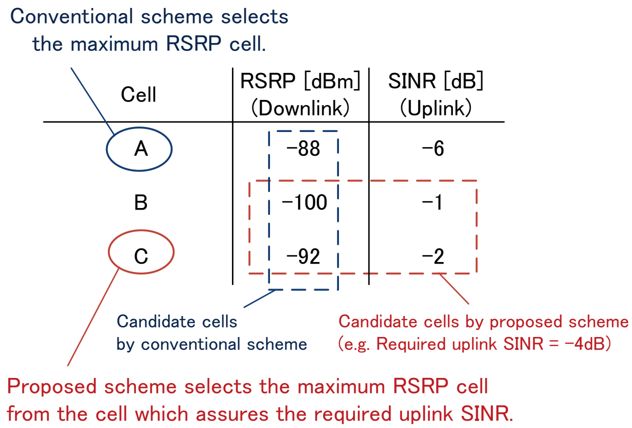

Figure 4. An example of the behavior of the both cell selection schemes.

Figure 4 shows an example of the behavior of both cell selection schemes. The conventional scheme selects the maximum RSRP cell within the neighbor cells. The proposed scheme selects the maximum RSRP cell from the cell which assures the required uplink SINR. In Figure 4, the required SINR sets to -4dB. In this case, cell B and cell C become the candidate cell assuming the required SINR and cell C which has higher RSRP level is selected.

V. Simulation Results

TABLE II. Simulation Parameters

Carrier Frequency	900 MHz
System Bandwidth	10 MHz
Number of Cells	21 cells
Inter-Site Distance	1732 m
Pathloss	$120.9+37.6 \log_{10}(d)$
Shadowing	Standard deviation: 8 dB, Correlation distance: 50 m, Correlation between cells: 0.5
Fading	Typical Urban 6path
Number of UEs	2100 UEs
Mobility	Random Walk, 3 km/h
Traffic	Full queue
Handover	T300: 1 s, T301: 500 ms, T304: 400 ms, T311: 10 s, delay (X2): 60 ms, delay (intra-eNB): 10 ms, T_ue_context: 1 s Time to Trigger: 256 ms
Cell selection	Qqualmin: -8 dB
RLF Detection	Qin: -6 dB, Qout: -8 dB, N310: 1, N311: 1, T310: 1 s
Optimization	HO Opt. Interval: 30 s, Ocn: -10dB(initial) Cell selection Opt. Interval: 60 s, Required SINR(uplink): -4 dB

In this section, the proposed scheme is evaluated through computer simulations. The simulation parameters are summarized in Table II. The other parameters are given in 3GPP Case1 scenario [12]. In the simulations, we also evaluate a scheme that selects a cell with maximum RSRP level as the conventional scheme. Therefore, in the conventional scheme, the cell selection parameter *Qrxlevmin* is set to a sufficiently small value (e.g. -140dBm). The proposed scheme selects a cell which fulfills the calculated threshold based on the measured uplink interference level.

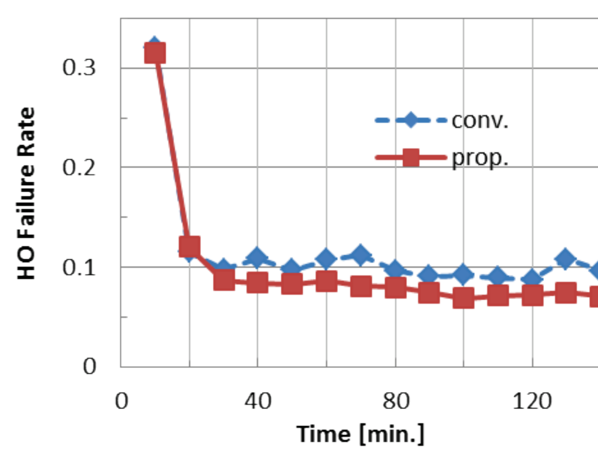

Figure 5. The history of the HO failure rate.

Figure 5 shows the history of the HO failure rate. From the results shown in Figure 5, it is confirmed that the HO failure rate is reduced over time by HO optimization. In addition, by using the proposed cell selection scheme, the HO failure rate is reduced by 3 percentage points in comparison with the conventional scheme.

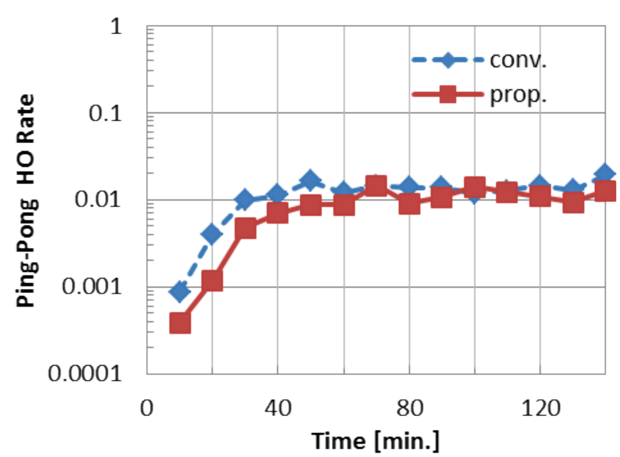

Figure 6. The history of the ping-pong HO rate.

Figure 6 shows the history of the ping-pong HO rate. From the figure, we can see that the ping-pong HO rate increases over time. That is because the objective of the HO optimization algorithm is to minimize HO failure and the total number of ping-pong HOs, but there is a tradeoff between the HO failure rate and the ping-pong HO rate [5]. In this simulation scenario, the initial HO failure rate is high compared to the ping-pong HO rate. Therefore, the HO optimization algorithm adjusts the HO parameter to reduce the HO failure rate. Nonetheless, we can see that the proposed scheme reduces the ping-pong HO rate by 0.5 percentage points compared to the conventional scheme.

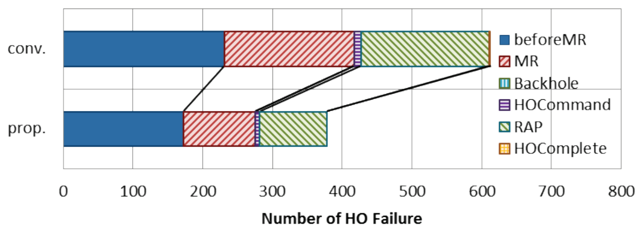

Figure 7. Causes of HO failure

In order to verify the effectiveness of the proposed scheme, the causes of HO failures are analyzed. Figure 7 shows the causes of HO failures. From the figure, it can be seen that the proposed scheme reduces the total number of HO failures by 38%. The main causes of HO failures are an RLF before measurement report transmission (noted as "beforeMR" in the figure), HO failure at measurement report transmission (MR), and HO failure during the random access procedure (RAP). By using the proposed scheme, the number of failures attributable to these major causes can be reduced by 25%, 44%, and 47%, respectively. Thus, the proposed scheme has a significant effect on measurement report transmission and the random access procedure. It shows that taking channel uplink quality into consideration makes a major contribution to the improvement of HO performance.

In order to verify the superiority of the proposed scheme, we evaluated the HO performance in terms of the change in interference on uplink, which is realized by changing the offered traffic of a UE. In Figure 8, we show the relationship between the offered load on uplink and the HO failure rate. Here, the traffic model over the downlink is full queue. The proposed scheme consistently reduces the HO failure rate by 2 percentage points to 4 percentage points compared to the conventional scheme. As the offered load increases, the proposed scheme achieves further improvements in the HO failure rate. In the conventional scheme, the HO failure rate increases with a high interference level. On the other hand, in the proposed scheme, UEs can reconnect to a suitable cell based on the current uplink interference level. Therefore, the proposed scheme has an almost stable HO failure rate.

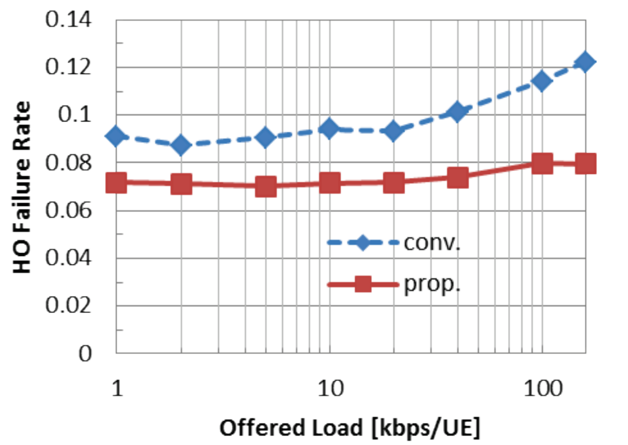

Figure 8. The relationship between the offered load on uplink and the HO failure rate.

VI. Conclusion

In this paper, we proposed a cell selection scheme to enhance the performance of HO optimization. In the proposed scheme, both the uplink and downlink channel quality is taken into consideration when selecting a suitable reconnected cell. Through the computer simulation, we can see that the proposed scheme reduces the HO failure rate and the number of HO failure by 3 percentage points and 38%, respectively. The analysis of the simulation results shows that the HO failures which are caused by the measurement report transmission and the random access procedure are decreased by 44% and 47%, respectively, and the fact that the uplink channel quality is taken into consideration makes a major contribution to the improvement of the HO performance. The proposed cell selection scheme is indispensable for HO optimization in LTE systems.

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