Performance evaluation of adaptive control CRE in HetNet with eICIC scheme

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Abstract: This paper describes the performance evaluation of a state-of-the-art adaptive control cell range expansion (CRE) technique in Heterogeneous Network (HetNet) with enhanced inter-cell interference coordination (eICIC) scheme. The features of the proposed adaptive control CRE technique are described through comparison with those of conventional methods. System-level computer simulation results such as average and 5-percentile user throughput are provided under the conditions of HetNet with eICIC, as parameters of almost blank subframe (ABS) ratio for eICIC. We confirmed that the proposed adaptive control CRE can improve 5-percentile user throughput while maintaining the average user throughput even for HetNet with eICIC.

Keywords: mobile communication, heterogeneous network, cell range expansion, enhanced inter-cell interference coordination

Classification: Terrestrial Wireless Communication/Broadcasting Technologies

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1 Introduction

A Heterogeneous Network (HetNet) is expected to increase system capacity in 4th-generation (4G) and 5th-generation (5G) mobile communication systems [1, 2]. A typical HetNet approach is to place a pico cell within the coverage area of a macro cell with the purpose of allowing user equipment (UE) to access pico cells with overlapping geographical coverage areas. Cell range expansion (CRE) technology, which encourages the data traffic movement of macro cell to a pico cell, may significantly assist HetNet deployment [3, 4]. For a HetNet approach to be effective, it is important to determine whether UE should communicate with macro cells or pico cells. Conventional CRE methods automatically offset UE to the power received from the pico cell. However, Conventional CRE may degrade the received signal-to-interference plus noise ratio (SINR) for UE when a cell selection offset (CSO) is provided for all UEs. Like this, it is unclear whether a fixed CSO should be provided for all UEs within a macro cell.

To comprehensively improve user throughput, we have proposed an adaptive control CRE that provides optimal CSO for each UE within a macro cell. Thus far, we have evaluated the throughput performance of proposed method [5, 6, 7]. However, the performance of a HetNet that employs enhanced inter-cell interference coordination (eICIC) has not been previously evaluated.

Motivated by this observation, in this paper, we focus on the performance of the proposed adaptive control CRE in HetNet with eICIC scheme [8]. The contributions of this research can be summarized as follows:

- We have proposed an adaptive control CRE in order to further increase of overall system performance.
- We have evaluated the throughput performance of the proposed adaptive control CRE in HetNet with eICIC as parameters of almost blank subframe (ABS) ratio.

Section 2 introduces the features of proposed adaptive control CRE in comparison with those of conventional methods. Section 3 describes system-level computer simulation conditions and their results such as 5-percentile and average user throughput as parameters of eICIC ABS ratio. This section also presents the performance of the proposed adaptive control CRE in comparison with conventional method. Finally, conclusions are summarized in Section 4.
2 Adaptive control CRE

CRE is commonly known as a technical approach used to extend the pico cell coverage within a macro cell in HetNet. In other words, CRE expands the coverage of a pico cell so that more UEs near cell edge can access the pico cell. Accordingly, if the traffic demands are increased within a macro cell served by a macro eNB, CRE enables offloading of the overload traffic to the pico eNB. CRE can be controlled using a reference signal received power (RSRP)-based method. Using this approach, UE is offset to the received pico cell power. The offset is defined by the CSO. Conventional CRE provides a fixed CSO for all UEs within a donor eNB.

We have proposed adaptive control CRE, which can assign several CSOs to UE according to the received SINR. Herein, we consider two CSOs.

\[ \gamma_i^u = \begin{cases} \text{CSO}_{\text{high}} & \text{if } \text{SINR}_u < \text{SINR}_{\text{th}} \\ \text{CSO}_{\text{low}} & \text{otherwise} \end{cases} \]  

where \( \gamma_i^u \) represents the CSO applied to user \( u \) located within and/or close to cell \( i \). \( \text{SINR}_u \) is the SINR measured for user \( u \) using the RSRP from a donor macro eNB. When CRE is applied to a pico eNB, pico cell coverage is extended for UE according to the rule of (1).

Fig. 1 shows the principle of proposed adaptive control CRE using the cumulative distribution function (CDF) of the SINR, where the SINR is measured for user \( u \) using the RSRP from a donor eNB. The threshold of SINR, \( \text{SINR}_{\text{th}} \), is determined by \( \alpha \), which is a point on the CDF of the SINR in a macro cell as shown in Fig. 1(a). Fig. 1(b) shows the decision procedure for whether \( \text{CSO}_{\text{high}} \) or \( \text{CSO}_{\text{low}} \) is used for each UE. \( \text{CSO}_{\text{low}} \) is applied to UEs with an SINR...
greater than SINR<sub>th</sub>. Similarly, CSO<sub>high</sub> is applied to UEs with an SINR lower than SINR<sub>th</sub>. Like this, the size of a pico cell for UE with CSO<sub>high</sub> appears to be wider compared with UE with CSO<sub>low</sub>. Fig. 1(c) illustrates the operation example of adaptive control CRE. The CRE size for UE with CSO<sub>high</sub> will be wider than that for UE with CSO<sub>low</sub>.

3 Performance evaluation

3.1 HetNet with eICIC scheme

In this paper, we focus on the performance of the proposed adaptive control CRE in HetNet with eICIC scheme which is an interference control technology. When the macro eNB has no transmission power at a subframe of “ABS”, interference from the macro eNB to UEs connected to a pico eNB can be significantly reduced. Accordingly, with eICIC, a macro cell and pico cells which share co-channel (same carrier frequency) are possible to use radio resource in different time ranges. In the simulation, we assumed that one radio frame of the macro cell has a duration of 10 ms and comprises 10 subframes. For example, when three subframes are used as an ABS, the ABS ratio is 3/10.

3.2 Throughput performance

System-level computer simulations are performed on the basis of LTE/LTE-Advanced standards under the condition of HetNet with eICIC. Table I summarizes the main simulation parameters. The macro cell layout is a hexagonal grid, and each cell is divided into three sectors. A macro eNB has much higher transmission power (+46 dBm) than a pico eNB (+30 dBm).

| Parameter                  | Macro Cell                          | Pico Cell                          |
|----------------------------|-------------------------------------|------------------------------------|
| Cell layout                | Hexagonal grid, 19 cell sites, 3 sectors per site | 4 Pico cells per sector, Uniform distribution |
| Cell radius (ISD)          | 289 m (500 m)                       | —                                  |
| Transmission power         | 46 dBm                              | 30 dBm                             |
| eNB antenna gain           | 14 dBi                              | 5 dBi                              |
| UE layout                  | 30UEs per sector, clustered distribution |                                     |
| Carrier frequency          | 2.0 GHz                             |                                    |
| System bandwidth           | 10 MHz (50 RBs)                     |                                    |
| Traffic model              | Full buffer                         |                                    |
| Scheduling algorithm       | Proportional fairness               |                                    |
| Link adaptation            | 15 Modulation and coding scheme     |                                    |
| Link to system mapping     | EESM                                |                                    |
| ABS ratio                  | 0/10 to 9/10                        |                                    |
| Adaptive Control CRE       | CSO<sub>high</sub> = 11 dB, CSO<sub>low</sub> = 8 dB |                                    |

Fig. 2 shows the simulation results such as the average and 5-percentile user throughput under the condition of HetNet with eICIC. Fig. 2(a) shows the relation-
ship between average user throughput and ABS ratio when adaptive control CRE is used. In the simulation, assuming different two CSOs, $\text{CSO}_{\text{high}}$ and $\text{CSO}_{\text{low}}$ are 11 dB and 8 dB respectively. The ABS ratio is parameterized from $0/10$ to $9/10$. The blue circle shows the average user throughput for all UEs within the macro cell (all UEs). The gray square indicates the performance for UEs connected to the pico eNB (pico UEs). The orange triangle shows the performance for UEs connected to the macro eNB (macro UEs). A larger ABS ratio can improve the average user throughput for “all UEs”, since the average user throughput for “pico UEs” can be significantly improved as shown in Fig. 2(a).

Fig. 2(b) shows the relationship between 5-percentile user throughput and ABS ratio. An ABS ratio of $3/10$ provides the best performance for “all UEs”. However,
the performance decreases when the ABS ratio exceeds $3/10$. A larger ABS ratio cannot allocate sufficient radio resource blocks to “macro UEs”.

Fig. 2(c) shows the average and 5-percentile user throughput of adaptive control CRE (Proposed) when ABS ratio is $3/10$. The throughput performance of the conventional method for three types of fixed CSOs (CSO = 0, 8, 11 dB) are also included. The black bar shows the average user throughput corresponding to the left-side axis, while the gray bar shows the 5-percentile user throughput corresponding to the right-side axis. As shown in Fig. 2(c), the proposed adaptive control CRE technique can improve 5-percentile user throughput while maintaining the average user throughput in comparison with conventional CRE with CSOs of 0 dB, and 8 dB, and 11 dB.

4 Conclusion

This paper presented the user throughput performance of a proposed adaptive control CRE in a HetNet with eICIC scheme. We confirmed that ABS ratio of $3/10$ provided the best performance for 5-percentile user throughput. We also confirmed that the proposed method with CSO$_{\text{high}}$ of 11 dB and CSO$_{\text{low}}$ of 8 dB improved 5-percentile user throughput while maintaining the average user throughput in comparison with conventional CRE providing a fixed CSO for all UEs. This work was obtained in part by Mr. K. Kikuchi who is a graduate of Kogakuin University.