Picocell Range Expansion for UEs Connected to Macro-BSs in HetNets

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***Abstract*—In a heterogeneous network (HetNet), the cell range expansion (CRE) technique enables more user equipment (UE) to connect to picocells, thereby expanding picocell coverage. In conventional CRE techniques, a fixed cell selection offset (CSO) is applied to all UEs. This paper proposes a new type of CRE that focuses on UEs connected to macro base stations (macro-BSs). First, the principle and algorithm of the proposed CRE are described and compared with those of the conventional approach. Then, we present the average and 5-percentile user throughput for the proposed CRE in comparison with conventional CRE by using system-level computer simulations. The simulation results confirm that the proposed CRE can improve the average user throughput compared with the conventional method, although the 5-percentile user throughput deteriorates.**

Keywords—mobile communication, heterogeneous network, cell range expansion, personal picocell scheme

I. Introduction

Heterogeneous network (HetNet) is an effective and simple way to increase system capacity, i.e., to accommodate a huge number of mobile data traffic. HetNet consists of macrocells operated by high-power base stations (macro-BS) and picocells operated by low-power base stations (pico-BS) within the same coverage, as shown in Fig. 1. When the bandwidth of the pico-BS is large, the HetNet deployment must ensure that the picocells operated by the pico-BS can support enough UEs, even if the transmit power of pico-BS is small compared to that of macro-BS. Cell selection for UEs in HetNet is typically performed by comparing the downlink reference-signal received power (RSRP) from macro-BS and the downlink RSRP from pico-BS. In general, macro-BS connection ratio is greater than pico-BSs connection ratio, because the macro-BS transmit power is greater than the pico-BS transmit power.

Conventional cell range expansion (CRE) technique for picocells in HetNet uses a positive cell selection offset (CSO) for the downlink RSRP from the pico-BS, and picocell coverage appears wider, thus increasing the connection ratio of the pico-BS. However, CRE degrades the downlink RSRP of UEs with a connection changed from macro-BS to pico-BS; according to the drawbacks of CRE, the received signal-to-interference plus noise ratio (SINR) of the UEs may deteriorate, and the user throughput of the UE may deteriorate [1]–[6].

To overcome this drawback, adaptive control CRE was proposed, which provides different CSO for each UE and can form the optimal picocell for each UE [7].

In [7]–[13], when providing CSO for UEs, all UEs located within the coverage of the dominant macro-BS were targeted. That is to say, the adaptive control CRE targeted both UEs connected to the macro-BS and UEs connected to pico-BS in the microcell before triggering CRE.

In this paper, we propose a new type of CRE that focuses on the UEs connected to macro-BS, which is called “macro-UE”. On the other hand, “pico-UE” connected to pico-BS in the macrocell are excluded. In this way, the proposed CRE focuses only on macro-UE when setting the CSO, however pico-UE is not subject to CRE. In this study, we evaluate user throughput of the new type of CRE by using system-level computer simulations.

This paper is organized as follows. In Section II, we introduce the principle and algorithm of the proposed CRE. In Section III, we first show the parameter optimization of the proposed CRE by evaluating user throughput of HetNet, using system-level computer simulations. We then demonstrate the average and 5-percentile user throughput of the proposed CRE in comparison with conventional method. Finally, we conclude our study in Section IV.

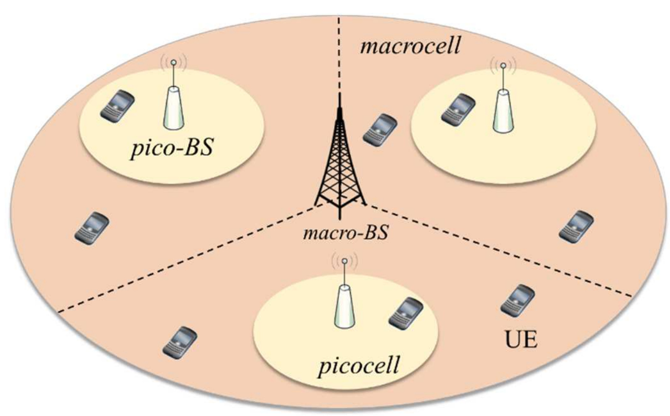

Fig. 1. Configuration of HetNet.

II. PICOCELL RANGE EXPANSION TECHNIQUE

A. Personal picocell scheme

In the CRE technique, the connection ratio to the pico-BS can be increased by adding a positive CSO to the downlink RSRP from the pico-BS. In this case, the picocell coverage is wider for the UE as an "extended picocell". In conventional CRE, a fixed CSO is provided for all UEs, so the size of the extended picocell is the same for all UEs.

Figure 2 shows a personal picocell scheme using proposed CRE to form an extended picocell independent of each UE. CSO_u is applied to each optimal macro-UEs in this scheme. A unique value of positive CSO (i.e., CSO_u) is applied to UE_2 with a low downlink RSRP from the dominant macro-BS to encourage the connection to pico-BS. Conversely, no positive CSO is applied to UE_1 with a relatively high downlink RSRP from the dominant macro-BS. Consequently, the picocell coverage of UE_2 looks wider than that of UE_1. This is merely an example with two macro-UEs.

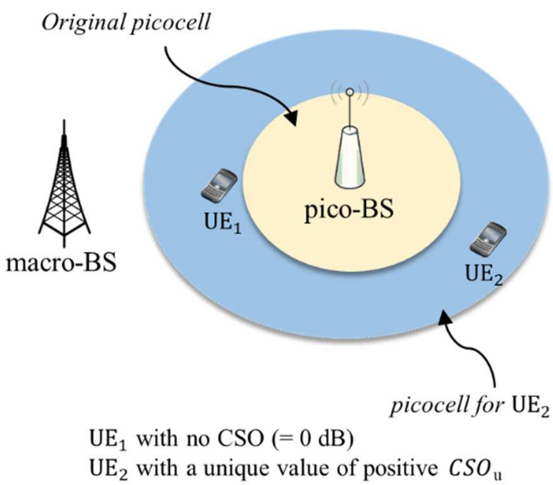

Fig. 2. Personal picocell sheme in HetNet.

B. Principle of new type of CRE

We propose a new type of CRE that focuses on the UEs connected to macro-BS before triggering CRE. In contrast, "pico-UE" connected to pico-BS are excluded. In this way, the proposed CRE focuses only on macro-UE when setting the CSO, however pico-UE is not subject to CRE.

Figure 3 shows the CSO setting for the proposed CRE. This process is performed for each macro sector. First, macro-UEs are listed in increasing order of the $RSRP_{macro}$, which is the reference signal received power at UE receiver of the transmission signal from a macro-BS. Second, a limited number of macro-UE (i.e., from UE_1 to UE_j) is determined when providing a positive j, as shown in Fig. 3. The remaining macro-UEs will not be assigned the CSO_u, i.e., set the CSO at 0 dB. Consequently, some of the macro-UE (UE_1 to UE_j) are forced to connect to pico-BS within the dominant macro-BS after triggering the CRE.

Figure 4 shows the connection sequence between macro-UE and pico-BS or macro-BS. First, macro-UE is assumed to maintain a radio resource control (RRC) connection with the macro-BS. The macro-UE reports downlink $RSRP_{macro}$ and $RSRP_{pico}$ as measurement reports to the dominant macro-BS. Then, the macro-BS produces the ranking table using the $RSRP_{macro}$ for all macro-UEs. All macro-UEs are listed in increasing order of the $RSRP_{macro}$ for each macrocell or macro sector. Based on the ranking table, the dominant macro-BS determines which macro-UE to assign a positive CSO_u. If $RSRP_{macro} < RSRP_{pico} + CSO_u$, then the macro-UE will be connected with the pico-BS.

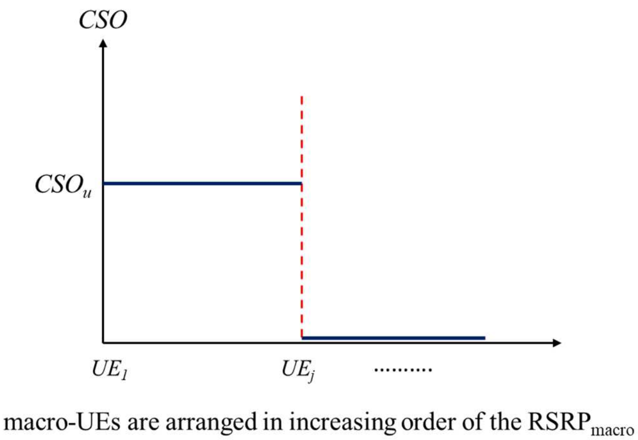

Fig. 3. CSO setting for proposed CRE.

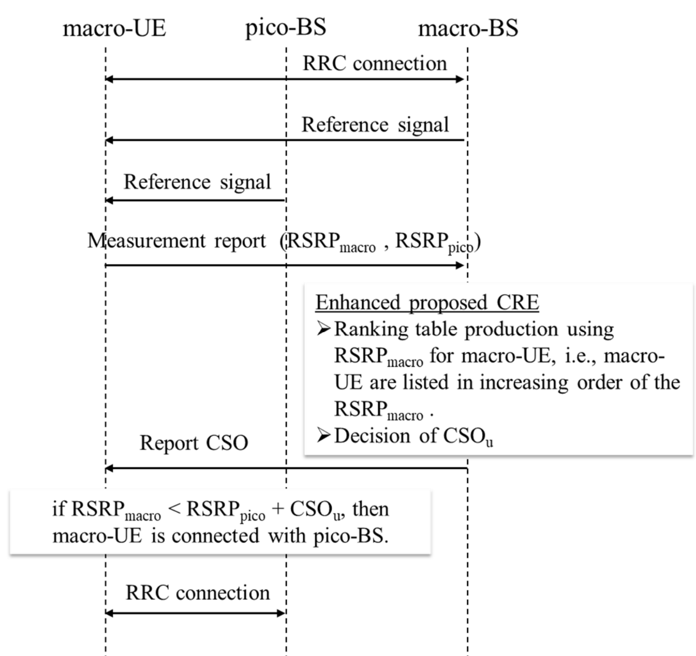

Fig. 4. Connection sequence of proposed CRE.

III. SIMULATION CONDITIONS AND RESULTS

A. Simulation conditions

In this section, we evaluate the user throughput of HetNet, which consists of macrocells using the 2 GHz band and picocells using the 4.5 GHz band, using system-level computer simulations.

The main simulation parameters are listed in Table I. The system bandwidths of the macro-BS and pico-BS are assumed to be 10 MHz and 100 MHz, respectively. In this simulation, there are 19 macro base stations, which are configured into three sectors. There are 30 UEs per macro sector, and two-thirds of those UEs belong to clusters. For link adaptation applied to the downlink, 32 different modulation and coding schemes (MCS) incorporating 1024-QAM are used [12].

Full buffer (FB) traffic model is used which provides a theoretical framework used to analyze the behavior of packet switched networks.

TABLE I. PRIMARY SIMULATION PARAMETERS

Parameter	Assumption	
	macro-BS	pico-BS
Cell layout	Hexagonal grid, 19 cell sites, 3sectors per site	4 Picos per sector
Cell radius	289 m (ISD = 500 m)	-
Carrier frequency	2.0 GHz	4.5 GHz
System bandwidth	10 MHz	100 MHz
Number of resources	50	500
FFT size	1024	8192
Tx power	46 dBm	25 dBm
Tx height	32 m	10 m
Tx antenna gain	14 dBi	5 dBi
Antenna downtilt angle	15 deg	10 deg
UE distribution	2/3 clustered distribution, 30 UEs per sector	
Link adaptation	32 MCS (QPSK to 1024-QAM)	
Traffic model	Full Buffer	

B. Parameter optimaization for proposed CRE

First, we determine the parameter optimization of the proposed CRE., i.e., CSO_u and the number of UEs expressed in j. Figures 5, 6, and 7 show the average and 5-percentile user throughput of HetNet versus the number of macro-UEs "j" for CSO_u = 15, 18, 21 dB, respectively. The j = 0 indicates that the number of target macro-UEs is zero, that is, CRE is not activated. The blue bars indicate the average user throughput corresponding to the left-hand axis, and the orange bars indicate the 5-percentile user throughput corresponding to the right-hand axis.

In any CSO_u, as j increases, the bottom 5% user throughput improves, but the average user throughput degrades. When j increases, the probability of macro-UEs connecting to pico-BS increases. This is the reason why the 5-percentile user throughput improves as j increases.

Link these, as j increases, the 5-percentile user throughput increases, however the average user throughput decreases. From the perspective of enhancing 5-percentile while mitigating degradation in the average throughput, CSO_u = 18 dB, and j = 8 or 10 are determined to be the best.

Figures 8 and 9 are the result of analysis for macro-UEs and pico-UEs after triggering CRE.

Figure 8 shows the average and 5-percentile user throughput of only macro-UEs, however Figs. 5 to 7 show the user throughput of HetNet, including both macro-UEs and pico-UEs. As shown in Fig. 8, the proposed CRE can increase both average and 5-percentile user throughput when j increases. The reason is that, due to CRE, some macro-UEs are connected to pico-BSs; in other words, the number of macro-UEs connecting to macro-BSs decreases, which leads to improved throughput for the macro-UEs.

In contrast, as the value of j increases, the average and 5-percentile user throughput of only pico-UEs decreases as shown in Fig.9. The reason is that the number of pico-UEs connecting to pico-BSs increases due to CRE.

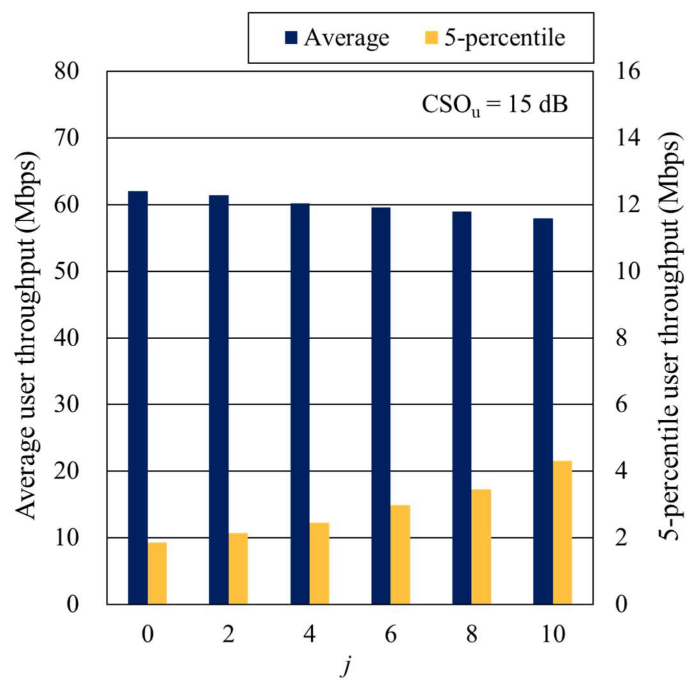

Fig. 5. User throughput versus j when CSO_u is 15 dB.

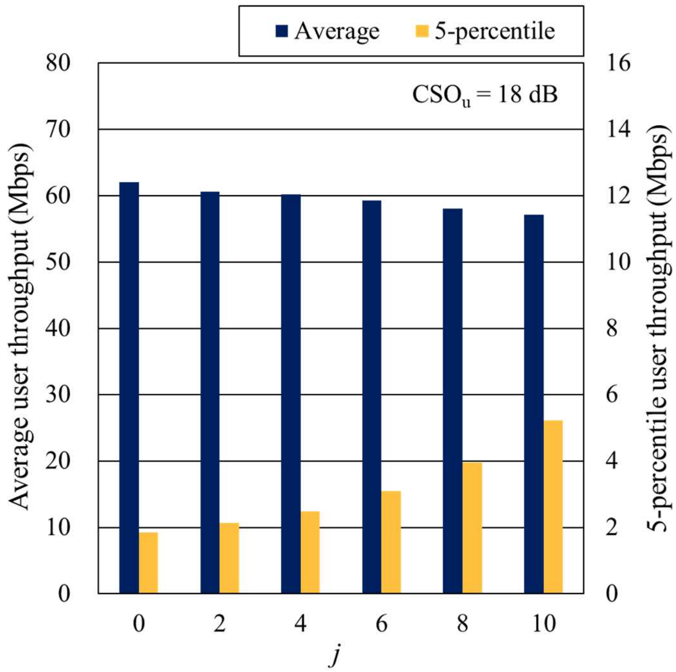

Fig. 6. User throughput versus j when CSO$_u$ is 18 dB.

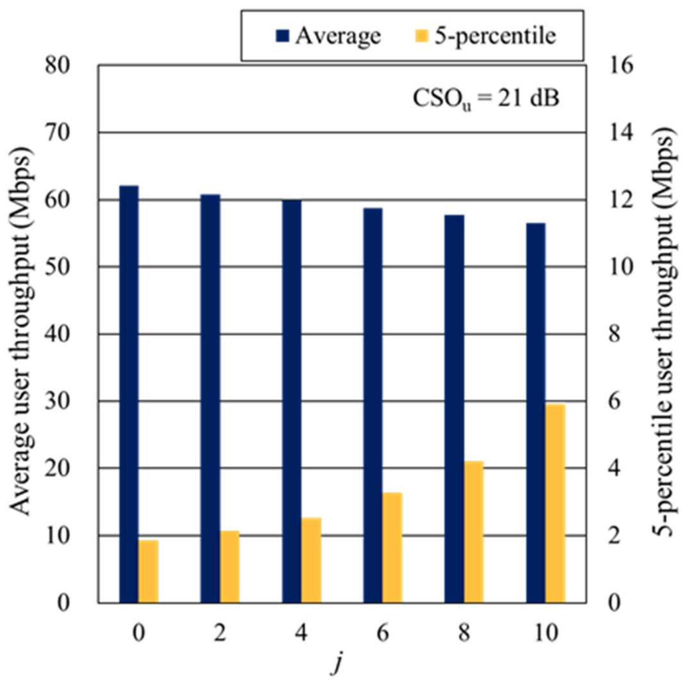

Fig. 7. User throughput versus j when CSO$_u$ is 21 dB.

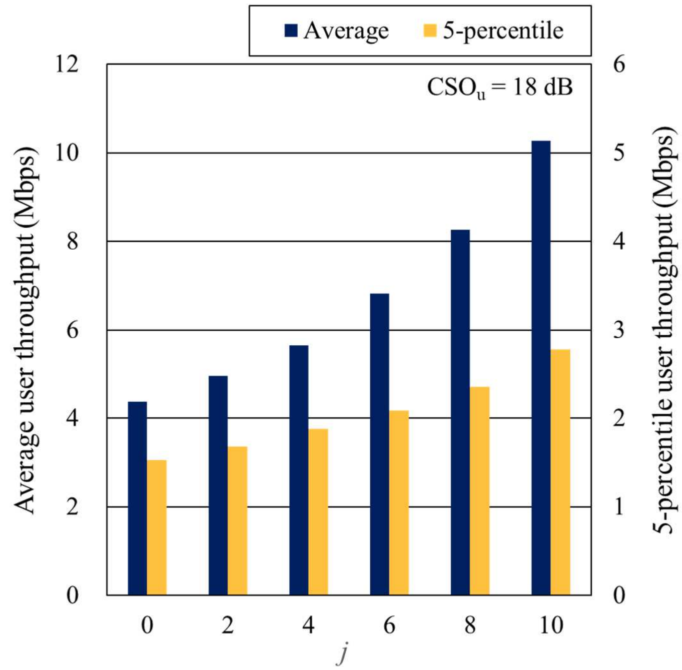

Fig. 8. Analysis for macro-UEs after triggering CRE.

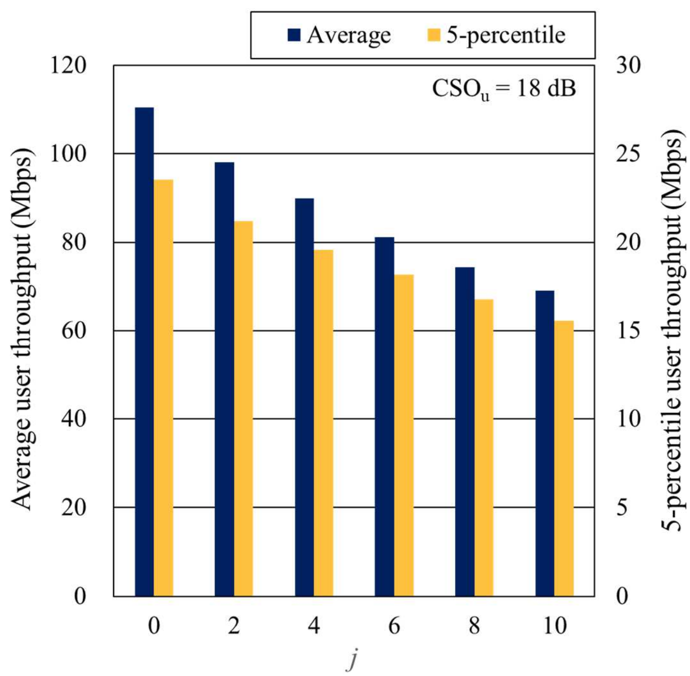

Fig. 9. Analysis for pico-UEs after triggering CRE.

C. Comparison with the conventional

Figure 10 shows the average and 5-percentile user throughput of the proposed CRE (Proposal) using the optimal parameters compared with those for the coventional method and homogeneous network (HomoNet). HomoNet consists of only macrocells without picocells.

It is confirmed that the proposed CRE can improve the 5-percentile user throughput while maintaining the average user throughput compared with the case without CRE (CSO = 0 dB). The simulation results also confirmed that the proposed CRE can improve the average user throughput compared with the conventional method (CSO = 18 dB). Here, in the conventional method, CSO = 18 dB provides for all UEs that includes both macro-UEs and pico-UEs.

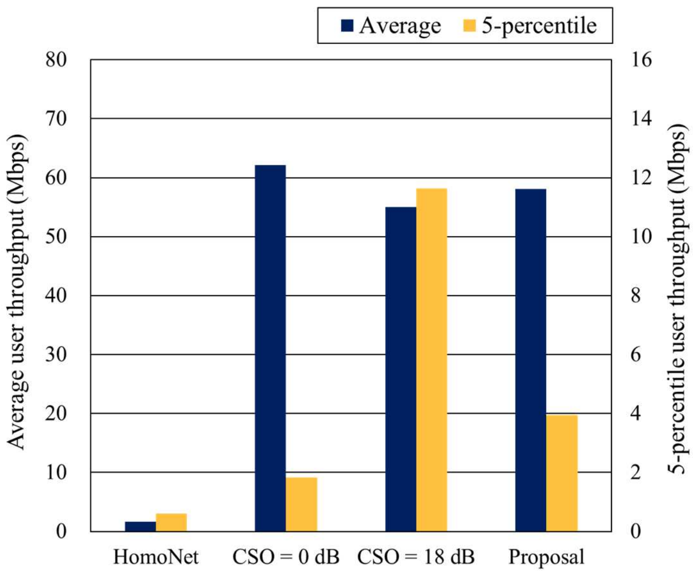

Fig. 10. Comparison with proposal and conventional.

IV. Conclusion

In this paper, we proposed new type of CRE that focuses on UEs connected to macro-BSs.

First, the principle and algorithm of the proposed CRE were described and compared with those of the conventional approach. Next, we optimized the parameters of the proposed CRE, i.e., CSO and the number of applicable macro-UEs. We them presented the average and 5-percentile user throughput for the proposed CRE, compared with conventional CRE, using system-level computer simulations. The simulation results confirmed that the proposed CRE can improve the 5-percentile user throughput while maintaining the average user throughput compared with the case without CRE (CSO = 0 dB). The simulation results also showed that the proposed CRE can improve the average user throughput compared with the conventional method, although the 5-percentile user throughput deteriorates.

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