Throughput Performance of Adaptive Control CRE in Multicarrier HetNets

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Abstract:

Multicarrier heterogeneous networks (HetNets) are promising technique of 5th-generation mobile systems to increase system capacity. This paper proposes a personal-cell scheme using an adaptive control cell range expansion (CRE) in multicarrier HetNets, which combined with a macrocell with a carrier frequency of 2.0 GHz and a picocell with a carrier frequency of 3.4 GHz. Average and 5-percentile user throughputs of the proposed adaptive control CRE are presented using system-level computer simulations in comparison with the conventional CRE.

Using these results, we validate the design of the adaptive control CRE in multicarrier HetNets.

Keywords: Heterogeneous networks, Multicarrier deployment, Cell range expansion, 256-QAM

Classification: Wireless Communication Technologies

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1 Introduction

Heterogeneous Networks (HetNets) that uses multiple carrier frequencies are expected to further increase the system capacity in fifth-generation (5G) mobile systems and beyond [1]–[3]. In HetNets deployments, cell range expansion (CRE) technique that virtually expands the picocell coverage plays an important role from the increase of system capacity perspective. In general, CRE applies fixed cell selection offset (CSO) to downlink reference signal received power (RSRP) from a picocell. Therefore, CRE can make more user equipment (UE) to access the picocell. Previously, we proposed an adaptive control CRE that can provide an optimal different CSO for each UE aiming for personal-cell scheme, although the conventional CRE method provides a fixed CSO for all UE [4], [5].

To increase data rates is also one of 5G targets, and a straightforward method is the use of higher-order modulation. Towards 5G, the use of 256- and 1024-quadrature amplitude modulation (QAM) has been discussed especially in downlink.

In Ref. [5], we evaluated user throughput for adaptive control CRE, however the conditions were in co-channel (single-carrier) HetNet using 2.0 GHz and modulation scheme was up to 64-QAM.

In this paper, we focus on the throughput performance of the adaptive control CRE and also the improvement effect for the use of 256-QAM in multicarrier HetNets. We demonstrate the average and 5-percentile user throughput of the adaptive control CRE in comparison with the conventional method using system-level computer simulations. In Section 2, we show the concept of the adaptive control CRE in multicarrier HetNet. In Section 3, we present the computer simulation conditions and their results such as the average and 5-percentile user throughputs. Finally, we conclude our work in Section 4.

2 Personal-cell scheme using adaptive control CRE

Figure 1(a) shows the concept of adaptive control CRE in multicarrier HetNet in which a macrocell using 2.0 GHz is combined with picocells using 3.4 GHz. As shown in Fig. 1(a), the picocell coverage are independent for each UE although the transmission power of all pico-eNB is fixed. Like this, the proposed adaptive control CRE is based on personal-cell scheme in HetNets. To realize it, each UE must have ideally optimal CSO in CRE. However, conventional CRE provide a fixed CSO for all UE after CRE activation. Accordingly, the conventional CRE may reduce downlink received signal to interference plus noise power ratio (SINR) measured at UE. The adaptive control CRE can solve this problem because the adaptive control CRE does not provide a fixed CSO for all UE but provides optimal CSO for each UE considering the received SINR.

In this paper, two different CSOs are assumed for the proposed adaptive control CRE, i.e., CSO\textsubscript{high} and CSO\textsubscript{low}, in which the CSO\textsubscript{high} is higher than CSO\textsubscript{low}. Figure 1(b) illustrates the operation principle of the adaptive control CRE using CSO\textsubscript{high} and CSO\textsubscript{low} in picocell. The picocell coverage for UE with CSO\textsubscript{high} is wider than that for UE with CSO\textsubscript{low}.

Figure 1(c) shows how to determine whether CSO\textsubscript{low} or CSO\textsubscript{high} is used. α is a
point on the cumulative distribution function (CDF) of $\text{SINR}_m$, where $\text{SINR}_m$ is obtained by measuring the downlink RSRP derived from the macro eNB. $\text{CSO}_{\text{low}}$ is applied to UE with an SINR greater than $\text{SINR}_{\text{th}}$. Similarly, $\text{CSO}_{\text{high}}$ is applied to UE with an SINR lower than $\text{SINR}_{\text{th}}$, where $\text{SINR}_{\text{th}}$ is assumed to meet $\alpha$.

![Diagram of multicarrier HetNet and adaptive control CRE](image)

(a) Adaptive control CRE in multicarrier HetNet

(b) Picocell expansion using $\text{CSO}_{\text{high}}$ and $\text{CSO}_{\text{low}}$.

(c) Decision of $\text{CSO}_{\text{low}}$ and $\text{CSO}_{\text{high}}$ in adaptive control CRE.

**Fig. 1.** Multicarrier HetNet and adaptive control CRE

### 3 Performance evaluation

The primary simulation parameters are listed in Table I. The carrier frequencies of macrocell and picocell are 2.0 and 3.4 GHz, respectively. The number of UE in macro sector is 30. The UE distribution is realized by the way that 2/3 of UE are
nearby pico eNB and others are uniformly set within the macro eNB.

From the modulation and coding sets (MCS) perspective, two types of MCS are used, one is up to 64-QAM, and another is up to 256-QAM, although the number of MCS is assumed to be limited by 15.

| Table I. Simulation parameters |
|-------------------------------|
| **Parameter** | **macro cell** | **pico cell** |
| Cell layout     | Hexagonal grid, 19 cell sites, 3 sectors per site | 1-4 pico eNBs per sector, Uniform distribution |
| Cell radius (ISD) | 289 m (500 m) | — |
| eNB Tx power    | 46 dBm          | 30 dBm          |
| eNB antenna gain | 14 dBi          | 5 dBi           |
| UE distribution | 30 UEs per sector, 2/3 clustered distribution | |
| Carrier frequency | 2.0 GHz      | 3.4 GHz          |
| System bandwidth | 10 MHz        | 10 MHz           |
| Traffic model   | Full buffer     |                 |
| CSO             | From 0 to 16 dB, 4dB step |                 |
| Adaptive Control CRE | CSO$_{low} = 8$ dB, CSO$_{high} = 16$ dB, $\alpha = 0.4$ |         |

Figure 2(a) shows the average and 5-percentile user throughputs of adaptive control CRE with the CSO$_{low}$ of 8 dB and CSO$_{high}$ of 16 dB whose values provides best performance in this condition, as well as the conventional. The blue bar shows the average user throughput corresponding to the left-side axis, and the orange bar shows the 5-percentile user throughputs corresponding to the right-side axis. By increasing CSO up to 12 dB in the conventional CRE, 5-percentile user throughput increases and the average user throughput decreases. When CSO is greater than 12 dB, the conventional CRE decreases both the average and 5-percentile user throughputs. However, adaptive control CRE can improve the 5-percentile user throughput while maintaining the average user throughput. Compare with the conventional CRE with a fixed CSO of 16 dB, the adaptive control CRE improves the average and 5-percentile user throughput by 3% and 16.4%, respectively.

Figure 2(b) shows the average user throughput versus number of pico-eNBs per macro sector for two types of MCSs; one is up to 64-QAM (QPSK to 64-QAM) shown by blue bar, and another is up to 256-QAM (QPSK to 256-QAM) shown by orange bar. When the number of pico-eNB is one, the MCS including 256-QAM can improve the average user throughput by 13% compared to that of the use of MCS up to 64-QAM. However, when the number of pico-eNBs is three, the improvement by use of 256-QAM decreases to 6% because of increase of the interference among picocells.
4 Conclusion

This paper first presented our concepts of personal-cell scheme using an adaptive control CRE in multicarrier HetNets and then described the average and 5-percentile user throughput of the adaptive control CRE. We confirmed that the adaptive control CRE with the CSO\textsubscript{low} of 8 dB and CSO\textsubscript{high} of 16 dB can improve the average and 5-percentile user throughput by 3% and 16.4%, respectively, compared to the conventional (CSO of 16 dB). Furthermore, it is confirmed that the use of MCS including 256-QAM can improve the average user throughput by 13% compared to that of the use of MCS up to 64-QAM when the number of pico-eNB is one per macro sector in multicarrier HetNets.

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