Throughput performance of mmWave HetNets using three-sector picocell

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Abstract: Heterogeneous networks (HetNets) which combine with macro-cell and picocell in the same coverage are key technology to increase the system capacity. Millimeter wave (mmWave) technology is expected to achieve higher data rates or user throughput in fifth-generation (5G) mobile systems. In HetNets, cell range expansion (CRE) technique, which virtually expands the picocell coverage using cell selection offset (CSO), is very important. In this paper, we investigate average and 5-percentile user throughput of the mmWave HetNets using three-sector picocell as a function of CSO in the CRE using system-level computer simulations. We also compare the throughput with those of non-sector picocell, i.e., omni picocell. We confirmed that a CSO of 36 dB can provide the best performance, assuming that the signal bandwidth of picocell is 10 times wider than that of microcell. We also confirmed that the proposed “three-sector picocell” can improve the average and 5-percentile user throughputs by 2.1 and 1.8 times, respectively, compared with conventional “omni picocell”.

Keywords: millimeter wave, heterogeneous network, cell range expansion, cell selection offset, three-sector picocell

Classification: Wireless Communication Technologies

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1 Introduction

Heterogeneous networks (HetNets) are one of noteworthy denser infrastructures, in which picocell with low-power evolved node-B (eNB) is overlaid with the existing macrocell. HetNets can increase system capacity by offloading traffic from macrocell to picocell [1, 2]. In HetNets deployment, cell range expansion (CRE) technique that virtually expands the picocell coverage is very important, which can allow more user equipment (UE) to access the picocell. In CRE, UE are provided a positive cell selection offset (CSO) to the received power from the picocell in a cell selection process.

Recently, 5G network solutions refer to millimeter wave (mmWave) bands have attracted a lot of attention to achieve higher data rate because the amount of bandwidth available at mmWave frequency is enormous compared to that used by previous mobile networks [3, 4], although mmWave signals suffer from high path loss. Thus far in most cases, picocell is assumed to be omni type (non-sector) with an omni antenna. Also, an optimal CSO in CRE for the multiband HetNets using mmWave (mmWave HetNets) has not been sufficiently evaluated.

In [5], we have proposed mmWave HetNets using three-sector picocell with a wider bandwidth to overcome high path loss. However, the comparison with non-sector picocell, i.e., omni picocell, has not been evaluated. Therefore, we show the user throughput of mmWave HetNets using three-sector picocell in comparison with that of omni picocell.

Section 2 introduces the features of proposed mmWave HetNet using three-sector picocell operating at a carrier frequency of 28 GHz. This section also describes the principle of CRE in HetNet. Section 3 describes system-level computer simulation conditions and their results such as 5-percentile and average user throughput as a function of CSO in CRE. Finally, conclusions are summarized in Section 4.

2 HetNets using three-sector picocell

Figure 1(a) shows the proposed mmWave HetNet combined with a microcell and three-sector picocell with a wider signal bandwidth that uses 28 GHz band. The three-sector picocell means that a pico-eNB with three-sector antenna covers single picocell, whereas a conventional omni picocell is covered by pico-eNB with single omni antenna. Therefore, the three-sector picocell can increase the transmission antenna gain as well as the system capacity compared with the conventional omni picocell.
Figure 1(b) shows the principle of CRE for the picocell in HetNet, in which the picocell coverage can be increased using a positive CSO for the downlink reference signal received power (RSRP) from the picocell. Therefore, the picocell coverage appears to be wider when CRE is operated. If $\text{RSRP}_{\text{pico}}$ from pico-eNB plus CSO is larger than $\text{RSRP}_{\text{macro}}$ from macro-eNB, the UE is connected to the pico-eNB. Consequently, UE in the CRE zone can be connected to the pico-eNB, even though the $\text{RSRP}_{\text{pico}}$ is actually lower than $\text{RSRP}_{\text{macro}}$.

![Configuration of mmWave HetNet using three-sector picocell.](image)

(a) Configuration of mmWave HetNet using three-sector picocell.

![Extended picocell using a positive CSO in picocell.](image)

(b) CRE using a positive CSO in picocell.

**Fig. 1.** mmWave HetNet combined with macrocell and three-sector picocell with a wider bandwidth operating at a carrier frequency of 28 GHz.

### 3 Simulation results

We first investigate the average and 5-percentile user throughput of the proposed mmWave HetNet as a function of CSO using system-level computer simulations. Then, we compare it with those of the conventional omni picocell. In this paper, we assumed that carrier aggregation or dual connectivity between macro and picocells is not considered. The primary simulation parameters are listed in Table I. The carrier
frequencies used in the macro- and pico-eNBs are 2 and 28 GHz, respectively. The signal bandwidth of pico-eNB is 10 times wider than that of macro-eNB. The number of UE is fixed to 30 per macro sector. The UE layout is based on the cluster distribution, in which two-thirds of the UE are distributed within the cluster size of the pico-eNB, and the remaining one-third UE are distributed outside it [6]. The transmission power of macro- and pico-eNBs are assumed to be +46 and +22 dBm, respectively [7]. The path-loss model and other assumptions refer to [8]. We use 22 types of modulation and coding scheme (MCS) for a downlink adaptation, which is different from that used in [5].

Table I. Primary simulation parameters.

| Parameter              | Assumption                                      |
|------------------------|-------------------------------------------------|
|                        | Macro eNB                                       |
|                        | Pico eNB                                        |
| Cell layout            | Hexagonal grid, 19 cell sites, 3 sectors per site| 4 picos per macro sector, 3 sectors per site |
| Cell radius            | 289 m                                           | -                                               |
| Carrier frequency      | 2.0 GHz                                         | 28 GHz                                          |
| System bandwidth       | 10 MHz                                          | 100 MHz                                         |
| eNB antenna height     | 32 m                                            | 6 m                                             |
| eNB Tx power           | 46 dBm                                          | 22 dBm                                          |
| eNB antenna gain       | 14 dBi                                          | 23 dBi                                          |
| UE distribution        | 30 UEs per macro sector, 2/3 clustered distribution |
| Link adaptation        | QPSK to 256-QAM (22 MCS)                        |
| MIMO                   | 2x2 SU-MIMO                                      |
| Traffic model          | Full buffer                                     |

Figure 2(a) shows the average and 5-percentile user throughput in the downlink as a function of CSO. By increasing the CSO up to approximately 36 dB, the average user throughput increases. However, the performance decreases gradually when the CSO exceeds 36 dB. Likewise, by increasing the CSO up to approximately 36 dB, the 5-percentile user throughput increases. However, the performance decreases when the CSO exceeds approximately 36 dB. One reason is that a larger CSO decreases the received SINR of UEs connected to pico-eNB. Consequently, when the transmission power of pico-eNB is 22 dBm, the optimal CSO is approximately 36 dB in CRE operation. Compared to no CRE (CSO = 0 dB), the CSO of 36 dB can improve the average and 5-percentile user throughput by 1.4 and 25 times, respectively.

Figure 2(b) shows the average and 5-percentile user throughput of the “three-sector picocell” as well as those of conventional omni picocell. It is shown that the “three-sector picocell” can improve the average and 5-percentile user throughput by approximately 2.1 and 1.8 times compared with the “omni picocell”, respectively, when CSO is 0 dB.
4 Conclusion

We clarified the throughput of mmWave HetNet using a three-sector picocell with a wider signal bandwidth that uses 28 GHz band in comparison with omni picocell. We first presented the user throughput as a function of CSO in CRE using system-level computer simulations. We confirmed that a CSO of 36 dB provides best performance, and can improve the average and 5-percentile user throughputs by 1.4 and 25 times, respectively, compared with no CRE, assuming that the transmission power of pico-eNB was 22 dBm and the bandwidth of three-sector picocell was 10 times wider than that of macrocell. We also clarified that the proposed “three-sector picocell” can improve the average and 5-percentile user throughput by approximately
2.1 and 1.8 times compared with the conventional “omni picocell”, respectively.

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