

# Efficient Load Balancing Scheme in 5G Heterogeneous Cellular Networks

Jin-Bae Park

Department of Electrical and Electronic Engineering  
Yonsei University  
Seoul, South Korea  
spacey2k@yonsei.ac.kr

Kwang Soon Kim

Department of Electrical and Electronic Engineering  
Yonsei University  
Seoul, South Korea  
ks.kim@yonsei.ac.kr

**Abstract**—Heterogeneous cellular networks (HCNs) where conventional macro cells are being overlaid with low-powered small cells and the millimeter wave (mmW) frequencies are considered as a way to efficiently enhance the spectral efficiency per area with the availability of huge bandwidths. However, how to efficiently manage small cells and mmW frequencies is still an open question. In this paper, a load balancing problem for 5G HCNs is discussed with different band operation modes and a joint user association (UA) scheme using a hybrid self-organizing network (SON) is suggested for a practical clustered HCN.

**Index Terms**—mmWave, Load Balancing, Hybrid SON.

## I. INTRODUCTION

In order to deal with unprecedented high wireless data traffic demands from state-of-the-art applications such as augmented or virtual reality (AR or VR) [1] in 5G, the millimeter wave (mmW) frequencies will be used owing to the availability of huge bandwidths. However, compared to  $\mu W$  macro-cell BSs (mBSs) in heterogeneous cellular networks (HCNs), deploying mmW BSs is limited because the propagation conditions of the mmW frequencies are so harsh in terms of robustness that it is difficult to cover most of the given area. Therefore, mmW BSs need to be efficiently installed to provide dynamic coverage, considering given user locations. Also, in order to enhance the spectral efficiency per area, more small-cell BSs (sBSs) are expected to be installed with the conventional mBSs, forming a HCN. In such a HCN where sBSs support  $\mu W$  or mmW frequency bands, some of the important challenges are how to efficiently perform beam management [2] and power control with dynamic bandwidth management for the mmW frequencies and how to balance the loads among cells [3]. In this paper, a load balancing problem for 5G HCNs is discussed with different band operation modes and a joint user association (UA) scheme using a hybrid self-organizing network (SON) is suggested for a practical HCN.

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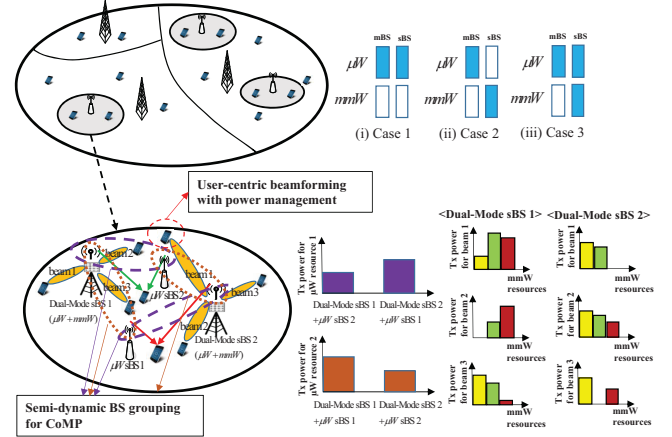


Fig. 1. The HCN model with different usage of  $\mu W$  and mmW frequencies: (i) Case 1:  $\mu W$  band is shared between mBS and sBS, (ii) Case 2:  $\mu W$  band and mmW band are assigned to mBS and sBS, respectively, (iii) Case 3: Both  $\mu W$  and mmW bands are used for sBS while only  $\mu W$  band is for mBS.

## II. SYSTEM MODEL AND LOAD BALANCING PROBLEM

Consider a downlink two-tier cHCN in which macro cells are overlaid with (clustered) small cells using a lower transmit power as shown in Fig. 1. Here, it is assumed that some sBSs support both  $\mu W$  and mmW frequency bands while the other sBSs and mBSs only support the  $\mu W$  frequency band, which reflects the fact that 5G encompasses both an evolution of traditional 4G-LTE networks and the addition of a mmW radio access technology. As shown in Fig. 1, for different usage of  $\mu W$  and mmW frequencies, the HCN model can be divided into the following 3 cases : (i) Case 1:  $\mu W$  band is shared between mBS and sBS, (ii) Case 2:  $\mu W$  band and mmW band are assigned to mBS and sBS, respectively, (iii) Case 3: Both  $\mu W$  and mmW bands are used for sBS while only  $\mu W$  band is for mBS. In the first case, users at edges of small cells can suffer from strong inter-tier interference from mBS while users in the interior of clustered small-cell hotspots can also suffer from intra-tier interference so that load balancing schemes should carefully take these interference issues into account. In the second case, inter-tier interference between macro cells and small cells is no longer an issue.

Also, the intra-tier interference issue becomes trivial due to narrow beam operations in mmW networks. Instead, to provide uniform service quality even for users at cell edges, a transmit power for mmW bands needs to be dynamically increased by limiting effective mmW bandwidth if needed. To do that, an efficient power allocation scheme with dynamic bandwidth management for mmW bands should be introduced, based on given user locations. In the last case, in addition to the issues in the first and second cases, power allocation between  $\mu W$  and mmW frequency bands needs to be considered based on given user locations for a good load balancing capability.

### III. PROPOSED HYBRID SON SCHEME IN A cHCN

To deal with the load balancing problem in the clustered HCN (cHCN) where some sBSs only support  $\mu W$  band while others support both  $\mu W$  and  $mmW$  bands, as in the first and third cases in Fig. 1, respectively, a joint user association and radio resource optimization scheme using a hybrid SON can be considered for a practical cHCN as in [5]. Here, for the  $\mu W$  band, with optimizing resource partitioning for the semi-dynamic approach as in [5], a proper power allocation for different resources is incorporated while a user-centric beamforming with efficient power management is considered for the mmW band and corresponding radio resource variables such as power and bandwidth for mmW resource partition of each directional beam are optimized. The network-wide fairness utility can be considered for the load balancing in a cHCN, which can be written as

$$\Upsilon = \sum_{\mathbf{u} \in \mathbf{U}} U(R_{\mathbf{u}}), \quad (1)$$

where  $R_{\mathbf{u}}$  denotes the average rate of user  $\mathbf{u}$  and  $U(r)$  denotes the general  $\alpha$ -fairness utility function for a rate  $r$ . Note that small-cell users in dual-mode sBSs can be served by multiple resources in  $\mu W$  or  $mmW$  bands.

Although a centralized approach for the above problem as in [4] can achieve an optimal solution, it requires formidable signaling overhead and computational complexity. To efficiently perform user association and radio resource optimization, a hybrid SON is adopted with a typical LTE network where EPC-MME is connected to all the mBSs and sBSs via small-cell cluster gateway or C-MME in each small-cell cluster. Here, C-MME performs user association and radio resource management in its local area, including power allocation optimization with dynamic bandwidth management for given mmW fixed beams in dual-mode sBSs. Then, a 2-level hybrid SON scheme is performed as follows. The EPC-MME performs the macroscopic UA based on the user reported information and the cluster uplink information from the C-MME in each cluster. On the other hand, the C-MME in each cluster determines the joint UA for its local cluster based on its local information and updates the cluster uplink information, which are performed in an iterative manner (Refer to [5] for more details).

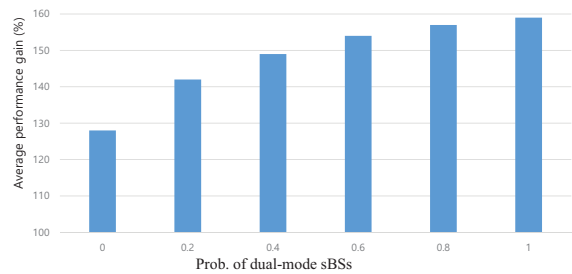


Fig. 2. The average performance gain of the proposed H-SON over SD-SON as the density of dual-mode sBSs increases.

### IV. SIMULATION RESULTS

In order to evaluate the advantages of the proposed hybrid SON, denoted as “H-SON”, the conventional single-cell based e-ICIC scheme, denoted as “SD-SON”, is compared in a two-tier cHCN, where dual-mode sBSs are deployed together with the conventional  $\mu W$  mBSs and sBSs. It is assumed that  $\alpha = 1$ , i.e., proportional fairness maximization, and the available bandwidth in mmW frequencies is 40 times larger than that in  $\mu W$  frequencies. Also, all the sBSs are assumed to use the same total power. For more details, please refer to [5].

In Fig. 2, in order to evaluate the average performance gain of the proposed H-SON over SD-SON in practical cHCN scenarios, the ratios of the bottom 5 % average user rates are evaluated as the probability of dual-mode sBSs among the total sBSs increases. It is noted that as there are more dual-mode sBSs, the superiority of the proposed scheme increases, which implies that the proposed scheme is expected to work well if applied to a practical cellular network, such as 5G HCNs.

### V. CONCLUSION

In this paper, a load balancing problem in 5G HCNs was discussed. It is noted that mmW frequency bands in 5G should be carefully used with an efficient power control management scheme with dynamic bandwidth management to provide user-centric coverage for a good load balancing capability. To deal with it, a joint user association scheme using a hybrid SON was suggested for a practical cHCN in 5G, where dual-mode sBSs are deployed together with the conventional  $\mu W$  mBSs and sBSs, and it was shown that it would be beneficial to apply the proposed solution to a practical cellular network for better network utilization.

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