Decentralized Radio Resource Management for Dense Heterogeneous Networks

(Invited Paper)

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***Abstract*—Heterogeneous network (HetNet) consisting of many small base stations (SBSs) within a present macro base station (MBS) is considered. The impact of SBS power on/off is discussed on network power consumption, throughput, and handover, and also the decentralized dynamic channel assignment.**

Keywords*— *heterogeneous network; power on/off; handover; throughput; channel assignment

I. Introduction

Due to the limited available bandwidth, the spectrum-efficiency was the most important concern for the last few decades. Also, the available energy, in particular for battery operated user equipments (UEs), is limited. Therefore, the energy-efficiency will be an important concern for the next generation 5th generation (5G) mobile communications. To improve both the spectrum-efficiency and energy-efficiency, networks need to be significantly restructured. One promising solution is the introduction of small-cell structured networks. However, wide range of user mobility is problematic and causes frequent handover. Furthermore, traffic density is not necessarily high everywhere. Recently, heterogeneous network (HetNet) is attracting much interest for 5G. In HetNet, a number of small base stations (SBSs) are deployed in a macro BS (MBS) [1]. In this paper, we discuss the impact of SBS power on/off on network power consumption, throughput, and handover (HO) and the decentralized dynamic channel assignment.

II. HetNet Radio Resource Management

HetNet model considered in this paper is illustrated in Fig. 1. HetNet consists of one MBS and B SBSs, $\mathsf{B}=\{1,...,b,...B\}$. B SBS are distributed uniformly in a macro cell, at the center of which the MBS is located.

A. Power On/Off Algorithm

The bth SBS chooses four strategies (i=1,2,3, and 4), corresponding to transmission power levels $\xi_{b,i}(t)$=0, 1/3, 2/3, and 1 at time t while MBS always takes strategy 4. Transmission power of the bth SBS is given by

$$P_b(t)=\zeta_{b,i}(t)\cdot P_{b\,MAX}^{Transmitted}, \tag{1}$$

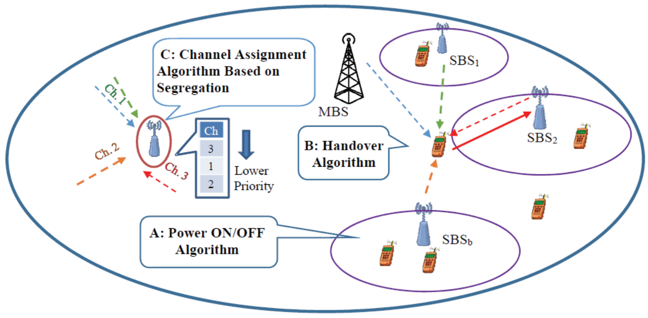

Fig. 1: System model.

where $P_{b\,MAX}^{Transmitted}$ is the maximum transmission power of the bth SBS. Each SBS decides its strategy based on noncooperative game theory [2]. Utility $u_b(t)$ of the bth SBS at time t is formed by its total power consumption $P_b^{Total}(t)$ and traffic load $\rho_b(t)$ as

$$u_b=-\left(\alpha_b\,P_b^{Total}(t)\big/P_{b\,MAX}^{Transmitted}+\beta_b\rho_b(t)\right), \tag{2}$$

where α_b and β_b $(\alpha_b>0,\beta_b>0)$ are weighting coefficients for power consumption and traffic load, respectively. These coefficients control the degree of influence of power consumption and traffic load. Traffic load of each BS (MBS or SBS) is the sum of traffic loads of all UEs connected to it. Note that UE's traffic load is defined as the ratio of its required date rate and its link capacity. Each SBS omputes its average traffic load $\hat{\rho}_b(t)$ using the first order filtering with learning rate $n(t)$ as

$$\hat{\rho}_b(t)=\hat{\rho}_b(t-1)+n(t)\cdot\left(\rho_b(t)-\hat{\rho}_b(t-1)\right), \tag{3}$$

which is then broadcasted via periodic beacons to all UEs for cell association (finding an initial BS to connect to) or HO.

B. Handover Algorithm

Each UE receives the average traffic load $\hat{\rho}_b(t)$, BS location data, and BS cell radii through beacons transmitted from its surrounding BSs. It is assumed that UE gets its velocity by a speed sensor and its location using global positioning system (GPS). The HO decision of each UE is based on these information and received power $P_b^{RX}(t)$. Let

$v_b(t)(-\infty < v_b(t) < +\infty)$ be the velocity of UE in the direction of the connected BS. For cell association or HO, each UE at location x selects the BS $b(x,t)$ at time t according to [3]

$$b(x,t) = \arg\max_{b \in B} \left\{ (\hat{\rho}_b(t) + \varepsilon_b)^{-\delta} \cdot P_b^{RX}(t) \cdot d_b(t)^{-\lambda} \right\}, \quad (4)$$

where ε_b is the offset and δ $(\delta > 0)$ and λ $(\lambda > 0)$, are weighting coeeficients which control the degree of influence of average traffic load $\hat{\rho}_b(t)$ and the distance $d_b(t)$ between UE and the bth BS, respectively.

C. Channel Assignment Algorithm Based on Segregation

Available channels are reused among BSs in HetNet in a decentralized fashion. In order to minimize the co-channel interference (CCI), each BS carries out a channel segregation algorithm similar to [4] to select a channel based on its channel priority table. This priority table is formed based on the CCI level. The information of chosen channel by each BS is broadcast by beacon to all UEs.

III. Computer Simulation

Simulation parameters are summarized in TABLE I. A HetNet consisiting of one MBS and B=9 SBSs is considered. A low mobilty case is assumed: an average velocity of each user is 4km/h. Mean offered traffic per UE is 180kbps. Cell radii of MBS and SBS are 250m and 40m, respectively. Maximum transmission power of MBS and SBS are 46 dBm and 30 dBm, respectively. Our proposed on/off algorithm combined with HO (case 1) is compared with two benchmarks, i.e., BSs are always ON (case 2) and only one MBS available (case3). An ideal case with no CCI is assumed (i.e., enough number of available channels). Power on/off and HO decision are performed every 1s. Total simulation time is 10,000s.

Figs. 2 and 3 show the total power comsumption power in HetNet and the average throughput per UE as a function of the number of UEs, respectively. Our proposed algorithm (case 1) can reduce the power comsumtion by about 39% compared to always ON (case 2) with only 6% reduction in the average throughput per UE when the number of UEs is 120. It is worth noticing that the case of only one MBS available (case 3) provides slighly less power consumption compared to our proposed algorithm (case 1), but its achievable throughput is much lower.

TABLE I. Simulation condition

Parameter	Value
Path loss (d: distance of BS and user (m)) (unit: dB)	
MBS – UE	$15.3+37.6\log_{10} d$
SBS – UE	$27.9+36.7\log_{10} d$
Algorithm parameters	
Power threshold P^{TH}	-60 dBm
Distance threshold d^{TH}	20 m
Weighting coefficients, α and β, for power consumption and traffic load	α =10 and β =5
Weighting exponents, δ and λ, for traffic load and distance	δ =1 and λ =0.5

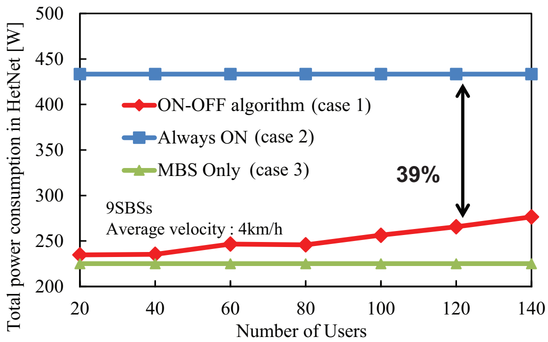

Fig. 2. Total power consumption.

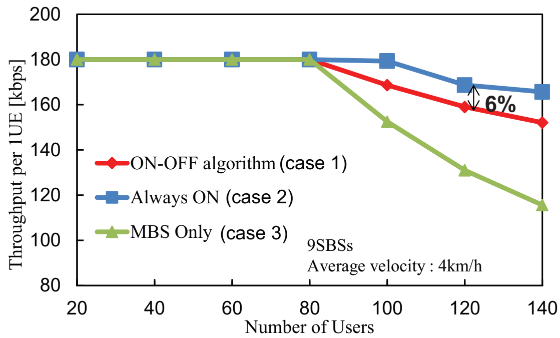

Fig. 3. Average throughput per UE.

IV. Conclusion

In this paper, a SBS power on/off algorithm based on noncooperative game theory, handover (HO), and decentralized channel segregation were proposed within the context of HetNet. It was confirmed that the proposed SBS power on/off algorithm can reduce the power consumption with slight throughput degradation even when HO is considered. In this paper, no CCI was assumed in evaluating the total power consumption and throughput. The impact of channel segregation on the total power consumption and throughput is left as our future study.

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