A Novel Handover and Base Station Sleep Mode Algorithm in HetNet

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***Abstract*—The demand for wireless resources is increasing at high pace. Heterogeneous network (HetNet) is a key solution to address this increased demand. This paper presents a handover (HO) algorithm for BS sleep mode algorithm in HetNet. The proposed algorithm yields improvement in HO times compared to the conventional algorithms in dense SBS deployment and higher UE densities.**

***Index Terms*—HetNet, handover, base station sleep mode algorithm, game theory, energy efficiency, mobility**

I. Introduction

The demand for wireless resource is increasing at high pace. Video streaming and social media [1] contribute to this increase to a great extent. Consequently, traffic load and energy consumption in wireless cellular system is increasing accordingly and this urges the necessity of designing more energy and spectral efficient systems.

Heterogeneous networks (HetNets), consisting of macro cell base stations (MBSs) and small cell base stations (SBSs), are proven to be highly effective in improving spectral efficiency [2]. The consumption energy in HetNets reduces when combined with sleep mode algorithms which adapt to network traffic conditions. Autonomous distributed sleep mode algorithms do not need any information exchange through back haul communication. In such algorithm, each BS decides independently to turn ON or OFF depending on its traffic load and consumption power.

To the best of our knowledge there has been no study on mobility in HetNets which employ sleep mode algorithms. If users move, UEs' received power from connected BS changes because of change of BS's transmission power, path loss and so on. If the received power is low, the BS can not communicate with the BS effectively. As a result, a handover (HO) process is initiated. In this paper, we propose a HO algorithm for UEs, combined with an sleep mode algorithm for BSs in a HetNet scenario. The HO algorithm comprises of two different phases, i.e., HO necessity estimation phase (HONEP) and HO execution phase (HOEP).

II. System Model

In this paper, we focus on the downlink transmission in HetNet, assuming one MBS and several SBSs, $\mathcal{S} = \{1, ..., S\}$, distributed uniformly within a macro cell, at the center of which the MBS is located. Fig. 1 shows an example realization of such HetNet scenario.

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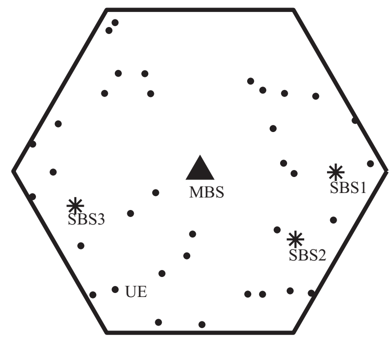

Fig. 1. HetNet topology.

Each BS chooses its strategy (transmission power level), using Table I. MBS's strategy is strategy 1 or 4 in Table I. Transmission power of s th BS is given according to:

$$P_s(t) = \xi_s(t) \cdot P_{sMAX}^{TX}, \quad (1)$$

where $\xi_s(t)$ is the transmission power level and P_{sMAX}^{TX} is the maximum transmission power of s th BS. A BS's total consumption power is decided by its transmission power [1]. A BS's load is the summation of all UEs' traffic load in the cell. Please note UE's traffic load is defined as the ratio of its required date rate over its actual link capacity. Utility of s th BS is formed by its total consumption power, $P_s^{All}(t)$, and traffic load , $\nu_s(t)$ according to:

$$u_s(t) = -(\phi \cdot P_s^{All}(t)/P_{sMAX}^{TX} + \varphi \cdot \nu_s(t)), \quad (2)$$

where ϕ and φ ($\phi > 0, \varphi > 0$) are weighting factors of consumption power and traffic load. These constants define the influence of consumption power and load.

III. Algorithms

We use the sleep mode algorithm in [1] as shown in Algorithm 1. The proposed UE association algorithm is shown in Algorithm 2.

A. Traffic load estimation

Each BS estimates its traffic load, $\hat{\nu}_s(t)$, according to:

$$\hat{\nu}_s(t) = \hat{\nu}_s(t-1) + n(t) \cdot (\nu_s(t-1) - \hat{\nu}_s(t-1)), \quad (3)$$

where $n(t)$ is the learning rate. $\hat{\nu}_s(t)$ is then transmitted via periodic beacons to all UEs.

TABLE I
Transmission Power Levels.

Identification Number of Strategy i	Transmission Power Level $\xi_s(t)$
1	0
2	1/3
3	2/3
4	1

Algorithm 1 : Sleep mode algorithm at BS [1].

Initialization: $\mathcal{S} = \{1, ..., S\}$;
while do
  $t - 1 \rightarrow t$,
  BS's strategy selection
  Calculation of traffic load estimation $\hat{\nu}_s(t)$ and transmission to all UEs
  Calculation of traffic load $\nu_s(t)$, power consumption $P_s^{All}(t)$ and utility $u_s(t)$
  if $\nu_s(t) > 1$ **then**
    Select UEs to connect
  end if
  Update of utility estimation $\hat{u}_{s,i}(t)$
end while

Algorithm 2 : Association algorithm at UE.

Input: $\hat{\nu}_s(t)$ and $P_s^{RX}(t)$
Output: $s(z, t)$
if UE is not currently connected to any BS **then**
  UE chooses a new BS, $s(z, t)$, based on $\hat{\nu}_s(t)$ and $P_s^{RX}(t)$
else
  Decide whether to HO or not
  if HO is necessary **then**
    UE chooses a new BS, $s(z, t)$, based on $\hat{\nu}_s(t)$ and $P_s^{RX}(t)$
  else
    UE does not change its BS
  end if
end if

B. HO Algorithm

Each UE receives the traffic load estimation $\hat{\nu}_s(t)$, data about BS position and the cell radius r from all BSs through beacon signals. UE obtains the velocity and position information using its integrated GPS. UE decides about HO based on these information and received power $P_s^{RX}(t)$. Algorithm 3 shows HONEP at UE. In this algorithm, $v(t)(\geq 0)$ is the velocity of UE and $v_b(t)(-\infty < v_b(t) < +\infty)$ is its velocity component in the direction of the connected BS. $d(t)$ is the UE's distance to its connected BS. For new UEs or UEs needing HO, each UE at point z selects the BS to connect to (HOEP), $s(z, t)$, based on the following criterion:

$$s(z, t) = \arg\max_{s \in \mathcal{S}} \{(\hat{\nu}_s(t) + \varsigma_s)^{-\varpi} \cdot P_s^{RX}(t) \cdot (d_s(t))^{-\lambda}\}, \quad (4)$$

where ς_s is offset and ϖ ($\varpi > 0$) and λ ($\lambda > 0$) are coefficients which define the influence of traffic load estimation, $\hat{\nu}_s(t)$, and the distance between UE and s th BS, $d_s(t)$, respectively.

IV. Computer Simulation

Simulation parameters are summarized in Table II. Total simulation time is 10000 s and time interval for each iteration is 1 s. Cell radius of MBS and SBS are 250 m and 40 m. Maximum transmission power of MBS and SBS are 46 dBm and 30 dBm. We compare our proposed joint HO and sleep mode algorithm with the benchmark in [1].

TABLE II
Simulation Parameters.

Parameter	**Value**
Path loss (d:Distance of BS and user (m))	(unit: dB)
MBS - UE	$15.3+37.6\log_{10}$(d) [1]
SBS - UE	$27.9+36.7\log_{10}$(d) [1]
Algorithm Parameters	
Power Threshold P^{TH}	-60 dBm [3]
Distance Threshold d^{TH}	20 m
Weighting Coefficients for Power Consumption and Traffic Load, ϕ, φ	10, 5
Weighting Exponent of Traffic Load and Distance, ϖ ,λ	1, 0.5

Algorithm 3 : HONEP at UE.

if UE is connected to MBS **then**
  Always search for a new BS using (4)
else
  (UE is connected to SBS)
  if $d(t) > r_{SBS}$ (r_{SBS}: small cell radius) **then**
    search for a new BS using (4)
  else
    if $v_b(t) < 0$, $d(t) \leq d^{TH}$ (d^{TH}: distance threshold) and $P_s^{RX}(t) \leq P^{TH}$ (P^{TH}: power threshold) **then**
      search for a new BS using (4)
    else
      Do not change current connected BS
    end if
  end if
end if

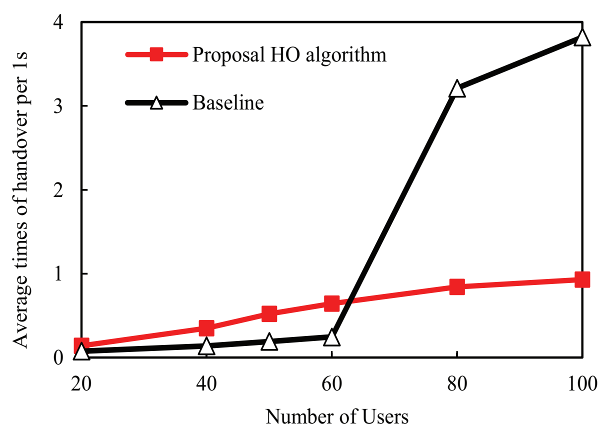

Fig. 2. Total number of HOs for 1 s *vs* different number of UEs for 7 SBSs and average velocity 4 km/h.

In Fig. 2, we observe that for lower number of UEs, the benchmark makes less HOs than the proposed algorithm. This is because the benchmark algorithm does not initiate enough HOs to prevent degradation in communications quality. The benchmark algorithm does not make UEs frequently select SBSs unlike our proposed algorithm. However, as the number of UEs increase, the number of HOs in benchmark algorithm increases significantly. This is because the benchmark algorithm causes pingpong effect and make UEs implement unnecessary HOs.

This proves the effectiveness of the proposed algorithm for higher UE densities.

V. Conclusion

In this paper, a joint distributed handover (HO) and base station sleep mode algorithm was proposed within the context of HetNet. It was noticed that the proposed algorithm yields significant improvement in HO times compared to conventional algorithms in high UE densities.

References

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