A Novel Handover Algorithm with Load Balancing for Next Generation HetNet

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***Abstract*—The demand for wireless resources is increasing at high pace. Heterogeneous networks (HetNets), i.e., network composed by base stations (BSs) with different coverage area, are useful solutions to cope with this increased demand. Previously, we proposed a handover (HO) algorithm based on users velocity, users place, users received power strength from BSs and traffic load of BSs. Due to difficulties in obtaining the information for users velocity and users position, in this paper, we improve our former research and propose an HO algorithm which is only based on received power strength and traffic load. In the first step of the HO algorithm, user equipments' (UEs') received power and its estimation are employed to determine the necessity of HO. This phase, i.e., HO necessity estimation phase (HONEP), helps reducing the unnecessary HOs and consequently save more energy. After HONEP, in the second step UEs select the new BS based on received power, received power estimation and average traffic load of BSs which is advertised through beacon signals. A game-theoretic sleep mode algorithm is executed parallel to HO algorithm in BSs. The performance of the new algorithm, such as system power consumption and BSs' average traffic load is evaluated by means of computer simulation.**

***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] are mainly responsible for this increase. 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 BSs (SBSs), are proven to be highly effective in increasing the wireless resources [2]–[4]. The total consumption energy in HetNets reduces when combined with sleep mode algorithms which adapt to traffic conditions in the network. In [3], a centralized sleep mode algorithm is proposed. It is shown that this algorithm can improve the energy efficiency in HetNets. However, if centralized approaches are used, the number of control signals increases with an increased information exchange between BSs. On the other hand, connecting all BSs to data processing centers, e.g. cloud radio access network (cloud-RAN), through high capacity backbone links, is an expensive solution and probably not yet suitable for some geographic areas. Sleep mode algorithms which rely on self-distribution control, do not need any information exchange through backhaul communication. In such algorithm, each BS decides independently to turn ON or OFF depending on its traffic load and consumption power.

In this paper, we use the similar sleep mode algorithm as in [1], in which a non-cooperative, mixed strategy, game is used to decide the ON, OFF condition of each BS. Here, *OFF mode* refers to idle condition in which BS consumes power only for detecting user equipments (UEs). In strategic form games [5], each player, i.e., BS, selects its strategy (action) only to maximize its utility, i.e., a function which evaluates each player's outcome. In non-cooperative games, players decide their strategies independently without negotiating with other players. Later, we propose a handover (HO) algorithm for UEs, in combination with the aforementioned sleep mode algorithm. Previously we employed velocity, the received signal strength (RSS), traffic load and distance parameters for HO decision in UEs [6]. However, due to technical difficulties in obtaining information for UEs position and velocity, in this paper, we propose another HO algorithm, which is only based on received power strength and BSs traffic load. The HO algorithm comprises of two different phases, i.e., HO necessity estimation phase (HONEP) and HO execution phase (HOEP). In the first phase, only, the UE's RSS and its time average are checked. If certain conditions are met, then the algorithm goes into the second phase and decides about the best target BS. First phase is important for reducing the number of unnecessary HOs. In the second phase UEs select the new BS based on the RSS, its estimate and average traffic load of BSs which is advertised periodically through beacon signals.

The rest of this paper is organized as follows. In Section II, system model is described along with power consumption, load, and utility function models. Section III discusses our proposed algorithm, Section IV provides the simulation results

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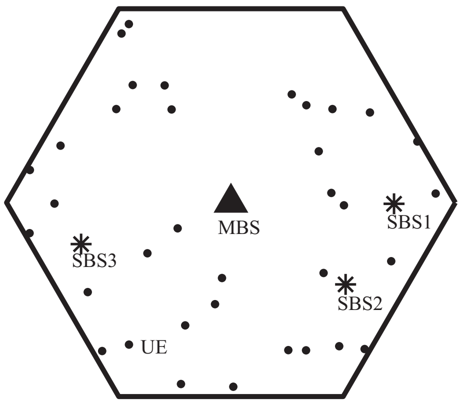

Fig. 1. HetNet topology.

and the evaluation of our algorithm. Sections V concludes the paper.

II. System Model

In this paper, we focus on the downlink transmission in HetNet, consisting of a MBS and several SBSs, $\mathcal{S} = \{1, ..., S\}$, which are distributed uniformly within the macro cell. Fig. 1 shows an example realization of such HetNet scenario. Each BS chooses its strategy (transmission power level) from Table I.

Transmission power of sth BS is given according to:

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

where $\xi_s(t)$ is the transmission power level and P_{sMAX}^{TX} is the maximum transmission power of sth BS.

A. Consumption power

When one BS is in OFF mode, the BS consumes power only for detecting UEs in the macro cell. The consumption power of sth BS at time t is given by [7]:

$$P_s^{All}(t) = \begin{cases} \frac{P_{radio}+P_{base}}{\chi} = P_s^{Idle} \quad (OFFmode) \\ \frac{P_s(t)}{\eta\chi(1-\chi_{feed})} + P_s^{Back} + P_s^{Idle} \quad (ONmode), \end{cases} \tag{2}$$

with

$$\chi = (1-\chi_{DC})(1-\chi_{main})(1-\chi_{cool}), \tag{3}$$

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

where P_{radio}, P_{base} and P_s^{Back} are consumption power in radio frequency, baseband unit and backbone network. χ_{DC}, χ_{main}, χ_{cool} and χ_{feed} are losses in DC-DC conversion, main supply, cooling units and the feeder. η is the power amplifier's efficiency.

B. Traffic load

Signal to Interference plus Noise Ratio (SINR) of UE at point z is given by:

$$\varsigma_s(z) = \frac{P_s(t)g_s(z)}{\sum\limits_{\forall s' \in \mathcal{S}/s} P_{s'}(t)g_{s'}(z) + N}, \tag{4}$$

where $g_s(z)$ is UE's channel gain at point z and connected to sth BS. N is the noise variance.

Data rate of UE at point z is given by:

$$D_s(z) = w \log_2(1 + \varsigma_s(z)), \tag{5}$$

where w is the channel bandwidth.

Traffic load density of UE at point z is given by [8]:

$$\vartheta_s(z) = \frac{\kappa_s(z)v_s(z)}{D_s(z)}, \tag{6}$$

where $\kappa_s(z)$ is the packet arrival rate and $v_s(z)$ is the average packet size of UE at point s.

Traffic load is given by:

$$\nu_s(t) = \sum_{z \in \mathfrak{L}_s} \vartheta_s(z), \tag{7}$$

where $\mathfrak{L}_s$ is the coverage area of sth BS.

C. Utility

The smaller a BS's consumption power $P_s^{All}(t)$ and traffic load $\nu_s(t)$ are, the better condition for the BS is. Therefore, utility of sth BS consists of its consumption power $P_s^{All}(t)$ and traffic load $\nu_s(t)$ according to:

$$u_s(t) = -(\phi \cdot P_s^{All}(t)/P_{sMAX}^{TX} + \varphi \cdot \nu_s(t)), \tag{8}$$

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

III. Algorithm

We use the similar BS sleep mode algorithm in [1], as shown in Algorithm 1. The proposed algorithm, which is executed at UE is shown in Algorithm 2, where γ is learning rate and indicates the impact of instantaneous received power $P_s^{RX}(t)$. Received power estimation is used instead of distance in [6]. UE decides whether to implement HO or not based on $\hat{P}_s^{RX}(t)$ and $P_s^{RX}(t)$.

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

Input: $\hat{u}_{s,i}(t)$, $\hat{r}_{s,i}(t)$, $p_{s,i}(t)$
Output: $a_s(t+1)$
Initialization: $\mathcal{S} = \{1, ..., S\}$;
while do
  $t-1 \rightarrow t$,
  BS's strategy selection: $a_s(t) = f\left(p_{s,i}(t-1)\right)$
  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 $u_s(t)$
  Update of utility estimation $\hat{u}_{s,i}(t)$, regret $\hat{r}_{s,i}(t)$ and probability distribution $p_{s,i}(t)$
end while

Algorithm 2 : Algorithm at UE.

Input: $\hat{\nu}_s(t)$ and $P_s^{RX}(t)$
Output: $s(z,t)$
if UE isn't 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 with Algorithm 4
  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 doesn't change its BS
  end if
end if

Algorithm 3 : Strategy selection at BS.

Input: $p_{s,j}(t-1)$ $(j=1,2,3,4)$
Output: i
Select r $(0<r<1)$ randomly
if $p_{s,1}(t-1) > r$ **then**
  $i = 1$
else
  if $\sum_{j=1}^{2} p_{s,j}(t-1) > r$ **then**
    $i = 2$
  else
    if $\sum_{j=1}^{3} p_{s,j}(t-1) > r$ **then**
      $i = 3$
    else
      $i = 4$
    end if
  end if
end if

A. BS's strategy selection

Each BS has a set of strategies $\mathcal{A}_s = \{a_{(s,1)}, ..., a_{(s,A)}\}$ and $a_s(t)$ is the strategy chosen by sth BS at time t. It selects its strategy with their strategys probability distribution $p_{s,i}(t-1)$ at time t according to:

$$a_s(t) = f(p_{s,i}(t-1)), \tag{9}$$

where f is the conversion function from probability distribution to strategy and is elaborated in Algorithm 3. As previously described, strategies define transmission power levels of BSs, $\xi_s(t)$. It should be noted that MBS selects its strategy only from $i=1$ and $i=4$.

B. Traffic load estimation

Each BS calculates its load estimation, i.e., traffic load time average, according to:

$$\hat{\nu}_s(t) = \hat{\nu}_s(t-1) + n(t) \cdot (\nu_s(t-1) - \hat{\nu}_s(t-1)), \tag{10}$$

where $n(t)$ is the learning rate and indicates the impact of instantaneous value of load on load estimation. $n(t)$ is chosen in a way to make computation of traffic load estimation adequately slower than the UE association speed. If traffic load estimation changes rapidly, UEs change connected BS frequently. In this case, it may result in destabilizing the algorithm.

C. Computation of probability distribution

For ith strategy of sth BS, utility estimation, $\hat{u}_{s,i}(t+1)$, regret estimation, $\hat{r}_{s,i}(t+1)$, and probability distribution, $p_{s,i}(t+1)$, are updated according to [1].:

$$\begin{aligned}
\hat{u}_{s,i}(t+1) &= \hat{u}_{s,i}(t) + \iota_b(t+1) \cdot \mathbf{1}(t) \cdot (u_s(t) - \hat{u}_{s,i}(t)), \\
\hat{r}_{s,i}(t+1) &= \hat{r}_{s,i}(t) + \tau_s(t+1) \cdot (\hat{u}_{s,i}(t) - u_s(t) - \hat{r}_{s,i}(t)), \\
p_{s,i}(t+1) &= p_{s,i}(t) + \varrho_s(t+1) \cdot (G_{s,i}(\hat{r}_{s,i}(t)) - p_{s,i}(t)),
\end{aligned} \tag{11}$$

with

$$\mathbf{1}(t) = \begin{cases} 1 & (if \quad a_s(t+1) = a_s(t)) \\ 0 & (if \quad a_s(t+1) \neq a_s(t)), \end{cases} \tag{12}$$

and

$$G_{s,i}(\hat{r}_{s,i}(t)) = \frac{\exp\left(\varepsilon_s \hat{r}_{s,i}(t)\right)}{\sum_{i' \in \mathcal{A}_s} \exp\left(\varepsilon_s \hat{r}_{s,i'}(t)\right)}, \tag{13}$$

where $G_{s,i}(\hat{r}_{s,i}(t))$ is the Boltzmann distribution and ε_s is the temperature parameter. $\iota_s(t)$, $\tau_s(t)$ and $\varrho_s(t)$ are learning rates

Algorithm 4 : HO necessity estimation algorithm at UE.

if UE is connected to MBS **then**
  Search for a new BS
else
  (UE is connected to SBS)
  if $\hat{P}_s^{RX}(t) < P_1^{TH}$ (P_1^{TH}: received power threshold 1) **then**
    Search for a new BS
  else
    if $\hat{P}_s^{RX}(t) < P_2^{TH}$, $\hat{P}_s^{RX}(t) < \hat{P}_s^{RX}(t-1)$ and $P_s^{RX}(t) < P_2^{TH}$ (P_2^{TH} ($P_2^{TH} > P_1^{TH}$): received power threshold 2)) **then**
      Search for a new BS
    else
      Do not change current connected BS
    end if
  end if
end if

which follow a form like $1/t^c$ (c: power parameter) and should meet the following criterion.

$$\begin{aligned}
&\lim_{t\to\infty}\sum_{m=1}^{t}\iota_s(m)=+\infty, \quad \lim_{t\to\infty}\sum_{m=1}^{t}\tau_s(m)=+\infty,\\
&\lim_{t\to\infty}\sum_{m=1}^{t}\varrho_s(m)=+\infty, \quad \lim_{t\to\infty}\sum_{m=1}^{t}\iota_s^2(m)<+\infty,\\
&\lim_{t\to\infty}\sum_{m=1}^{t}\tau_s^2(m)<+\infty, \quad \lim_{t\to\infty}\sum_{m=1}^{t}\varrho_s^2(m)<+\infty,\\
&\lim_{t\to\infty}\frac{\tau_s(t)}{\iota_s(t)}=0, \qquad \lim_{t\to\infty}\frac{\varrho_s(t)}{\tau_s(t)}=0.
\end{aligned} \tag{14}$$

D. HO Algorithm

Each UE receives the traffic load estimation, $\hat{\nu}_s(t)$, through beacon signals and received power, $P_s^{RX}(t)$, from all BSs in the macro cell. Later, UE computes each BS's received power estimation according to:

$$\hat{P}_s^{RX}(t)=\hat{P}_s^{RX}(t-1)\cdot(P_s^{RX}(t)/\hat{P}_s^{RX}(t-1))^{\gamma}, \tag{15}$$

UEs estimate HO necessity using algorithm 4. UEs which are not connected to any BS or UEs needing HO in point z, selects BS $s(z,t)$ to connect to based on the following criteria:

$$s(z,t)=\arg\max_{s\in\mathcal{S}}(\hat{\nu}_s(t)+\varsigma_s)^{-\varpi}\cdot\hat{P}_s^{RX}(t)\cdot\acute{P}(t), \tag{16}$$

with

$$\acute{P}(t)=\begin{cases} P_a \\ (BS\ \ s\ \ is\ \ SBS\, and \quad \hat{P}_s^{RX}(t)>\hat{P}_s^{RX}(t-1)) \\ 1 \\ (Other\ \ case), \end{cases} \tag{17}$$

and

$$P_a>1, \tag{18}$$

where ς_s is an offset and P_a is an inflating value.

TABLE II
SIMULATION PARAMETERS.

Parameter	Value
Network	
Noise Variance N	-168 dBm/Hz
Arrival Rate $\kappa_s(z)$	180 kbps
MBS	
Maximum Transmission Power P_{sMAX}^{TX}	46 dBm
Minimum MBS-SBS Distance	75 m
Cell radius r_{MBS}	250 m
SBS	
Number of SBSs	7
Maximum Transmission Power P_{sMAX}^{TX}	30 dBm
Minimum SBS-SBS Distance	40 m
Cell radius r_{SBS}	40 m
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	
Weighting Coefficients for Power Consumption and Traffic Load, ϕ, φ	10, 5
Learning Rate of Load Estimation $n(t)$	$1/t^{0.9}$
Learning Rate Exponents c for ι_s, τ_s, ϱ_s	0.6,0.7,0.8
Boltzmann Temperature ε_s	10
Power Threshold P_1^{TH}, P_2^{TH}	-60 dBm, -50 dBm
Learning Rate of Power Estimation γ	0.93
Weighting Exponent of Traffic Load for BS Selection ϖ	1
Offset ς_s	0.5
Inflating Value P_a	7 dB

IV. COMPUTER SIMULATION

Simulation parameters are summarized in Table 2. Users velocities are Gaussian distributed. Total simulation time is 10000 s. Time interval of Sleep mode algorithm and HO algorithm are 1 s. Time interval for calculating received power estimation is 0.1 s. In this part, we compared our proposed HO algorithm with the one in [6]. Fig. 2 shows the total consumption power in HetNet *vs* different number of UEs. In this graph, total consumption power in our proposed HO algorithm is smaller than the one in [6] by 40 UEs. This is mainly due to the effect of RSS in proposed HO algorithm which is bigger than that in [6]. Therefore, UEs select BSs with higher RSS more frequently. However, in 50 SBSs, total consumption power in our proposed HO algorithm is bigger than the one in [6]. This is because the effect of RSS in the proposed HO algorithm is small.

Fig. 3 shows the average traffic load per BS *vs* different number of UEs. The average traffic load per BS in the proposed algorithm and the one in [6] is almost the same. Here, we deduct that the HO algorithm is not dependent to traffic load of the BSs.

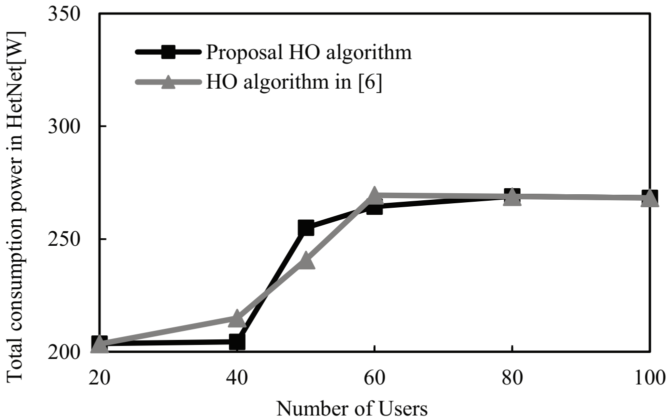

Fig. 2. The average traffic load per BS *vs* different number of UEs at an average velocity of 4 km/h.

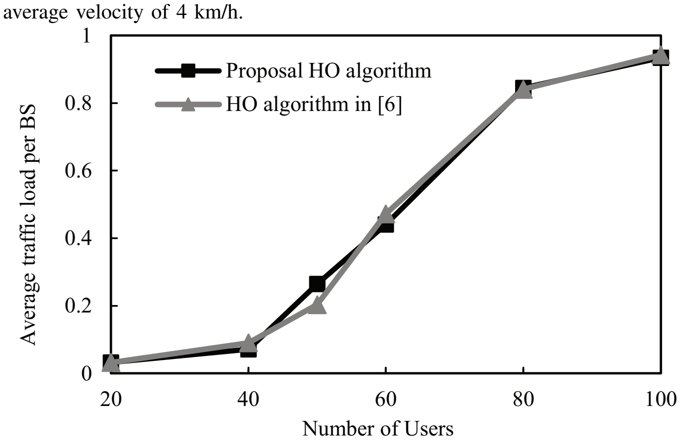

Fig. 3. The total consumption power in HetNet *vs* different number of UEs at an average velocity of 4 km/h.

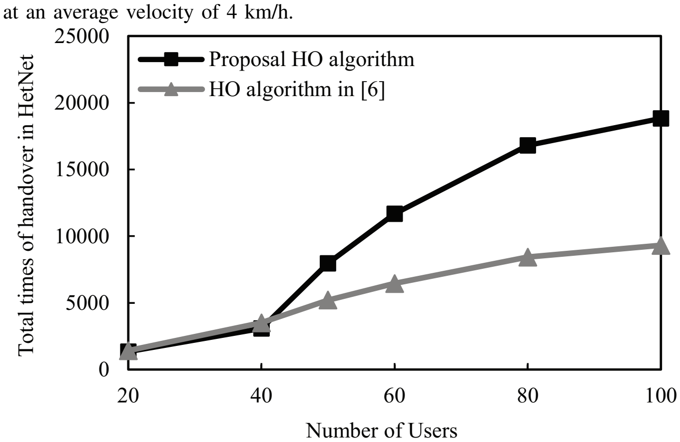

Fig. 4. Total number of HOs *vs* different number of UEs at an average velocity of 4 km/h.

Fig. 4 shows the total number of HOs *vs* different number of UEs. Total number of HOs in our proposed HO algorithm is bigger than the one in [6]. This is mainly due to occurring of Ping-Pong effect in algorithms which rely more on RSS. Please note that Ping-Pong may indirectly contribute to higher energy loss.

In general, the algorithm in [6] may have slightly better performance than the proposed algorithm. However, please note that the proposed algorithm is more feasible to be implemented in practical scenarios.

V. Conclusion

In this paper, a handover (HO) algorithm using only received signal strength (RSS) and traffic load is proposed. A BS sleep mode algorithm is coupled with the HO algorithm, which helps reducing the energy consumption in HetNet. In the first stage, each UE estimates the necessity of HO based on RSS of the current connected BS. If HO is needed, in the second stage, UE selects the BS to be connected to based on only RSS and BSs' traffic load. Simulation result indicates that the benchmark outperforms the proposed algorithm. However, the proposed algorithm is more feasible to be implemented in practical scenarios due to simplicity.

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