Network Selection Cooperation among Mobile Users in Heterogeneous Wireless Networks with Evolutionary Game Approach

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Abstract

In this paper, we consider the cooperation among users in heterogeneous wireless networks (HetNets). An important issue for service providers in terms of load balancing and quality of serves are investigated. We propose a method toward load balancing in HetNets including three tiers: macrocell, picocell and femtocell. We study the competition among sub-area mobile users to share the limited amount of bandwidth in each network. This problem is formulated as evolutionary game. By modeling as an evolutionary game approach, we find a Nash equilibrium to maximize mobile user demands and load balancing among heterogeneous cells. The numerical results show the effectiveness of proposed scheme.

I. Introduction

Recently, the future wireless network is shift to new paradigm by deploying the heterogeneous cells that include three tier: macrocell, picocell and femtocell [1],[2],[3]. When deploy the heterogeneous networks, some challenges as load-balancing and association are major problems that has been considered [3].

In our proposal, we propose a simple method for load balancing and associating in HetNet. In which, the evolutionary approach [6] is applied to toward load balancing in HetNets including macrocell, picocell and femtocell. In additional, we study competition among sub-area mobile users to share the limited amount of bandwidth in each network. Then, we find a Nash equilibrium to maximize mobile user demands and load balancing among heterogeneous cells.

The rest of this paper is organized as follows. The system model and assumptions are presented in section II. The evolutionary game approach formulation is discussed in session III. Then, some numerical results are showed in session IV. Finally, some conclusions and future works are discussed in session IV.

II. System model and assumptions

In our works, we consider a HetNets includes of macrocells, picocells and femtocells that coexistence in a geographic area of one services provider. In access network, a mobile users are able to access to different networks. In practically, due to the mobiles user's properties, some mobile users can be existed in different areas as show in figure 1 and table 1. In each area, the mobile users make an optimal decision to choose network for their connections. In this system model, we do not consider the mobility of the user explicitly. The whole the HetNets system is managed by a network controller which called mobile virtual network operator (MVNO).

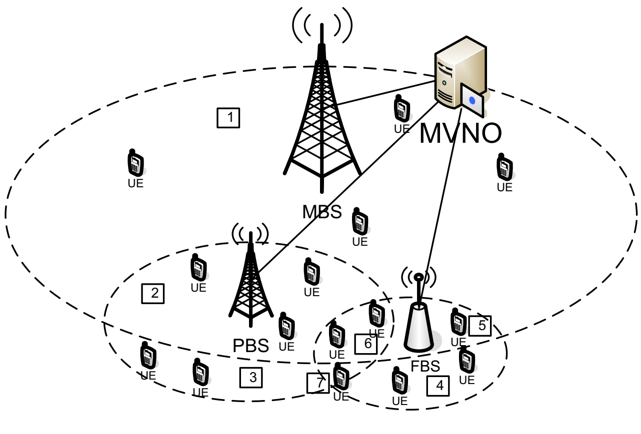

Figure 1: The system model

Moreover, in economic point of view, we assume that the services providers use a linear pricing model. In particular, the price per connection/users correspond to coverage area cause by power levels of each type of network.

Network	Area1	Area2	Area3	Area4	Area5	Area6	Area7
Macro	x	X				X	
Pico		x	X			X	X
Femto				x	x	X	x

Table 1: The division of HetNets coverage into areas.

III. Evolutionary game formulation.

In this section, the mobile users in Hetnets are divided into the different areas and each of user in each area computes with others to share the available bandwidth form different wireless networks. In stochastic network environment, we capture the dynamics of network selection. A mobile user observe its payoff, if its payoff is less than the average payoff of all users in the same group, the mobile user will change its network selection strategy. The evolutionary game is ensure that all mobile users in the same group can receive identical payoff.

In this paper, we construct the evolutionary game include of players, population, strategy and payoff as in figure 2. In which, mobile users are players that can choose among multiple wireless networks in each area as in table 1. With population parameter, the population is set of mobile users in each services area by some providers.

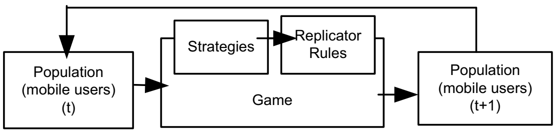

Figure 2: The evolutionary game model

For example, the mobile users in area 2 form a population. With each mobile users in each area, the mobile users make a strategy by choosing a network in set of network that it be able connect to. Each of action connect to one network, the mobile user will receive the utility that determine by his net utility.

In order to find optimal solution to maximize the payoff function, based on [6], we form the payoff function for each $A \in \Phi$ as a concave utility function to qualify a mobile user's satisfaction as follows:

$$P_i^{(A)} = H\left(\frac{C_i^{(A)}}{\sum_{A\in\Phi} N^{(A)} x_i^{(A)}}\right) - p_i \sum_{A\in\Phi} N^{(A)} x_i^{(A)} \quad (1)$$

Where, x denote the vector of the proportion of users choosing different networks in all areas. p_i is virtual price of power for connection to different type of network, it also estimate the cost that allocate to each users and users usage this parameter for helping load balancing of wireless provider. $N^{(A)}$ represents the number of mobile users in area A and $x_i^{(A)}$ is the proportion of users choosing network *i*. $C_i^{(A)}$ is the network capacity of network *i* in area A that is total associated capacity of three tiers in one area.

In order to solve the evolutionary game, the mobile users will repeat follow epoch time t. In each time t, a mobile user observes the network utility of others mobile users in the same area. Then in the next period, the user control parameter ₩delta and gives strategy with a higher payoff. The rate of strategy change is given by the replicator dynamics as follows:

$$\frac{d(x)}{dt} = \delta x_i^{(A)}\left(P_i^{(A)}(x) - \overline{P}_i^{(A)}\right) \quad (2)$$

Where $\overline{P}_i^{(A)}$ is the average payoff of the mobile users in area A. Based on this replications dynamic of the users in area A, the number of users choosing network I increase if their payoff is above the average payoff.

Proposition: The game has equilibrium and the game is stable.

Proof: Since the rate of the mobile users strategy adaption is zero i.e $\frac{d(x)}{dt} = 0$, so the game is stable and achieve evolutionary equilibrium [4],[5].

We can archive optimal solution to the different equation corresponding to the replicator dynamics,, Rngge-Kutta method is applied. This evolutionary game method is based on the individual behavior of the mobile users to achieve evolutionary equilibrium and stability of network.

IV. Implementation of the network selection algorithm.

1, Users' network selection are randomly chose.

Loop

2, Each user computes payoff $P_i^{(A)}$ in each area that it belong to with the size of allocated bandwidth and price and send to controller by using (1).

3. The controller computes $\overline{P}_i^{(A)} = \sum_u P_i^{(A)} / N^{(A)}$ and broadcast it back to the users.

4. If $P_i^{(A)} \leq \overline{P}_i^{(A)}$ then

if $\text{rand}() \leq \frac{\overline{P}_i^{(A)} - P_i^{(A)}}{P_i^{(A)}}$ then

choose network j, where j≠ i and $\overline{P}_i^{(A)}$

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        end if
    end if
end loop for all users in all areas.
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IV. Simulation results

We consider a heterogeneous wireless network model as in figure 1. Each channel has orthogonal with bandwidth equal 192 kb/s. The total transmission rate in each the femtocell is 5Mb/s, the total transmission rate in each the Picocell is 20Mb/s, the total transmission rate in each MBS is 100 Mb/s. Each mobile user is allocated with constant power = 100mW. The number of users in each area is $N^{(A)} = (7-A)*V$ users, A = 1,2,..7. We set $p_i = 0.01$, for the replicator dynamics, we set $\delta = 1$. We run our proposal algorithm with greedy scheme and random scheme for network selection.

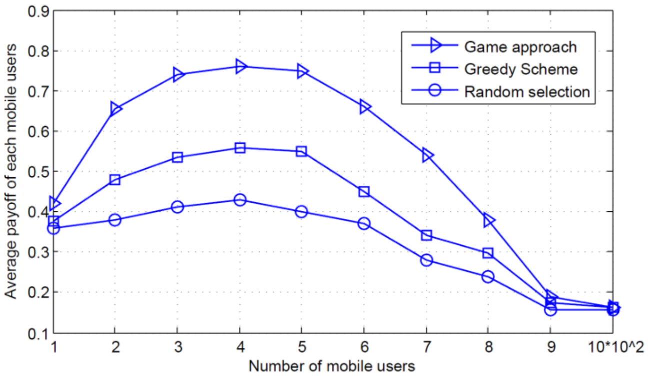

Figure 3: The average payoff of each mobile users in HetNets.

In figure 3, we can see that, the average payoff of each users in network depend on number of users exist in HetNets. By performing our algorithm, we can achieve the results better than other schemes.

V. Conclusions and future works

In this paper, we have introduced a simple method to provide load balancing in HetNets. A centralization scheme are proposed. We applied the evolutionary game approach and considered the competition among sub-area mobile users to share the limited amount of bandwidth. We found a Nash equilibrium to maximize mobile user demands and load balancing among heterogeneous cells.

Acknowledgement

This research was supported by Basic Science Research Program through National Research Foundation of Korea (NRF) funded by the Ministry of Education(NRF-2014R1A2A2A01005900). Dr. CS Hong is the corresponding author.

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