Cell Selection Game in 5G Heterogeneous Networks

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Abstract. Recently, the deployment of small-cell with overlay coverage has emerged as a reliable solution for 5G heterogeneous network (HetNets). While they provide useful properties, these architectures bring several challenges in network management, including interference alignment, extensive back-hauling, and cell selection within HetNets. In this work, we model the cell selection paradigm in 5G HetNets using a non-cooperative game-theoretic framework, and we show that it admits an equilibrium using mixed strategy Nash Equilibrium (NE) method.

Keywords: Game theory · 5G heterogeneous networks · Cell selection

1 Introduction

Over the last decade, anywhere and anytime wireless connectivity has become a reality and has resulted in the increase of data traffic. 5G networks are anticipated to form a new generation of cooperative ubiquitous mobile networks meeting the demand of mobile users. The noticeable growth of the resulting data traffic is assumed to pose enormous loads on the radio spectrum resources in future 5G networks.

Therefore, network densification using small-cells is considered to be a key solution in the emerging networks. The deployment of small-cell in a given area permit to provide a huge capacity gain and bring small base stations closer to users' devices. Nevertheless, the great deployment of small-cells presents several challenges in network management, including interference alignment, extensive back-hauling, and cell selection within HetNets.

Indeed, since the cell selection procedure is generally based on the received signal strength, the heterogeneity of transmission power in the HetNets raises the complexity of the network planning. However, such criterion is no longer applicable due to the disproportion of transmission power. In addition, the maximum Signal to Interference plus Noise Ratio (SINR) based cell selection in the case of HetNets affects the load balancing and does not guarantee the intended performance in terms of spectral efficiency. For these reasons, we use game theory to study the cell selection issue while maintaining the quality of service (QoS) level required by users and maximizing the spectral efficiency.

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Consequently, the main contributions of this paper are as follows:

- We propose a non-cooperative game theoretic model describing the cell selection in 5G HetNets composed of small and macro-cells belonging to two different tiers. The proposed model considers two players User Equipment (UE) and Base Station (BS) with different utility functions.
- We prove the convergence of the proposed game using a mixed strategy NE.
- We design a cell selection method for 5G HetNets where we consider simultaneously the UEs' strategies and the BSs' strategies. We show through simulation the effectiveness of the proposed game in reducing the users' blocking rate and enhancing the network performances in 5G HetNets.

This paper is organized as follows. Section 2 gives a brief profile about related work. In Sect. 3, we describe the network architecture and we present the cell selection game model. In Sect. 4, we present the equilibrium determination in the cell selection game model. Section 5, we evaluate the performance of the proposed game through simulation work. Finally, Sect. 6 concludes the paper.

2 Related Work

Game theory is a part of applied mathematics which is concerned with the decision made in a conflict situation. It provides a large set of mathematical tools modeling and analyzing interactions among the rational entities based on the gain perceived by these entities. In addition to the economic domains, game theory is also employed in communication engineering to solve several kinds of problems concerning power control, resource allocation, radio access technology (RAT) selection, and node participation. It has been widely used to analyze the cooperative and non-cooperative behaviors of mobile nodes in the cell selection issue within a HetNet. In this context, many studies have been conducted toward the application of game theory in cell selection issue within the HetNets.

Authors in [5] proved the convergence to the NE for a wireless interface selection with three main broadband technologies. Authors in [1] studied the dynamics of RAT selection games in HetNets where users selfishly select the best RAT while maximizing their throughput. Through simulation results they noticed that the proposed game converge to NE within a small number of switching. However, in these works, the throughput is considered as the only objective function without considering the pricing scheme.

In [8], authors proposed a non-cooperative game for RAT selection where they considered a throughput function and a pricing function. However, through simulation results, they concluded that the convergence time and the pertinence are improved when users have sufficient information about each other and about the network, which is not the case in the real world applications.

Moreover, the aforementioned papers consider that the HetNet belongs to the same network operator. In [2], authors investigated cell selection issue in a HetNet composed of small and macro-cells belonging to two different tiers. They proposed a non-cooperative game getting the best distribution of UEs among small and macro BSs and they proved the convergence to a NE. However, since each BS is able to serve a limited number of users, the users' blocking rate could increase when the users' number is growing, which may decrease the system QoS.

Therefore, this work consider a non-cooperative cell selection game in 5G HetNets composed of small and macro-cells belonging to two different tiers. The proposed game takes into consideration a capacity and a pricing functions. In this game the users' blocking rate is improved by contributing several BSs of different network operators in the communication. Such network operators must have build a prior agreement between them (as referred to as communication agreement [4]) allowing a free movement over the cells of different operators (Table 1).

Table 1. Comparison between existing works

Reference	Cells belonging to different tiers	No need for other users' information	No need for network's information	Cross-tiers interference protection	Users' blockage protection
Naghavi [8]		×			
Dhifallah [2]	×	×	×	×	
Our proposal	×	×	×	×	×

3 Network Architecture and Model Description

3.1 Network Architecture

We consider a HetNet, depicted in Fig. 1, consisting of small-cell base stations ($S-BSs$) added in the area of macro-cell base station ($M-BS$) improving the system throughput and enhancing the flexibility to offload data traffic from $M-BSs$. $M-BSs$ and $S-BSs$ are deployed by different operators and they interact according to communication agreements. The coverage area of $M-BSs$ may be overlapped to deal with the coverage hole problem. Moreover, we assume that the entire spectrum is divided into sub-bands, where each sub-band is assigned to a specific BS to reduce the cross-tiers interference. We also assume that users are in mobility and may request a service from a $M-BS$ or a $S-BS$.

Indeed, when a mobile user selects a $S-BS$, this latter accepts to serve it only when its maximum capacity is not reached yet, otherwise, it can redirect the request to the closest $M-BS$ of the same operator, or to a $M-BS$ of an other operator according to the communication agreement established between the operators. However, when the user selects a $M-BS$ to serve it, this latter may accepts the request whenever its maximum capacity is not yet reached, or forward the request to the closest BS belonging to the same or different operator.

Therefore, the $BS's$ decision depends on its own capacity and on the neighboring node's capacity, which represents the maximum number of users that can serve. The capacity of each BS is limited in order to guarantee the required QoS. Hence, the income of each BS depends on the total number of UE that it serves and on the total number of UE served by the whole network. Once the $UE's$ request is accepted by a given BS, the latter must pay the service fees. These fees are shared between the BSs involved in the communication.

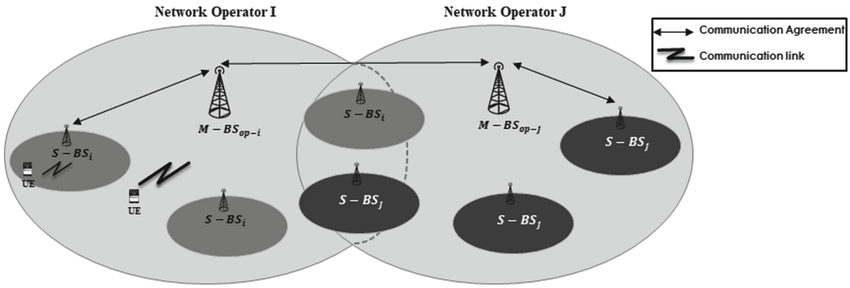


Fig. 1. Heterogeneous network architecture

3.2 Cell Selection Game Model

This sub-section is devoted to present the theoretical model that we proposed in order to find an appropriate cell selection scheme in a HetNet. To this end, we consider that, at the time t, a UE is near to a $S-BS$ and receives a high SINR from the close $M-BS$, as well. We assume that there is a QoS threshold defined in advance permitting the $S-BS$ to delegate the UE to the best closest $M-BS$ even if that decreases its revenue. Therefore, we propose a non-cooperative game with two players (UE and BS). Each player has different set of pure strategies, Table 2, where it selfishly selects the strategy that ensures him the greater payoff. Thus, the $UE's$ utility function is based on the link capacity with the selected BS. However, the $BS's$ utility function depends on the service price of a served user at a time t. Therefore, we propose the following strategy combinations:

Select $S-BS_i$ ***&*** $S-BS_i$ ***Serves*** UE***:*** In this strategy combination, the UE is very close to the $S-BS_i$ and its signal is stronger than its $M-BS_i$. At the same time, the $S-BS_i$ strategy is to serve this UE because the maximum number of UEs that it can serve is not reached. In this case the UE and the BS have the same strategy. Therefore, the $UE's$ payoff is:

$$X_{11} = C_{S-BS_i}(t) + G_{UE,S-BS_i}(t)$$

where $C_{S-BS_i}(t)$ is the normalized link capacity when the UE is associated to the $S-BS_i$, expressed by:

$$C_{S-BS_i}(t) = \frac{W_{S-BS_i}(t) log_2(1 + SINR_{S-BS_i})}{max(C_{S-BS_i}(t))}$$

With $W_{S-BS_i}(t)$ is the used bandwidth and $SINR_{S-BS_i}$ is the signal to interference plus noise ratio of the $S-BS_i$.

$G_{UE,S-BS_i}(t)$ is the $UE's$ gain when it selects the $S-BS_i$, expressed by:

$$G_{UE,S-BS_i}(t) = \frac{W_A}{W_T} + C_{S-BS_i}(t)$$

with W_A is the available sub-band and W_T is the total sub-band.

The $BS's$ payoff is: $Y_{11} = P_{UE,S-BS_i}(t)$, where $P_{UE,S-BS_i}(t)$ is the price of the service provided by the $S-BS_i$ to the UE at time t, expressed by:

$$P_{UE,S-BS_i}(t) = \frac{P_{S-BS_i} \times N_{S-BS_i}}{N_T}$$

With P_{S-BS_i} is the unit price of $S-BS_i$' service, N_{S-BS_i} is the total number of UEs served by $S-BS_i$, and N_T is the total UEs' number in the network.

Select $S-BS_i$ ***&*** $M-BS_i$ ***Serves*** UE***:*** The UE in this case is close to the $S-BS_i$, but this latter can not serve it because the maximum number of UEs that it can serve is reached. The $S-BS_i$ receives the request of the UE and redirects it to its $M-BS_i$. In this case, the UE payoff is:

$$X_{21} = C_{M-BS_i}(t)$$

Where $C_{M-BS_i}(t)$ is the normalized link capacity when the UE is associated to the $M-BS_i$, expressed by:

$$C_{M-BS_i}(t) = \frac{W_{M-BS_i}(t) log_2(1 + SINR_{M-BS_i})}{max(C_{M-BS_i}(t))}$$

with $W_{M-BS_i}(t)$ is the used bandwidth and $SINR_{M-BS_i}$ is the signal to interference plus noise ratio of the $M-BS_i$. The $BS's$ payoff is:

$$Y_{21} = \frac{P_{UE,M-BS_i}}{2}$$

where $P_{UE,M-BS_i}(t)$ is the price of the service provided by the $M-BS_i$ to the UE at time t, expressed by:

$$P_{UE,M-BS_i}(t) = \frac{P_{M-BS_i} \times N_{M-BS_i}}{N_T}$$

With P_{M-BS_i} is the unit price fixed for the $M-BS_i$, N_{M-BS_i} is the total number of users served by $M-BS_i$, and N_T is the total number of users in the whole network. $P_{UE,M-BS_i}(t)$ is divided by 2 because the request of the UE is firstly sent to the $S-BS_i$ then it is redirected to the $M-BS_i$. In this case, the price of the service is shared between $S-BS_i$ and $M-BS_i$.

Select $S-BS_i$ ***&*** $M-BS_j$ ***Serves*** UE***:*** The UE in this case is close to the $S-BS_i$, but this latter can not serve it because the maximum number of UEs that it can serve is reached. The $S-BS_i$ receives the request of the UE and redirects it according to a communication agreement to the closest $M - BS_j$ through the $M - BS_i$. Therefore, $UE's$ payoff is:

$$X_{31} = C_{M-BS_j}(t)$$

where $C_{M-BS_j}(t)$ is the normalized link capacity when the UE is associated to the $M - BS_j$ belonging to an other operator, expressed by:

$$C_{M-BS_j}(t) = \frac{W_{M-BS_j}(t)log_2(1 + SINR_{M-BS_j})}{max(C_{M-BS_j}(t))}$$

With $W_{M-BS_j}(t)$ is the used bandwidth and $SINR_{M-BS_j}$ is the signal to interference plus noise ratio of the $M - BS_j$. The $BS's$ payoff is:

$$Y_{31} = \frac{P_{UE,M-BS_j}(t)}{3}$$

Where $P_{UE,M-BS_j}(t)$ is the price of the service provided by the $M-BS_j$ to the UE at time t, expressed by:

$$P_{UE,M-BS_j}(t) = \frac{P_{M-BS_j} \times N_{M-BS_j}}{N_T}$$

With P_{M-BS_j} is the unit price fixed for the $M - BS_j$, N_{M-BS_j} is the total number of users served by $M - BS_j$, and N_T is the total number of users in the whole network. $P_{UE,M-BS_j}(t)$ is divided by 3 because the communication includes three entities ($S - BS_i$, $M - BS_i$, and $M - BS_j$). In this case, these entities will share the price of the service paid by the UE.

Select $M-BS_i$ ***&*** $S-BS_i$ ***Serves*** UE***:*** In this case the UE selects the $M-BS_i$ as it provides the best signal strength, but this latter cannot serve it because the maximum number of UEs that it can serve is reached. So, the $M - BS_i$ redirects it to the closest $S - BS_i$ in order to balance the load and provides a better QoS to the served UEs.

Therefore, the $UE's$ payoff is: $X_{12} = C_{S-BS_i}(t)$.

And, the $BS's$ payoff is: $Y_{12} = \frac{P_{UE,S-BS_i}(t)}{2}$, where $P_{UE,S-BS_i}(t)$ is divided by 2 because the request is firstly sent to the $M - BS_i$ then it is redirected to the $S - BS_i$ belonging to it. Therefore, $M - BS_i$ and $S - BS_i$ will share the service price paid by the UE.

Select $M - BS_i$ ***&*** $M - BS_i$ ***Serves*** UE***:*** In this strategy combination, the UE selects the $M-BS_i$ while the $M-BS_i$ strategy is to serve the UE because in this instant it is off-loaded. In this case the UE and the BS have the same strategy. Therefore, $UE's$ payoff is:

$$X_{22} = C_{M-BS_i}(t) + G_{UE,M-BS_i}(t)$$

$G_{UE,M-BS_i}(t)$ is the $UE's$ gain when it selects the $M - BS_i$, expressed by:

$$G_{UE,M-BS_i}(t) = \frac{W_A}{W_T} + C_{M-BS_i}(t)$$

The $BS's$ payoff is: $Y_{22} = P_{UE,M-BS_i}(t)$.

Select $M - BS_i$ ***&*** $M - BS_j$ ***Serves*** UE***:*** The UE in this case is close to the $M - BS_i$, but this latter can not serve it because the maximum number of UEs that it can serve is reached. In this case, the $M - BS_i$ redirects the request of the UE to the closest $M - BS_j$ that offers the best QoS according to a communication agreement.
Therefore, $UE's$ payoff is: $X_{23} = C_{M-BS_j}(t)$.
The $BS's$ payoff is: $Y_{23} = \frac{P_{UE,M-BS_j}(t)}{2}$,
$P_{UE,M-BS_j}(t)$ is divided by 2 because the request is firstly sent to the $M - BS_i$ then it is redirected to the $M - BS_j$ which has a communication agreement with. Therefore, $M - BS_i$ and $M - BS_j$ will share the service price paid by the UE.

Table 2. Matrix game

BS \ UE	select $S - BS_i$	select $M - BS_i$	$q - mix$
$S - BS_i$ serves UE	(X_{11}, Y_{11})	(X_{12}, Y_{12})	$qY_{11} + (1-q)Y_{12}$
$M - BS_i$ serves UE	(X_{21}, Y_{21})	(X_{22}, Y_{22})	$qY_{21} + (1-q)Y_{22}$
$M - BS_j$ serves UE	(X_{31}, Y_{31})	(X_{23}, Y_{23})	$qY_{31} + (1-q)Y_{23}$
$p - mix$	$p_1X_{11} + p_2X_{21} + (1 - p_1 - p_2)X_{31}$	$p_1X_{12} + p_2X_{22} + (1 - p_1 - p_2)X_{23}$	

4 Equilibrium Determination in Cell Selection Game

The NE represents the solution for players in non-cooperative games. One of the essential objectives in this work is to prove the existence of NE. There are two main types of NE defined in non-cooperative game [7], the pure strategy and the mixed strategy. In a pure strategy, each player's strategy is the best response to the strategies of other players. However, it is not suitable for the cell selection game because it leads to the non-causal problem even if the game processes a pure strategy [3]. Thus we introduce the concept of mixed strategy NE.

A mixed strategy for player i is a probability distribution over his set of available actions. In other words, if player i has K_i actions, a mixed strategy is K_i dimensional vector $p = (p_1, p_2, ..., p_K)$ where $0 \leq p_k \leq 1$ and $\sum_{k=1}^{K} p_k = 1$.

In our situation, we consider that each UE has 2 possible actions consisting of $K_{UE} = \{select\ S - BS_i,\ select\ M - BS_i\}$, and each BS has 3 possible actions consisting of $K_{BS} = \{S - BS_i\ serves\ UE,\ M - BS_i\ serves\ UE,\ M - BS_j\ serves\ UE\}$. According to the NE theory, there is a mixed strategy NE where $player_1$ playing $(action_1, p_1^*, p_2^*)$ and $player_2$ playing $(action_1, q^*)$ do not have interest to change their actions. Our objective is finding p_1^*, p_2^*, and q^*.

Theorem

Let $p_1^* \in [0, \frac{G_{UE,MBS_i}(t)}{G_{UE,MBS_i}(t)+G_{UE,SBS_i}(t)}]$ and $p_2^* = \frac{p_1^* \times G_{UE,SBS_i}(t)}{G_{UE,MBS_i}(t)}$, be the optimal probabilities of the UE when it decides to select $S - BS_i$ and let $q^* = \frac{2P_{UE,MBS_i}(t)-P_{UE,SBS_i}(t)}{2\left(P_{UE,SBS_i}(t)+P_{UE,MBS_i}(t)\right)} + \frac{P_{UE,MBS_i}(t)-P_{UE,SBS_i}(t)}{2P_{UE,SBS_i}(t)+\frac{2}{3}P_{UE,MBS_i}(t))}$, be the optimal probabilities of the BS when it decides that the $S - BS_i$ serves the UE.

There is a mixed strategy NE, UE (select $S-BS_i$, p_1^*, p_2^*), BS ($S-BS_i$ serves the UE, q^*) where the UE selects the $S-BS_i$ if the probability $p_1 > p_1^*$ and $p_2 > p_2^*$ and the $BS's$ action is $S-BS_i$ serves the UE if $q > q^*$.

Proof

- We consider the UE strategies:
  - If the UE plays (select $S-BS_i$), its expected payoff is:

$$E(select \quad S-BS_i) = p_1 X_{11} + p_2 X_{21} + (1-p_1-p_2)X_{31}$$

  - If the UE plays (select $M-BS_i$), its expected payoff is:

$$E(select \quad M-BS_i) = p_1 X_{12} + p_2 X_{22} + (1-p_1-p_2)X_{23}$$

After all calculation made, the UE will select the $S-BS_i$ when $E(select \quad S-BS_i)$ is greater than $E(select \quad M-BS_i) \Longrightarrow p_1 > p_1^* \quad and \quad p_2 > p_2^*$, where:

$$p_1^* \in [0, \; \frac{G_{UE,MBS_i}(t)}{G_{UE,MBS_i}(t) + G_{UE,SBS_i}(t)}] \; and \quad p_2^* = \frac{p_1^* \times G_{UE,SBS_i}(t)}{G_{UE,MBS_i}(t)}$$

with $0 < p_1^* \leq 1$; $0 < p_2^* \leq 1$.

- We consider the BS strategies:
  - If the BS plays ($S-BS_i$ serves the UE), its expected payoff is:

$$E(S-BS_i \; serves \; the \; UE) = qY_{11} + (1-q)Y_{12}$$

  - If the BS plays ($M-BS_i$ serves the UE), its expected payoff is:

$$E(M-BS_i \; serves \; the \; UE) = qY_{21} + (1-q)Y_{22}$$

  - If the BS plays ($M-BS_j$ serves the UE), its expected payoff is:

$$E(M-BS_j \; serves \; the \; UE) = qY_{31} + (1-q)Y_{32}$$

After all calculation made, the BS will choose the strategy $S-BS_i$ serves the UE when $E(S-BS_i \; serves \; the \; UE)$ is greater than $E(M-BS_i \; serves \; the \; UE)$ and greater than $E(M-BS_j \; serves \; the \; UE) \Longrightarrow q > q^*$, where:

$$q^* = \frac{2P_{UE,MBS_i}(t) - P_{UE,SBS_i}(t)}{2\left(P_{UE,SBS_i}(t) + P_{UE,MBS_i}(t)\right)} + \frac{P_{UE,MBS_i}(t) - P_{UE,SBS_i}(t)}{2P_{UE,SBS_i}(t) + \frac{2}{3}P_{UE,MBS_i}(t))}$$

4.1 System Features

In this game, the two set of players have different requirements, the UEs' need is to select the cell that provides the required QoS during mobility, whereas, the BSs' aim is to distribute the users between different cells in order to balance the load. These requirements are affected by the variation of the number of users served in the whole network. Moreover, the players' strategies are based on the probability value that depends principally on their requirements.

As indicated before, p_1^* and p_2^*, represent the optimal probabilities of the UE when it decides to select $S-BS_i$. Their expressions depend on the $UE's$ gain. These probabilities are affected by the increased number of users in the network. Therefore, p_1^* and p_2^* will decrease when the number of users served by the cell is increasing, because more the cell becomes charged, more the QoS is deteriorated.

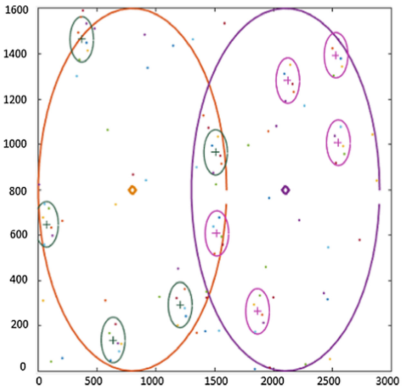
On the other hand, q^* represents the optimal probability of the BS when it decides that the $S-BS_i$ serves the UE. Its expression depends on the service price, which is firstly affected by the number of users in the whole network. Indeed, when the number of users in the whole network is increasing, q^* will increase because in load time, the BS player decides that the $S-BS_i$ serves the users in order to balance the load. However, when the network is few charged, the $M-BS_i$ accepts most of users' request as the required QoS is respected.

Also the expression of q^*depends on the number of BS involved in the communication, which is denote by α and can take three possible values ($\alpha = 1,\ 2,\ or\ 3$). Indeed, in the case of $\alpha = 1$, the UE and the BS select the same strategy, then the service price is given to the cell that serves the UE. In the case of $\alpha = 2$, the UE selects $S-BS_i$ or $M-BS_i$ and the BS redirects the request to an other one belonging to the same operator, or, the UE selects $M-BS_i$ and the BS redirects the request to $M-BS_j$ belonging to an other operator, then the service price is divided between the selected cell and the serving cell. Finally, in the case of $\alpha = 3$, the UE selects $S-BS_i$ and the BS redirects the request to $M-BS_j$ belonging to an other operator, then the service price is divided between $S-BS_i$, $M-BS_i$ and $M-BS_j$.

5 Performance Evaluation

In this section, we evaluate the performances of the proposed non-cooperative cell selection game within 5G HetNets using MATLAB software. As depicted in Fig. 2(a), we consider an urban zone implementing two macro-cell BSs with radius of 800 m for each one. We assume that the coverage areas of the $M-BSs$ are overlapped. In addition, we consider that each $M-BS$ is overlaid by 5 $S-BSs$ where each $S-BS$ radius is equal to 100 m. We also assume that the network is full charged when each $M-BS$ serves 30 $users$ and each $S-BS$ serves 10 $users$ simultaneously. The main parameters of this simulation are based on works presented in [2] and in [6] and they are listed in Fig. 2(b).

In Fig. 3, we present the best response function of each player when the network is half charged (55 UEs). As indicated in the previous section, q represents the probability of the BS to decide that $S-BS_i$, $M-BS_i$, or $M-BS_j$ serves the UE. However, $p_2 = \frac{p_1 \times G_{UE,SBS_i}(t)}{G_{UE,MBS_i}(t)}$ represents the probability that the UE selects $S-BS_i$ or $M-BS_i$ during mobility. Indeed, when the BS decides that the $S-BS_i$ serves the users with less than 50% of probability q, the UE should choose to select $S-BS_i$ with 0% of probability p_2. And whenever BS chooses



a- Network Topology

Parameters	Values
M-BS transmission Power	40W
S-BS transmission Power	2W
Frequency band	2,6GHz
5G bandwidth	60GHz
$SINR_{M-BS}$	5dB
$SINR_{S-BS}$	30dB

b- Simulation Parameters

Fig. 2. Communication environment

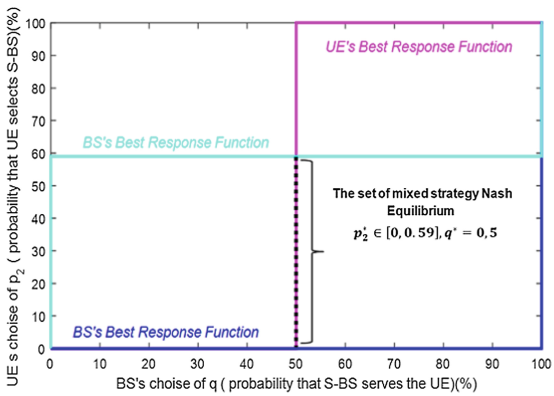
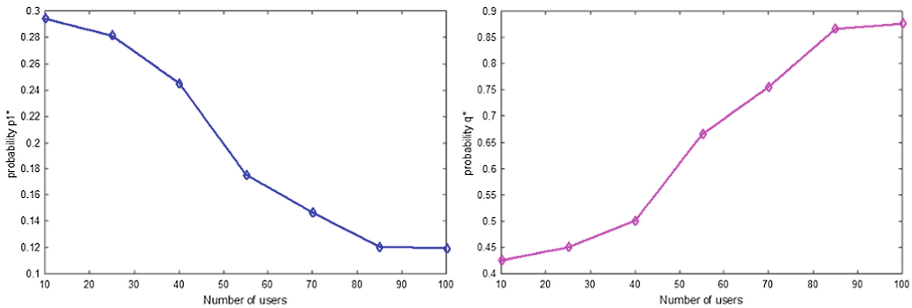


Fig. 3. Combined best response functions

that the $S - BS_i$ serves the users with more than 50% of probability q, the UE should choose to select $S - BS$ with 100% of probability p_2.

The same thing for UEs' strategies. When the UE selects $S - BS_i$ with a rate lower than the range between [0%, 59%] of probability p_2, the BS should choose that $S - BS_i$ serves the UE with 0% of probability q. And whenever the UE selects $S - BS_i$ with a rate more than the range [0%, 59%] of probability p_2, the BS should decide that $S - BS_i$ serves the UE with 100% of probability q. Since p_2 varies according to the variation of p_1 between p_{1-min} and p_{1-max}, a set of p_2 optimal probability are detected. Therefore, the mixed strategy NE is the set of values ($p_2^* \in [0,\ 0.59]\ and\ q^* = 0.5$) representing the intersection of the $BS's$ best response functions with the $UE's$ best response function.

Now, we study the evolution of $(p_1^*,\ q^*)$ according to the variation of the UEs number. p_1^* represents the optimal probability of the UE when it decides to select $S - BS_i$ strategy. Figure 4(a), shows the behavior of p_1^* with the growth



a- Variation of p1* in function of UEs number   b- Variation of q* in function of UEs number

Fig. 4. Evolution of p_1^*, q^* in function of UEs number

of the UEs' request on the network. Indeed, when the network is half charged (UEs number $\leq$ 40 users), p_1^* is around 0.3. In this case, the $S-BS_i$, $M-BS_i$, and $M-BS_j$ offer the same QoS to the UE. However, when the number of UEs associated to the $S-BS_i$ increases, p_1^* decreases until it reaches the minimum when the network is full charged. In this case, the UE looks for the cell that provide a better QoS than its best $S-BS_i$.

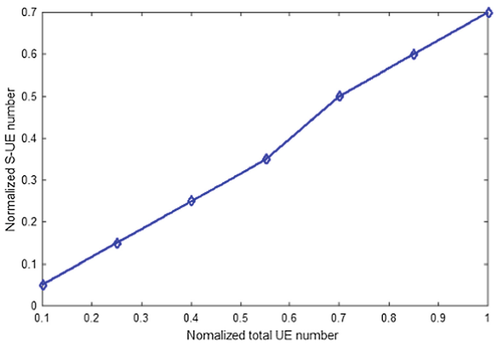


Fig. 5. The rate of $S-UE$ from the total UE number

Figure 4(b), shows the evolution of q^* with the increase of the total number of UEs associated to the whole network. q^* represents the optimal probability of the BS when the $S-BS_i$ serves the UE. We notice that q^* increases slightly until the network becomes half loaded. When the UEs number exceeds the half of the network capacity, q^* increases significantly until reaching its maximum when the network is full loaded. In the beginning of the load time, the BS decides that the $S-BS_i$ serves a few number of UEs' request since the $M-BS_i$ is low loaded. However, in load-off time, $S-BS_i$ accepts most of the received requests, as long as the required QoS is respected, in order to balance the load.

Figure 5 presents the load of the $S - BS$ network compared to the overall load. In the loaded time, the global network strategy tends to associate UEs to the $S{-}BSs$ in order to balance the load between macro and small-cells. However, in the load-off time, the selection strategy tends to distribute the UEs.

6 Conclusion

In this paper, we focused on the cell selection issue during mobility in 5G HetNets. To this end, we proposed a non-cooperative cell selection game with two players (UE and BS). This game realizes an equilibrium in the UEs distribution while respecting the required QoS and maximizing the network's gain. Simulation results are provided to show the performance of the proposed game.

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