Using Game Theory for Radio Resource Management of RRC Layer in LTE-A

Zhirong LUAN [a], Hua QU [b], Jihong ZHAO [b]
[a b] The School of Electronic and Information Engineering,
Xi'an Jiaotong University, China
Corresponding Author: luanzr@163.com

***Abstract*—The radio resource management is one of the important contents of the core key technologies of LTE-A, especially in the RRC (Radio Resource Control) layer. Most radio resource management schemes only consider part of the radio resource, but not the overall system performance. Recently, game theory has become a useful tool in the research on radio resource management. According to the 3GPP, in this article, we focus on how to define the radio resource management in the RRC layer as a game and present the concept of "virtual access users", which helps to describe the wireless communication environment. Game theory is used to improve the overall performance of RRC layer in LTE-A. To be more specific, in the game, first, the characteristics of RAC (Radio Access Control) and RBC (Radio Bearer Control) are analyzed. Second, we created utility function of the game to balance real users and the "virtual access users". Third, the best solution of the game is reached, and proved to be reasonable. By computer simulations, we investigate the performance of proposed scheme and analyze our simulation results.**

***Keywords*—Game Theory, Radio Resource Management, RRC, RAC, RBC, LTE-A**

I. Introduction

The radio resource management is one of the important contents of the core key technologies of LTE-A. In the E-UTRAN radio interface, RRC (Radio Resource Control) belongs to access stratum. The major role of RRC is to set-up, reconfiguration as well as release the radio resource of radio bearer services [1]. By now, most researches about RRC layer are about connection establishment [2], message transmission [3] and state transition [4]. These works don't discuss the overall system performance. Aiming to enhance the radio resource utilization efficiency of the whole RRC layer, we focus on resource allocation between the RAC (Radio Access Control) and the RBC (Radio Bearer Control).

Recently, the game theory has become a useful tool in the research on radio resource management. As a powerful tool, it shows advantages in the area of resource allocation [5]. Reference [6] [7] use the game theory to allocate the bandwidth according to the different services. In [8], the signal channel management is discussed as a game and his work improves the performance of delay, jitter and Throughput. These works only care one function module and ignore the relationship between different radio resource management modules. Basing on the former analyze, we use game theory to control radio resource allocation between RAC and RBC. The game allocates resource of the BS (Base Station) to users and the "virtual access users". And finally, it performed simulation tests.

The rest of this paper is organized as follows. In section 2, we outline the system model and definite the virtual access user. In section 3, we present the algorithm for the game between RBC and RAC, and analyze the proposed scheme. The simulation results are analyzed in section 4. The conclusion and future research are provided in section 5.

II. System Model and Virtual Access Users

A. *Game for RBC and RAC*

RBC and RAC are two important parts of radio resource management in the RRC layer. The major task of RBC is to build, maintain and release the radio bearer. When building a radio bearer, RBC should take all the radio resource of the cell into consideration. Radio resource changes because of dynamic environment and user movement. Then RBC will maintain radio bearers of existing users and release the bearers

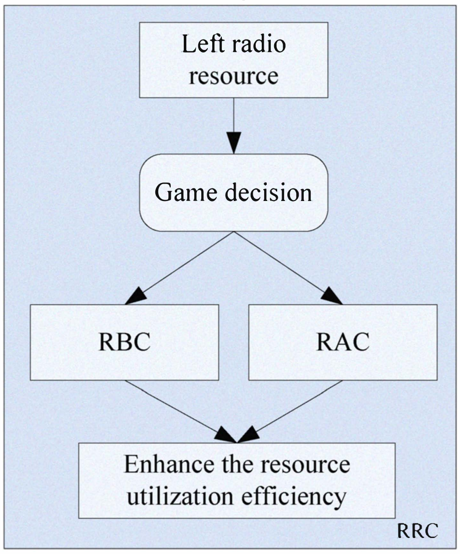

Fig.1 Structure of the game between RBC and RAC

after users end their communication. Meanwhile, the major task of RAC is to decide whether to build a new bearer or not. The same as RBC, RAC should consider radio resource in the cell. A new bearer will be built only the radio resource in the cell is surplus. Since RAC and RBC will compete for radio resource in the cell, the left radio resource in the cell is set as game space. The game of RBC and RAC is showed in fig.1.

B. Virtual Access Users

In theory, all the radio should be allocated to existing users and new users that RAC agree to build a bearer. But because of multipath effect, shadow effect, white Gaussian noise, movement form users and some other reasons, users' Qos decreases. To enhance the overall resource utilization efficient, we have to pain attention to these negative side effects. These negative side effects can be treated as some virtual users take radio resource from the existing users. We define virtual access users to be the combination of all the possible negative effects and the real access users, as showed in fig.2.

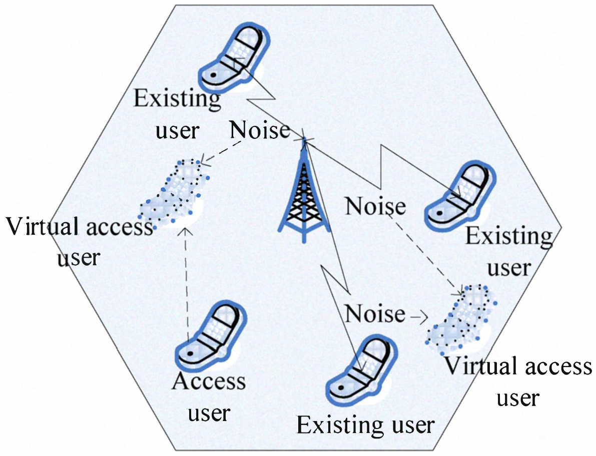

Fig.2 definition of virtual access users

The radio resource allocated to virtual users can be described as follows.

$$R_{VAU}=\sum_{k=1}^{n}p_kR_k \tag{1}$$

In which R_{VAU} stands for the radio resource which virtual access users take. R_k means one negative side effect, and p_k refers to weight of each effect. The detail of each R_k would be our future work. Now, we consider the virtual access users as Poisson arrival.

III. GAME METHOD FOR RADIO RESOURCE ALLOCATION

A. Construction of Utility Function for The Game

Base on the analysis in section 2, overall performance of the system depends upon the radio resource allocation scheme between RBC and RAC. Imbalance of the allocation will waste radio resource or will bring over competitive of the resource. Because we only consider about the users and radio resource in their own cell, what we focus on is the users' radio resource allocation in a single cell and the overall performance in a single cell.

The overall performance can be described by utility function. According to the relationship between RBC and RAC, during time T, we suppose that there are m1 existing users and m2 virtual access users. The utility function can be defined as fellow.

$$F\left(r_i,r_j,\eta\right)=\prod_{i=1}^{m1}(r_i-R_{i,\min})\prod_{j=1}^{m2}r_j \tag{2}$$

St.

$$\sum_{i=1}^{m1}r_i=\eta R \tag{3}$$

$$\sum_{j=1}^{m2}r_j=(1-\eta)R \tag{4}$$

r_i Radio resource that BS allocates to existing users;

$R_{i,\min}$ Least radio resource to support the existing user i;

r_j Radio resource that BS allocates to virtual access users;

η the ratio that existing user take resource from the whole cell radio resource, and also the ratio of RBC resource from the whole cell radio resource. $1-\eta$ is the ratio of RAC resource from the whole cell resource;

R Whole cell radio resource.

The utility function consists of two parts. One is the resource of existing users (RBC) and the other is the resource of virtual access users (RAC). The utility shows resource utilization efficiency of the system.

What we need is to make (2) become the maximum under the condition of (3) (4). Actually we don't concern about the exact value of $F\left(r_i,r_j,\eta\right)$, but the value of η when $F\left(r_i,r_j,\eta\right)$ is the maximum, which means the balance of all users and maximize the overall performance.

To simplify the calculation, we define $F\left(r_i,r_j,\eta\right)$ as follow.

$$f(r_i,r_j,\eta)=\ln\left(F(r_i,r_j,\eta)\right) \tag{5}$$

That's to say:

$$f(r_i,r_j,\eta)=\sum_{i=1}^{m1}\ln(r_i-R_{i,\min})+\sum_{j=1}^{m2}\ln r_j \tag{6}$$

B. Best Solution to The Utility Function

Using Lagrange Multiplier Method to have the extreme value, we have the following equation.

$$L(r_i,r_j,R_{i,\min},\lambda,\mu)=\sum_{i=1}^{m1}\ln(r_i-R_{i,\min})+\sum_{j=1}^{m2}\ln r_j-\lambda(\sum_{i=1}^{m1}r_i-\eta R)-\mu(\sum_{j=1}^{m2}r_j-(1-\eta)R) \tag{7}$$

The partial derivative of r_i, r_j are:

$$\frac{\partial L(r_i, r_j, R_{i,\min}, \lambda, \mu)}{\partial r_i} = \frac{1}{r_i - R_{i,\min}} - \lambda = 0 \quad (8)$$

$$\frac{\partial L(r_i, r_j, R_{i,\min}, \lambda, \mu)}{\partial r_j} = \frac{1}{r_j} - \mu = 0 \quad (9)$$

Then, we have $r_i = \frac{1}{\lambda} + R_{i,\min}$ and $r_j = \frac{1}{\mu}$. Bring them into (3) (4), we can eliminate an unknown quantity λ and μ. The solutions to r_i, r_j are:

$$r_i = \frac{\eta R - \sum_{i=1}^{m1} R_{i,\min}}{m1} + R_{i,\min}, \quad r_j = \frac{(1-\eta)R}{m2} \quad (10)$$

Bring (10) into (2), we will find that the function f only has relationship with μ.

$$f(\eta) = \sum_{i=1}^{m1} \ln \frac{\eta R - \sum_{i=1}^{m1} R_{i,\min}}{m1} + \sum_{j=1}^{m2} \ln \frac{(1-\eta)R}{m2} \quad (11)$$

To have the extreme value, we can define the derivative of η to be zero.

$$f'(\eta) = \sum_{i=1}^{m1} \frac{m1}{\eta R - \sum_{i=1}^{m1} R_{i,\min}} . \frac{R}{m1} + \sum_{j=1}^{m2} \frac{m2}{(1-\eta)R} . \frac{-R}{m2} = 0$$

(12)

If we have the value of η, we will have the best performance of $f(\eta)$. From (12),

$$\eta = \left(\frac{1}{m2} + \frac{\sum_{i=1}^{m1} R_{i,\min}}{R.m1}\right) . \frac{1}{\frac{1}{m1} + \frac{1}{m2}} \quad (13)$$

All of the parameters in (13) is positive, so η >0. Meanwhile,

$$\eta = \left(\frac{1}{m2} + \frac{\sum_{i=1}^{m1} R_{i,\min}}{R.m1}\right) . \frac{1}{\frac{1}{m1} + \frac{1}{m2}} < \left(\frac{1}{m2} + \frac{1}{m1}\right) . \frac{1}{\frac{1}{m1} + \frac{1}{m2}} = 1$$

(14)

From (14) and the former analysis, η is between 0 and 1, which means our radio resource allocation to RBC and RAC is rationality

When η satisfies (13), $f(\eta)$ gets its extreme value. It's easy to find that the second derivative of η is negative. So the $f(\eta)$ gets the maximum value at (13).

IV. SIMULATIONS

In this section, we present the numerical results to the game theory on radio resource management between RBC and RAC.

We assume that number of existing users ranges from 20 to 80, whose radio resource requirements meet normal distribution with the mean value of 2 and the variance of 1. Number of virtual access users is 40. The number of total radio resource in a cell is 1000. The simulation result is showed in fig.3.

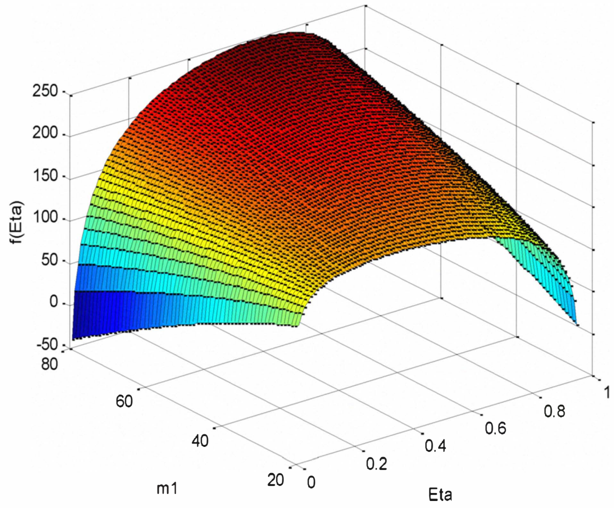

Fig.3 value of $f(\eta)$

In which, $f(\eta)$ (f (Eta)) is the overall performance; m1 is the number of existing users; η (Eta) is the resource allocation ratio for RBC. With the increase of existing users, the Nash equilibrium point of existing users and virtual access users changes.

When the number of existing users, m1, stays still, we can conclude from that $f(\eta)$ keeps increasing until the Nash equilibrium point, which is the best performance of the system. And after the Nash equilibrium point, $f(\eta)$ decreases. This means that with the increase of existing users, the radio resource of RBC can't support existing users. To maximize the overall performance, system allocates more resource for RBC. However, this brings shortage of resource to RAC. So the overall performance decreases after the Nash equilibrium point.

When considering about the number of existing users, m1, with the increase of m1, the Nash equilibrium point changes from 0.8 to 1 on η label. This means the system allocates more resource to RBC. To get the best overall performance, BS will not keep much radio resource for RAC.

V. CONCLUSIONS

In this research we have investigated the radio resource management scheme for RBC and RAC in RRC layer by using game theory. A new parameter, "virtual access user", is defined to describe all the negative side effects. With the help of virtual access user, we maximize the overall system performance and find out the Nash Equilibrium as the simulation has shown.

The future problem involves: analyzing each possible negative effect to existing users, and defining the detailed design of "virtual access user".

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