Securing Auction Using Mobile Agent in Cognitive Radio Networks

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ABSTRACT: *In this paper, we propose a model for resource allocation in cognitive radio network (CRN) and provide a secure communication between primary user (PU) and secondary users (SUs). Here, PUs takes the help of the mobile agents (MAs) for calling the auction on behalf of PU Access Point (PUAP) and work as interface between PUAP and SU. MAs handle multiple task to make the system fast, redundant, secure and robust. The problem is modeled using cooperative game theory between the MAs, MAs make the system distributed and simplifies the life of PUAP. MAs analyzes the behavior of the SU in the multiple aspects and forward the collected data to PUAP. The existence of MAs with the PUAP increase the efficiency of the model.*

Keywords: Cognitive Radio Network (CRN), Mobile agent (MA), Game theory, Pareto Optimal Boundary (POB)

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1. Introduction

Demand of the bandwidth is always high; users want higher bandwidth for higher data rates. Efficient utilization of bandwidth is always been a problem for the various regulating organization, according to survey conducted by FCC 15-80 % [1] of the bandwidth is un-utilized on an average. Cognitive radio network (CRN) emerged as the most promising technique for the efficient bandwidth utilization. CRN provides the cognitive capabilities to users; CRN users are called secondary users (SUs) [1]. SUs can find the holes in frequency bands and have the capabilities to start transmission over the holes. PUs have unused license bands and SUs can start transmission over these bands. PUs restricts SUs from arbitrary transmission by implementing the auctioning techniques. PUs leases their unused bandwidths to the SUs to generate revenue.

PUs is not so intelligent compared to the SUs,for that reason Mobile agents (MAs) are used for helping PUs to increase their intelligence. MAs are the piece of software autonomous in nature. In this model MAs will works on many critical aspects of the spectrum leasing, MAs will provide an interface between PUs and SUs and create a three layer hierarchy. In this hierarchal structure PU access point (PUAP) will take part on the behalf of all PUs, MAs work under the PUAP and interacts with SUs. Although, MAs are the intelligent units and have the capability of decision making, but PUAP reserve the right of taking decisions. MAs use the cooperative game to optimize the problem of auctioning. There are multiple MAs and they conduct multiple auctions simultaneously, under the guidance of central MA (CMA). CMA directly interacts with PUAP and shares the sorted data.

1.1 Related work and Paper organization

There are lot of literature available for game theory and auction theory which are used in CRN for various purposes. Haykin [3] provides the underline structure of CRN. Stanojev [4] modeled a cooperative game scenario between users and relays. Model implements the auction theory to select the preferable relay for sending user's information. In this method, a slot is re-transmitted over the allocated spectrum by the relay, relay has to forward the data of the user as well as obtain an opportunity to send his own data. This technique resolves the problem of both user and relay, but relay may be vulnerable. Cooperative game strategy used by [5] for spectrum sharing. In this system, both players communicate via centralized authority and find out some key factors for transmission like interference cap. This type of strategy helps player to get maximum pay-off, but comes with some limitation of information security and speed of gaming. Simeone *et al.* [6] proposes the cooperative model between the users for the spectrum sharing. Li *et al.* [7] proposes a model of spectrum leasing by PUs. The model is based on the coalitional strategy and differ from the [6], [8] only on the aspect of pricing, of the spectrum.

MAs are the most commonly investigated in robotics, computer systems or software engineering, research models that tackle the use of such MAs in wireless communication networks are few. However, recently the need of such MAs in wireless networks has become noticeable importance due to the emergence of next-generation networks [9]. Saad *et al.* [10] proposes the interactive approach for using MAs in the wireless networks, by realizing the agents for multiple domain and simulates the game between the tasks and the agents. The model proposed in this paper is different from the model proposed by Li and others, in the following aspects.

- It provides a systematic solution for spectrum leasing *via* auctioning.
- Cooperative model is used by PUAP to lease the spectrum using MAs.
- Markov process is used to remove the vulnerability of Vickery auction technique, and to reduce system complexity.
- PUAP limits the interference provided by SUs, using MAs and Markov process.

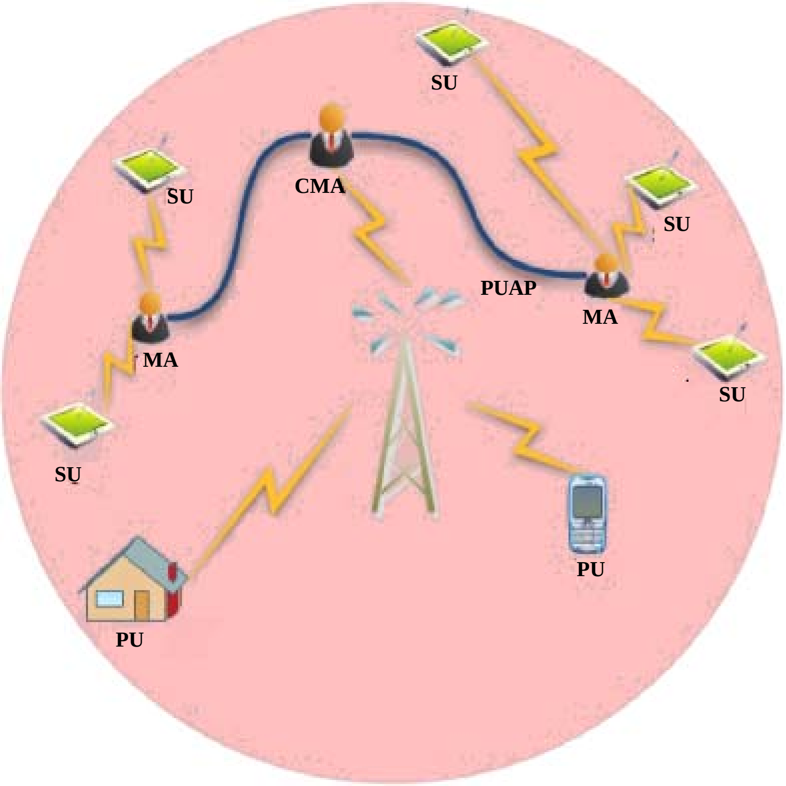


Figure 1. Scenario for auctioning

MAs efficiently help the PUAP to lease their bandwidth. In the proposed strategy complexity and time delay caused by the PUAP is reduced. Behavior of PUAP depends on the information conveyed by the MAs of SUs. PUAP works adaptively, if SU play fair then the PUAP paly fair otherwise PUAP will terminate the agreement. Application of the Markov chain is also proposed to remove the vulnerability of the Vickery auction mechanism.

In this paper, II covers the overview of the system model and includes the behavior of MAs and the SUs to work on there utility, it also includes the collational game between MAs. Strategy followed by PUAP, MAs and SUs for auction is discussed in III. Numerical results are discussed in IV and concluding remarks are provided in V.

2. System Model

Consider a network consisting of N PUs having L number of sub-carriers out of which l is unutilized, therefore, to utilize the bandwidth PUAP allows CMA to auctions the sub-carriers one by one. Those SUs which are willing to get the bandwidth, they participate in the auctioning process. CMA will make this auction a distributive system by using M MAs as the auction and transaction nodes, shown in *Figure 1*. MAs will forward all the necessary details of the auction, like the bandwidth detail and the process to be followed in auctioning and SUs will send their respective bids. The model proposed in this paper formulate the three tier architecture for the leasing of spectrum. PUAP are at the top of the architecture and SUs occupy the lowest level, while MAs are at the middle of the architecture. MAs provides an intelligent insulation for PUAP from SUs.

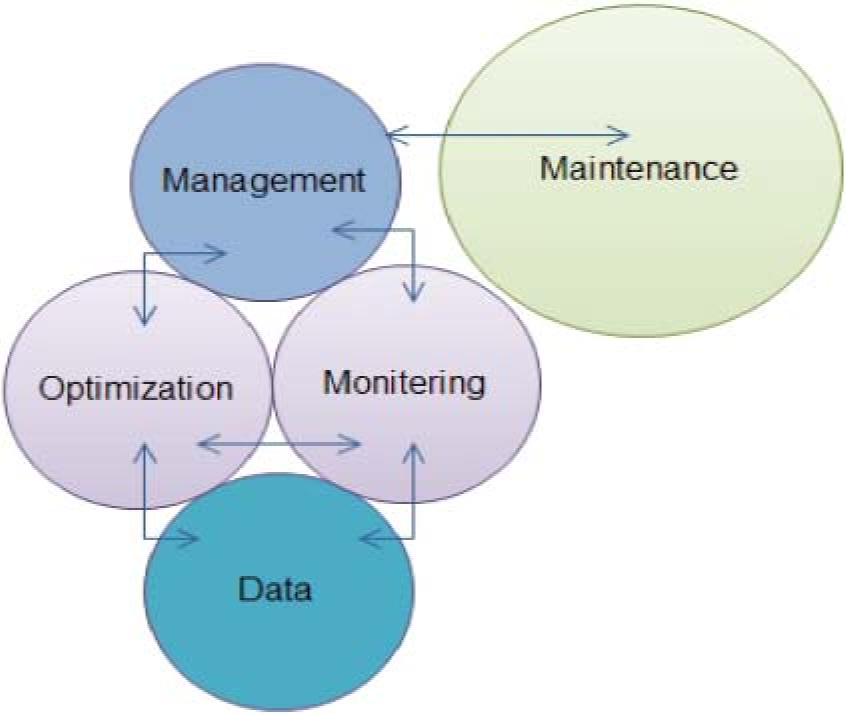


Figure 2. MAs assigned to different sets and showing there relationship characteristics

2.2 Need of Mobile Agent

MAs provide heterogeneous, distributed environment. MA’s works in many dimensions, it is inherent to have selforganizing autonomous nodes (agents) that can service the networks at different levels, such as data collection, monitoring, optimization, management, maintenance, among others [10]. These nodes belong to the PUAP and have to perform a very specific task at different points in time. Distributed environment provides very less dependence over the centralized authority [10], [11], [12].

MAs are not the free stuff, keeping the personal agents are always been costly (i.e.) $M < N$. Instead of every PU is handling MAs only PUAP is authorize to handle the MAs, CMA assist PUAP during the deployment, working environment and about the task of the MAs. MAs are intelligent unit and able to do multiple tasks of different kind, but PUAP and CMA creates sets for the MAs on the basis of the task allocation. Sets for task allocation are listed below.

1) Data collection: MAs belongs to this set interacts with SUs and store their information and the data provided by them. These type of MAs helps the PUAP to take the decision about the SUs, even the future of the SUs in the auction depends on the information provided by these MAs.

2) Monitoring: MAs monitors the behavior of the SUs and store the logs with MAs handling the database, these MAs can also be called as the cops.

3) optimization: MAs belonging to this set are higher in order and they are authorize to access the MAs handling database and can provide interaction among multiple MAs to enhance the utility of MAs.

4) management: MAs responsible for the smooth run of the model, *i.e.* according to work load on the sets these MAs varies the number of the MAs in any sets.

5) maintenance: MAs kept on the reserve, if any MAs found to be threat or likely to be infected by intruders these MAs replace them efficiently.

The combination of sets form the group, and the combined effect of group makes the auction possible. The set of the MAs described above are partially dependent over the other sets, for the formulation of game theory between them the best possible game theoretic approach is cooperative game theory. The relationship between the different sets are shown in the *Figure 2*. Data collection set is sharing information with the monitoring and optimization set, these sets analyzes the data and provides the information to the management set. Management set will decide the future steps of the group, on the basis of the information provided by the sets and the need of maintenance set.

1*) Collational game between MAs:* There are M MAs out of which M^d are the MAs belongs to the set of data, M^m belongs to the monitoring set, M^o are MAs assigned to set of optimization, M^{ma} are assigned for management purposes, while M^{mi} are kept in maintenance set as a reserve agents. The game triplet shown below is the game formulation between the MAs belonging to different sets.

$$\begin{array}{c} G = \{[M^d, M^m, M^o, M^{ma}, M^{mi}], \\ [\alpha(M^d), \alpha(M^m), \alpha(M^o), \alpha(M^{ma}), \alpha(M^{mi})] \\ ,[u(M^d), u(M^m), u(M^o), u(M^{ma}), u(M^{mi})]\} \end{array} \quad (1)$$

Here, $\alpha(M^d)$, $\alpha(M^m)$, $\alpha(M^o)$, $\alpha(M^{ma})$, and $\alpha(M^{mi})$ are the strategy adopted by the MAs, while sharing there respective data according to the formation shown in *Figure 2*. The utility of the MAs are the $u(M^d)$, $u(M^m)$, $u(M^o)$, $u(M^{ma})$, $u(M^{mi})$ for data collection, monitoring, optimization, management, and maintenance respectively.

3. Auction Framework

MAs formulates the game theoretic auction model which is a mathematical game represented by a set of players, a set of actions (strategies) available to each player, and a utility function is associated to each combination of strategies. Generally, the players are the buyer's and the seller's. The action set of each player is a set of bid functions or reservation prices. Each bid function maps the player's value (in the case of a buyer) or cost (in the case of a seller) to a bid price. The payoff of each player under a combination of strategies is the expected utility (or expected profit) of that player under that combination of strategies. Here, PUAP is the seller and SUs are the buyer's, PUAP has un-utilized spectrum. To utilize this spectrum, PUAP goes for spectrum leasing by auctioning technique using MAs. PUAP have total L sub-carriers out of which l are un-utilized. So, the necessary condition for spectrum leasing is:

$$L \geq l \geq 0 \quad (2)$$

PUAP allows MAs to auctions the l sub-carriers one by one till $l = 0$. Interested SUs take part in the auction process. SUs pass on their bids to MAs. The bid B_j ($j = 1, 2, 3, ..., n$ represent j^{th} user) depends on three parameters R_j^s, D_j, and Pr_j. Where, R_j^s, D_j, and Pr_j represents the reliability evaluated by SU, data to be transmitted, and price for the bandwidth respectively. The reliability to be followed in this paper is:

- R_j^s evaluated by j^{th} SU itself on the basis of the number of re-transmissions needed to successfully transmit a chunk of data between SU to AP (CR base station). As the number of re-transmissions increases reliability of the user decreases [4]. Based on this, the proposed reliability R_j^s is calculated as follows:

$$R_j^s = \frac{(D_j)}{[(t_j) + (e_j^{re})]C_j^{o,s}} \tag{3}$$

Here, t_j, e_j^{re}, $C_j^{o,s}$ represent the time taken to transmit data, number of re-transmissions, and average data rate between SU to AP respectively.

From (3), if $e_j^{re} = 0$, R_j^s is 1. As the value of of *ere* increase, R_j^s tends to decrease.

$$0 \leq R_j^s \leq 1 \tag{4}$$

- R_j^{sp} is the reliability of the j^{th} SU as evaluated by PUAP. The basis of the evaluation is the pay-off achieved by the SU *w.r.t* the POB. R_j^{sp} can take only two values 0 and 1. R_j^{sp} is set to be 1, If the pay-off of SU is not harming the pay-off of other users otherwise it is set to 0 value.

MAs calls the auction for l sub-carriers one by one, *i.e.*, number of auctions equals to l. MAs distributes the auction on the basis of bids provided by SUs. MAs will calculate the importance of the bid, T_b:

$$T_j^b = f\{R_j^s, Pr_j, l\} \tag{5}$$

Major portion of T_j^b depends on the value of R_j^s. The effect of Pr_j is a constraint of l. When unutilized sub-carriers are less PUAP expect high Pr for sub-carriers.

PUAP arranges the bid in descending order (on the basis of T_j^b). Without loss of generality $j = 1$ is the highest bidder A_1 be the SU which is having maximum T^b (T_1^b) which acquires the sub-carrier. After each auction:

$$l = l - 1 \tag{6}$$

MAs plays a crucial role, while implementing this auction framework. Groups of MAs calls auction at multiple locations on different time instants, each MA is allocated with an specified task. Task allotment to the MAs are according to their sets. M^d MAs handle the data collection process, they store the bids of the SUs in the format discussed above, these MAs also act as relay. M^m ensures there is no intruder or any SUs is not trying to harm the rights of PUAP. To optimize the behaviors of MAs, also rescheduling the number of MAs in each set has been taken care by M^o. M^{ma} manages all the set and also have control over M^{mi}, used in case of security emergency.

3.1 System Performance over Vickery technique

MAs formulates the auction for the PUAP and the type of auction called by the MAs are Vickery second price auction mechanism. A Vickrey auction is a type of sealed-bid auction, where bidders submit the bids without knowing the bid of the other people in the auction, and in which the highest bidder wins, but the price paid is the second-highest bid [4]. Vickery auction provides benefit to PUAP and attracts more SUs. However, SUs may exploit the vulnerability of the Vickery auction. The vulnerability and the beauty of this auction mechanism is same *i.e.* second price is paid by the winner. Highly enthusiastic users can call for higher bids to get the auction, even if they are not capable enough. To remove this vulnerability, we propose to use Markov chain model. PUAP will find out the reliability assets R_1^{sp} of the SU. If $R_1^{sp} = 0$, the user is vulnerable in nature and bid shifts to next user A_2 and so on.

The Markovian structure of the process is shown in Figure 3. There are total $n + 1$ states with the initial state represents

PUAP calling auction. MAs are not shown in the markov chain process because the capability of decision making remains with the PUAP. State A_1 is represented by the SU having $max(T^b)$. $A2$ represents the SU having second highest bid and all other states from $A_2, A_3, \ldots\ldots, A_n$ represent the SU with descending value of bid. Transition between the states depends on the value of R_j^{sp}. Before transition, every state holds the sub-carrier for the T duration. This duration is called probation period shown in Figure 4. During probation period MAs finds out the R_j^{sp} of SU.

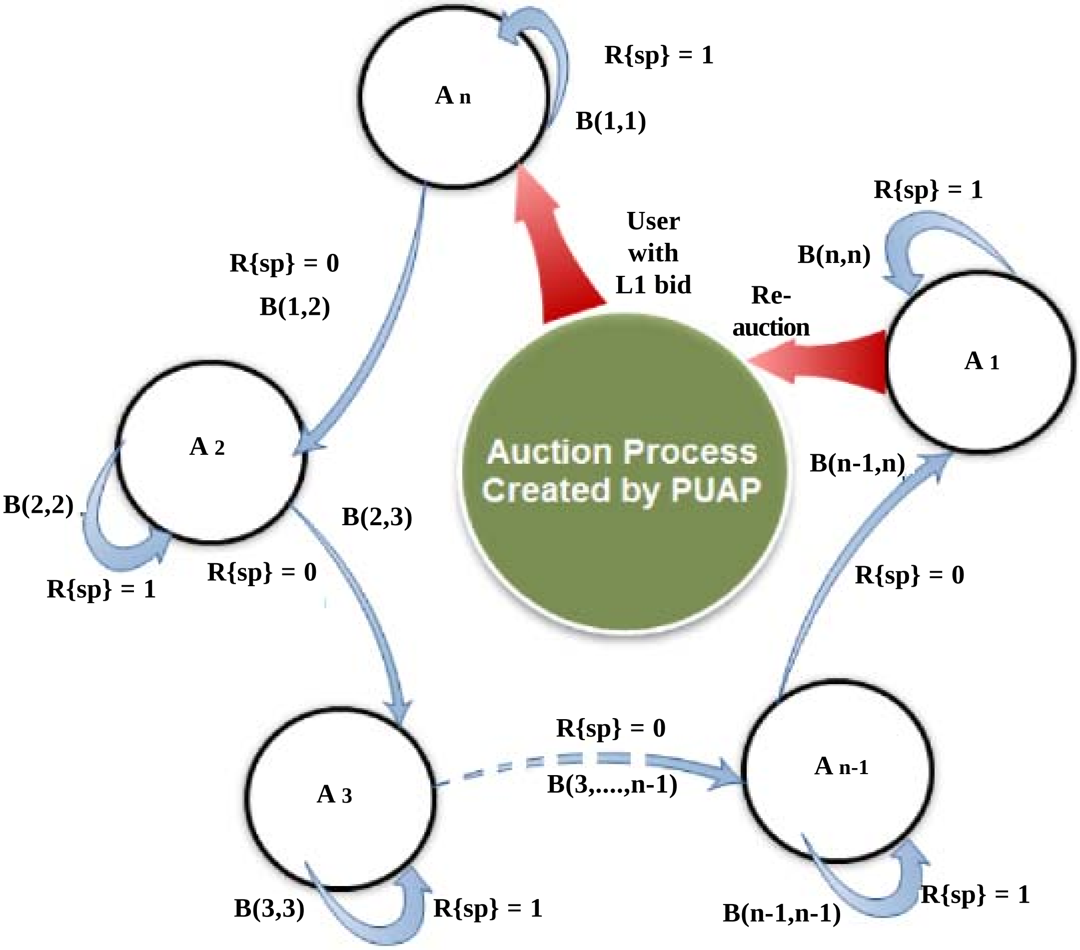


Figure 3. A conceptual illustration of an auction technique using Markov chain model

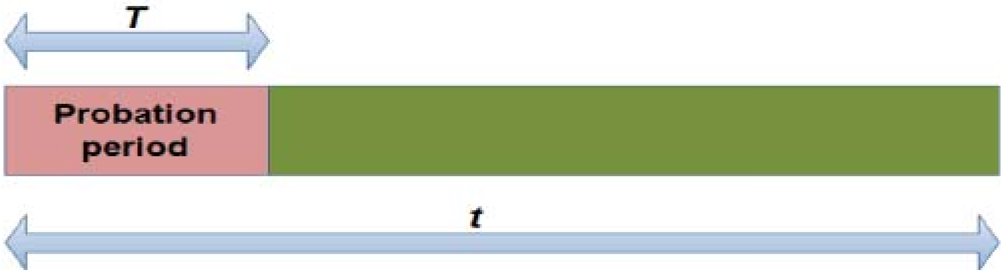


Figure 4. Total transmission time t and the probation period T

- If $R_1^{sp} = 1$:

Markov process founds the stable state. SU moves out of the probation period. SU can hold the sub-carrier for t duration.

- If $R_1^{sp} = 0$:

There is transition of state from A_1 to A_2 and so on.

3.2 Behavioral analysis of SUs

SUs are the selfish users and always try to increase their utility function. Information rate of the SUs is their utility function given by

$$r = log_2 \left(1 + \lambda \frac{p_s \mid h_{ss} \mid^2}{p_p \mid h_{ps} \mid^2 + \sigma^2} \right) \tag{7}$$

Here, h_{ss} and h_{ps} is the channel gain between CR base station to SU and PU to SU through MAs, respectively and λ is a selfishness parameter.

Those SUs actively participate’s in the auction process has to follow the given conditions:

- If SU tells a lie for reliability asset R^s_j:
  - To get the sub-carrier, R^s_j should be high.
    - * If SU does not fulfill the R^s provided, time taken by the SU to transmit data increases. After t duration, PUAP reallocates that sub-carrier to somebody else. So, transmission of SU remains incomplete.
    - * To maintain the R^s_j, SU has to increase the rate by increasing some parameters. Considered parameter in this paper is power.
  - – Increased power increase the probability of interfering with Pareto Optimal Boundary (POB), because SUs don’t know the limits. So, the R^{sp}_j is set to be 0.
- If secondary user tells a lie for data D:
  - SU shows bigger chunk of data to increase the transmission time.
  - The value of reliability asset R^s_j depends on the data. Relation shown in (3).
- If SU is vulnerable for price Pr:
  - Price Pr is on the second position after the R^s_j. But, for very high price, SU can get the sub-carrier.
  - The selfishness parameter λ of user increases with each effort. After paying very high price, λ plays big role for the information rate achieved by SU.

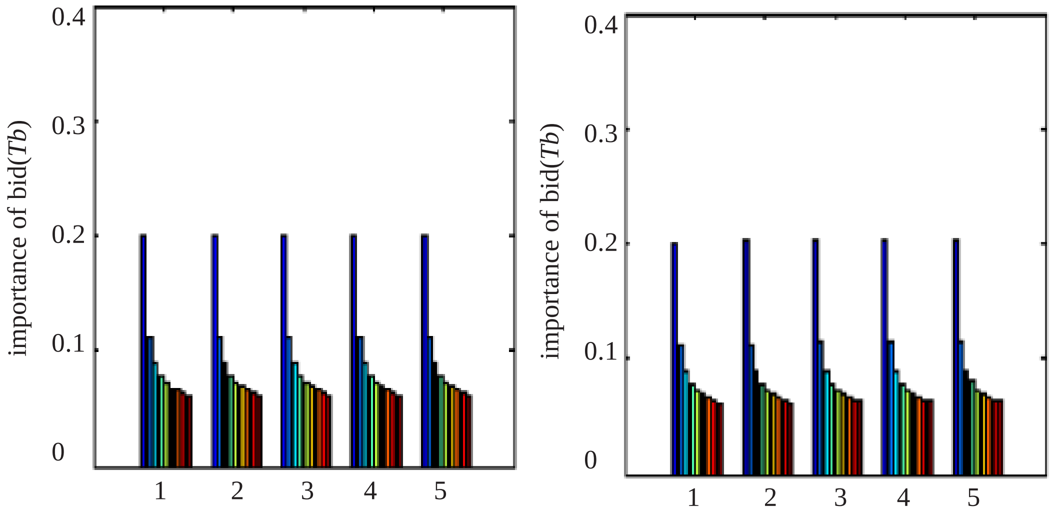
4. Numerical Results

In this section, we illustrate the transmission behavior of the SUs with the help of numerical results. We consider a simple geometrical model where SUs are placed at approximately same distance d ($0 < d < 1$) from MAs and $1 - d$ from primary receiver. Considering the channel as Rayleigh fading channel. We further assume $Pr > l^2$ as a initial condition for the auction. Here, we consider $l = 10$ the number of subcarriers allocated to SUs and $N = 3$ MAs are provided for an PUAP.

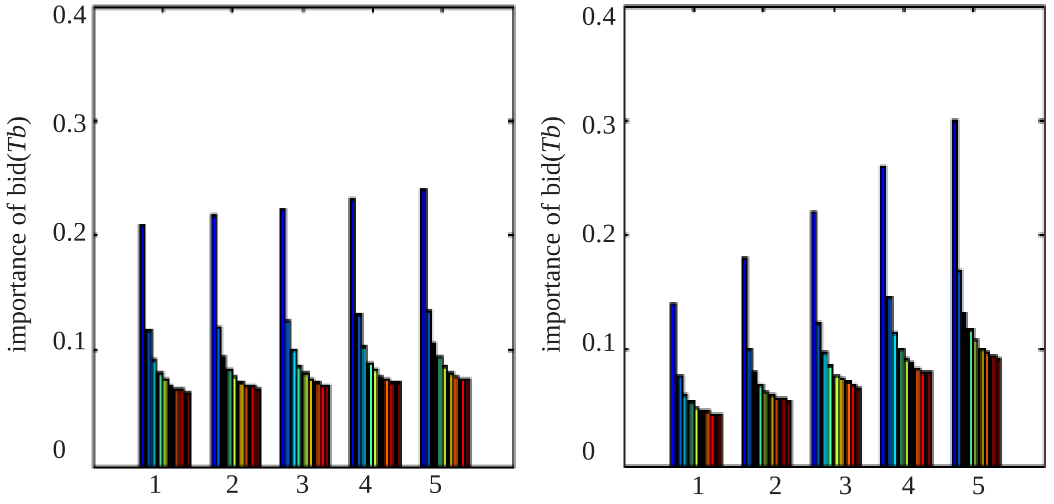
In Figure 5, succeeding users have increment in the value of Pr of 2, 10, 100, and 1000 in figure 5-(a), 5-(b), 5-(c), and 5-(d) respectively. Further each users have a value of T^b_j for the values of R^{sp}_j varies from 1 with decrement of 0.1 till it reaches to 0. Firstly T^b_j is calculated as follows:

$$T^b_j = \frac{Pr}{\{1 - R^s_j\}^{2l}} \tag{8}$$

Here, R^s_j effect the value of T_b maximum shown in Figure 5. Effect of Pr depends on the value of l. For small values of l, Pr is dominant parameter. Generally, the selfishness factor depends on the strategy adopted by the SUs to acquire the subcarriers from PUAP. Here, we have assumed $\lambda = 0.7$. POB is the important parameter for calculating the value of R^{sp}_j . If there are n users transmitting simultaneously, achievable rate region for each user can be easily calculated. The outer boundary of the total achievable rate region is POB [13]. Handling the multiple MA increases the complexity of the system but Figure 6 can



(a) Users with incr. in *Pr* (2 times)   (b) Users with incr. in *Pr* (10 times)



(c) Users with incr. in *Pr* (100 times)   (c) Users with incr. in *Pr* (1000 times)

Figure 5. Simulation result showing the variation in the values of normalized T_b, *w.r.t* to the R_j^s which varies 0 to 1 for each user. *Pr* is varying from user to user with a specific rate.

show that this increase in complexity also increase the efficiency of the system. As, the number of SUs approaching for auction increases, then this model will be highly efficient shown in the Fig. 6. The number of SU tested by MAs are more compared to the PUAP, in a given time period. Here, arrival rate follows the exponential distribution.

5. Conclusion and Future Work

In this paper we have implemented a auction model for spectrum sharing in CRN. Here, PUAP controls the spectrum leasing process and use MAs to handle the auctioning process. It has been shown that this model is secure, robust and efficient for large number of users. In this paper application of Markov chain model is proposed to remove the vulnerability of Vickery auction mechanism. In future work, PUAP can formulate the cooperative game with the reliable SUs to obtain higher data efficiency.

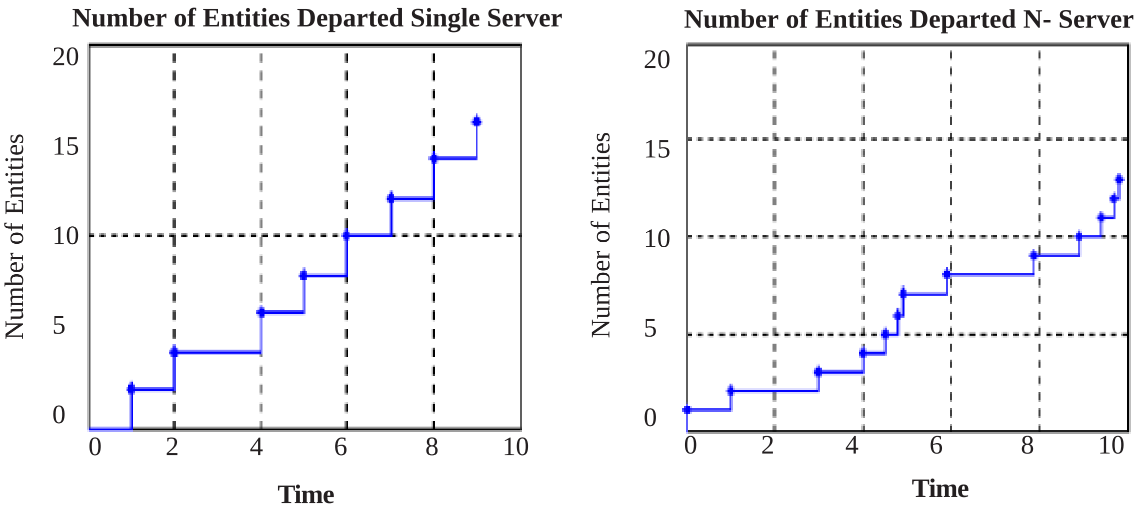


Figure 6. Simulation result showing the efficiency of PUs and MAs. Figure (a) represents the PUAP acting as a server, Figure (b) represents MAs (N = 3) acting as a server

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