Advanced Research in Electrical and Electronic Engineering
Print ISSN: 2349-5804; Online ISSN: 2349-5812 Volume 2, Number 4 January-March (2015) pp. 337-340

http://www.krishisanskriti.org/areee.html

Auction based Spectrum Sharing in Cognitive Radio Networks

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Abstract—*Cognitive Radio (CR) is the technique of spectrum sharing between primary (licensed user) and a secondary (unlicensed user) user and it improve the utilization of available radio frequency spectrum, in this paper we are typically considering the spectrum sharing between the licensed and unlicensed user by using bandwidth auction based approach .Here we are encountering the problem based on bandwidth auction in which the secondary user makes bid for the amount of spectrum And each primary user may assign the spectrum among secondary users by itself according to the information from secondary users without break down its own performance. The solution for this is Nash equilibrium and game theory is the solution .we consider a single primary user network to investigate the existence and uniqueness of Nash equilibrium, and further discuss the fairness among secondary users under given conditions, in which we considering dynamic spectrum allocation in which each secondary users achieve the Nash equilibrium in a distributed manner.*

Index Term*: cognitive radio, Spectrum sharing, primary user, secondary used, DSA, Game theory and Nash equilibrium.*

1. INTRODUCTION

The software developed for the radio and the cognitive radio both are introduced to enhance the efficiency of spectrum usage [1]. The current static spectrum allocation policies cause under-utilization of radio frequency spectrum. As per Federal Communications Commission (FCC) [2], the limited spectrum and inefficiency in spectrum usage necessitate a new communication paradigm to exploit the existing spectrum opportunistically.

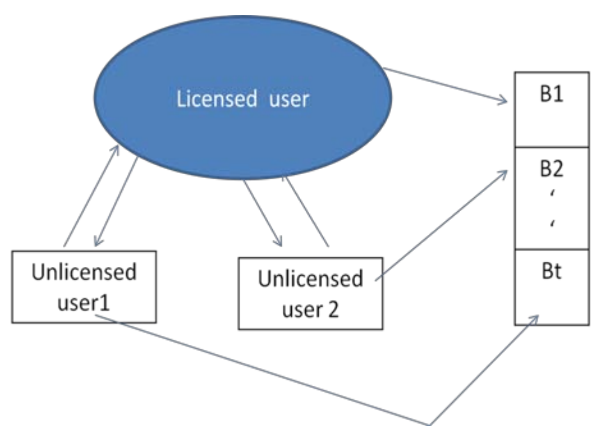
Software radio provides a programmable and scalable software platform for a wireless radio transceiver and enables the radio receiver to operate in multiple frequency bands by using multiple transmission protocols. Cognitive radio is an extension of software radio, which is able to change its transmission parameters and adapt itself intelligently to the wireless environment. With this agility and cognitive ability of the radio transceiver, frequency spectrum can be shared among licensed and unlicensed users to improve spectrum utilization.

In this paper, we propose a auction based model to characterized and analyze some existing feature (competition in among the secondary users and uncertainty about the wireless environment for secondary users) in the problem of DSS for CRN. Based on this model we are going to study how the primary user takes precaution to avoid the breakdown of its own performance. Assume secondary users and normally selfish. Here we show that the secondary users are non-cooperative and each secondary user rationally behaves to maximize its own performance.

In this paper next section we are discussing about the basic related work, feature of cognitive radio network, functional block of cognitive radio network and we will further describe the auction based bandwidth scheme and also present a distributed algorithm to achieve the Nash equilibrium and study its stability. And also we given simulation result to evaluate system performance and analyze the effectiveness of proposed algorithm.

2. BASIC RELATED WORK

The basic definition of Cognitive radio is "Where cognitive radio was defined as an intelligent wireless system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets.".



B1, B2……=B_t = total bandwidth

Fig. 1: System Model

The fundamental cognitive tasks as well as the behaviors of cognitive radio were discussed. In [4], a comprehensive survey of the functionalities and research challenges in cognitive radio networks (also referred to as NeXt Generation (xG) networks) was presented.

3. FEATURE OF COGNITIVE RADIO

1. *Cognitive capability*: Using this feature the cognitive radio dynamically checks the entire spectrum and finds portion for its transmission. Spectrum sensing, spectrum management and spectrum sharing are the components of the cognitive capability.

2. *Reconfigurability:* It is the parameter adjustment capability without any modification in the hardware components. The parameters are Operating frequency, Modulation and Transmission power etc.

4. FUNCTIONAL BLOCK OF CRN

CRN have a five main functional block that are given below: in [5]

1) **Spectrum management**: It checks how long the spectrum holes are available for the use of the secondary user (unlicensed users).

2) Spectrum mobility: Is used to maintain without dropping communication during the transition to better spectrum. if the portion of spectrum which is in use is required by the primary user the communication needs to be done in another portion, so spectrum mobility is required for the cognitive radio.in[5]

3) Transmission and hand shake: Once a portion of the spectrum is allocated for the communication, the receiver of the communication should also know about the indicated spectrum. Hence this protocol is known as transmitter-receiver handshake protocol is required for the communication between the cognitive radio nodes.in[5]

4) Spectrum sharing: Distribute the available spectrum among the secondary users (unlicensed user/s).

5) Spectrum sensing: The aim of this Spectrum sensing is to determine availability of spectrum and the presence of the licensed users (Primary users), a secondary user can only allocate to a portion of the spectrum if that portion is not used by a primary user.

5. SYSTEM MODEL

1. Primary (licensed) user and secondary (unlicensed) user: Let us consider a simple system where only one primary user and number of secondary users (SU) S=(1,2…….n).the total spectrum is allocated to the primary user (PU) is B_t which is shown in figure ,who wants to share the spectrum allocated to the PU. in this system the PU takes efficient use of spectrum by sharing some portion of the bandwidth Bi(Bi<Bt) with SU n(n ϵ s) the primary user retain the given amount of bandwidth Brm to guarantee its own performance, The constraint on the remaining bandwidth held by the primary user is given as

Follows:

$$Brm = \mathrm{Bt} - \sum_{i\epsilon n} \mathrm{Bi} > Breq \quad (1)$$

Where Breq is the required bandwidth for the primary user to provide a particular quality of service requirement. It is noted that this requirement may be time-varying. The primary user charges secondary users for the spectrum at a price of p per unit bandwidth. After the allocation, the secondary users may transmit in the allocated spectrum using adaptive modulation to enhance the transmission performance. The revenue of the secondary user i is denoted by ri per unit of achievable transmission rate.

6. SPECTRUM SHARING SCHEMES BASED ON AUCTION

Considering the problem of spectrum sharing as an auction in that the secondary user makes the bid for bandwidth allocation to the primary user. An auction is a decentralized market mechanism for allocating resources in an economy. Based on the assumption about rational behavior, an auction is essentially a non-cooperative game, where the players are the bidders, the strategies are the bids, and both allocations and payments are functions of the bids. A well known auction scheme is the Vickrey-Clarke-Groves (VCG) auction [22], which requires gathering global information from the network and performing centralized computations. However, the communication overhead and computational complexity make VCG auction unsuitable to this scenario. To characterize the behaviors of the interaction between the primary user and multiple secondary users, we propose an auction which has relatively simple rules as described below.

Information: Each SU i know its revenue ri per unit of achievable transmission rate, and it also knows its spectral efficiency ki of transmission through channel estimation. ri relates to the QoS in a real network. In other words, the higher the QoS required by the SU s is, the greater the revenue ri will be. As for the precise relationship between QoS levels required by SU i and ri, it is not our focus in this paper. The PU announces a positive reserve bid $\beta > 0$ and the price $p > 0$ to all SUs before the auction starts.

2. *Bids*: The SU i submits a bid bi ($0 \leq bi \leq Bt$) which generally represents the maximum bandwidth that SU desires for data transmission.

3. Allocation*: The* PU allocates bandwidth according to (here we only consider the FDM scheme, and OFDM scheme is more applicable. Once the bandwidth is allocated by PU, there is no contention among SUs. Thus, MAC layer or DLL layer is not involved here.)

$$Bi = \frac{bi}{\Sigma bj + \beta} Bt \quad (2)$$

4. Payment secondary user I pays the primary users

$$Ci = p\alpha ibi \quad (3)$$

Where α_i is a user-dependent priority parameter (i.e., this payment differentiation is in a spirit similar to the”price discrimination” in an economical market). In this auction, we adopt a ”prepay” mechanism that each SU pays for the bandwidth it bids instead of that it is assigned by the PU. in [6]

7. DISTRIBUTED ALGORITHM TO ACHIEVE NASH EQUILIBRIUM

Algorithm: Seeking the best price p*
1. **Set** p = p, announce p to all SUs.
2. SU i calculates its best response b^*i, ∀i ∈ s
3. **if** $b^* i \leq Bt$, ∀i ∈ ŋ
then go to step 5.
4. PU increments p = p +△p and updates p to all SUs,
then go to step 2.
5. **Stop**, and declares the best price $p^* = p$.

8. STABILITY ANALYSIS

We can write the equation for dynamic updating function in a matrix Form as follows:

$$B(t+1) = S\{b(t)\} \quad (4)$$

At the equilibrium, we have b(t+1) = b(t) = b, namely b = S(b), where S is the self-mapping function of the fixed point b.

9. PERFORMANCE EVALUATION

Let us consider a cognitive radio environment with one primary user (PU) and two secondary users (SUs) sharing a frequency spectrum of size Bt = 10 MHz. The target BER for both SUs is BER^{tar}

$_i$ = 10−4. The revenue of a SU per unit transmission rate is ri = 10, ∀i ∈s. First, let us assume that SNR informatiγon $_i$ is already available to SUs by channel estimation, and later in the case of multiple primary users network we will adopt a location-based model in which SNγR $_i$ is determined by distances. In this case, the PU sets the price p = 10 per unit bandwidth and reserves bid β = 0.2 (i.e., the PU is idle at a given time and uses only a tiny amount of bandwidth to transmit control signals).

10. NUMERICAL RESULT

We first set α1 = α2 = 1, which leads to a strict fairness among SUs. Figure 3 shows the best response of both SUs in this auction. The best response of each SU is a nonlinear function of the other user’s strategy (i.e., bid). The Nash equilibrium is located at the point at which the best responses of both the SUs intersect. It is observed that under different channel qualities, the Nash equilibrium is located at the different places. Since the SU can achieve a higher transmission rate from the same spectrum size due to adaptive modulation, an SU with a better channel quality (or spectral efficiency) prefers to bid a larger spectrum size. Also, the trajectory of spectrum sharing in the dynamic updating process is shown for the case of α1= α2 = 0.14. Again, we observe that with the same speed adjustment parameter, a better channel quality results in more fluctuations in the trajectory leading to the Nash equilibrium. Based on the eigenvalues of the Jacobian matrix derived in (45), the relationship between α1and α2 to provide stable spectrum sharing can be obtained. In particular, the stability

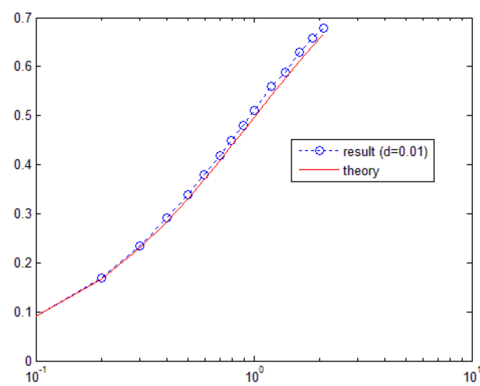


Fig. 2

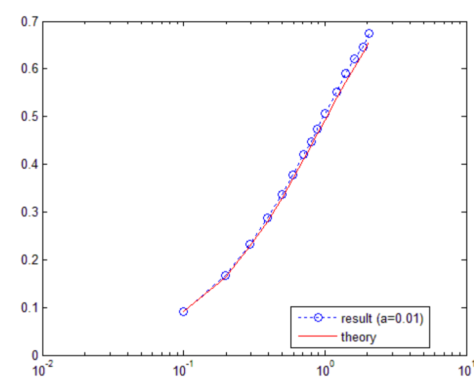


Fig. 3

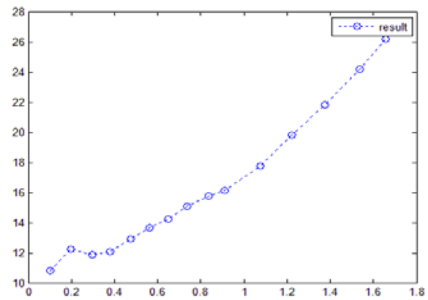


Fig. 4

Fig. 2, 3 and 4The Nash equilibrium of revenue under different channel qualities.

The adaption of SU's bids under different channel qualities is presented in Figure 2,3 and 4 then the variation of revenues is presented in Figure 2,3 and 4. As expected, the SU 2 bids more bandwidth and achieves higher revenue when its channel quality becomes better. Also, we observe that the channel quality of one secondary user affects the bid and the revenues of the other secondary users. We observe that one SU's reaction to the improvement of its opponent's channel quality is divided into two cases.

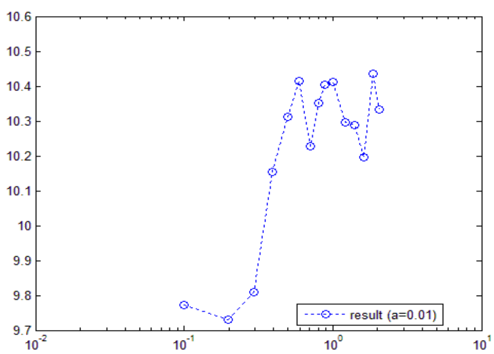


Fig. 5: Nash equilibrium fluctuations

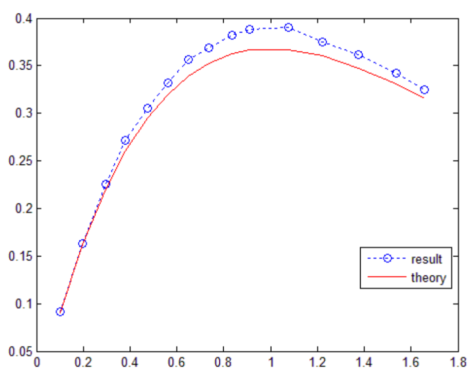


Fig. 6: The best response and trajectories to Nash equilibrium.

If we set with the values in the dotted region (i.e., region indicated by dotted in Figure 5), the spectrum sharing is stable and the Nash equilibrium would be reached. Otherwise, the sharing would be unstable, and fluctuations would occur.

11. CONCLUSION

In this paper we discussed one of the spectrum sharing technique and it is a one of the key function for the cognitive radio network .in the cognitive radio network consist of one primary user and number of secondary users sharing the same frequency spectrum, and we introduced a Nash equilibrium. We discussed the local stability and also analyzed the numerical method, the primary user is going to share available frequency spectrum with the secondary user by using the auction based spectrum theory.

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