A Literature Survey on Spectrum Management in Software Defined Radio by using Game Theory Concepts

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ABSTRACT
Cognitive radio network is an emerging technology in a wireless communications for effectively utilizing the unused spectrum, which are called "spectrum holes". This paper gives the scope for analyzing the literature which manages the spectrum through game theory approach.This work is an analysis of various games through which the cognitive users utilize the spectrum based on the agreement with the primary users for optimum utilization of the spectrum.The differentgames designs provide a state-of-art for addressing the various criteria's and challenges are encountered during the allocation of spectrum.This papersummarizes different games and its strategies to allocate the spectrum to the cognitive users**.**

Keywords
Cognitive radio, spectrum allocation, cooperative game, non-cooperative

1. INTRODUCTION
The applications of wireless technology has raised huge demand for the spectrum and the wireless spectrum available is limited which leads to scarcity of the spectrum.For meeting these demands, one of the solutions is to determinethe underutilized spectrumcalled as "spectrum holes" or "white space". The cognitive radio networks (CRN) has four core functionalities [1] i) Spectrum Sensing: To determine the unused spectrum without causing interference.ii)Spectrum Sharing: sharing the available spectrum among the CR users.iii)Spectrum Management: To avail the best spectrum for bettercommunication requirements.iv)Spectrum Mobility: Transition between the spectrums foreffective communication.

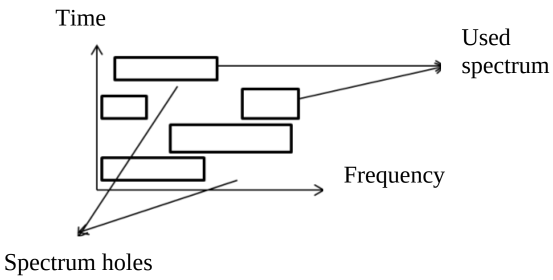

Fig.1. Detection of Spectrum holes

In order to manage the spectrum and to identify the modifying characteristics the cognitive cycle can be described as shown in Fig. 1. The spectrum holes are detected by using the game theory approach[2].

The spectrum holes are detected using either a cooperative game or non-cooperative game. Here depending on the strategy one of the players can win and the spectrum is allocated to the user. The advantage of game theory is serving the purpose of decision, which is taken by the primary user to share the spectrum without creating the interference. The Fig.2. Shows the functionality of Cognitive Radio Networks.

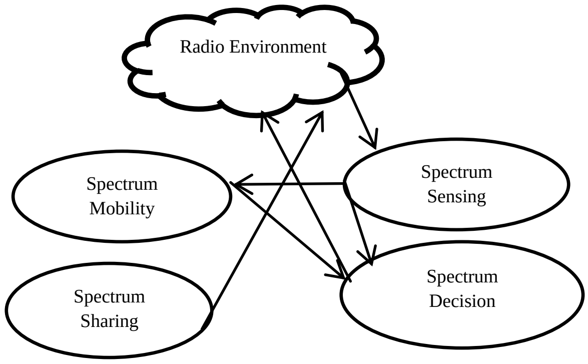

Fig.2. Cognitive Radio Functionality

This study has exploredvarious research papers of game theory approach to manage the spectrum dynamically. The spectrum sensing, channel allocation, mobility of the spectrum are discussed through the game theory. The Game theory has its numerousapplications in different fields of research. This theoryallows analyzing and designing the model for managing the spectrum with reference to the demand raised by the secondary network. By applying game theory different strategiesmay be framed for identifying the behavior of the Cognitive users and the primary users.The Strategies can also be extended to decision making in spectrum allocation in Software Define CRN.

The following sections are organized as follows: Section 2 is about the spectrum sensing, section3 describes the terminologies used for modeling the game, section 4 describes the management of the spectrum through various game theory.

2. SPECTRUM SENSING
The spectrum sensing is to detect the unused spectrumand share without any interference. Sensing can be classified into three categories namely transmitter detection or non-cooperative, cooperative and interference based.Further, transmitter detection is classified into three categoriesnamely energy detection, matched filter and cyclo-stationary[3].

a. Energy detection: This method detects the primary signal based on sensed energy. The signal is passed through the band pass filter and integrated with time interval to obtain the output. The threshold is pre-defined and the output obtained is compared to the threshold. By hypothesis test the signal can be detected.

b) Matched filter: In this method the known signal is been correlated with the unknown signal. The unknown signal is convolved with the impulse response and matched with the reference signal to maximize the SNR.

c) Cyclo-Stationary: the periodicity is used in the receiver to identify the primary user. The periodicity is embedded in carrier, pulse train, spreading code hopping sequence or cyclic prefix of the signal.

3. GAME THEORY FOR MODELING

Game theory is a study of mathematical models used for decision making. Game theory is applied in various fields like physiology, Biology, Economics and Computer Science [5]. In [4], the notation of the game is represented as G=<N,A,{u i}> where G is Game, Nis number of players; A is the set of actions and u i is the utility functions. The following subsection briefs some of the terminologies of game theory:

Players: players are the decision makers.

Actions: set of choices which are available for theplayers. The action is a Cartesian product formed solely by the players with in the action space.

Outcome: Each action vector produces a certain outcome. All this action are inter-relation and mapped to the outcome of the game.

Utility Function: It can be used to transform the ordinal relationship of the players to the cardinal relationship.

Here the spectrum allocation is modeled as a game where the primary users and secondary users are considered as players and the strategy of the game is to allocate the spectrum depending on the demand of the secondary users. The decision is made depending on the fulfillment of the secondary user. To create an action space the secondary user has to raise the demands for the primary user. In turn the primary user agrees to rent the spectrum. The utility function describes the decision process by the primary user for satisfying the demand of spectrum.The Fig. 3.shows the demand for the spectrum by the Secondary user.

Fig.3. Demand by the Secondary user

4. MANAGING THE SPECTRUM WITH GAME THEORY

In cooperative game there is a collation between the players rather than individual player.Where as in non-cooperative game the players are independent.

4.1 Cooperative Game

The cooperative game is in the form of a characteristic function, as (N, v) where N is an integer and describes the number of participants. Then v is the Eigen function which defines a mapping from $2N = \{S/S \subseteq N\}$ to set of real numbers RN. The Eigen function is given by $v = 2N \rightarrow RN$. The resources are allocated combined with auction theory. The Vickery-Clarke-Groves mechanism is used to allocate the spectrum for the secondary user. The Matching game is a cooperative game in which the user and channels are matched with bilateral market. To manage the spectrum effectively, Partially Observable Markov Decision Process (POMDP) model is used to analyze the characteristics of secondary user [6]. The secondary users are matched according to the payoffs of maximizing system information statics.

4.2 Non-cooperative Game

In non-cooperative game the players plays the game independently. A single strategy can be chosen for each player, the objective is to maximize the utility of the spectrum. Other non –cooperative games are cournot game, Bertrand game, Stackelberg game, repeated game, supermodel game, potential game, evolutionary game, auction game.

4.2.1 Nash-Equilibrium

One of the non-cooperative game is Nash Equilibrium where the maximum utility to allocate the resources to the secondary users.Consider an example for Nash equilibrium problem withtwo player's player1 is a primary user (PU1) and strategy is "Allocated", player2 is secondary user (SU2) and the strategy is "Demand". Then payoff matrix can be as shown in Table1.

Table1. Payoff Matrix

	Allocated	**Demand**
A	0,4	2,2
B	1,2	0,1

As show in the table, the spectrum can be allocated to the secondary user depending on the free spectrum holes. The number underlined indicates that four primary users ready for sharing the spectrum out of which two are required. Similarly the secondary users are demanding for spectrum.The pay-off matrix indicates how effectively the spectrum can be managed.

4.2.1 Cournet Game

This game belongs to information static game. It is an economic model where the participants can independently compete. In the reference [7],used a model to study the behavior of the non-cooperative spectrumallocation. The primary user purchases the spectrum and can identify the behavior of the other primary user with different quantity and sales. The primary user is ready to lease the spectrum for the price to the secondary user. Considering the differences of spectrum and the simulation of cournot algorithm shows the different analysis of the allocation of spectrum [8]. To analyze the behavior of primary user the leasing of spectrum was used. Comparing the static allocation and cournot, the cournot game is effective for allocation of spectrum in terms of price [9].

4.2.2*Bertrand Game*

The purpose of Bertnard game was to optimize the sale price of the spectrum by the primary user. The oligopoly model had constraint, and used novel transformation method. The algorithm "StrictBest", "StrictBR", and "QoSBEST" were used to make best price fit for primary user.

4.2.3Stackelberg Game

This game belongs to the dynamic game. To observe the interaction between primary and secondary user a game of union was constructed, to assign the subband to the secondary user and combined with layered structured in stackelberg game

[10]. The stackelberg game was used to allocate the resources to the secondary user when there is asymmetric information about the market.

4.2.4 Repeated Game

This game is a dynamic modelwhich is composed of multiple game phases. There are two convergences in game[11]: the best response game and better response game.

In best response game at every stage, one player is permitted to deviate from ai to some randomly selected actionb i∈ A i if u i (a i,bi) ≥ u i (ci, a i) ∀ ci ≠ bi and u I (bi, a i). In better response game at every stage, one player i ∈ N is allowed to deviate ai to some randomly selected action b i∈ A i if u i (b i, a i) ≥ u i (a i, a -i). The repeated game provided at-most utility of the spectrum when the primary user was completely free. By repeated game algorithm the through put was maximum to utilize the spectrum where the participants are active in their respective role [12].

4.2.5 Supermodular Game Model

In this model [13], the service provider sold their spectrum for maximizing the profit and to optimize the price for spectrum leading as an optimal solution for the price. The supermodel game can coexist with Nash equilibrium.

4.2.6 Potential Game

In this model, channel allocation is based on the behavior of CR. The potential game is dynamic for allocation of spectrum and results in best performance [14]. But the drawback is to know how to reduce the cost for allocation of the spectrum.

4.2.7 Evolutionary Game

In this model, the primary user lease their free spectrum to the secondary user, the SU has been allocated based on the selection strategy. The secondary service provider leased the spectrum form the brokers to provide service to the SU. The service selection can be modeled as a dynamic service selection in the evolutionary game [15]. The evolutionary game can also be cooperative in which the sharing of spectrum between the PU and SU improved the through put in terms of utilizing the spectrum [16].

4.2.8 Auction Game

In this game the primary users calls a bid, the secondary user can utilize this spectrum for transmission of information over the spectrum. There is asymmetric cooperation when the SU bids for the allocation [17]. There is a secondary system decision center to select a bid for the primary user as a best channel.

5. CONCLUSION

This paper gives an overview of different Game theory concepts found in the literature including allocation of the spectrum in CRN. The game of spectrum sharing and decision making may be better modeled using Game theory concepts. In general, the spectrum sharing is based on the availability of the spectrum and the agreement between the primary user and the secondary user. The spectrum is rented by the primary user based on the gaming strategies that are formed in different games. Also the primary user calls for the bid, secondary user bids and based on the strategy the spectrum is allocated. The performance and utilization of the spectrum is expected to improve by designing suitable game and appropriate strategies. In the future work , software defined cognitive Radio Networks are investigated with its potential applications in various fields by applying graph/ game theory concepts. The game theory provides an effecitive mechanism for managing the spectrum, in future non-cooperative games will be applied to study the different criteria such has topology, throughput and Signal-to-Noise Ratio.

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