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APPLICATION OF INTELLIGENT GAME THEORY APPROACH IN COGNITIVE RADIO AD HOC NETWORKS

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Abstract: Cognitive Radio (CR) technology is imagined to solve the problems in Wireless Ad-hoc NETworks (WANET) resulting from the limited available spectrum and the inefficiency in the spectrum usage by exploiting the existing wireless spectrum opportunistically. Game theory is a process to analyze multi-person decision making situation, where each decision maker tries to maximize his own utility. In this paper, we illustrates how various interactions in Cognitive Radio Ad Hoc Network (CRAHN) can be modeled as a game. It also illustrates a problem with solution approach that uses intelligent game theory technique in CRAHN.

Keyword: Cognitive radio; Cognitive radio ad-hoc network; Game theory; Players

INTRODUCTION

In modern era, use of wireless network [1] increases rapidly. It sometimes may be infrastructure or infrastructure-less based on requirement. There are various types wireless network available such as wireless sensor network [2], [3] wireless ad-hoc network [4], [5], wireless mesh network. Cognitive Radio Ad Hoc Network (CRAHN) is one type ad-hoc network which is infrastructure-less and dynamic in nature. It is an emerging field of Wireless Ad-hoc NETwork (WANET) with Cognitive Radio (CR) technology. Basically CRAHN consists of two networks such as primary network and secondary network. A primary network consists of one or more Primary Users (PUs) and one or more Primary Base Stations (PBS). It has proper licensed to use the spectrum and coordinate the PBS. In this network, each node communicates with the help of base station. Generally the PUs as well as PBS does not have CR properties. On the other hand, a secondary network comprises of one or more Secondary Users (SUs). It may or may not contain a Secondary Base Station (SBS). In this network, the spectrum access is managed and handled by the helps of SBS. It acts as a central hub or access point for the SU network. Each node of this network communicates with each and other through base station within the range. Example of this type networks are Internet of Things (IoT) as well as Vehicular Adhoc NETwork (VANET). Fig. 1 illustrates architecture of CRAHN. Due to randomness and unpredictable nature of CRAHN several challenges raised given in Table 1. Cognitive Radio Networks (CRN) addresses the several problems of spectrum scarcity by permitting SUs to utilize the unused spectrum of PUs without causing interference. It helps to obtains knowledge of its environment to manage information within PUs and SUs. SUs are unlicensed users and PUs are licensed users. Functions of cognitive radio shown in Fig. 2. In this network, spectrum sensing can be conducted in one of two ways: non-cooperatively and cooperatively given as:

- Non-cooperatively:- In this system, each SU senses its own environment and makes independent spectrum transmission decision.
- Cooperatively: - In this system, each SU cooperate to sense the spectrum band and share their results within environment.

Due to above sensing method, application of this network spreads rapidly in various sector such as e-commerce [6] for transaction business to consumer and vice-versa, transportation, industrial, science and engineering etc.

In last few decades, game theory has been excessively used in several areas such as psychology, biology, economics, political science etc. to manage and solve the several problems. Now it extensively used in wireless networks also, to manage and model several network issues by the helps of mathematical modelling [7] in proper way. It works based on cooperation and conflict mathematical model for dissimilar strategic of decision making. It helps to studying and modelling interactions within cognitive radios to handle in communication system by the helps of five basic elements shown in Fig 3. This scheme helps to manage battery power efficiently as well as optimal path selection.

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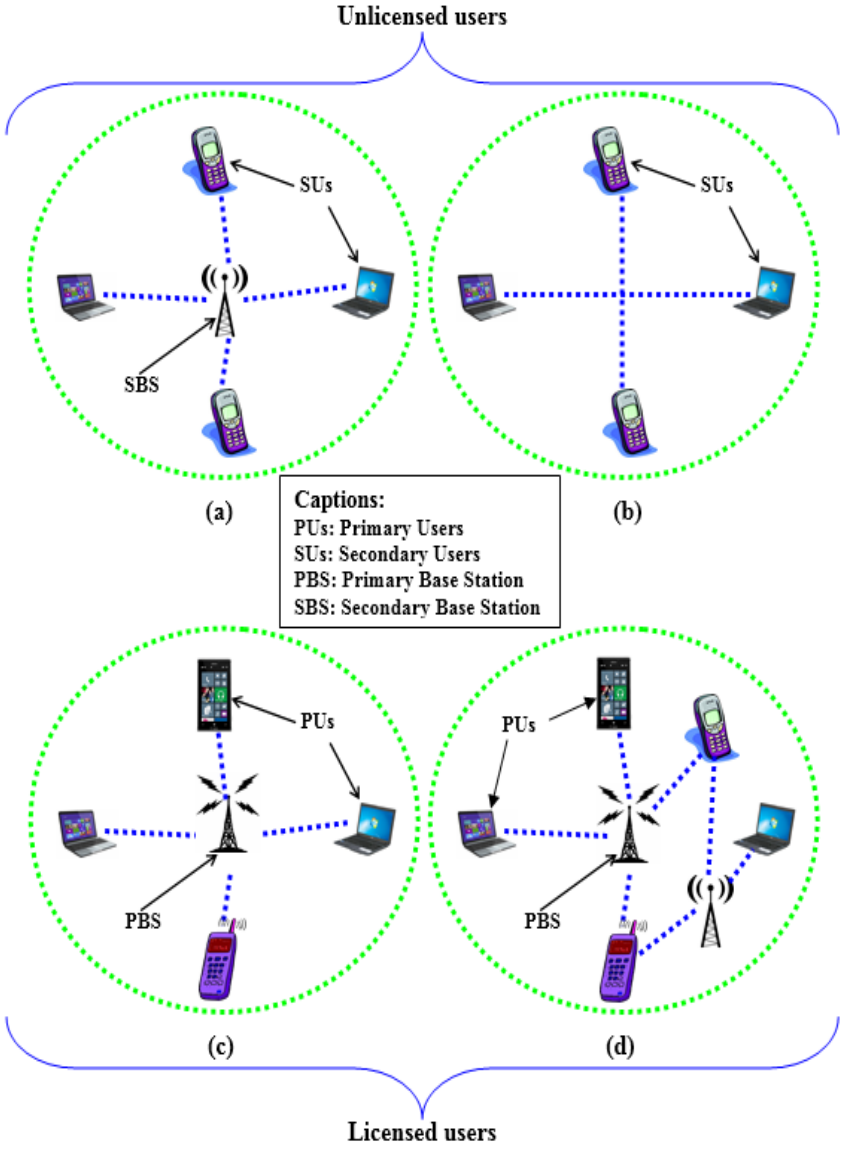

Figure 1. Architecture of cognitive radio ad-hoc network.

Table 1: Several challenges of CRAHN

Sl. no.	Challenges
1.	High mobility
2.	Packet scheduling
3.	Priority assignment
4.	Security
5.	Varying interference

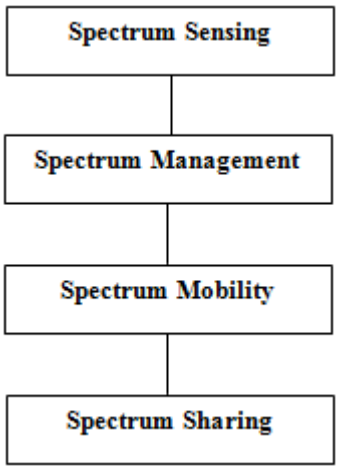

Figure 2. Cognitive radio functions.

MOTIVATION

In last few decades, various works are proposed for cognitive radio ad-hoc network. All are based on either mathematical modelling or heuristic approach. Each approach has its own merit and demerit. But none of the approach discussed different strategy of the network to model into game strategy. This paper model cognitive radio ad-hoc network into game model to achieve routing purpose.

CONTRIBUTIONS

In this paper, game theory is used to model several strategies into game where nodes plays the role to player, different resources plays the role of actions and some specific rules or algorithm plays the role of utility functions.

Figure 3. Basic elements of game theory.

ORGANIZATION OF THE PAPER

The remainder of this paper is organized as follows. In Section 2, literature reviews are presented. In Section 3, general ideas of several preliminaries that are plays vital role to design the proposed model are offered. The concise description and formulation of the proposed model described in Section 4. Finally, conclusion and future scope are outlined in Section 5.

LITERATURE REVIEW

In this section, some literature review are discussed based on various approaches such as artificial intelligence, soft computing, fuzzy set theory etc.

Artificial intelligence [8] is used to investigate and builds intelligent software and machines in which an intelligent factor performs actions that maximize the possibility of success.

Barbancho et al. [9] proposed a routing scheme for wireless network based on artificial intelligence technique. It help to choose optimal path between source and destination node which helps to minimize energy consumption and enhanced QoS.

Soft computing [10], [11] is used to exploit tolerance for imprecision, uncertainty, approximation and partial truth to achieve low cost solution.

Sharma et al. [12] proposed a routing approach for wireless mesh network based on soft computing techniques. It helps to find shortest path by the helps of two algorithms: Big Bang Big Crunch (BB-BC) and Biogeography Based Optimization (BBO). It has low computational time complexity and high convergence speed.

Fuzzy logic [13], [14] is derive from fuzzy set theory. It works with intermediate value of true and false. It helps to reduce uncertainty related to information in any domain. Its application areas are ad-hoc network, grinding process [15], geometric programming modelling [16], ontologies [17], surface roughness [18] etc.

Das et al. [19] proposed a multi-cast routing protocol for ad-hoc network. In this protocol decision maker derive an optimal path between source and multi-cast group which has sufficient energy and shortest distance. But in this scheme, the author used point based membership function which is less expressive to capture vagueness of information. So the author proposed a new scheme [20] based on vague set. It work with interval based membership function which is more expressive than point based membership function.

PRELIMINARIES

In this section, some preliminaries are discussed which provide a detailed analysis of the proposed model.

PRIMARY USER

Primary User (PU) is the licensed user of the spectrum which have obtained regulatory permission to operate in that spectrum band.

SECONDARY USER

Secondary User (SU) is the unlicensed user which uses the spectrum band in cooperation with the primary user.

SPECTRUM SENSING

Spectrum sensing is the term associated with detection of all wireless channel that are available to use in the surrounding area of secondary user.

GAME

A game is an interactive decision problem which is structured or semi-structured. Basically, it is used for enjoyment or sometimes as educational tools. Key components of games are goals, rules, challenge, and interactivity.

GAME THEORY

Game theory is a branch of applied mathematics which is describes and studies interactive decision problems. It studies different strategic interactions among rational players, where players choose different actions in order to maximize their returns.

PROPOSED MODEL

In this section, proposed model is described briefly. In the proposed network model, G is an undirected graph as G = (V, E). The set of vertices (nodes) and edges (links) are represented as V and E respectively. Each link incident with two nodes [21], [22]. The proposed network model shown in Fig. 4. In this model, V is a set of eight nodes (n_1 to n_8) and E is a set of nine edges (e_1 to e_9).

Here, cognitive network model into game and relation between them given in Table 2. Here, n_1 is the source node and n_8 is the destination node. The cost of each link measured by residual energy. It measured by randomization process which is making something random between two values. It is not haphazard process. It is

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a sequence of random variables between two numbers are α_1 and α_2 whose outcomes does not follows deterministic pattern. Utility function is shown in Eq. 1, it indicates maximum price the source node n_1 is willing to pay to transmit data packet to the destination node n_8.

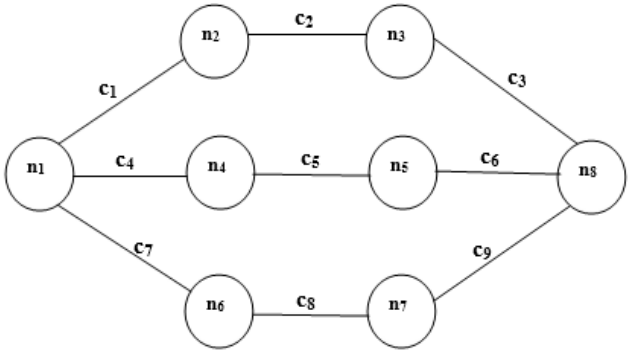

Figure 4. Proposed network model.

Table 2: Relation between network and game model.

Sl. no.	Game	Network
1.	Players	Nodes
2.	Actions	Battery power
3.	Utility function	Algorithm or Rule

$$U_{func} = Max_{cost} - Min_{cost} \quad (1)$$

Let the first randomization process, $\alpha1=1$, $\alpha2=10$ and values generated by random process for c1 to c9 are c1=4, c2=6, c3=8, c4=2, c5=1, c6=3, c7=10, c8=7 and c9=5. The cost for three path are 18, 6 and 22. Hence, minimum cost path is Path2 = {n1 → n4 → n5 → n8}. In this model, there are two paths that bypasses nodes (n1 and n8) are Path1 and Path3. The cost of bypass paths are 18 and 22. Decision maker select cost of Path3 for maximum return. Now, value of utility function is 22+6=28. Therefore, pay for each path $\lambda1=22-6+2=18$, $\lambda2=22-6+1=17$, and $\lambda3=22-6+3=19$. Total paying cost is $\lambda1+\lambda2+\lambda3=54$ which is greater than utility function. So this path will not accepted try another randomization.

Let the second randomization, the value of $\alpha1$ and $\alpha2$ are remain same. But generated cost by random process is slightly changed for link5 (i.e. c5) is 10. The cost for three path are 18, 15 and 22. Hence, minimum cost path and bypass paths are same. Now, new value of utility function is 22+15=37. Therefore, pay for each path $\lambda1=22-15+2=9$, $\lambda2=22-15+1=8$, and $\lambda3=22-15+3=10$. Total paying cost is $\lambda1+\lambda2+\lambda3=27$ which is smaller than utility function. So this path will be accepted for data transmission.

CONCLUSION AND FUTURE SCOPE

In this paper, stable routing is proposed based of residual energy parameter. In this method game theory is used to model cognitive radio ad-hoc network into game model and convert all network entities into game entities to derive optimal path based on utility function and pay of each path. Cognitive radio ad-hoc network is dynamic due to infrastructure less property, so its topology is changes frequently. This variation affect the utility function and pay of each link. Therefore, optimal path is not fixed, its changes based on network topology. Future scope, model this approach into either NS-2 or NS-3 simulator and validate simulator results with analytical results.

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