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ANovel Technique for Channel Allocation in Cognitive Radio Networks using Game Theory

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Abstract

With the increase in usage of wireless communication technology the problem of bandwidth scarcity increased. The concept of cognitive radio has been introduced to solve this problem. Cognitive radio network is a network that enhances the utilization of spectrum band by allowing licensed users to share licensed spectrum with unlicensed users. But CRN has its own challenges one of them is channel allocation while establishing route for data transmission of secondary user. Game theory is used to solve this problem. Game theory analysis the interactions between different nodes and gives an optimized solution to this situation. In this paper our aim is to establish a route between source and destination such that route causes minimum interference to other nodes, maximum packet delivery ratio and minimum delay. These terms are assigned some weight according to requirements and then the network performance has been compared by varying weights of terms.

Keywords:*cognitive radio network; wireless network; game theory; channel allocation; cooperative and non-cooperative game theory*

1. Introduction

Cognitive radio technology is emerging a powerful technology for wireless communication [1-3]. Cognitive radio network is the network in which cognitive nodes intelligently senses the spectrum band for holes and opportunistically access the spectrum band without disturbing primary users[7]. Primary users have access to licensed spectrum band. Cognitive (secondary) users uses unlicensed spectrum band. Cognitive users can access the licensed spectrum when it is not used by primary users and leaves the licensed spectrum when primary user become active and starts accessing that channel for packet transmission. Hence secondary users dynamically access the licensed spectrum band. To support dynamic access to spectrum, secondary nodes are equipped with cognitive a radio that continuously senses the licensed spectrum and detects spectrum holes or also known as white space. By using these white spaces, utilization of spectrum can be considerably increased[6] and solves the problem of spectrum scarcity [4, 5].

Cognitive radio must satisfy following condition while selecting a channel for communication

1. Interference to primary users should not be increased then before.
2. It should exploit all the possible channels available for transmitting packets.

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Due to coexistence of primary users and secondary users CRAHN faces the problem of multi-objective optimization. To solve this problem game theory has been used[8]. In literature game theory has been shown as powerful tool for designing channel allocation algorithm. Game theory provides a good solution for a situation in which many users try to access same resources.

In this paper we have tried to improve network performance by allocating channels to nodes such that path causes minimum interference to primary users, maximize packet delivery ratio, and minimize delay. These terms are weighted according to requirements and different scenarios are analysed. A path satisfying the requirements (optimal path) will be selected for routing. Proposed work has been implemented in MATLAB-10.

Rest of the paper is organized as follows: In section II it has been discussed how game theory has been CRAHN for channel allocation. Section III gives proposed algorithm for channel selection. Section IV gives simulation setup and parameters. In Section V results and conclusion are given followed by references.

2. Channel allocation: Literature review

Game theory is a mathematical tool that is used to study various interactions between rational players. It provides the tools for predicting the result of various interactions between users with conflicting goals. In the recent years game theory has become very popular in the field of CRN. Game theory plays animportant role in managing resources in CRN.

Broadly game theory can be classifies as

1. Cooperative game theory:It considersthat all CR users are cooperative and their aim is to maximize total network performance by achieving Nash Bargaining state. Individual user shares their vital information like utility function with other users in network and based upon that information players select their next action.
2. Non cooperative game theory: It considers that CR users are rational user and their aim is to maximize their own utility function i.e. allocating resources. This type of game converges at Nash equilibrium state. Individual users don’t have access to the strategies and payoff of other users. As CRN have rational nodes there for non cooperative game theory has been extensively used to analyze cognitive radio network in game theoretic framework.

Basically game theory has three components [9, 10]

1. Set of players: in this context players are nodes of CRN.
2. Set of actions: in this context actions may be available modulation scheme, coding rate, protocol, flow control parameter, transmit power level, or any other factor that is under the control of the node.
3. Utility function: in this context it can be Delay, SINR, Throughput, and QoS of CRNs.

Modeling utility function properly has been one of the most challenging aspects of the application of game theory. Utility Function is a set of objective functions that each player wishes to maximize. Action chosen by a player is denoted by ai and action chosen by other players is denoted by a-i. a lot of utility functions have been considered related to the resource allocation problem in CRNs. Commonly used utility functions is signal-to-interference-plus-noise ratio (SINR) which has been used to maximize the efficiency of spectrum.

[11]Considered the utility function as total throughput of links. For [12] utility function is based on interference to other links and interference from other links. While the utility

function considered in [13] is weighted sum of received power, interference to other links and interference from other links. Here links are fixed i.e. network is not mobile. Weights of these terms can be varied according to requirement of network i.e. high overall throughput, low interference or a tradeoff between both. Throughput of CRN should not be increased at the cost of interference. Simulation showed best results when all the terms are weighted 1. Performance index has been calculated based on overall throughput and interference to other users for measuring network performance.

A spectrum management model has been proposed by [14]using game theory (SMG) and without game theory considering network performance.

Cooperative game theory considers that nodes share their vital information with other nodes and have all the information before making a decision but players only have partial information in advance for making a decision. This scenario has been considered in [15] and an algorithm has been proposed based on game theory for resource allocation. According to proposed game player are cognitive radio terminals, strategy is to choose best resources differently from the operating environment and the opponent player's choices.

In order to achieve global optimization for distributed channel selection author in [16]proposed a POMDP and a game theoretic framework. This model maximizes the network throughput and minimizes network collision. This new spectrum sharing model enhances the cooperation between users of network and reduces collision. POMDP determines the access probability of each unlicensed user and reduces the collision with licensed users. Potential game theoretic framework and joint strategy fictitious play determines the access probability of unlicensed user and reduces the collision with other unlicensed users. This enables the cooperation between licensed users and multiple unlicensed users.

3. Proposed work

In this paper we attempted to design an algorithm that maximizes the throughput of network without increasing the interference level as it was before introducing secondary users.

Here the channel selection is being based on three terms:

- Interference
- Delay
- Percentage of packets delivered

The terms considered for route selection can be explained as below:

- All channels are allocated some power for transmission. If the transmission power allocated to channel is high interference will increase. If the transmission power allocated low signal may not be received by next node. There for transmission power should be allocated such that a path is created and interference is low. Path with minimum transmission power is desired.
- Channels should be assigned such that path have minimum delay and minimum hop-count. Here we have considered path delay and switching delay.
- For any path it is required that maximum number of packets should be delivered. Higher is the percentage better is performance.

These factors are assigned equal weights that are 0.5. Based on these factors a performance index is calculated for each path. Weights can be adjusted as per requirement. Value for performance index is calculated as:

PI=0.5*PDR + 0.5/energy + 0.5/delay + 0.5/hop-count

Path with highest PI is considered as optimal path and used for routing.
The algorithm used for routing is given below:

1. Set the initial values of distance matrix and energy matrix. Transmission power required is given as

$$P_{tr} \alpha \text{ (Distance}_{\text{node1, node2}})^2$$

2. Set the free n busy timing of channels.
3. Select source node and destination node randomly.
4. Send hello message from source node to destination node to fine route from source to destination.
5. Add the routes to a matrix selected paths.
6. Calculate PDR, switching delay, end-to-end delay, transmission energy and hop count for each path.
7. Calculate PI of each path.
8. Select the path with highest PI for communication.

Figure 1. Algorithm used for proposed work

Aim of the optimal route selection is:

- Hop count should be reasonable. It should neither be too high nor too low. If hop count is high it may increase switching delay also low hop count may increase power required for signal transmission and hence increases interference to other users.
- Energy required for transmitting data from source to destination should be minimum. It saves energy of mobile nodes as well as decreases SINR.
- End-to-End delay should be minimum so that data transfer rate can be fast.
- Primary node must be preferred for routing as it is more reliable then secondary user.
- Packet delivery ratio should be high so that maximum data can be transferred on that route and increases throughput.

Game theory has been used to analyze all the interaction between secondary users and find an optimal path for routing.

4. Implementation

4.1. Network parameters

Implementation of this paper has considered 24 cognitive nodes and 16 primary nodes. The nodes can transmit in a range of 400m. The area assumed for placing nodes is

1500m*1500m. Mobility model considered for cognitive nodes is random-waypoint while primary nodes are fixed. For simulation following parameters have been considered.

Table 1. Network parameters

Area	1500m*1500m
Range of transmission	400
Number of PUs	16
Number of SUs	24
Positioning of SUs	Random
Positioning of PUs	Square matrix
No. of iteration	15
No. of channels per node	1
Source node	Randomly selected from SUs
Destination node	Randomly selected from SUs
Max velocity of SUs	15 /sec

4.2 Simulation

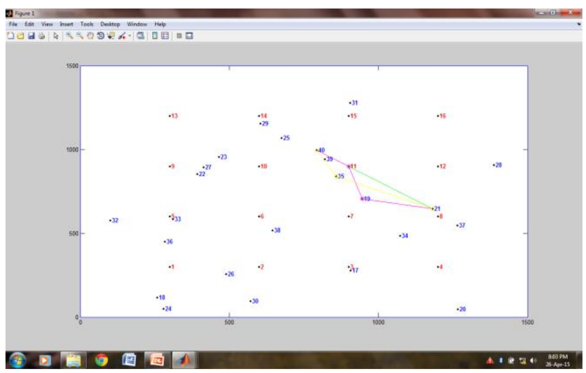

Figure 2. Simulation of routing from node 41 to 21

Using three different scenario by varying weights [0 1 1 1], [1 0 1 0], [1 1 1 1] we have got three different paths;First is path with minimum interference denoted by pink color, second is path with maximum throughput denoted by green color and third i.e. proposed path have both minimum interference and maximum throughput denoted by yellow color.In Fig 2 three paths are shown from node 40 to node 21.

4.3. Results

After execution of program different parameters have been analyzed for 20 iterations. Average value of parameters (in Fig 3, 4, 5 and 6) have been computed and compared for different paths.

Fig 3 shows the impact of varying weights on PDR of different routes. The value of PDR is highest for optimum route.

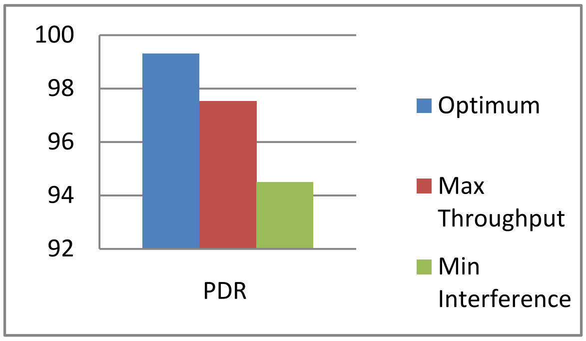

Figure 3. Average PDR comparison

Fig 4 shows the impact of varying weights on energy required for transmitting data on that route. Path withminimum interference require minimum transmission power.

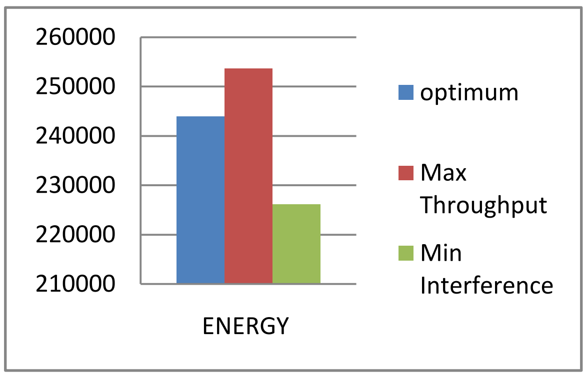

Figure 4. Average energy consumed comparison

Fig 5 shows the impact of how change in weights affects the hop-count of a path. Simulation shows that optimal and Max throughput path have minimum number of hop-count needed for routing.

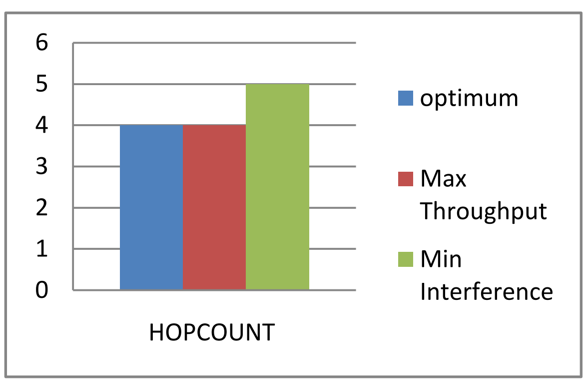

Figure 5. Average Hop-count comparison

Fig 6 shows that impact on delay of varying weights of different terms. It has been observed that optimum route has minimum delay.

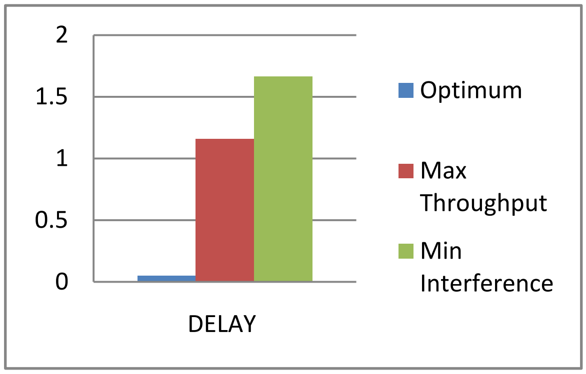

Figure 6. Average delay comparison

5. Conclusion

From the simulation results it has been concluded that optimum path gives overall better performance for network. A tradeoff between max throughput path and min interference needs to be done for improving the performance of network.

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