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An Efficient Algorithm for Throughput Maximization and Delay Minimization in Cognitive Radio Wireless Mesh Network

M. Minupriya[1], C. Vennila[2]

PG Student, Department of ECE, Saranathan College of Engineering, Trichy, India[1]

Professor, Department of ECE, Saranathan College of Engineering, Trichy, India[2]

Abstract: The main issue in current wireless network is radio resource usage. The main goal of cognitive radio networks is to increase spectrum utilization. Cognitive Radio Network is the current wireless technology requirement as it solves the problem of spectrum scarcity. In cognitive radio, route has been established between source and destination such that route causes minimum interference to other nodes, maximum packet delivery ratio and minimum delay. This project presents an improved method for channel allocation in cognitive radio wireless mesh network based on game theory and path is chosen based on highest value of performance index. Performance gains in terms of end-to-end throughput and end-to-end delay are demonstrated in comparison to a distributed algorithm. The algorithm is implemented using MATLAB.

Keywords: Game theory, Channel allocation, Performance index, Cognitive Radio Network.

I. INTRODUCTION

A wireless mesh network (WMN) is a communication network made up of radio nodes organized in a mesh topology. The unique feature of mesh nodes is highly mobile. Due to this, the nodes keep on changing their network topology.
A mesh network is reliable and offers redundancy. When one node can no longer operate, the rest of the nodes can still communicate with each other, directly or through one or more intermediate nodes.
Typically, a WMN consists of static wireless mesh routers which are also known as access points. These static mesh routers will form backbone of WMN and serve the mesh and conventional clients. Each AP connects mobile nodes to the wired network through multihop wireless routing in [16].
The mesh nodes are directly connected to the wired network through access points.For a WMN, CR represents a way to improve overall utilization of available spectrum and expand the spectrum available to individual networks.
The wireless mesh network is used particularly for large areas of coverage. Using wireless mesh networks, the cost and complexity of installing fibre /wires between buildings, on campus grounds and business parks are eliminated. Wireless Mesh is very useful for areas where there is lack of sight or where network configurations are intermittently blocked. Wireless Mesh is also extremely convenient where wall connections may be lacking, such as in outdoor environments, warehouses or transportation settings.
Public Safety and emergency response demand wireless connectivity that supports coverage of large geographic areas, high speed mobility and high quality video surveillance in [17]. Wireless Mesh Networks are ideal to deliver high throughput and highly reliable wireless connectivity. Wireless Mesh Networks deliver both indoor and outdoor connectivity. Wireless Mesh is an instant, complete solution for covering large areas without sacrificing quality of the wireless network. Wireless Mesh Networks are a reliable source of wireless connectivity for a variety of public safety applications.

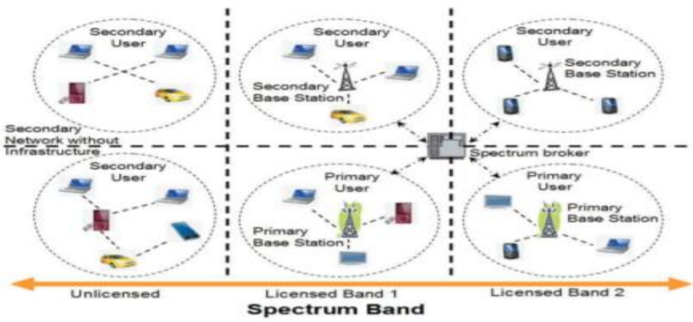

Fig. 1. A Cognitive Radio Network Architecture with Primary and Secondary User Networks

A cognitive radio network architecture includes components corresponding to both the secondary users (secondary network) and the primary users (primary network) as shown in Fig.1. The secondary network is composed of a set of secondary users with or without a secondary base station, all of which are equipped with CR functions in [13].
A secondary network with a base station is referred to as the infrastructure-based CR network; the base station acts as a hub collecting the observations and results of spectrum analysis performed by each CR secondary user and deciding on how to avoid interference with the primary networks. As per this decision, each CR secondary user reconfigures communication parameters.
A secondary network without a base station is referred to as the infrastructure less cognitive radio ad hoc network (CRAHN).
In a CRAHN, the CR secondary users employ cooperation schemes to exchange locally observed information among the devices to broaden their knowledge on the entire network, and decide on their actions based on this perceived global knowledge.
A primary network comprises of primary users and one or more primary base stations, all of which are in general not equipped with CR functions.
Hence, if a secondary network is required to be able to detect the presence of a primary user and direct the secondary transmission to another available band that will not interfere with the primary transmission.

II. RELATED WORK

In literature [7], authors propose a two fair Bandwidth allocation problems based on a simple max-min fairness model and lexicographical max-min (LMM) fairness model. Using linear programming (LP)-based optimal and heuristic algorithms, they solved the above problems. The main drawback of this paper is not considered about performance metrics such as throughput.
In literature [6], authors propose a cross-layer routing and channel allocation algorithm. End to end packet dropping probability is minimized. The design have limited scalability and centralized one.
In literature [12], authors propose a Cooperative spectrum sharing in cognitive radio networks. Cooperative spectrum sharing scheme among a PU and multiple SUs is proposed, where each PU selects the proper set of SUs to serve as cooperative relays for the transmission. The selection strategy includes the selection of the SU that is associated with the least channel access time left. However, in this scheme, the PU focuses only on selecting a certain number of SUs among which the one that fulfills its criteria of least access time, leaving the rest of SUs in a starvation state.
In literature [11],authors propose a we present a survey on DSA protocols for distributed CWNs. In particular, we first address the challenges in the design and implementation of distributed DSA protocols. Then, they categorize the existing distributed DSA protocols based on different criteria, such as spectrum sharing modes, spectrum allocation behaviours, spectrum access modes, the usage of common control channel, spectrum usage strategies, the number of radios, and spectrum sensing techniques. They also discuss the advantages and disadvantages of each category under diverse classification criterion. Moreover, they make a comprehensive survey of the state-of-the-art distributed DSA protocols using different spectrum access modes, which can be categorized into contention-based, time-slotted, and hybrid protocols. Through the study, they find out that most of distributed DSA protocols fall into the contention-based and hybrid protocols.
In literature [5], authors presented the effects of imperfect sensing on the performance of opportunistic spectrum access (OSA) in cognitive radio (CR) networks are are considered.The system is modeled as a continuous-time Markov chain (CTMC). Performance is evaluated in terms of the probabilities of users being blocked or dropped.

III. PROBLEM IDENTIFICATION

Due to co-existence of two types of networks with conflicting goals, users will cooperate only if it is beneficial to them in terms of resources, and hence there is a great challenge while allocating resources to users as they can behave in non -cooperative manner. In order to resolve the challenges in CRN, we need some analysing tools that can control the CRN and optimize the performance of network.
Game theory provides variety of mathematical tool that that can be efficiently used in studying, modeling, and analysing the cognitive interaction process, and designing efficient, self-enforcing, distributed and scalable spectrum sharing schemes.

IV. PROPOSED SYSTEM

Resource allocation problem occurs in cognitive radio mesh networks. . In order to overcome this problem, maximizes the aggregate utility function of all traffic streams. It can be formulated as follows:

$$\max_{y} \sum_{f\in F} U_f(\min_{v\in V_f} {\mu^f}_v)$$

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This can be rewritten as,

$\max_y \sum_{f \in F} U_f(z_f)$

Presence of the min term inside the utility function makes the problem significantly more difficult. To simplify the problem, min term was transformed into a set of linear inequality constraints. This transformation simplifies the objective function and allows us to use the Lagrange duality theory to find a decentralized solution in existing system.

Game theory is a mathematical tool which 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 gained popularity in CRN. Game theory plays a significant role for resource management in CRN.

The game theory-based scheme proposed in this paper tries to aggregate the interference caused in the link while enforcing the fact that each SU must get an equal opportunity to access the band and transmit the data, thereby ensuring no starvation.

ALGORITHM FOR CHANNEL ALLOCATION:

Step 1: Array of available channels is created.

Step 2: Create array for storing the interference value for each available channels.

Step3: Array that stores the number of radios that each secondary user are created.

Step4: Array for storing the Utility calculated for each available channel is created.

Step5: Initially the channel interference value is equal to zero.

Step6: Allocate channel based on utility

Utility= channel interference × number of radio nodes

Step7: Utility values are sorted.

Step8: The channels will now be allocated on the basis of increasing order of utility.

ALGORITHM FOR ROUTING

Step1: Assign the initial values of distance matrix and energy.

Step2: Set the free n busy timing of channels and select source node and destination node randomly.

Step3: Send hello message from source node to destination node to fine route from source to destination.

Step4: Add the routes to a matrix selected paths.

Step5: Calculate PDR, switching delay, end-to-end delay, transmission energy and hop count for each path.

Step6: Calculate PI of each path.

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

Step7: Select the path with highest PI for communication.

V. SIMULATION RESULTS

In this section, results of proposed algorithms are included. We analyse the performance of our proposed algorithms. We implement algorithm in MATLAB with the network topology.

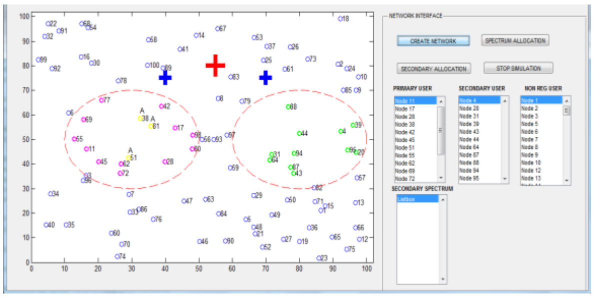

Fig. 2. Network creation

In this Fig.2., Network creation process is shown. Primary and secondary users are random distributed among them. Active nodes are highlighted. Primary nodes are represented in pink colour.

Secondary nodes are represented in green colour. An active network is a network in which the nodes is programmed to perform custom operations on the messages that pass through the node.

Based on transmission range and distance matrix, nodes are classified. Transmission range taken is 100m. Transmission range is the maximum distance a node can send its data to another node. Distance matrix is calculated using Least squares method.

Spectrum used for sharing between users is 1 to 10 GHz in cognitive radio wireless mesh network. Number of nodes taken is 100.Nodes present outside the coverage range are Non- regional nodes.

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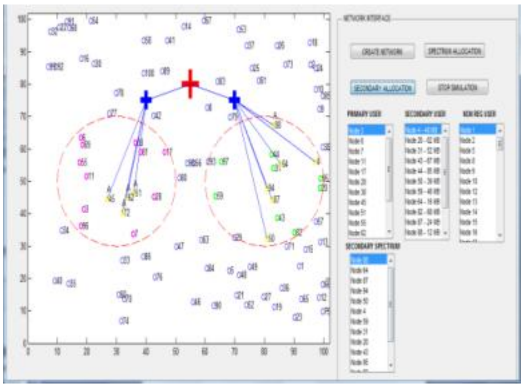

Fig. 3. Spectrum allocation to secondary nodes

Fig.3., Secondary allocation process is being allocated to the active secondary users and to provide connections them. This process is done based on the size of the data to be transmitted. In this nodes with low data rate is allowed to use the spectrum**.** Graph shows about frequency allocated to 3 primary active nodes and 4 secondary active nodes.

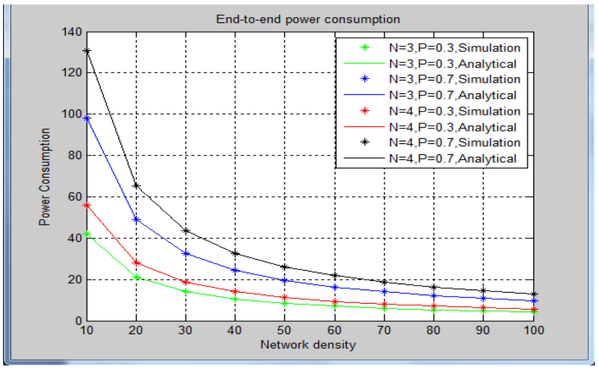

Fig. 4. End to end power consumption variation with respect to Network density

Fig.4. shows End-to-end power consumption against network density. N is the number of aggregated channels, and P is the PU activity. In this both the simulation and the analytical results are being compared.
The optimization of transmission power depends on the expected node degree and node distribution. Power consumption of nodes is reduced in proposed algorithm compared to existing algorithm. For any set of nodes in a network, there is a finite number of relationships possible. Each node can serve as the source or the target of a relationship with every other node. Network density is the proportion of possible relationships in the network that are actually present.
Transmission power decreases when the network density increases. End-to-end power consumption in high frequency band is larger than that of the low frequency band, as the high frequency band suffers more path loss. In addition, for a given probability of PU being active, Power consumption is reduced when the number of aggregated channels increases due to the infamous bandwidth-power inverse relationship. Power consumption increases as P increases due to the fact that a higher PU activity will reduce the potentially available bandwidth.

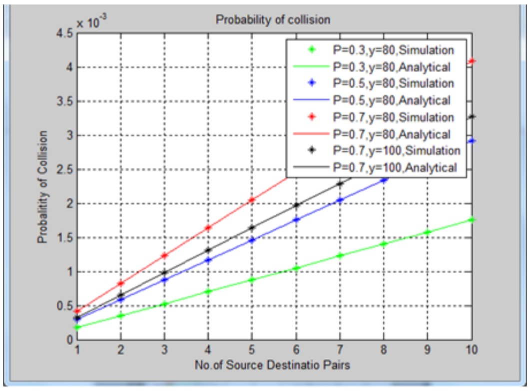

Fig. 5. Probability of collision

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Fig.5. shows the probability of collision against the number of source and destination pairs, λ is the network density, P is the PU activity. In this both the simulation and the analytical results are being compared.

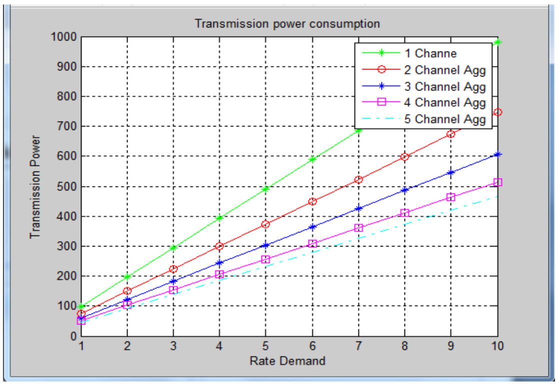

Fig. 6. Transmission power

Fig.6. shows transmission power consumption against the rate demand for various channel aggregation. Here up to 5 channels aggregation process is being conducted. The transmit power is further reduced as more channels are aggregated. However, as the number of aggregated channels increases, the transmit power gain is decreased. This is because the CR node has to overcome more attenuation (path loss and fading) of the aggregated channels when the number of aggregated channels are increased.

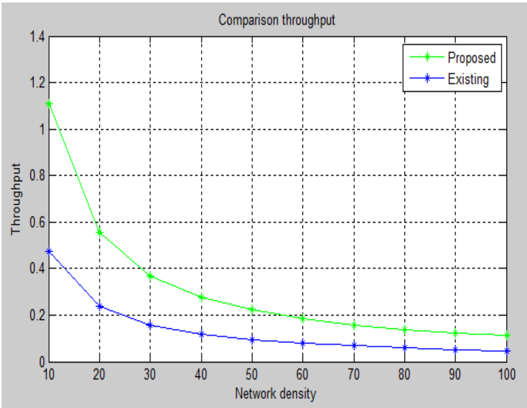

Fig.7. Throughput

Fig.7. shows the comparison of throughput having existing and proposed system. Amount of data moved successfully from one node to another node in a given time period, and typically measured in bits per second (bps).

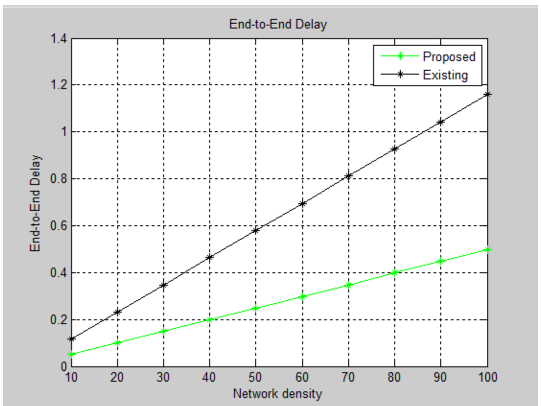

Fig. 8. End to end delay

Fig. 8. shows the comparison of end to end delay having existing and proposed system. End-to-end delay refers to the time taken for a packet to be transmitted across a network from source to destination.

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VI. CONCLUSIONS AND SCOPE FOR FUTURE WORK

This project proposes an algorithm using game theory for channel allocation as well as for routing algorithm. We have also conducted a performance comparison to other existing work in literature. Proposed method shows a great improvement while comparing with existing system. Implementation is done in MATLAB R2012b. Performance gains in terms of end-to-end throughput and end-to-end delay are demonstrated in comparison to a distributed algorithm. Simulation results are demonstrated in terms of average capacity, probability of collision, and for power consumption of node.

In future, secondary users will be equipped with successive interference cancellation (SIC) using topology control algorithm to mitigate the interference from primary users thereby making secondary users enable to access the spectrum more aggressively than previous works.

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