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

Minupriya. M
P G Student
Saranathan College Of Engineering Trichy,
India

C. Vennila
Professor
Saranathan College of Engineering Trichy,
India

Abstract— **The main issue in current wireless network is radio resource usage. The main goal of cognitive radio networks is to increase spectrum utilization. Spectrum allocation plays a major role in the performance of cognitive radio wireless networks. In order to have a better channel allocation and to obtain a maximum throughput of different traffic streams, we present an efficient distributed algorithm in this paper. Performance gains in terms of end-to-end throughput and average delay are compared to a uniform allocation scheme and the max-min bandwidth allocation scheme. The algorithm is implemented using MATLAB. Numerical results show that there is 20% decrease in average delay compared to uniform allocation scheme and 12% reduction in average delay compared to max-min bandwidth allocation scheme.**

Keywords— spectrum allocation, Lagrange Duality theory

I. INTRODUCTION

Wireless mesh network (WMN) is a communication network which contains radio nodes organized in a mesh topology. The components used in wireless mesh networks are WMN client, WMN router and WMN gateway in [10]. WMN clients can access the network for using applications such as email, VOIP. It has limited power and routing capability.

WMN routers are used to route the network traffic. Scalability in a multihop mesh environment is obtained with help of media access control protocol (MAC) in a mesh router. By having multiple interfaces, WMN gateways can connect to both wired and wireless networks.

When one node becomes inoperative, then the rest of the nodes can still communicate with each other directly. A mesh network provide cost effective, reliable, high bandwidth over a specific coverage area and it also improves the network performance like load balancing, throughput.High chances of redundancy, Set-up and maintenance of this topology are the drawbacks of this network.

Infrastructure/ backbone WMN, Client WMN, Hybrid WMN are the types of architectures in WMN. Only mesh routers are used in Infrastructure/ backbone WMN. It is used in community and neighbourhood networks which are able to build infrastructure mesh. The client WMN provides a peer to peer network to the clients. The hybrid WMN is used to provide access to the cellular networks, Wi-Fi, WIMAX, sensor networks in [9].

Cognitive radio is a one of the developing area for wireless technology. To overcome spectrum scarcity and effective utilization of resources, cognitive radio network is used.

The network consists of licensed users and unlicensed users.Primary users are the license-holders of the spectrum band of interest. They have priority access to use the spectrum band.Unlicensed users are allowed to have opportunistic access to idle spectrums without causing harmful interference to the Primary user. A cognitive radio mesh network is a wireless mesh network (WMN) consists of cognitive radios. Opportunistic and dynamic spectrum access is operated by cognitive radios. Due to having advantages in increasing spectrum utilization and overcoming spectrum scarcity, cognitive radio mesh networks are used in several applications.

Congestion present in the conventional WMNs is reduced by the a cognitive radio wireless mesh network through search for the available channels in the primary band. Some of the mesh clients are moved to those available channels. In this paper, we use distributed algorithm to achieve maximum throughput.

The flow of the paper is organized in such a way that literature surveys are given in section II, , problem statement is described in section III, section IV gives the network model, section V explains channel model, section VI details the proposed system , experimental results are given in section VII and section VIII explains about conclusion and future work of this paper.

II. RELATED WORK

In literature [1], the authors have proposed a Power-Controlled Rate-Adaptive MAC (CPCRA) protocol for single transceiver based Cognitive Radio Networks (CRNs) which combines adaptive modulation and coding with dynamic spectrum access. Simulation results prove that CPCRA can achieve better performance in terms of lower delay and higher throughput.

In literature [2], authors described about Spectrum-aware Channel Assignment (SaCA) algorithm for multi-radio, multi-channel cognitive radio networks. The number of primary users, number of channels and primary user activity ratio are varied. The algorithm used in this paper describes about computation of ranking function values on the basis of channel characteristics and assigns the channel with higher ranking function value to different interfaces.

In literature [3], 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 [4], describes about two new cooperative spectrum sensing strategies such as amplify-and-relay(AR) and detect –and-relay(DR). In AR strategy, the received signal is amplified from primary user and then directly forwards to the secondary transmitter by relay SU. In DR strategy, not only amplifies and forwards the signal, but also involves its independent detection results to decide whether it should relay or not.

In literature [5], authors presented an overview of the RF- powered cognitive radio networks and challenges. It also describes about dynamic channel selection problem in a multi-channel RF- powered cognitive radio networks.

In literature [6], the authors proposed a novel cooperative spectrum sensing technique for cognitive radio networks based on sensing with equal gain combining (SEGC). Sensed results are transmitted by cognitive radios to the fusion center (FC) over multipath fading reporting channels simultaneously.

In literature [7], authors described about the use of two trust parameters, location reliability and malicious intention (LRMI)in order to improve both malicious user detection and primary user detection in mobile CRNs under attack. In case of honest user, when it moves from a good location to a bad location, we should give low weight to its report, due to bad location ,report will not be reliable.

In literature [8], authors presented the effects of imperfect sensing on the performance of opportunistic spectrum access (OSA) in cognitive radio (CR) networks 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.

In literature [9], 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.

III. PROBLEM STATEMENT

In this work, solution for the resource allocation problem in cognitive radio wireless mesh network is obtained. The main aim of resource allocation is to obtain maximum aggregate end-to-end throughput of the different traffic streams in the network. End-to-end delay constraint can be different for different streams according to their Quality of Service requirements.

The utility maximization problem is expressed as a non-linear integer programming (NIP) problem. Uniform allocation scheme and the max-min bandwidth allocation scheme are compared with our proposed method in terms of performance metrics such as throughput, end-to-end delay.

Distributed algorithm is used to solve the limitations presented in paper [9] as well as implemented in large networks are addressed in this work. Maximum throughput as well as reduced delay is obtained using this algorithm.

IV. NETWORK MODEL

The cognitive user shares the spectrum band with primary network which has N transmitter-receiver pairs. Each primary network operates a unique channel with similar bandwidth. Primary transmission occurs at the beginning of time slot. Cooperative spectrum sensing technique is used to detect the channel availability. TDMA is used in cognitive radio wireless mesh network for channel access.Each node will opportunistically access the idle primary channels to transmit its packets in each time slots.

Time division multiple access (TDMA) is one of the channel access methods. It allows numerous users to share the same frequency channel by dividing the signal into different time slots. Multiple stations are allowed to share the same transmission medium. TDMA is used in the digital 2G cellular systems, Personal Digital Cellular (PDC) and Digital Enhanced Cordless Telecommunications (DECT) standard for portable phones.

V. CHANNEL MODEL

The wireless channel is modelled as a Rayleigh flat fading channel with additive white Gaussian noise. Success and failure of packet reception is characterized based on outage events and outage probabilities. In flat fading, the coherence bandwidth of the channel is large compared to the bandwidth of the signal. All frequency components of the signal have the same magnitude of fading.

VI. PROPOSED SYSTEM

The optimization problem is to find a resource allocation. In order to overcome this problem, aggregate utility function of all traffic streams has to be improved in the network.

The average service probability per time slot is calculated using queuing theory,

$$\mu_d^l = \frac{1}{T}\sum_{s=1}^{T} a_d^{l,s} \tag{1}$$

where d is a node, s is time slots, l is the data stream, $a_d^{l,s}$ is the probability of a packet being serviced from node d along the route of data stream l .The best use of resource with maximum utility function is the optimization problem. This optimal problem is simplified using this transformation. Lagrange duality theory is used to find a decentralized solution. Decision variable is defined a, $b_{l,j}^{s,c} = 1$

if channel is allocated in given time slots to data stream f over link, otherwise $b^{s,c}_{l,j} = 0$.

DISTRIBUTED ALGORITHM

This algorithm is an iterative procedure.

Information is exchanged between nodes

at each iteration.

Step1: Assume that b node is feasible point

Step2: The value of b node is assigned to x variable

Step3: For every iteration resource is allocated using below equation,

$$b^{s,c}_{l,j}(i+1) = x^{s,c}_{l,j}(i) + k[\,{}^{1}_{ml,d1}(i)\,\beta^{c}_{j} - {}^{2}_{md1,s}(i) - {}^{3}_{md1,s}(i) - {}^{3}_{md2,s}(i) - \sum_{j' \in g_j} {}^{4}_{m\,j,s,c}(i) + {}^{5}_{ml,d1}(i)\,\beta^{c}_{j}\,] \tag{2}$$

${}^{1}_{ml,d1}, {}^{2}_{md1,s}, {}^{3}_{md1,s}, {}^{3}_{md2,s}, {}^{4}_{m\,j,s,c}, {}^{5}_{ml,d1}$ are Lagrange multipliers. d1 is the source node of edge j, d2 is the destination node of edge j, k is constant(k>0). The channel is allocated in given time slots for the nodes using above equation. Resource allocation solution is broadcasted to every node within interference range.

Step4: Using gradient projection method, the value of Lagrange multipliers are calculated.

VII. SIMULATION RESULTS

It includes the results of Distributed algorithm. Performance of this algorithm is compared to max-min bandwidth allocation algorithm (MMBA) and uniform allocation scheme. The values of various parameters are illustrated in Table I.

TABLE I: SIMULATION PARAMETERS

PARAMETER	VALUE
NODES ARRANGEMENT	SQUARE GRID WITH A SIDE LENGTH OF 250M
TRANSMISSION RANGE	100m
NO OF TIME SLOTS IN A TDMA FRAME	20
TRANSMISSION POWER	100mW
SNR THRESHOLD	20 dB
PATH LOSS EXPONENT	3.7
POWER SPECTRAL DENSITY	10^{-11} W/HZ

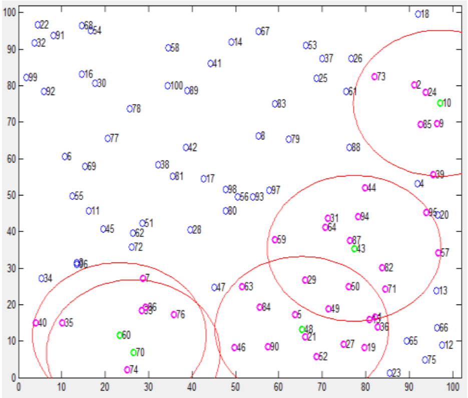


Fig. 1. PRIMARY NODE AND SECONDARY NODE

Nodes which present in interference range are primary nodes. Fig. 1 shows about node arrangement.

The numbers of nodes taken are 100. In each time slots, node will access the idle primary channels to transmit its packets. If the idle channel is detected, the node will transmit the packet to its destination using queuing theory. The channel keeps sensed in subsequent time slots if idle channel is not available.

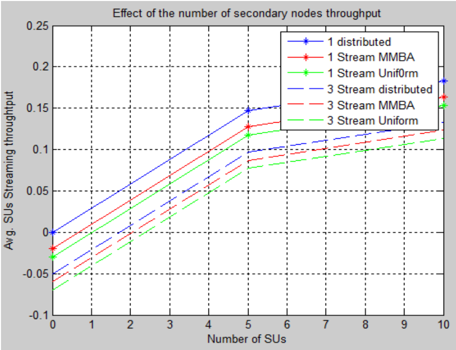


Fig. 2. THROUGHPUT

As number of secondary users is increased, throughput is increased in proposed algorithm compare to MMBA algorithm and uniform allocation algorithm.

The effect of the number of secondary mesh nodes on the per stream throughput is analysed using Fig. 2.

As the number of nodes increases, the node density increases, and hence nodes are closer together. Therefore, links tend to be shorter in length, and paths tend to have fewer hops.

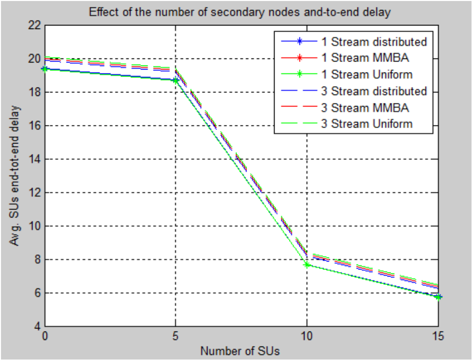


Fig. 3. END TO END DELAY.

The effect of the number of secondary nodes on different stream, average end-to-end delay is analysed using Fig. 3.

The proposed method shows that there is decrease in end-to-end delay compared to other algorithm. As the number of nodes is increased, average end-to-end delay of the secondary users for different traffic streams was reduced.

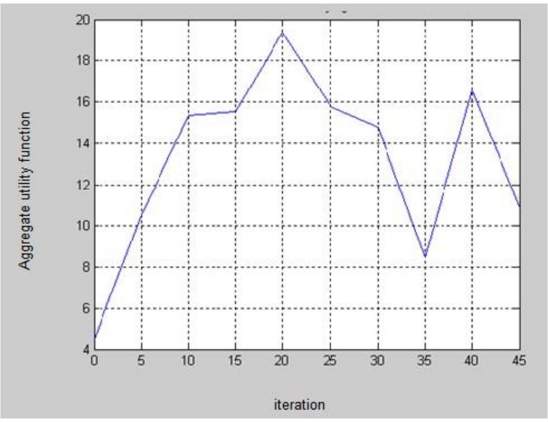
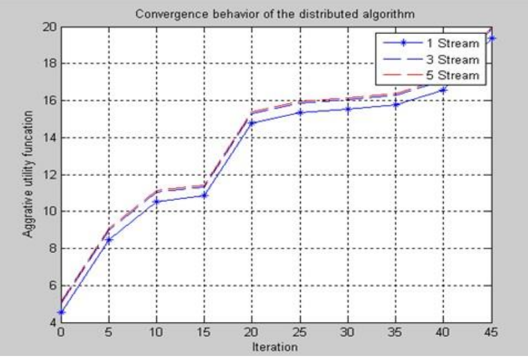


Fig .4. UTILITY FUNCTION WITH RESPECT TO ITERATION

Network behaviour is analysed in terms of aggregate utility function with respect to number of iterations are shown in Fig. 4.

As the number of iteration is increased, resources utilization of different streams are reduced. Channel availability is detected based on sensing techniques.

Based on the value of decision variable, channel is allocated for the node in a given time slots.



.

Fig. 5. CONVERGENCE BEHAVIOUR

Convergence behaviour of different streams is analysed as shown in Fig. 5. The algorithm converges with respect to number of iteration.

Aggregate utility function is increased for different streams are illustrated. The effect of shorter links gives lower outage probability, and fewer hops result in more resources being allocated to each hop.

VIII. CONCLUSION & FUTURE WORK

The objective of the resource allocation is to maximize the aggregate end-to-end throughput of the different traffic streams in the network. Hence, throughput is improved using distributed algorithm compared to MMBA and Uniform allocation algorithms. Implementation is done in MATLAB.

The MMBA algorithm in [3] maximizes the sum of the throughput of all traffic streams in the network while achieving max-min fairness among them. The optimization variables in the MMBA algorithm are the bandwidth allocated to each link and the fraction of time a given link is active. However, this algorithm is centralized.

There is a 20% decrease in the average delay for the proposed algorithm compared to uniform allocation, and 12% decrease compared to MMBA.

Results demonstrate the efficiency of the proposed decentralized solution scheme, and its ability to adapt to varying network loads.

Performance gains of the proposed algorithm in comparison with uniform resource allocation and max-min bandwidth allocation are demonstrated.

In future work, SINR balancing power control algorithm will be implemented in order to reduce the rise in power level of cognitive radio.

REFERENCES

[1] Kiam Cheng How," Supporting Differentiated Service in Cognitive Radio Wireless Mesh Networks," Computer and Information Science, vol. 3, no. 3; August 2010.

[2] Ejaz ahmed, Muhammad shiraz, Abdullah gani," spectrum-aware distributed channel assignment for cognitive radio wireless mesh networks," Malaysian Journal of Computer Science, pp.232-250.

[3] Jian Tang,Roberto Hincapié,Guoliang Xue,Weiyi Zhang, and Roberto Bustamante,"Fair Bandwidth Allocation in Wireless Mesh Networks With Cognitive Radios," IEEE Transactions on Vehicular Technology, vol. 59, no. 3, March 2010.

[4] Qian Chen__,Mehul Motani__,Wai-Choong Wong,__Arumugam Nallanathan ,"Cooperative Spectrum Sensing Strategies for Cognitive Radio Mesh Networks," IEEE Journal of Selected Topics in Signal processing, vol. 5, no. 1,February 2011.

[5] Lu Xiao, Ping Wang, Dusit Niyato, and Ekram Hossain," Dynamic Spectrum Access in Cognitive Radio Networks with RF Energy Harvesting," IEEE_Wireless_Communications ,vol. 21, Issue.3, June 2014 .

[6] Doha Hamza, Sonia Aïssa and Ghassane Aniba,"Equal Gain Combining for Cooperative Spectrum Sensing in Cognitive Radio Networks ," IEEE Transactions on Wireless Communications, voL. 13, no. 8, August 2014.

[7] Shraboni Jana, Kai Zeng, Wei Cheng, and Prasant Mohapatra, Fellow, IEEE ,"Trusted Collaborative Spectrum Sensing for Mobile Cognitive Radio Networks, IEEE Transactions on Information Forensics and Security, vol. 8, no .9, September 2013.

[8] O.Altrad, S.Muhaidat, A.Al-Dweik, A.Shami, and P.D. Yoo," Opportunistic Spectrum Access in Cognitive Radio Networks Under Imperfect Spectrum Sensing" IEEE Transactions on Vehicular technology, vol. 63,no .2, February2014.

[9] Amithineni Jyothsna,, Ch.V.Phani Krishna, Pavan Kumar , Rajasekhara Rao K, V.Samson DevaKumar," Cognitive Radio Wireless Mesh Networks: A Survey on Routing Protocols," IJCSET |April 2013 | vol. 3, Issue 4, 129-13.

[10] C. Xin, B. Xie, and C. Shen, "A novel layered graph model for topology formation and routing in dynamic spectrum access networks,"in *Proc. IEEE DySPAN*, Baltimore, MD, USA, pp. 308–317, November 2005.

[11] A. El-Sherif, A. Mohamed, and Y. C. Hu, "Joint routing and resource allocation for delay sensitive traffic in cognitive mesh networks," in *Proc. IEEE Globecom Workshop RACCN*, Houston, TX, USA, pp. 947–952, December 2011.

[12] F.P.Kelly, A.Maulloo and D.Tan, "Rate control for communication networks: Shadow prices, proportional fairness and stability,"*J. Operat. Res. Society*, vol. 49, no. 3, pp. 237–252, 1998.

[13] K. Haghighi, E. G. Strom, and E. Agrell, "On optimum causal cognitive spectrum reutilization strategy," *IEEE J. Select. Areas Commun.*, vol. 30, no. 10, pp. 1911–1921, November 2012.

[14] M. Levorato, U.Mitra, and M. Zorzi, "Cognitive interference management in retransmission-based wireless networks," *IEEE Trans.Inf. Theory*, vol. 58, no. 5, pp. 3023–3046, May 2012.