A Review: Routing Protocols for Cognitive Radio Networks

Gaurav Singh Negi
B.T.Kumaon Institute of Technology,
Dwarahat,Uttarakhand gauravsnegi747@gmail.com

Naveen Chandra Arya
B.T.Kumaon Institute of Technology, Dwarahat,Uttarakhand

Yogesh Chandra Tripathi
B.T.Kumaon Institute of Technology, Dwarahat,Uttarakhand

Varun Kumar Kakar
B.T.Kumaon Institute of Technology, Dwarahat,Uttarakhand

Abstract-Research works in cognitive radio networks mainly focused on spectrum sharing and sensing, scheduling for single and multihop communication systems. Routing is an important issue in multi-hop cognitive radio networks and is responsible for the performance of a network under different network conditions. Recent advances have led to many protocols designed specifically for CRN'S where different approaches are used. In this paper we present a review of various routing protocols for CRN's like CogLEACH, SEARCH etc.

Keywords**:** Cognitive, Cluster head, Spectrum, Routing, Communication segment.

I. Introduction

According to a report by Federal Communication Commission the spectrum bands allotted on the basis of static allocation strategies are used over a bounded geographical area or for a limited amount of time resulting in underutilization of resources. Cognitive radio network is a new paradigm and is now seen as a solution to the 'spectrum scarcity' problem in wireless communication systems. Cognitive radio network takes benefit of the vacant spaces also called 'white spaces' or 'spectrum holes' present in spectrum licensed for T.V. broadcast, public services etc and uses them for communication purposes. In this paper the author proposes a hybrid routing protocol which selects the optimal route with highest and lowest rate and delay respectively

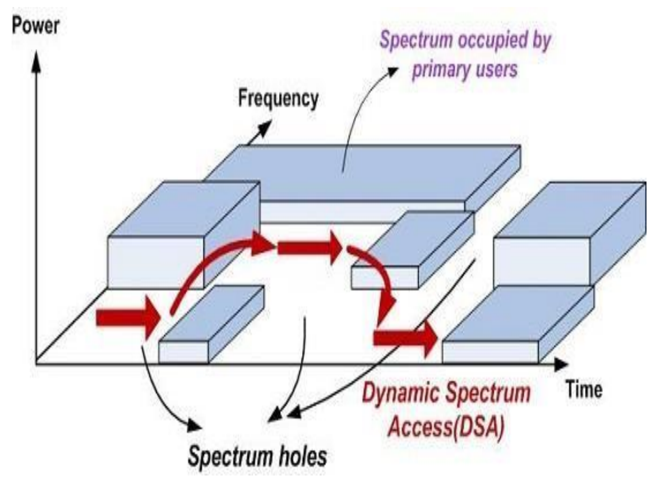

Figure 1. White Spaces or Spectrum Holes in Spectrum

In Cognitive radio networks, two types of users share the same spectrum band but with different strategies: primary or licensed users and secondary or unlicensed user. Primary users have been allotted a specific band of spectrum to carry out the communication. This spectrum when not being used by the PU is used opportunistically by the SU without causing any disturbance to PU. A secondary user must be equipped with a good sensing capability and an efficient radio control because it has to change various operating parameters such as frequency, transmission power etc frequently. This ability to change its operating frequency is known as Dynamic Spectrum Access which gives CRN's the ability to use the white spaces available in the spectrum.

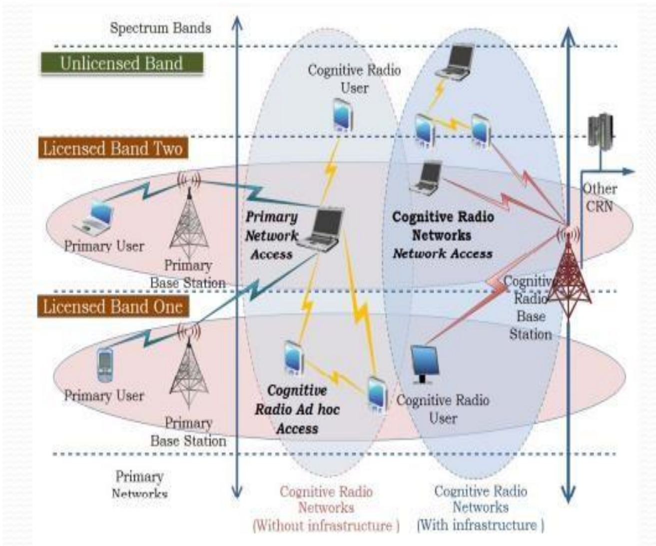

Figure 2. Cognitive Radio Network

Figure 2 shows how a primary user can only access the licensed band while a cognitive user can use both licensed and unlicensed band in an opportunistic manner. CRN's can be classified on the basis of architecture in two types: Infrastructure based CRN's where the communication has centralized control known as Base station and In Infrastructure-less CRN's the control is decentralized also known as Ad-hoc Networks. Cognitive user basically works in following steps:

(1) It first senses the spectrum environment.

(2) Then it searches the vacant or white spaces.

(3) After that it selects the optimal band according to availability and uses it.

Routing is different in cognitive radio networks then the conventional ad-Hoc networks. Cognitive radio networks are more adaptive to changes taking place in spectrum availability. Some of the problems faced in designing routing strategy for CRN's[4]:

(1) Change in topology of the network due to activity of PU's.

(2) Channels have different characteristics like delay, bandwidth etc.

(3) Large number of handoffs due to the frequent change in operating frequency of PU.

(4) Limitations on power supply and computational capability.

II. Literature Review

In this section we are describing working operation of various routing protocols for cognitive radio networks and are as follows:

2.1 On Demand Hybrid Routing for Cognitive Radio Ad-Hoc Networks

Mahdi Zareei et.al. IEEE ACCESS 2016.In this paper the author proposes a hybrid routing protocol which selects the optimal route with highest and lowest rate and delay respectively. It is a hybrid protocol which uses proactive routing for intra-cluster communication and reactive routing for inter-cluster communication [6]. In this protocol, clustering is defined as maximum vertex biclique problem and a cluster head election value is defined to select optimal cluster head. Cluster head is selected taking into account the mobility of the node and total number of neighbors to avoid frequent clustering, providing stability to the cluster.

Source nodes send the CHRReq packet to cluster head which in response sends CHRRep to the source if the destination is in the same cluster. Otherwise, it broadcast the request packet attaching its id, hop count, achievable data rate, density and cluster channel with it. After destination receives CHRReq packet it will calculate the weight for available routes and will choose the path with minimum value of M(r).

Path optimization is done by using Evolutionary dynamic weighted aggregation method and optimal route selection is formulated as

$$M(r) = \min\left(w_1 . \mu T^{C}(r) + w_2(r) . \frac{1}{\ } + w_3(r) . H_T(r)\right) \quad \text{.................. (1)}$$

$$\text{s.t. } w_i(r) \geq 0 \quad \text{where } \sum_{i=1}^{3} w_i(r) = 1$$

where $w_1(r)$, $w_2(r)$, $w_3(r)$ are the weights assigned to
C

DOI-10.18486/ijcsnt.2017.6.1.03
ISSN-2053-6283

density($\mu T(r)$),achievable data rate($R_T(r)$) and hop count($H_T(r)$) respectively. Values of these weights change periodically between 0 to 1 resulting in a set of Pareto optimal solutions instead of a single solution. OCHR performance does not get affected due to increase in the number of PU due to adaptive clustering mechanism.

2.2 Cog-LEACH: A Spectrum Aware Clustering Protocol For Cognitive Radio Sensor Networks

Rashad M.Electreby et.al. CROWNCOM 2014.This protocol is an extension to state of art LEACH [8] protocol with spectrum aware characteristics. Primary user activity is modeled as a semi-Markov on-off process. To protect PU's from interference from SU's IPR(interference protection range) is defined[10]. Primary objective is to minimize P_i (t) which is given by

$$P_i(t) = \min(k \frac{C_i}{\sum_{J=1}^{N} C_j}, 1) \quad \text{..................} (2)$$

where c_i and c_j denotes the number of idle channels for node i for node j respectively and k is total number of clusters in the network. This protocol works in four phases:

In Phase1 the every node senses the available channels and determines the number of idle channels. After that Phase2 starts and cluster head is selected on the basis of value obtained in the phase1.Phase3 is cluster formation phase in which cluster head sends CH_Tentative_Announcement message replied by non-CH nodes by Tentative_Join_Request. Then the channel is selected which is common for the most number of requesting nodes, CH_Final_Announcement is broadcasted and TDMA schedule is transmitted to all the nodes. Finally, phase4 accounts for data transmission to cluster head using DSSS spreading code.

In this protocol, clustering is performed using a minimum number of message transmissions for different network models. Protocol performance is studied under three models differentiated on the basis of spatial and spectrum similarities between the primary users:-

(1) Spatial and Spectrum Similarity model: Every node is in the range of PU's and have same stationary probability of idle channel($p_{f.}$) for different channels ensuring similar onoff characteristic

$$Pi(t) = \min (k \frac{Ci}{N\mu}, 1)s. \text{.....................} (3)$$

μ represents mean of binomial distribution responsible for number of channels can be sensed.

(2) Spectrum similarity model: Some nodes are not in the range of PU's and different pf but have same on-off characteristics.

$$P_i(t) = \min(k \frac{Ci}{N1 * pf1 * m + N2 * pf2 * m}, 1) \text{............} (4)$$

Where N_1 and N_2 are subset of nodes with in range and out of range of PU's selected according to PU effective area.

(3) Arbitrary Model: Every characteristic discussed above of PU systems are different in this model. $P_i(t)$ is broadcasted by the base station after sensing idle channels resulting in a centralized solution of the estimation.

2.3 Energy-aware Routing Protocol for Cognitive Radio Ad Hoc Networks

S.M.Kamruzzaman et.al IET Communications 2012. In this paper, author has proposed routing protocol based on Dynamic source routing to increase the network lifetime by combining the selection of route and channel timeslot allocation[7]. A Pair of channel and timeslot is known as 'communication segment'. Frame is divided into three windows:

(i)Sensing window: vacant channels not used by primary users are searched.

(ii)Ad-hoc traffic indication messages: first the beacon sensing is performed in a time division mode getting aware about free segments among total number of communication segments. Then the control packets are exchanged which have information regarding the routes.

(iii) Communication window: CR users transmit or receive the data in this part of the frame.

Routing problem is formulated as choosing the path with maximum nodal residual energy and minimum hop count with these three constraints:

Hop count ≤ time to live.

$$E_{\text{residual energy}} \geq E_{\text{threshold}}.$$

Communication segment available ≥ Bandwidth required of route requested

This Routing protocol works in three phases:

DOI-10.18486/ijcsnt.2017.6.1.03
ISSN-2053-6283

(1) Route discovery: RREQ is broadcasted by the source node. Lowest battery energy value (ME_{res}) is received by the destination node which is known as 'minimal residual path energy'. Battery energy of node should be higher than the threshold energy level (E_{th}) to take part in route discovery. (2) Route selection: After RREQ packets are received by the destination, it replies by sending RREP packet containing the route utility and route record. Source node receives the RREP packet, changes the state of channels to reserve and begins data transmission.

(3) Route maintenance: Communication segment is reassigned in case of destination unable to receive data and is known as 'Segment Reassignment'. If source finds no segments free for allocation or destination goes far from transmission range then source decides to change the route and process is known as 'Local Recovery'. If local recovery is not feasible then RERR packet is sent to source which is called 'Route Rediscovering'. In 'Route Discovery by Cached route' backup paths are searched in route cache stored in the previous step chosen according to highest priority.

2.4 SEARCH: A Routing Protocol for Mobile Cognitive Radio Ad-hoc Networks

Kaushik R.Chowdhury, Marco Di Felice, IEEE 2009.The author proposed a geographical location based protocol primarily designed for multi-hop CRN's. It selects short paths based on geographical forwarding routing, keeping route out of the regions of PU activity [5]. Then the channel switching is scheduled by the destination node minimizing the hop count. This protocol works in two phases:

A. Route Setup: Route request is sent from the source node to every channel free from PU use. Each intermediate node adds its ID, current location, time stamp and flag status with the RREQ packet. Two modes are designed according to the situation:

(1) Greedy forwarding: This phase decides which of the node should be chosen to pass RREQ to minimize the hop count to the destination. It must be out of the coverage region of PU and should lie in a specific area around the current forwarder called 'Focus Region' having an angular range of 2ϴ centred around line joining source to destination.

(2) PU avoidance: When the nodes in the focus region of current forwarder come in PU activity region it is marked as decision point and this mode is activated. Now the route circumvent around the destination nodes until the current node finds candidate node in its focus region changing PA flag status from set to reset.Route is altered around destination node till greedy forwarding is resumed.

(3) Joint path channel optimization: Once the destination receives RREQ packet, it chooses the channel and end to end path for the data transmission.

B. Route Enhancement: Feasible path is discovered by the destination node checking gain of the paths on different channels within ɳ hops from DP and selected after comparing latency with the previously used paths.

III. Conclusion

Routing in multi-hop CRN's is different from Conventional Networks due to variation in channel availability with time and parameters other than distance affecting the network availability. In this paper, we discussed the difference in suggesting routing strategy for CRN's from conventional networks and a survey of the available routing techniques with different approaches highlighting the routing operation. Present day techniques use the conventional routing metrics which are unable to use the dynamic characteristics of the CRN's. So there is a need to design new routing metrics according to the behaviour of the CRN's.

References

[1] F.C.Commission, "Fcc adopted rules for unlicensed use of television white spaces, tech.rep.et docket no.04-186, second report and order and memorandum opinion and order," **(2004)**.

[2] S. Haykin, "Cognitive Radio: Brain –empowered Wireless Communications," IEEE Journal on selected areas in communications, vol.23, no.2, pp. 201-220,**(2005).**

[3] I.F.Akyildiz, W.Y.Lee, M.C.Vuran, and S.Mohanty, "NeXt Generation/Dynamic Spectrum Access/Cognitive Radio Wireless Networks: A Survey", Elsevier Computer Networks Journal, 50:2127-2159, September **(2006)**.

[4] W.Heinzelman, A.chandrakasan, and H.Balakrishnan, "An Application-specific Protocol Architecture for Wireless Microsensor Networks", IEEE Transactions on wireless communication, vol1, no.4, pp. 660-670, **(2002).**

DOI-10.18486/ijcsnt.2017.6.1.03
ISSN-2053-6283

[5]. K.chowdhury and M.felice, “SEARCH: A Routing Protocol for Mobile Cognitive Radio Ad-hoc Networks”, computer communication, pp.1983-1997, **(2009)**.

[6]. Mahdi Zareei et.al., “On-demand Hybrid Routing for Cognitive Radio Ad-Hoc Network”, IEEE Access, **(2016)**.

[7]. S.M.Kamruzzaman et.al., “Energy-aware Routing Protocol for Cognitive Radio Ad hoc Networks”, IET Communications **(2012).**

[8]. Jamal N. Al-Karaki and Ahmed E. Kamal, “Routing technique in wireless sensor networks: A Survey,” in Magnetism, vol. III, G.T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271-350.

[9]. Cesana, M., Cuomo,et.al., “Routing in Cognitive Radio Networks: challenges and solutions”, Ad Hoc Networks, pp.228-248 **,(2011)**.

[10]. Purnendu Shekhar Pandey,Rajesh Singh ,A Paper titled ‘‘ECG Monitoring System in Wireless Personal Area Network simulation and design using Zigbee Transceiver Module for Health Care Solution” published in IJCA(0975-8887) Volume 46 No.18 on May 2012.

[11]. Purnendu Shekhar Pandey,Nitin Gupta ,Ajay Raturi, BanitNegi,A paper tittle “Design and Simulation of Message Display on LCD Integrated with Power Line Carrier Communication Modem with Biometrics System” International Journal of Computer Applications (0975 – 8887) Volume 85 – No 13, January 2014.

[12] R.M. Eletreby, H.M. Elsayed, and M.M. Khairy, “Cog LEACH: A Spectrum Aware Clustering Protocol for Cognitive Radio Sensor Networks”, cognitive radio oriented wireless networks and communications (CROWNCOM), 2014 9th international conference on. IEEE,pp. 179-184,**(2014)**.

[13] Ashish Bagwari, GS Tomar, "Cooperative Spectrum Sensing with Adaptive Double-Threshold Based Energy Detector in Cognitive Radio Networks" Springers International Journal of wireless personal Communication, Vol. 73, No.3, pp 1005-19, Dec 2013.

[14]. Ashish Bagwari, GS Tomar, "Cooperative Spectrum Sensing in MEDs Based CRNs Using Adaptive Double-Threshold scheme", Taylors and Francis - International Journal of Electronics, Vol. 101, Issue 4, pp 37-41, Feb 2014.

[15]. Ashish Bagwari, GS Tomar, “Cooperative Spectrum Sensing with Multiple Antennas using Adaptive DoubleThreshold Based Energy Detector in Cognitive Radio Networks”, Springers Journal of Inst of Engg, India, Series B, Vol.95 No.2 pp.107-112, 2014.