ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

Spectrum Aware Any-path Routing In Cognitive Radio Networks

[1]Ramya.R, [2]S.Radhika

PG Scholar, Department of ECE, Sri Venkateswara College of Engineering, Sriperumbudur, Chennai, India

Assistant Professor, Department of ECE, Sri Venkateswara College of Engineering, Sriperumbudur, Chennai, India

ABSTRACT: In the proposed work create a Cognitive Radio Networks(CRNs) which consists of 5 channels, 10 Primary Users(PUs) and 50 Cognitive Radio Routers(CR Routers).let us consider the created network as Cognitive Capacity harvesting(CCH) Network. Now introduce the Spectrum Aware Any-path Routing(SAAR) in the CRNs. A new cognitive any-path routing metric is designed based on channel and link statistics to accurately estimate and evaluate the quality of an any-path under uncertain spectrum availability. A polynomial-time routing algorithm is also developed to find the best channel and the associated optimal forwarding set and computes the least cost any-path.

KEYWORDS:Cognitive Radio Networks(CRNs), Spectrum Aware Any-path Routing(SAAR).

I. INTRODUCTION

With remarkable the increase of smartphone, many mobile applications, such as mobile social networks, mobile health, online gaming and so on, have been widely developed, resulting in tremendous growth in mobile data traffic. This trend will continue, leading to serious spectrum crisis. Cognitive radio networks (CRNs) have been emerging as a promising technique to improve the spectrum efficiency to meet this increasing mobile traffic demand.

The performance of CRNs heavily depends on routing protocols. On one hand, the routing protocols should be spectrum-aware and consider the spectrum uncertainty feature of CRNs. On the other hand, it should provide reliable performance in unreliable network environment of CRNs due to the unreliable characteristic of wireless medium. As one of the most promising solutions to address unreliable nature of wireless transmission, any-path routing has been well-studied in traditional wireless networks, which achieves significant performance improvementas compared with unicast routing. However, there isnot much research devoted to the any-path routing algorithms for CRNs is too high to be implemented in practice. It is also very challenging to develop an efficient routing protocol to compute the optimal any-path in CRNs, since the searching space grows exponentially fast as the number of available channels and the size of the network increase protocol design for CRNs. One of the main challenges is to accurately estimate and evaluate the quality of an any-path under uncertain spectrum availability, which is a salient difference between CRNs and traditional wireless networks and must be carefully considered and modelled in the routing metric. In addition, the computational complexity of existing any-path routing algorithms for CRNs is too high to be implemented in practice. It is also very challenging to develop an efficient routing protocol to compute the optimal any-path in CRNs, since the searching space grows exponentially fast as the number of available channels and the size of the network increase.

To overcome these challenges, in this paper, we propose a novel spectrum-aware any-path routing protocol (SAAR) for multi-hop CRNs. We use a recently proposed network architecture for CRNs, called Cognitive Capacity Harvesting networks (CCHs) [1]-[3],as an example to illustrate our design. CCH consists of a secondary service provider (SSP), cognitive base stations (BSs), cognitive radio routers (CR routers), and secondary users (SUs). The SSP is the operator and manager of CCH, which harvests spectrum resource and allocates it to the network. The CR routers are equipped with cognitive radios, which perform spectrum sensing, collect demand from SUs, and transmit their data around over available licensed spectrum. The BSs are interconnected with high-speed wired links and serve as the gateways of CCH. SUs include wireless devices using traditional wirelessaccess technologies, and also include wireless devices that are equipped with advanced cognitive radios for communication. CCH forms a spectrum cloud and facilitates the access of SUs with or without cognitive radio capability (See Section 3 for details), which represents a design paradigm shift from individual benefit to collective welfare. Note that the any-path routing protocol SAAR we proposed can be used in any multi-hop CRN with a central node that can perform channel and link information collection and routing table computation, which is not limited to CCHs.

The main contributions of this paper can be summarized as follows:

- We take both the spectrum uncertainty of CRNs and the unreliable transmission characteristics ofwireless medium into consideration, and quantify their effects on the cost to transmit a packetfrom the source node to the destination alongan any-path in CRNs in a new routing metric to better estimate the performance of the any-path.
- We extend the Bellman-Ford algorithm and develop a polynomial-time routing algorithm tofind the best channel and the associated optimal forwarding set and compute the least costany-path with low computation overhead.
- Extensive simulation results demonstrate that SAAR significantly increases packet delivery ratio and reduces end-to-end delay, which makesit suitable and scalable to be used in practicalmulti-hop CRNs

II. RELATED WORK

As an important issue in CRNs, the routing problem has drawn considerable attention. Chowdhury et al. [4], [5] and Jin et al. [6] develop distributed routing protocols for cognitive radio ad-hoc networks by considering geographic information. Pan et al. [7] and Li et al.[8]formulate the routing problem in CRNs as a joint routing and link scheduling optimization problem. Ji et al. [9] design an effective semi-structure routing scheme to minimize induced latency and energy consumption. It incorporates power control into the routing framework and realizes energy-efficient routing for CRNs. Liang et al. [10] investigate the spectrum-mobility-incurred route switching problem in both spatial and frequency domains for CRNs, and address the routing problem with game theory.

Ping et al. [11] propose a spectrum aggregation-based cooperative routing protocol for cognitive radio ad hoc networks. Chen et al. [12]develop a cooperative routing algorithm using mutual-information accumulation for underlay CRNs by dynamically controlling the transmission power of SUs so that its interference to PUs is tolerable. Youssef et al. [13] review the routing metrics utilized in CRNs, such as the delay, hop count, routing stability, power consumption, etc., and summarize the generally adopted routing algorithms. The aforementioned works build only one single path from a source to a destination, which is not robust to unreliable wireless links in CRNs. Liu et al. [14]-[16] exploit the broadcast nature of the wireless medium and propose an opportunistic routing scheme. They introduce a cognitive transport throughput metric and propose a heuristic algorithm to calculate routing paths. Lin et al. [17], [18] analyze the opportunistic routing in CRNs with a traffic model. Zeng et al. [19], [20] model the opportunistic routing problem as an optimization problem and introduce a heuristic algorithm to calculate the optimal forwarding set and routing path.

III. PROPOSED ALGORITHM

A. *Design Considerations:*

The architecture of CCH [1]-[3] is shown in Fig. 3.1. It consists of four types of network entities: an SSP, a few number of BSs, and a large number of CR routers and SUs. We assume that SSP has its own spectrum (called basic band) and its deployed network facilities (BSs and CR routers) can use the basic band to provide basic reliable services. The BSs and CR routers are equipped with multiple cognitive radios, which can tune to any basic band or harvested band for communication. With cooperation of BSs and CR routers, the SSP harvests spectrum resource and allocates it on demand. The SSP, BSs, and CR routers form a spectrum cloud and could provide service for SUs with or without cognitive capability. In this spectrum cloud, the SSP is the manager, the BSs act as gateways of the cloud and further connect to Internet or other data networks, and the CR routers and BSs are the access points which facilitate SUs to access the CCH.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

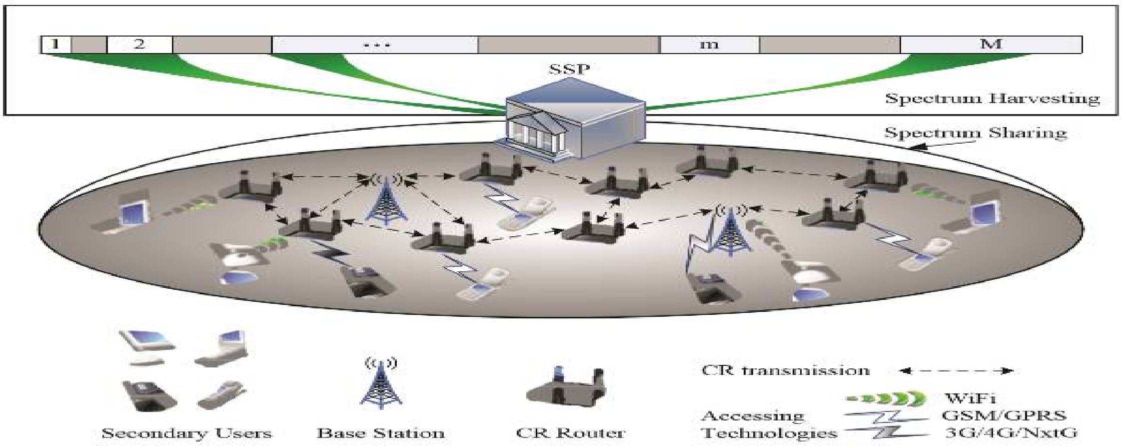

Fig. 1 Cognitive Capacity Harvesting(CCH) networks

The SUs can be any wireless device using any accessing technique (e.g., Laptops, tablets, or desktop computers using Wifi, cell phones using GSM/GPRS, smart phones using 3G/4G/NxtG, etc.). If a SU has cognitive capability, it could communicate with CR routers and BSs over both harvested bands and basic band. Otherwise, it could only communicate over the basic band. As a spectrum cloud, the performance of CCH heavily depends on the routing protocol, which needs to provide optimal and reliable routing between any two nodes (two CR routers, two BSs, or one CR router and one BS) for internal communication in the CCH domain, or a node (CR router) and multiple gateways (BSs) for external communication.

B. *Description of the Proposed Algorithm:*

The proposed algorithm is consists of three main steps. Suppose there are N_B BSs and N_R CR routers equipped with multiple cognitive radios in our CCH. Let N denote the total number of nodes in the CCH, i.e., $N = N_B + N_R$. With cooperation of BSs and CR routers, the SSP has the statistical knowledge about every channel and every location. A channel in the basic band is used as the common control channel (CCH) for signalling exchange, and there are M orthogonal channels that can be used for transmitting packets. We model the network as a hypergraph $G = (V, E)$, where V is the set of BSs and CR routers, and E represents a set of hyperedges or hyperlinks. For each link from node i to j, there is a packet delivery c for each channel m = 1,..,M. A hyperlink is an ordered pair (i, J_i^m) ∈ E, where i ∈ V and is the forwarding set of node i on channel m. The hyperlink probability p_{ij}^m on channel m is define as the probability that a packet transmitted by node i is successfully received by atleast one node in J_i^m.

Step 1: Calculate hyperlink delivery probability p_{ij}^m can be calculated as

$$p_{iJ}^m = \prod_{j \in J_i^m} (1 - p_{ij}^m).$$

Step 2: Calculate channel quality q_i^m of node i on channel m as follows

$$q_i^m = \frac{E[T_{off}^m]}{E[T_{off}^m] + E[T_{on}^m]} * \frac{E[T_{off}^m]}{\max\limits_{k=1,\dots,M} E[T_{off}^k]}$$

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering
(An ISO 3297: 2007 Certified Organization)
Website: www.ijircce.com
Vol. 5, Special Issue 3, April 2017

Due to the randomness of the transmission activities of PUs, we model the occupation of PUs in each channel as an independently and identically distributed alteration between two states, i.e., ON state when PU is active and OFF state when PU is inactive. We can measure the expected channel OFF time E[T_{off}^{m}] and channel ON time E[T_{on}^{m}] by periodic sensing.
Where $\max_{k=1,\ldots,M} E[T_{off}^{k}]$ indicates the maximum expected channel OFF time on all feasible channels.

Step 3: Calculatingexpected cognitive any-path transmission (ECATX)

$$ECATX(i, J_i^m) = \frac{1}{p_{ij}^m * q_i^m}$$

A larger channel quality q_i^m indicates that channel m is better and more suitable for transmitting packets. The knowledge about packet delivery probability p_{ij}^m and channel quality q_i^m can be acquired by the SSP with the cooperation of BSs and CR routers.

IV. Pseudo code: SAAR Routing Algorithm

Step 1:**Input:**
Hypergraph G=(V,E)
Channel quality q^i
Packet delivery probability p^{ij}
Destination node set d
Output:
The optimal least-cost any-path from every node to the destination node set d,and the forwarding set for each forwarding channel at every node as well as their corresponding priorities along the path.

Step 2:**Initialization:**
for i=1 to N do
$D_i = \infty$,
for m=1 to M do
$D_i = \infty$,
$D_i^m = \infty$
$J_i^m = \emptyset$
end
if $i \in d$ then
$D_i = 0$,
$D_i^m = 0$ for m= 1 to M.
end
end
Step 3:**Any-path cost calculation:**
for loop = 1 to N-1 do
for i = 1 to N do
for m = 1 to M do
N(i) = GetNeighbours(i),
$\hat{J} = \emptyset$
$D_i^m = \infty$
while N(i) ≠ ∅ do
i = argmin (D_J),
j = 1,…..,|N(i)|
$\hat{J} = \hat{J} \cup j$,

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

$\widehat{D}_i^m = D_{i\hat{j}}^m + D_{\hat{j}}^m$,

if $\widehat{D}_i^m < D_i^m$ then

$J_i^m = \hat{j}$

else

break

end

N(i) = N(i) -{j}

end

end

$D_i = \sum_{m=1}^{M} \alpha_i^m D_i^m$

end

If none of value D_i changes in the loop then

break

end

end

Step 4:**Forwarding set Determination:**

for i = 1 to N do

Sort the forwarding sets of different channels for node i according to the values of q_i^m in descending order.

end

V. SIMULATION RESULTS

The simulation studies involve the deterministic small network topology with 60nodes as shown in Fig.2.

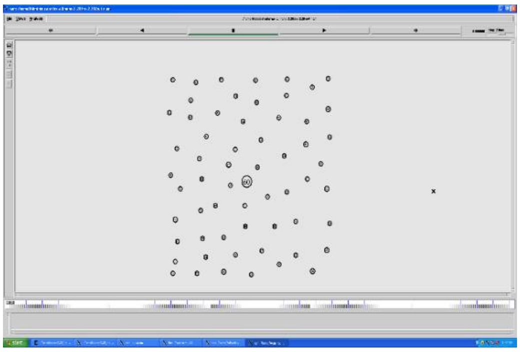

Fig. 2 Illustrates a small CRNs consisting of 60 nodes.

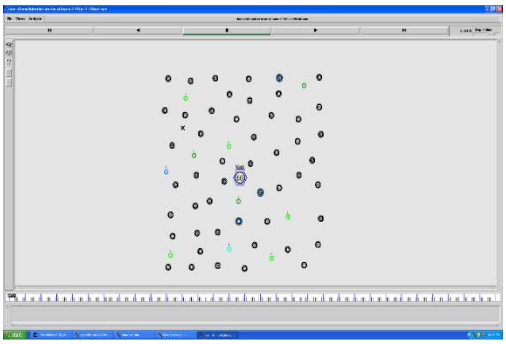

Fig. 3 Shows the movement of Primary Users(PUs)

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

SAAR algorithm

Input:

Enter the source node Id(10-60)

13

Enter the destination node Id(10-60)

59

Output:

The path from source to destination is:

13 49 19 27 45 59

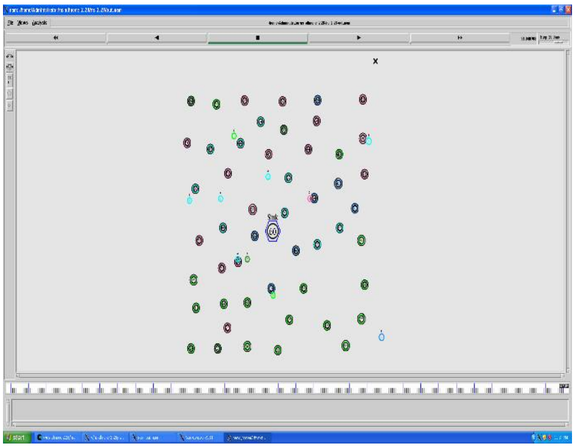

Fig. 4 Shows the nodes switching from one channel to another channel

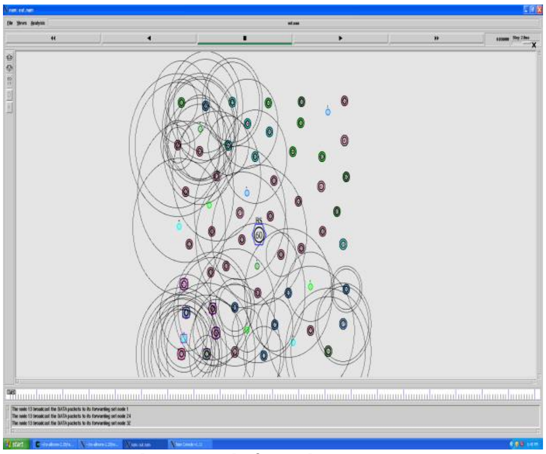

Fig. 5 Forwarding set node for node 13

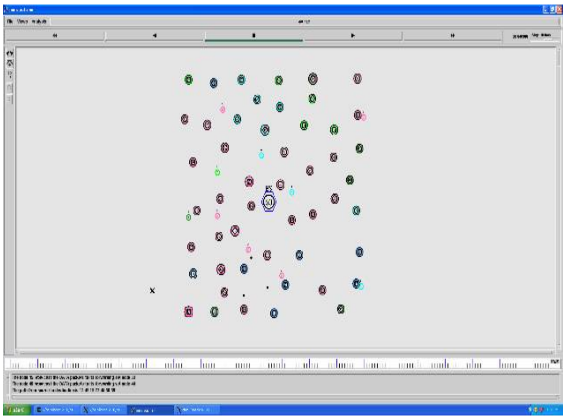

Fig. 6 Neighbours of node 13

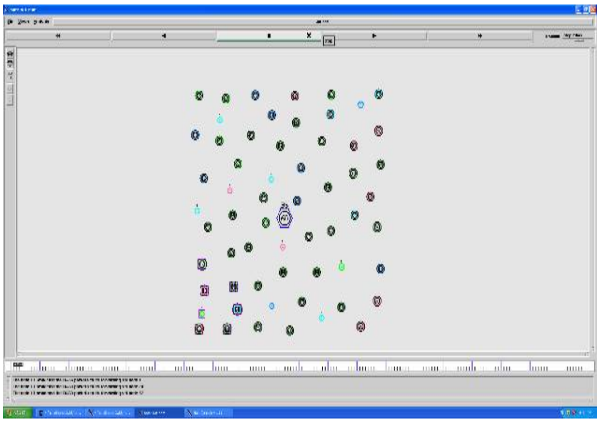

Fig. 7 Shows forwarding set for node 13

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

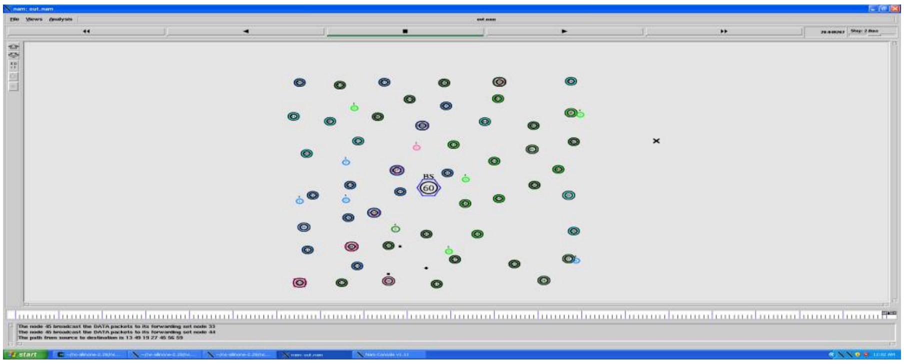

Fig 8 least cost any-path from node 13 to 59

VI. CONCLUSION AND FUTURE WORK

To improve the performance of CRNs and make it a robust spectrum cloud, taking cognitive capacity harvesting network as an example, we have developed a novel any-path routing mechanism SAAR. SAAR considers both the spectrum uncertainty of CRNs and the unreliable transmission characteristics of wireless medium. It could build an any-path between a source node and a set of destination nodes efficiently, where the path and gateway for each packet are determined.

REFERENCES

1. M. Pan, C. Zhang, P. Li, and Y. Fang, "Spectrum Harvesting and Sharing in Multi-hop Cognitive Radio Networks underUncertain Spectrum Supply," IEEE Journal on Selected Areas inCommunications, vol. 30, no. 2, pp. 369-378, Feb. 2012.
2. M. Pan, H. Yue, C. Zhang, and Y. Fang, "Path Selection underBudget Constraints in Multi-hop Cognitive Radio Networks, "IEEE Trans. on Mobile Computation, vol. 12, no. 6, pp. 1133-1145,Jun. 2013.
3. H. Yue, M. Pan, Y. Fang, and S. Glisic, "Spectrum and Energy Efficient Relay Station Placement in Cognitive Radio Networks," IEEE Journal on Selected Areas in Communications, vol. 31, no.5, pp. 883-893, May 2013.
4. K. R. Chowdhury and M. D. Felice, "Search: A Routing Protocol for Mobile Cognitive Radio Ad-Hoc Networks," Computation Communication, vol. 32, no. 18, pp. 1983-1997, Dec. 2009.
5. K. R. Chowdhury and I. F. Akyildiz, "CRP:A Routing Protocol for Cognitive Radio Ad Hoc Networks," IEEE Journal on Selected Areas in Communications, vol. 29, no. 4, pp. 794-804,Apr. 2011.
6. X. Jin, R. Zhang, J. Sun, and Y. Zhang, "TIGHT: A Geographic Routing Protocol for Cognitive Radio Mobile Ad Hoc Networks," IEEE Trans. on Wireless Communication, vol. 13, no. 8, pp.4670-4681, Aug. 2014.
7. M. Pan, C. Zhang, P. Li, and Y. Fang, "Joint Routing and Link Scheduling for Cognitive Radio Networks under UncertainSpectrum Supply," in Procedure IEEE INFOCOM 2011, Shanghai,China, Apr. 2011, pp. 2237-2245.
8. M. Li, S. Salinas, P. Li, X. Huang, Y. Fang, and S. Glisic,"Optimal Scheduling for Multi-radio Multi-channel Multi-hopCognitive Cellular Networks," IEEE Trans. on Mobile Computing, vol. 14, no. 1, pp. 139-154, Jan. 2015.
9. S. Ji, M. Yan, R. Beyah, Z. Cai, Semi-Structure Routing and Analytical Frameworks for Cognitive Radio Networks, IEEETrans. on Mobile Computation, to appear.
10. Q. Liang, X. Wang, X. Tian, F. Wu, and Q. Zhang, Two-dimensional Route Switching in Cognitive Radio Networks:A Game-Theoretical Framework, IEEE Trans. on Networking, vol. 23, no. 4, pp. 1053-1066, Aug. 2015.
11. S. Ping, A. Aijaz, O. Holland, and A. Aghvami, SACRP: A Spectrum Aggregation-Based Cooperative Routing Protocolfor Cognitive Radio Ad-Hoc Networks, IEEE Trans. on Communication, vol. 63, no. 6, pp. 2015-2030, Apr. 2015.
12. H. Chen, L. Liu, J. D. Matyjas, and M. J. Medley, Cooperative Routing for Underlay Cognitive Radio Networks UsingMutual-Information Accumulation, IEEE Trans. on WirelessCommunication, vol. 14, no. 12, pp. 7110-7122, Aug. 2015.
13. M. Youssef, M. Ibrahim, M. Abdelatif, L. Chen, and A. V.Vasibakos, "Routing Metrics of Cognitive Radio Networks: ASurvey," IEEE Communication Surveys & Tutorials, vol. 16, no. 1, pp.92-109, Feb. 2014.
14. Y. Liu, L. Cai, and X. Shen, "Spectrum- Aware Opportunistic Routing in Multi-Hop Cognitive Radio Networks," IEEE Journal on Selected Areas in Communications, vol. 30, no. 10, pp.1958-1968, Dec. 2012.
15. Y. Liu, L. Cai, and X. Shen, "Joint Channel Selection and Opportunistic Forwarding in Multi-Hop Cognitive Radio Networks," in Procedure IEEE GLOBECOM 2011, Houston, USA, Dec.2011, pp. 1-5.
16. Y. Liu, L. Cai, X. Shen, and J. W. Mark, "Exploiting Heterogeneity Wireless Channels for Opportunistic Routing in DynamicSpectrum Access Networks," in Procedure IEEE ICC 2011, Kyoto,Japan, Jun. 2011, pp. 1-5.
17. S. C. Lin and K. C. Chen, "Spectrum Aware Opportunistic Routing in Cognitive Radio Networks," in Procedure IEEE GLOBE-COM 2010, Miami, USA, Dec. 2010, pp. 1958-1968.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

18. S. C. Lin and K. C. Chen, "Spectrum- Map Empowered Opportunistic Routing for Cognitive Radio Ad Hoc Networks," IEEETrans. on Vehicular Technology, vol. 63, no. 6, pp. 2848-2861, Jul.2014.
19. K. Zeng, Z. Yang, and W. Lou, "Opportunistic Routing in Multi-Radio Multi-Channel Multi-Hop Wireless Networks,"IEEE Trans. on Wireless Communication, vol. 9, no. 11, pp. 3512-3521,Nov. 2010.
20. K. Zeng, J. Yang, and W. Lou, "On Energy Efficiency of Geographic Opportunistic Routing in Lossy Multi-hop Wireless Networks," Wireless Netw., vol. 18, no. 8, pp. 967-983, Nov.2012.
21. H. Dubois-Ferriere, "Any-path Routing," PhD Dissertation, Ecole Polytechnique Federale De Lausanne, Nov. 2006. [22] H. Dubois-Ferriere, M. Grossglauser, and M. Vetterli, "Valuable Detours: Least-Cost Any-path Routing," IEEE/ACM Trans.on Netw., vol. 19, no. 2, pp. 333-346, Apr. 2011.
22. H. Dubois-Ferriere, M. Grossglauser, and M. Vetterli, "Valuable Detours: Least-Cost Any-path Routing," IEEE/ACM Trans.on Netw., vol. 19, no. 2, pp. 333-346, Apr. 2011.
23. X. Fang, D. Yang, and G. Xue, "A Distributed Algorithmfor Multi-Constrained Any-path Routing in Wireless MeshNetworks," in Procedure IEEE ICC 2011, Kyoto, Japan, Jun. 2011,pp. 1-5.
24. X. Fang, D. Yang, and G. Xue, "MAP: Multi-constrained Any-path Routing in Wireless Mesh Networks," IEEE Trans. OnMobile Computation, vol. 12, no. 10, pp. 1893-1906, Oct. 2013.
25. X. Fang, D. Yang, and G. Xue, "DART: Directional Any-path Routing in Wireless Mesh Networks," in Procedure IEEE MASS2011, Valencia, Spain, Oct. 2011, pp. 590-599.
26. R. Laufer, H. Dubois-Ferriere, and L. Kleinrock, "Multirate Any-path Routing in Wireless Mesh Networks," in Procedure IEEEINFOCOM 2009, Rio de Janeiro, Brazil, Apr. 2009, pp. 37-45.
27. R. Laufer, H. Dubois-Ferriere, and L. Kleinrock, "Polynomial-Time Algorithms for Multirate Any-path Routing in WirelessMulti-hop Networks," IEEE/ACM Trans. on Netw., vol. 20, no.3, pp. 742-755, June 2012.
28. R. Laufer, P. B. Velloso, L. F. M. Vieira, and L. Kleinrock, "PLASMA: A New Routing Paradigm for Wireless Multi-hop Networks," in Procedure IEEE INFOCOM 2012, Orlando, USA, Mar.2012, pp. 2706-2710.
29. P. Feng, F. Wu, B. Liu, and C. Dong, "DSMA: Optimal Multi-rate Any-path Routing in Wireless Networks with DirectionalAntennas," in Procedure 10th IEEE Conference on Wireless Communications and Mobile Computing, Hilton Nicosia, Cyprus, Apr.2014, pp. 381-386.
30. A. Basalamah, S. M. Kim, S. Guo, T. He, and Y. Tobe, "Link Correlation Aware Opportunistic Routing," in Procedure IEEE INFOCOM 2012, Orlando, USA, Mar. 2012, pp. 3036-3040.