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RESEARCH ARTICLE

QoS and Fuzzy Logic Based Routing Protocol for CRN

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Abstract – The tremendous development in wireless technologies and multimedia applications persuaded upsurge in spectrum utilization in the past. One of the adequate clarifications to overwhelm this limitation is by using Cognitive Radios (CR). These networks are likely to boost spectrum consumption professionally by permitting Secondary Users (SUs) to take advantage of the use of the approved spectrum of primary users (PUs). CR is a kind of a sensible radio that can sense the extraneous surroundings, analyze the past and build perspicacious conclusions to switch its transmission factors in step with the current state of the atmosphere. An Ad-hoc Network engaging Cognitive Radios (CR) can often be termed as Cognitive Radio Adhoc Network (CRAHN). Routing in CRAHN is not an easy mission due to spectrum availability, power, link stability, etc. Among all the parameters, the one among the best parameter for route selection is throughput. Since several applications need a high value of throughput like Audio & Video Broadcasting, Interactive audio & Video Streaming, etc. and some require the low value of throughput like E-mail, Telnet, etc. This paper design a routing strategy based on finding an optimal throughput path using fuzzy logic. To show the efficiency of a designed scheme it is compared with the shortest path routing mechanism. Our result shows that the proposed method is efficient than Shortest Spectrum.

Index Terms – Cognitive radios, Fuzzy Logic, Mamdami-Fuzzy Logic Controller, Quality of Service (QoS), Shortest Spectrum.

1. INTRODUCTION

Nowadays wireless technologies are shattering due to which spectrum's rectification is in demand. The radio frequency spectrum faces the deficiency issue in many nations subsequently the effective and convenient utilization of spectrum is needed. Solution to this problem can be Cognitive Radio (CR) [1, 2]. This technology looks forwards to intensify the spectral utilization in the licensed frequencies [3, 4, 5]. Cognitive radio [6, 7] can be presumed as a sensible radio that can sense extraneous surroundings, analyze the past and build perspicacious conclusions to switch its transmission factors in step with the current state of the atmosphere.

Cognitive Radio Ad-Hoc Network is a term for Ad hoc Network employing Cognitive Radios (CR). The two forms of users, one is Cognitive User (CU) and the other is Primary User (PU) play a significant role in CR [8, 9, 10]. PU's have their endemic frequency band due to which they are also admitted as licensed users while secondary users use the primary user's spectrum for communication due to which they are also admitted as unlicensed users.

The main notion of CR is to consume the unoccupied bands for communications resolutions [11]. As a CU, CR should not any harm to the PUs. Also, once a PU returns to its own channel, CU should abandon the channel rapidly and find

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another free channel [12]. CR permits the SUs to alter their transmission parameters (in reference to time and frequency domain) in accordance with the spectrum atmosphere while not inflicting any dangerous interference to PUs. There are certain limitations a protocol has to follow in order to provide efficient and reliable communication between a pair of distant nodes which are given below [13]:

- Limited Bandwidth
- Transmission Range
- Limitation in Power of Battery
- Mobility of Nodes

Certain applications require variable throughput [14] which is given in Table 1.

Type of Application	Traffic Class	Throughput (bps)
Non Real Time and Asymmetric	Web Browsing	<30.5K
Non Real Time and Asymmetric	Enhanced Web Browsing	<24K
Non Real Time and Asymmetric	Email	<10K
Non Real Time and Asymmetric	FTP	High
Non Real Time and Asymmetric	Telnet	<1K
Non Real Time and Symmetric	Internet, Relay Chat	<1K
Real Time and Highly Asymmetric	Audio Broadcasting	56-64K
Real Time and Highly Asymmetric	Video Broadcasting	1.2 to 60 M
Real Time and Highly Asymmetric	Interactive Audio on Demand	32-448K
Real Time and Highly Asymmetric	Interactive Video on Demand	1.2 to 60 M
Real Time and Highly Asymmetric	Telemetry	2K-52M
Real Time and Symmetric	Audio Conferencing	5.3 to 64K
Real Time and Symmetric	Audio graphics Conferencing	9.6-19.6K
Real Time and Symmetric	Video Conferencing	64 to 1920K
Real Time and Symmetric	Videophony	64 to 1920k
Real Time and Symmetric	Voice over IP	5.3 to 64K

Table 1: Throughput Requirement for various applications

Keeping aforementioned aspects in view we proposed a routing protocol based on QoS, which takes into consideration throughput along with the availability of a channel for path formation. Our paper is further designed as follows: the succeeding segment gives the literature survey. The proposal is given in section 3 followed by simulation set-up, results, conclusion, and references.

2. RELATED WORK

This section gives a broad analysis of routing protocols stated in the past research for CRN are enlisted.

Bahareh Najafi et al. [15] in their routing protocol used transmission count and channel selection to improve the performance of the protocol. They consider the spectrum and topology of the network to efficiently utilize the available channels. Cuimei Cui et al. [16] in their protocol used channel availability for path selection. To improve the performance of available spectrum Dual-Stage Collaborative Spectrum Sensing (DCSS) is used. Per-hop node performance was tried to maximize along their path by their protocol.

Bădoi, C. et al. [17] in their routing protocol considered hop-by-hop routing, geographical location, and spectrum availability. They also used basic information like the position of nodes and channel information and then take a hop-by-hop decision. Zhou, X. et al. [18] in their routing protocol consider destinations' node location. The direction of routing is found on the basis of the location of the source and destination nodes.

Bowen LI et al. [19] proposed a routing protocol based on Ant Colony. They used two types of ants on their proposed work. Forward ants (F-ants) are used to utilize spectrum achievable routes to destination and backward ants (B-ants) to accumulate data about the network and to keep routing table up-to-date.

Behrouz Jashni et al. [20] in their routing protocol make use of delay for path selection. They used queuing delay and transmission delay. They collected the information from the neighboring nodes and then evaluated the delays of all possible links and then select the optimal out of all for communication.

Anirudha R. Kulkarni and Anjali Agarwal [21] proposed protocol which considers end-to-end transmission power, channel availability, Presence of PU and link strength for route formation. Zhaoxia Song et al. [22] proposed a routing protocol which applied swarm intelligence into CRN routing protocol. They consider channel availability as a metric. Their proposed protocol minimizes delay.

Yongkang Liu et al. [23] designed a routing protocol based on geographical location details and channel availability. Next hop relay is selected by SU on the basis of locality and channel. They utilized Cognitive Transport Throughput (CTT) to evaluate the relay gain. K.R. Chowdhury and M.D. Felice [24] in their protocol undertake path and channel availability into consideration. They also consider node mobility during path formation. Their routing protocol minimized the hop count.

Nitul Dutta and Hiren Kumar Deva Sarma [25] in their protocol consider the probability of stability of channel for building the path from source to destination.

All listed available routing methods in literature are not beneficial for a specific type of application. Our proposal tries to solve this issue addressed by other routing protocols. The next section discusses the proposed protocol in detail.

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3. PROPOSED MODELLING

This section discusses the proposed work in detail along with the algorithm used.

3.1. Flow Diagram of Proposed Work:

The flow diagram of the proposed routing arrangement based on throughput is shown in Figure 1.

The procedure to select the best possible route can be explained as:-

1. First, the all possible route from source to destination is calculated along with the throughput of all those routes.
2. Of the entire possible path generated in step 1, Mamdami-Fuzzy Logic Controller (FLC) [26, 27] is applied to calculate the output weights.
3. For data transfer, the path having the maximum output weight is selected.

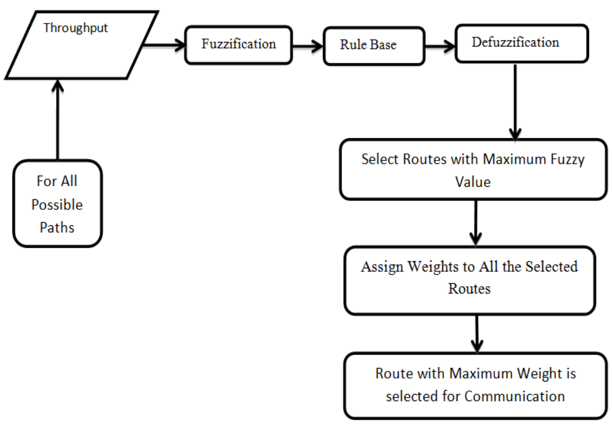

Figure 1 Flow Diagram of Proposed Scheme

3.2. Proposed Algorithm

1. PU=16 //Number of Primary Users
2. SU=20 //Number of Secondary User
3. P=0 //PDR
4. H=0 //Hop Count
5. Delay=0 //Delay
6. Throughput=0
7. Counter=0
8. Temp=0
9. allPath=[] //Stores all Possible Path
10. a=[]
11. min=99999;
12. fuzzy=0;
13. S=floor(random(SU)) //Source Node
14. D=floor(random(SU)) //Destination
15. If(path_existes(S-D)
    a. {Counter++
    b. Temp++
    c. H=length(path)-2
    d. D=H*random(2)
    e. for(i=1 to path.length-1){
        i. if(PU[path[i]].rate<min){
            1. min=PUarr[path[i]].rate;}
            }
    f. Throughput=min
    g. a.push(H)
    h. a.push(D)
    i. a.push(Throughput)
    j. fuzzy=Fuzzification(path)
        //Calculates Fuzzy Value
    k. a.push(fuzzy)
    l. a.push(temp)
    m. allPath.push(a)
    n. }
    o. else
    p. {
    q. Counter++;
    r. }
16. Function getPath()
    a. {
    b. Pos=-1;
    c. maxFuzzy=maxFuzz()
        //Calculates Maximum Fuzzy Value
    d. for(i=0;i<allPath.length;i++)
        i. {If(allPath[i][3]==maxFuzzy){
            a. Pos=i}}}
            b. P=allPath[pos][4]/Counter
    }

Algorithm 1 Proposed Algorithm.

The proposed algorithm is represented in Algorithm 1. Where "PU" represents the Primary User nodes and "SU" represents the Secondary User nodes. To calculate the PDR "Counter" and "Temp" is used. "Temp" is used to stores count of a number of times the path from source to destination is formed. "S" represents the randomly generated source node whereas "D" denotes the randomly generated destination node. "a" stores all relevant information about the specific path and "allPath" stores the all possible path from particular source to destination. Fuzzification function is used to calculate the fuzzy value of the path which is stored in the

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fuzzy variable. "P", "H", "D" represents PDR, Hop Count, and Delay respectively.

The fundamental blocks of Fuzzy Logic Controller (FLC) are enlightened as underneath [28, 29, 30]:-

- **Input-** To calculate the optimal path the input i.e. throughput is feed to the fuzzy logic Controller (FLC).
- **Fuzzification-** It is the process of changing crisp value into fuzzy values with the help of membership function (Crisp values) as shown in Figure 2.

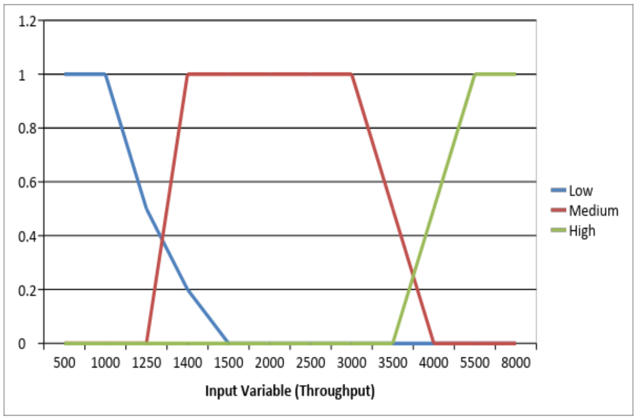

Figure 2 Crisp Values for Throughput

- **Membership Function of FLC Input-** Crisp Value for inputs can be same but membership function will be different. The semantic variable used as input is classified as below:-

T (input) = {(low, medium, high)}

- **Fuzzification Equation-** For fuzzification of input Table 2 is used in which Throughput (TH) is mapped according to Table 2 and output obtained is Optimality of Path (OP).

Membership Function	Optimality of path (OP)	Throughput (Input)
Low	1	$0 < TH \leq 1000$
	$3 - 0.002 * TH$	$1000 < TH \leq 1500$
Medium	$0.00095 * TH - 1904$	$1250 < TH \leq 1400$
	1	$1400 < TH \leq 3000$
	$4 - 0.001 * TH$	$3000 < TH \leq 4000$
High	$0.0005 * TH - 1.75$	$3500 < TH \leq 5500$
	1	$5500 < TH \leq 8000$

Table 2 Equations for Fuzzification

- **Rule Base-** Information related to the procedure of the process of the domain is stored in this. It is generally of the form IF-THEN. Rule base used in our proposal is given below:

1. If (Throughput is high) then (output is best)
2. If(Throughput is med) then (output is moderate)
3. If(Throughput is low) then (output is poor)

- **Defuzzification-** The reduction of a fuzzy set into a crisp set member is known as defuzzification. Proposed work used the Centre of Gravity (CoG)[31, 32] method employed for defuzzification is given in the below equation:-

$$Output = (m1 * A1 + m2 * A2)/(A1 + A2)$$

Where, m1 and m2 signify the membership functions calculated with the help of process of Fuzzification as {Poor, Moderate, and Best} and A1, A2 are the areas in the particular region.

- **FLC Output's Membership Function -** Output variable used in FLC basically defined optimality of route. The semantic variable used for output is categorized as below:

T (output) = {(Poor, Moderate, Best)}

It can be observed from Figure 3 that the path's optimality is less than or equal to 1.

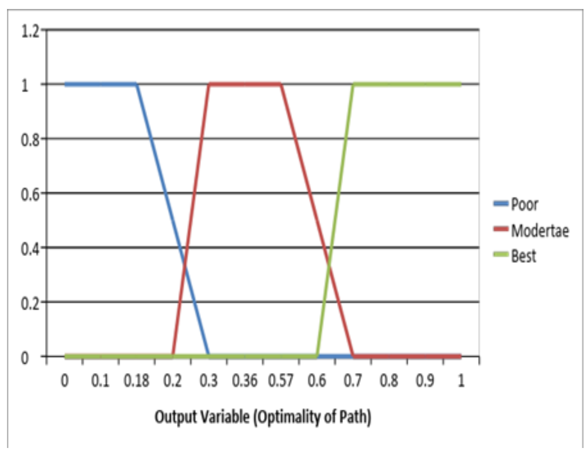

Figure 3 Crisp Values for Output

- **Defuzzification Equation-** For the defuzzification process Table 3 is used. It also characterizes the membership functions. It produces output weight taking Optimality of Path (OP) as input.
- **Weight-**Outputs are assigned some weights and the preference to maximum weight is selected as the optimal route.

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Membership Function	Output Weight	Optimality of path (input)
Poor	1	$0 < OP \leq 0.18$
	$2 - 5.56 * OP$	$0.18 < OP \leq 0.36$
Moderate	$10 * OP - 2$	$0.20 < OP \leq 0.30$
	1	$0.30 < OP \leq 0.57$
	$5.38 - 7.69 * OP$	$0.57 < OP \leq 0.70$
Best	$11.11 * OP - 6.67$	$0.60 < OP \leq 0.69$
	1	$0.69 < OP \leq 1$

Table 3 Equation for Defuzzification

4. SIMULATION SET-UP

The proposed routing protocol based on QoS is executed on JavaScript and comparison is done with the shortest spectrum is known routing protocol. This given segment provides information about the following:

- Setup Parameters,
- Portraits of the proposed scheme and
- Performance metrics used for comparison.

4.1. Simulation set-up parameters

Set-Up parameters employed to assess the efficiency of the proposed mechanism are given in Table 4.

Position of SU	Random
Position of PU	Fixed
Area	1500X1500
Number of PU nodes	16
Number of SU Nodes	20
Transmission Range of SU	300,400,450,500 Units
Mobility model	Random waypoint Model
Pause time	5 seconds
Simulation Time	50 sec
Throughput	8 Mbps Maximum
Number of Channels	2
Number of Iterations	15
Software Used	Javascript and its library p5.js

Table 4 Set-Up parameters

4.2. Portraits:

The path formed from source to destination using the proposed method is shown in Figure 4. PU nodes which are immovable are denoted by white color while SU nodes which are arbitrarily positioned and also movable are denoted by orange color. The Green line in Figure 4 demonstrates the path achieved from our proposed Quality of Service (QoS) based protocol.

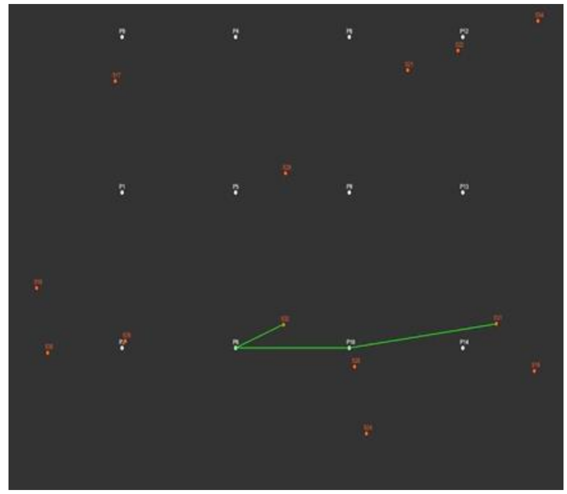

Figure 4 Visualization of Path Formation by our Proposed Method

4.3. Performance metrics used:

- **Packet Delivery Ratio (PDR):** The proportion of a number of packets delivered to the total number of packets sent from source [33] [34] is known as PDR.
- **Delay:** The time required to exchange a packet from beginning to end is known as Delay [35] [36].
- **Hop Count:** Number of intermediate nodes from a source to destination is known as hop count [37].
- **Throughput:** The speed in bits per seconds of the received data is known as throughput [38].

5. RESULTS AND DISCUSSIONS

To estimate the efficiency of the proposed protocol, the transmission range was varied as 350,400,450 and 500 units. The number of nodes is given above in the set-Up parameters.

The average throughput of our proposed protocol is higher than the shortest spectrum aware which can be seen from Figure 5 because our proposed protocol utilizes throughput during path selection while the latter consider hop count.

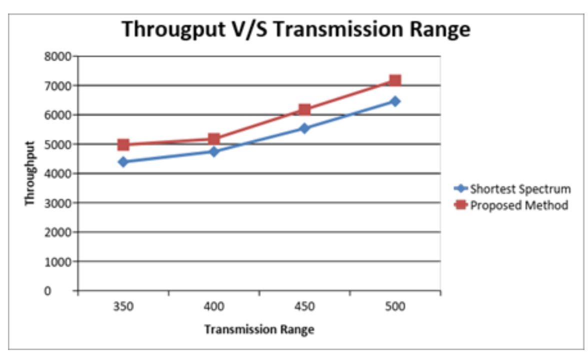

Figure 5 Throughput V/S Transmission Range

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Average Packet Delivery Ratio (PDR) in our proposed protocol is lower than the shortest spectrum aware as can be seen from Figure 6 as the latter has less hop count which boosts the PDR. Additionally, with an increase in transmission range PDR increases. This happened as with rising in transmission range the destination will most likely lie in the range of the nodes.

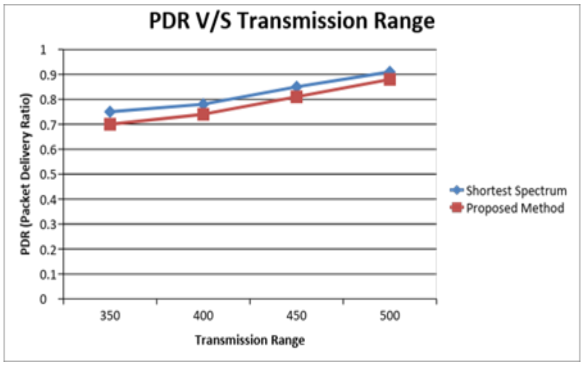

Figure 6 PDR V/S Transmission Range

Hop count in our proposed protocol is higher than the shortest spectrum aware as can be seen from Figure 7 because the shortest spectrum aware takes into account hop count and our proposed protocol takes into account throughput.

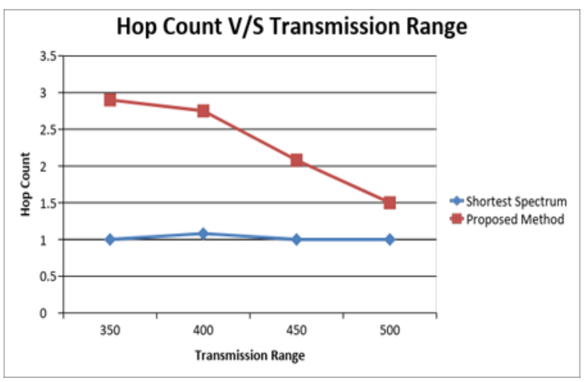

Figure 7 Hop Count V/S Transmission Range

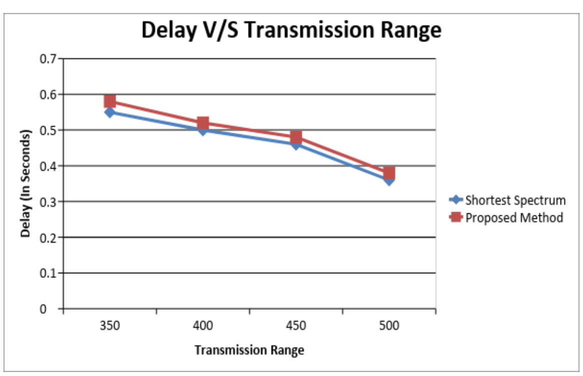

Figure 8 Delay V/S Transmission Range

Delay in our proposed protocol is higher than the shortest spectrum aware as can be seen from Figure 8 because the shortest spectrum aware selects the shortest path. Also, a number of hop counts are minimum in the shortest spectrum aware than our proposed routing protocol which also affects the delay.

6. CONCLUSION

This paper proposes a routing protocol which depends on one Quality of Service (QoS) Parameter i.e. throughput. It is an imperative parameter since different applications require variable values of throughput such as Live streaming requires a higher value of throughput in contrast to email transfer. Important corollaries which can be drawn from the results are as follows:

- Our protocol has high throughput since it selects the path which has maximum throughput.
- PDR is almost the same for both the routing scheme i.e. shortest path routing and the proposed scheme.
- Hop count and Delay values are high in case of the proposed scheme since it undertakes throughput for path selection instead of hop count.

REFERENCES

[1] Akyildiz, I. F., Lee, W. Y., Vuran, M. C., & Mohanty, S. "A survey on spectrum management in cognitive radio networks", IEEE Communications Magazine. Copyright 2008 IEEE, 2008, pp.40-48.

[2] Chen, D., Zhang, Q., & Jia, W. "Aggregation aware spectrum assignment in cognitive ad-hoc networks.", In 2008 3rd International Conference on Cognitive Radio Oriented Wireless Networks and Communications (CrownCom 2008), 2008, pp. 1-6.

[3] G. Cheng, W. Liu, Y. Li and W. Cheng, "Spectrum Aware On-Demand Routing in Cognitive Radio Networks," 2007 2nd IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks, Dublin, 2007, pp. 571-574.

[4] Liang, Y. C., Zeng, Y., Peh, E., & Hoang, A. T. "Sensing-throughput tradeoff for cognitive radio networks", In 2007 IEEE International Conference on Communications, 2007, pp. 5330-5335.

[5] Akyildiz, I. F., Lee, W. Y., Vuran, M. C., & Mohanty, S. "Next generation dynamic spectrum access cognitive radio wireless networks: A survey", Computer networks, Vol.50, Issue 13, 2006, pp. 2127-2159.

[6] Akyildiz, I. F., Lee, W. Y., & Chowdhury, K. R. "CRAHNs: Cognitive radio ad hoc networks. AD hoc networks", Vol.7, Issue 5, 2009 pp.810-836.

[7] Letaief, K. B., & Zhang, W. "Cooperative communications for cognitive radio networks", Proceedings of the IEEE, Vol. 97, Issue 5, 2009, pp. 878-893.

[8] S. M. Kamruzzaman, E. Kim and D. G. Jeong, "An Energy Efficient QoS Routing Protocol for Cognitive Radio and Ad Hoc Networks" International Conference on Advance Communication Technology (ICACT), 2011, pp.344-349.

[9] Dutta, N., Sarma, H. K. D., Srivastava, A., & Verma, S. "A SINR Based Clustering Protocol for Cognitive Radio Ad Hoc Network

RESEARCH ARTICLE

(CRAHN)" , International Conference on Information Technology,2009, pp. 69-75.

[10] Letaief, K. B., & Zhang, W. "Cooperative communications for cognitive radio networks" Proceedings of the IEEE, Vol.97, Issue 5, 2009, pp. 878-893.

[11] S. Kulkarni and S. Markande, "Comparative study of routing protocols in Cognitive Radio Networks," International Conference on Pervasive Computing (ICPC), Pune, 2015, pp. 1-5.

[12] Ren Han and Xiaoxia Huang, "Reliable link routing in Cognitive Radio networks," 2010 2nd International Asia Conference on Informatics in Control, Automation and Robotics (CAR 2010), Wuhan, 2010, pp. 55-58.

[13] Pradeep Kyasanur and Nitin H. Vaidya, "Protocol Design Challenges for Multi-hop Dynamic Spectrum Access Networks," International Symposium on New Frontiers in Dynamic Spectrum Access Networks, 2005, pp.645-648.

[14] Chen, Y., Farley, T., & Ye, N., "QoS Requirements of Network Applications on the Internet" ,Information Knowledge Systems Management,Vol.4, 2004, pp.55-76.

[15] Najafi, B., Keshavarz-Haddad, A., & Jamshidi, A., "A new spectrum path diversity routing protocol based on AODV for cognitive radio ad hoc networks," In 7th International Symposium on Telecommunications (IST'2014), 2014, pp. 585-589, IEEE.

[16] Cui, C., Man, H., Wang, Y., & Liu, S., "Cooperative spectrum-aware opportunistic routing in cognitive radio ad hoc networks," In 2014 IEEE Global Conference on Signal and Information Processing (GlobalSIP), 2014, pp. 1238-1241, IEEE.

[17] Bădoi, C. I., Croitoru, V., & Prasad, R., "IPSAG: an IP spectrum aware geographic routing algorithm proposal for multi-hop cognitive radio networks," In 2010 8th International Conference on Communications, 2010, pp. 491-496, IEEE.

[18] Zhou, X., Zhou, D., Kong, X., & Sheng, Q., "ACK signal based on-demand routing ,algorithm in Cognitive Radio Networks," In 2009 IEEE Pacific Rim Conference on Communications, Computers and Signal Processing, 2009,pp. 774-779,IEEE.

[19] Li, B., Li, D., Wu, Q. H., & Li, H., "ASAR: Ant-based spectrum aware routing for cognitive radio networks," In 2009 International Conference on Wireless Communications & Signal Processing,2009, pp. 1-5, IEEE.

[20] Jashni, B., Tadaion, A. A., & Ashtiani, F., "Dynamic link/frequency selection in multi-hop cognitive radio networks for delay sensitive applications," In 2010 17th International Conference on Telecommunications, 2010, pp. 128-132, IEEE.

[21] Kulkarni, A. R., & Agarwal, A., "Energy-efficient QoS based route management in cognitive radio networks," In 2015 IEEE International Conference on Data Science and Data Intensive Systems, 2015, pp. 304-310, IEEE.

[22] Song, Z., Shen, B., Zhou, Z., & Kwak, K. S., "Improved ant routing algorithm in cognitive radio networks," In 2009 9th International Symposium on Communications and Information Technology, 2009, pp. 110-114,IEEE.

[23] Liu, Y., Cai, L. X., & Shen, X. S., "Spectrum-aware opportunistic routing in multi-hop cognitive radio networks," IEEE Journal on Selected Areas in Communications, Vol. 30, Issue 10, 2012, pp. 1958-1968.

[24] Chowdhury, K. R., & Felice, M. D., "Search: A routing protocol for mobile cognitive radio ad-hoc networks," Computer Communications, Vol. 32, Issue 18, 2009, pp.1983-1997.

[25] Dutta, N., & Sarma, H. K. D., "A probability based stable routing for cognitive radio adhoc networks," Wireless Networks, Vol. 23, Issue 1, 2017, pp.65-78.

[26] H. Zhou, H. Ying, "A method for deriving the analytical structure of a broad class of typical interval type-2 mamdani fuzzy controllers," IEEE Trans. 420 Fuzzy Syst. Vol. 21, Issue 3, 2013, pp.447–458.

[27] El Masri, "A fuzzy-based routing strategy for multihop cognitive radio networks", International Journal of Communication Networks and Information Security, IJCNIS-2011, Vol. 3, Issue 1, 2011. pp. 74–82.

[28] Kukreja, V., Gupta, S., & Bhushan, B. "A fuzzy-based routing protocol for cognitive radio networks" International Journal of Fuzzy Computation and Modelling, Vol. 1, Issue 1, 2014, pp. 97-122.

[29] Castillo, O., Amador-Angulo, L., Castro, J. R., & Garcia-Valdez, M. "A comparative study of type-1 fuzzy logic systems, interval type-2 fuzzy logic systems and generalized type-2 fuzzy logic systems in control problems." Information Sciences, Vol. 354, 2016, pp.257-274.

[30] Nagpal, C.K., & Gupta, S. "A Delay and Spectrum Aware Fuzzy Logic Based Routing Protocol for CRN" International Journal of Computer Networks and Applications, Volume 3, Issue 1, 2016, pp.16-24.

[31] Amini, A., & Nikraz, N. "Proposing two defuzzification methods based on output fuzzy set weights" International Journal of Intelligent Systems and Applications, Vol. 8, Issue 2, 2016,pp.1-12.

[32] Namazov, M., & Basturk, O. "DC motor position control using fuzzy proportional-derivative controllers with different defuzzification methods," TJFS: Turkish Journal of Fuzzy Systems, Vol.1, No.1, 2010, pp.36-54.

[33] Rohal, P., Dahiya, R., & Dahiya, P. "Study and analysis of throughput, delay and packet delivery ratio in MANET for topology based routing protocols (AODV, DSR and DSDV)" International Journal for advance research in engineering and technology, Vol.1,Issue 2, 2013,pp.54-58.

[34] M. F. Khan, E. A. Felemban, S. Qaisar and S. Ali, "Performance Analysis on Packet Delivery Ratio and End-to-End Delay of Different Network Topologies in Wireless Sensor Networks (WSNs)," 2013 IEEE 9th International Conference on Mobile Ad-hoc and Sensor Networks, Dalian, 2013, pp. 324-329.

[35] B.Ruxanayasmin, B.Ananda Krishna, T.Subhashini, "Minimization of Power Consumption in Mobile Adhoc Network" International Journal of Communication Networks and Information Security (IJCNIS), 2014, pp. 38-44.

[36] Shah, S., Khandre, A., Shirole, M., & Bhole, G. "Performance evaluation of ad hoc routing protocols using NS2 simulation," Conference of Mobile and Pervasive Computing (CoMPC), 2008, pp.167-171.

[37] M. Youssef, M. Ibrahim, M. Abdelatif, L. Chen and A. V. Vasilakos, "Routing Metrics of Cognitive Radio Networks: A Survey," in IEEE Communications Surveys & Tutorials, Vol. 16, No. 1, 2014, pp. 92-109.

[38] Kadhim, A. S., & Alsabbagh, H. M. "Throughput Analysis for Cognitive Radio (CR) Systems", International Journal of Computer Networks & Communications, Vol.4, No.4, 2012, pp.211-222.

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