INTERNATIONAL JOURNAL OF RESEARCH IN COMPUTER APPLICATIONS AND ROBOTICS
ISSN 2320-7345

MULTI-CRITERIA BASED INTELLIGENT ENERGY EFFICIENT ROUTING FOR WIRELESS AD-HOC NETWORK

[1]Ramesh Kumar Sharma, [2]Abhishek Kumar, [3]Avinash Kumar, [4]Arun Prasad Burnwal

[1]Department of Computer Science, Gurunanak College, Dhanbad, Jharkhand, India-826001, sharmarameshdhn@gmail.com
[2]Department of ECE, BIT Mesra, Ranchi, Jharkhand, India-835215, abhishekec02@gmail.com
[3]Department of Mechanical Eng., Government Eng. Ramgarh, Jharkhand, India- 825101, avikr1208@gmail.com
[4]Department of Mathematics, GGSESTC, Bokaro, Jharkhand, India-827013, apburnwal@yahoo.com

Abstract: - Wireless Ad-hoc Network (WANET) is a decentralized type of wireless network. It is ad-hoc because it has no any pre-existing access point. Each node of this is dynamic due to mobility nature. A major challenge of this network is the selection of energy efficient route from the source node to the destination node, because the nodes are equipped with limited capacity of battery. So it is required to develop an energy efficient routing technique in wireless ad-hoc network which is attempted in this paper. The basic idea of this technique is to select the best path which reduces energy consumption based on multi-criteria decision making. It depends on the four network parameters such as hop-count, data packet, distance and energy. Among these input parameters, energy is the most vital parameter. So it compare with other three parameters based on multi-criteria to get rating of the route. Based on the mathematical analysis, it is observed that proposed routing protocol contributes to the performance improvements in terms of energy efficiency.

Keywords: Wireless ad-hoc network, Multi-criteria, Fuzzy logic, Expert system.

1. Introduction

A Wireless Ad-hoc Network (WANET) [1], [2], [3], [4], [5] is a distributed wireless network. This network does not have any infrastructure, and nodes are completely dynamic and moveable. Each node can make contact with the other node in specific range. Every node in this network participates in routing by forwarding data for other nodes, so the determination of which nodes forward data is made dynamically on the basis of network connectivity. The decentralized nature of wireless ad-hoc networks makes them suitable for a variety of applications [6], [7], [8], [9] where central nodes can't be relied on, and may improve the scalability of wireless ad-hoc networks compared to wireless managed networks. In the last few years minimal configuration and quick deployment make ad-hoc networks suitable for different applications such as tactical networks, emergency services, commercial and civilian environments, home and enterprise networking, education, entertainment, natural disasters or military conflicts etc. There is a huge potential market for providing palmtops, laptops, and personal communication systems with access to airline schedules, weather forecasts, or location dependent information, just to name a few. Ad-hoc networks can be used to provide radio devices with such services, anywhere and anytime. It enables users to impulsively form a dynamic communication system. They allow users to access the services offered by the fixed network through multi-hop communications, without requiring infrastructure in the user proximity.

The environment of an ad-hoc network is characterized by unpredictable connectivity changes, unreliable wireless medium, resource-constrained nodes, and dynamic topology. These features of ad-hoc network makes to numerous types of failures including: transmission errors, node failures, link failures, route breakages, and congestions. The environment of ad-hoc network can be categorized into three main states first an ideal state wherein the network is relatively stable with sufficient resources, second a congested state wherein some nodes, regions or the whole network is experiencing congestion and third an energy critical state wherein the energy capacity of nodes in the network is critically low. The main design goal of ad-hoc network is not only to transmit data from the source to the destination, but also to increase the lifetime of the network. This can be achieved by employing energy efficient routing protocols.

The framework of proposed protocol contains three phases such as multi-criteria intelligent, intelligent route establishment and energy efficient route selection. The first phase contains detail description of multi-criteria and there membership function used in proposed protocol. In second phase intelligent system establish rating of each route by the help of knowledge provided by expert system. In third phase output produces by second phase fed into the fuzzy rule matrix to evaluated rating strategy and find out energy efficient route. Finally, based on the simulation and comparative study of same with other existing protocols, it is observed that proposed routing protocol contributes to the performance improvements.

Rest of this paper is organized as follows: Section 2 provides related work done in energy efficient routing protocol for ad-hoc network. Section 3 addresses the preliminaries related to the proposed protocol as intelligent system, fuzzy logic and expert system. The details of different phases of proposed protocol are describes in section 4. Finally, Section 5 concludes the paper and future work is illustrates.

2. Related Works

Energy efficient routing is the main challenges of the ad-hoc network. There have been lot of works are done on energy efficient routing such as Wei et al. [10] proposed a new optimized priority based energy efficient routing algorithm PDSR. The main aims of this algorithm to add priority to the existing routing algorithm according to the residual energy proportion of the nodes. Lower residual energy means lower priority and the nodes with lower priority are less likely to forward packets to other nodes. It can also improve the performance of routing discovery, routing maintenance and route cache. But it has a limitation that hop count and distance are not considered for improvement and route maintenance. Su et al. [11] proposed the fuzzy logic modified AODV routing (FMAR) protocol for multicast routing in mobile ad-hoc networks. The main aim of this protocol is dynamically evaluate the active routes based on fuzzy logic weighted multi-criteria. It also helps to managing the limited bandwidths of wireless links. But it has some drawback that the proposed protocol does not considered all possible routes as evaluation of route lifetime by fuzzy logic multi-criteria, so it cannot be determine which routes are highly useful. Therefore, routes cannot repair and maintain partially or completely before they crashed. Matthew J. Miller and Nitin H. Vaidya [12] proposed a link layer protocol to provide k levels of power save and a routing protocol to use this link layer effectively. In this protocol the authors first to generalize the concept for ad-hoc networks by proposing the use of k levels of power save, each of which presents a different energy–latency tradeoff. Thus, previous work [13-16] only considered the case where k = 1 or k = 2. Guo et al. [17] proposed a multi-objective approach for proactive routing in a MANET. In this approach, the authors consider three routing objectives: minimizing average end-to-end delay, maximizing network energy lifetime, and maximizing packet delivery ratio. For the proposed multi-objective approach, the authors developed two efficient prediction methods first predicting queuing delay and energy consumption using double exponential smoothing, and second predicting residual link lifetime using a heuristic of the distributions of the link lifetimes in MANET. Kalantari et al. [18] proposed a soft computing method (RWSN) for energy efficient routing in wireless sensor network. The main aim of this method to determines reward of each route using reward function based on two parameters energy and distance. This function determines which actions have been good and which have been loaded. It gives a number to each pair (state/action). The action is good indicating that energy is high and distance is short. The action is loaded indicating that energy is low and distance is long. The reward function in this proposed system is obtained through fuzzy logic system. But it has some drawback that the proposed method does not considered hop count and data packet as parameters of energy efficient routing. R. Vadivel and V. Murali Bhaskaran [19] proposed a protocol EESRRP for MANET. The main aim of this protocol is that residual energy metric is estimated for providing energy efficiency and improved reliability. It also helps to provide security against malicious attacks using an effective intercept detection and correction (IDC) algorithm. Das et al. [20] proposed a soft computing method (ERPC) for energy efficient routing in wireless sensor network. The main aims of this method to demonstrate a strategy of power consumption system in wireless sensor network by using the concept of complete bi-partite graph. The basic parameters of this strategy are power and distance. Finally, it assigns priority to each route and determines the best and worst routing in wireless sensor network. But it has some limitation that the proposed method does not considered hop count and data packet as parameters of energy efficient routing. Because energy efficient routing not considering only energy and distance, it also cover hop count and transmitter packet. Das et al. [21] proposed a method (IECR) for energy efficient routing in wireless sensor network. The main aims of this method to generate some values for each and every route based on fuzzy inference engine. These values determine the different nature of the routes. Therefore, this value helps to determine which route is best and which route is worst for routing in term of energy efficiency. But it has some limitation that the proposed method does not considered hop count and data packet as parameters of fuzzy inference engine. Because energy efficient routing cannot determines by using two parameters such as energy and distance. Das et al. [22] proposed an energy efficient routing protocol based on vague set. In this protocol, energy and distance are used for interval based parameters to determine the routing between source and destination node. The author extends this work in [23], where performance analysis is extended in term of several network metrics. But, it has limitation that this protocol does not achieve optimization of network metrics. Hence, network lifetime cannot be enhanced properly.

However, none of the above methods address the energy efficient routing and network lifetime issues together based on four parameters such as hop count, data packet, distance and energy. Therefore, in the proposed protocol, we consider both these issues based on parameters hop count, data packet, distance and energy. The main advantage of this proposed protocol is that it assign rating of all possible routes by comparing multi-criteria strategy hop count with energy, data packet with energy and distance with energy. The energy parameter involve in all criteria because it is a major concern parameter, so this protocol helps to repair and maintain routes completely before they crashed.

3. Preliminaries

In this section, some preliminaries are discussed which serves as an important role in designing this protocol. Short descriptions of these preliminaries are given below:

3.1. Intelligent System

Intelligent system is a part of artificial intelligence system which is used to solve many complex [24], [25]. The main aims of this contribution to integration of different learning and adaptation techniques to overcome individual limitations and to achieve synergetic effects through the hybridization or fusion of these techniques. Therefore, intelligence system is an inference mechanism that is used to manage and process the data, interpret the data, and provide analytically-sound opinions to decision makers in order that they may make informed decisions with regard to various courses of action. And computational intelligence is a hybridization of different intelligent system such as Neural Networks (NN), Fuzzy Inference Systems (FIS), Probabilistic Reasoning (PR) and Evolutionary Computation (EC). Most of these hybridization approaches follow an ad-hoc design methodology to justified success in certain domains. This ad-hoc design methodology has different standard design for integrating intelligent systems such as NN-FIS, EC-FIS, EC-NN, FIS-PR and NN-FIS-EC [26], [27].

3.2. Fuzzy logic

In the present paper fuzzy logic considers as a main tool to design intelligent system of proposed routing protocol. Fuzzy logic is an inherent component of soft computing. Fuzzy logic is not fuzzy. Basically, fuzzy logic is a precise logic of imprecision and approximate reasoning. It derives from Fuzzy Set Theory (FST) that works with a range of value rather than crisp value to deal with imprecision data. It introduced in 1965 by Zadeh as a new way to represent vagueness in everyday life. The FST is a theory of graded concepts [28], [29]. It also a part of mathematical modelling which is the extension of the conventional set theory that handles the

Vol.5 Issue 1, Pg.: 24-32
January 2017

concept of partial truth between completely true and completely false [30]. In the real life, the human brain processes many fuzzy attributes (Large, Long, Small, Good, Tall, Expensive, Sporty, Costly, Intelligent, old, young, Superior, Genius etc.) as comparative interpretations. The theory of fuzzy logic will enable the model and the estimation process to handle the vagueness of the information acquired in early phases of a routing in MANET. It will help manage the uncertainty about the precise meaning of linguistic values used by the 'experts (decision maker)' when coming up with an estimate. One of the most important facts about the analytical capacity of the human brain is its ability to summarize information into labels of fuzzy sets, which bear an approximate relation to the primary data. So FST are a generalization of crisp sets and have greater flexibility to capture faithfully various aspects of incompleteness or imperfection in information. For an ordinary set, an element either belongs to it or not; while for fuzzy sets, an element can partially belong to the set. Many authors [31], [32], [33] used fuzzy logic based approaches in ad-hoc network to solve various network problems and came with good approximate solutions. So fuzzy logic provides is a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information.

3.3. Expert system

An Expert system is a knowledge based computer program which provides expert quality to solve any problem of any of the domains. The core elements of expert system are knowledge based system and inference engine. The first element knowledge based system is software that uses artificial intelligence techniques to solve any problem in a more efficient way. It includes a database of expert knowledge that helps to retrieve result based on specific queries or conditions. It also helps to transfer knowledge from one domain of knowledge to another for a specific purpose. The second element inference engine is also known as implication. It is a rule based knowledge representation which consists of two basic parts first condition or antecedent and the second is conclusion or consequent part. The first part antecedent describes the fact or conditions that must exist for the rule to fire. And second part, consequent describes the facts that will be established or the action that will be taken or conclusion that will be made. The design of expert systems by using inference engine is one of the most important applications of fuzzy logic and approximate reasoning. So expert system is also known as decision maker or intelligent program that has expert-level knowledge about a domain. The relation between intelligent system and expert system with fuzzy inference system illustrate in Fig 1. In this proposed protocol the main domain is wireless ad-hoc network, and intelligent system has entire knowledge about all characteristic and linguistic natures of ad-hoc network. So intelligent system knows how to use its knowledge to respond properly in every phase of proposed energy efficient routing protocol.

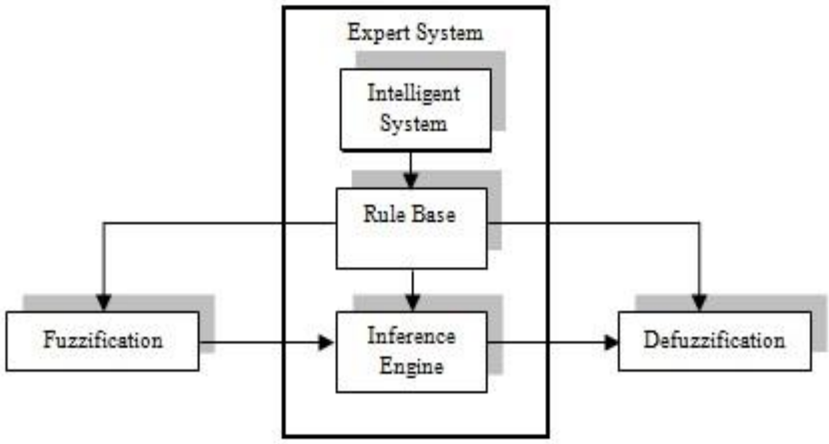

Figure 1: Relation between fuzzy inference system with expert system and intelligent system

4. Proposed Method

The proposed work is multi-criteria based intelligent energy efficient routing protocol, which divides entire design in three phases. These three phases design and evaluated by intelligent system. The intelligent system uses multi-criteria through rule base system and inference engine to solve this energy efficient routing problem. The assumptions and details of these phases will be described as given below:

4.1. Multi-criteria intelligent phase

This is initial phase of the proposed protocol. The main job of this phase is divided into two parts. The first part include membership function of four input variables as hop count, data packet, distance and energy and output variable as Rating Scale and their correspondence base values. All the input and output variables are divided into three linguistic variables such as Low (L), Medium (M), High (H). In this proposed protocol no. of hop count considered as 25, transmitted data packet as 500 kbps, distance as 200 meter and energy capacity as 50 joule. Membership functions corresponding to each input variables and output variable are describe in Table 1, Table 2, Table 3, Table 4, Table 5.

Table 1: Membership function of hop count (no.)

Linguistic Values	Notation	Range	Base value
Low	H_L	$[H_{La}, H_{Lb}]$	(0,0,12.5)
Medium	H_M	$[H_{Ma}, H_{Mb}]$	(0,12.5,25)
High	H_H	$[H_{Ha}, H_{Hb}]$	(12.5,25,25)

Table 2: Membership function of data packet (Mbps)

Linguistic Values	Notation	Range	Base value
Low	DP_L	$[DP_{La}, DP_{Lb}]$	(0,0,250)
Medium	DP_M	$[DP_{Ma}, DP_{Mb}]$	(0,250,500)
High	DP_H	$[DP_{Ha}, DP_{Hb}]$	(250,500,500)

Table 3: Membership function of distance (Meter)

Linguistic Values	Notation	Range	Base value
Low	D_L	$[D_{La}, D_{Lb}]$	(0,0,80)
Medium	D_M	$[D_{Ma}, D_{Mb}]$	(20,100,180)
High	DH	$[D_{Ha}, D_{Hb}]$	(120,200,200)

Table 4: Membership function of energy (Joule)

Linguistic Values	Notation	Range	Base value
Low	E_L	$[E_{La}, E_{Lb}]$	(0,0,20)
Medium	E_M	$[E_{Ma}, E_{Mb}]$	(5,25,45)
High	E_H	$[E_{Ha}, E_{Hb}]$	(30,50,50)

Table 5: Rating scale of different routes

Linguistic Variable	Very Bad	Bad	Satisfactory	Medium	Less Good	Good	Very Good	Excellent	Very Excellent
Notation	R_{VB}	R_B	R_S	R_M	R_{LG}	R_G	R_{VG}	R_E	R_{VE}

4.2. Intelligent route establishment phase

In ad-hoc network energy consumption occurred due to sending a packet, receiving a packet, the node when idle mode and the node when sleep mode which occurs when the wireless interface of the node is turned off. Power failure of a node not only affect the node itself but also its ability to forward packets on behalf of others and thus the overall network lifetime. Therefore, energy efficient routing indicates selecting routes that require minimum hops, instead of more no. of hops, low data packets, instead of high data packets, short distance, instead of long distance. Hence, to improve the network performance, the nodes should select the best route in terms of its remaining lifetime. The main concern parameter of remaining lifetime is energy, therefore intelligent system process Rule 1 to Rule 9 for energy with hop count, Rule 10 to Rule 18 energy with data packet and Rule 19 to Rule 27energy with distance. The detail description of all rules are given in Table 6.

Table 6: Rules process by intelligent system for route establishment

Based on energy and hop count
Rule 1: IF (Energy is Low) and (Hop-count is High) then (Rating of Route is Very Bad)
Rule 2. IF (Energy is Low) and (Hop-count is Medium) then (Rating of Route is Bad)
Rule 3: IF (Energy is Low) and (Hop-count is Low) then (Rating of Route is Satisfactory)
Rule 4: IF (Energy is Medium) and (Hop-count is High) then (Rating of Route is Medium)
Rule 5: IF (Energy is Medium) and (Hop-count is Medium) then (Rating of Route is Less Good)
Rule 6: IF (Energy is Medium) and (Hop-count is Low) then (Rating of Route is Good)
Rule 7: IF (Energy is High) and (Hop-count is High) then (Rating of Route is Very Good)
Rule 8: IF (Energy is High) and (Hop-count is Medium) then (Rating of Route is Excellent)
Rule 9: IF (Energy is High) and (Hop-count is Low) then (Rating of Route is Very Excellent)
Based on energy and data packet
Rule 10: IF (Energy is Low) and (Data Packet is High) then (Rating of Route is Very Bad)
Rule 11: IF (Energy is Low) and (Data Packet is Medium) then (Rating of Route is Bad)
Rule 12: IF (Energy is Low) and (Data Packet is Low) then (Rating of Route is Satisfactory)
Rule 13: IF (Energy is Medium) and (Data Packet is High) then (Rating of Route is Medium)
Rule 14: IF (Energy is Medium) and (Data Packet is Medium) then (Rating of Route is Less Good)
Rule 15: IF (Energy is Medium) and (Data Packet is Low) then (Rating of Route is Good)
Rule 16: IF (Energy is High) and (Data Packet is High) then (Rating of Route is Very Good)
Rule 17: IF (Energy is High) and (Data Packet is Medium) then (Rating of Route is Excellent)
Rule 18: IF (Energy is High) and (Data Packet is Low) then (Rating of Route is Very Excellent)
Based on energy and distance
Rule 19: IF (Energy is Low) and (Distance is High) then (Rating of Route is Very Bad)
Rule 20: IF (Energy is Low) and (Distance is Medium) then (Rating of Route is Bad)
Rule 21: IF (Energy is Low) and (Distance is Low) then (Rating of Route is Satisfactory)
Rule 22: IF (Energy is Medium) and (Distance is High) then (Rating of Route is Medium)
Rule 23: IF (Energy is Medium) and (Distance is Medium) then (Rating of Route is Less Good)
Rule 24: IF (Energy is Medium) and (Distance is Low) then (Rating of Route is Good)
Rule 25: IF (Energy is High) and (Distance is High) then (Rating of Route is Very Good)
Rule 26: IF (Energy is High) and (Distance is Medium) then (Rating of Route is Excellent)
Rule 27: IF (Energy is High) and (Distance is Low) then (Rating of Route is Very Excellent)

Let “S” is the set of three states, such as S1, S2 and S3 where S1={Sij; i=energy, j=hop-count}, S2={Skl; k=energy, l=data packet}, S3={Smn; m=energy, n=distance} and each i, j, k, l, m and n are linguistic values. Kalantari et al. proposed a technique 18] for finding the state S is defined as the ratio of each value of energy with other parameters such as hop count, data packet and distance. The priorities of the states are compared by using formula of rating Rpq=mean value of energy/mean value of other parameters. Each Rpq is a linguistic variable having different nature. The set R of different rating is given by R={r11, r12, r13, r14, r15, r16, r17, r18, r19, r21, r22, r23, r24, r25, r26, r27, r28, r29, r31, r32, 33, r34, r35, r36, r37, r38, r39}.

Table 7: List of different states

Based on Energy and Hop-count		Based on Energy and Data Packet		Based on Energy and Distance	
State	**Value**	**State**	**Value**	**State**	**Value**
S11	1.600	S21	0.080	S31	0.250
S12	0.800	S22	0.040	S32	0.125
S13	1.600	S23	0.080	S33	0.250
S14	3.200	S24	0.160	S34	0.500
S15	1.600	S25	0.080	S35	0.250
S16	3.200	S26	0.160	S36	0.500
S17	1.600	S27	0.080	S37	0.250
S18	0.800	S28	0.040	S38	0.125
S19	1.600	S29	0.080	S39	0.250

In Table 7 different states are found based on three different parameters with energy. To differentiate all states uniquely rating is calculated in Table 8.

Table 8: List of different rating

Based on Energy and Hop-count		Based on Energy and Data Packet		Based on Energy and Distance	
Route	**Rating**	**Route**	**Rating**	**Route**	**Rating**
R11	1.600	R21	0.080	R31	0.250
R12	0.800	R22	0.040	R32	0.100
R13	0.533	R23	0.027	R33	0.063
R14	4.000	R24	0.200	R34	0.625
R15	2.000	R25	0.100	R35	0.250
R16	1.333	R26	0.067	R36	0.156
R17	6.400	R27	0.320	R37	1.000
R18	3.200	R28	0.160	R38	0.400
R19	**2.133**	R29	**0.107**	R39	**0.250**

Thus all rating are arrange in descending order based on their rating values in Table 9. Each rating having its own linguistic nature which is shown in Table 10.

Table 9: Priority statistic of different rating

Based on hop count
R17>R14>R18>R19>R15>R11>R16>R12>R13
Based on data packet
R27>R24>R28>R29>R25>R21>R26>R22>R23
Based on distance
R37>R34>R38>R31>R35>R39>R36>R32>R33

Table 10: Linguistic nature of different rating

Sl. no	Linguistic Nature	Rating
1	R_{VE}	R17, R27, R37
2	R_E	R14, R24, R34
3	R_{VG}	R18, R28, R38
4	R_G	R19, R29, R31
5	R_{LG}	R15, R25, R35
6	R_M	R11, R21, R39
7	R_S	R16, R26, R36
8	R_B	R12, R22, R32
9	R_{VB}	R13, R23, R33

4.3. Energy efficient route selection phase

This phase is specially used to evaluate energy efficient route by the help of three fuzzy rule matrix. These rule matrix expresses different rules process by intelligent system in Table 6 in tabular form. These rules usually take two variables as input, mapping cleanly to a two-dimensional matrix. Table 11, Table 12 and Table 13 are three fuzzy rule matrix based on three different multi-criteria such as energy efficient route based on hop-count, energy efficient route based on transmitted data packet and energy efficient route based on distance. Each cell of these matrixes indicates linguistic rating scale of different route.

Table 11: Fuzzy rule matrix based on hop count and energy

Energy/Hop count	H_L	H_M	H_H
E_L	Rs	R_B	R_{VB}
E_M	R_G	R_{LG}	R_M
E_H	R_{VE}	R_E	R_{VG}

Table 12: Fuzzy rule matrix based on data packet and energy

Energy/Data packet	DP_L	DP_M	DP_H
E_L	Rs	R_B	R_{VB}

E_M	R_G	R_{LG}	R_M
E_H	R_{VE}	R_E	R_{VG}

Table 13: Fuzzy rule matrix based on distance and energy

Energy/Distance	**D_L**	**D_M**	**D_H**
E_L	Rs	R_B	R_{VB}
E_M	R_G	R_{LG}	R_M
E_H	R_{VE}	R_E	R_{VG}

Thus, each route has a specific value in the ad-hoc network. In routing between networks based on different parameters and rules are implemented by intelligent system using fuzzy logic system. This intelligent system design some states of both senders and receiver nodes. From Table 11, Table 12 and Table 13, if the source node (sender) is in R13, R23 or R33 (that is, it has the lowest energy and high intermediate hop-count or high transmitted packet or long away from the destination), it will receive the lowest rating value that is RVB and if the source node (sender) is in R17, R27 or R37 (that is, a node with the very highest energy and minimum number of intermediate hop-count or less number of transmitted packet or shortest distance to the destination), it will receive the highest rating value that is RVE. Fig 1 and Fig 2 show the states and rating scale of different route.

5. Conclusion

Energy efficiency routing is one of the main problems in wireless ad-hoc network. Since mobility of nodes, low residual energy, high transmitted data packet and maximum hop count causes route breakage and packet retransmission. Since, energy efficiency routing indicates to select best path in context of minimum no. of hop count, less data packet transmission and short distance. The main aim of this proposed method to design an energy efficient routing protocol based on multi-criteria evaluation. These multi-criteria involved some parameter such as energy, hop-count, data packet and distance. This method is also determining the rating of each and every route based on multi-criteria strategy. It also helps to repair and maintain routes quickly before they crashed.

REFERENCES

[1] S. K. Das, S. Tripathi, and A. Burnwal, “Design of fuzzy based intelligent energy efficient routing protocol for WANET,” *in Computer, Communication, Control and Information Technology (C3IT), 2015 Third International Conference on, IEEE*, 2015, pp. 1-4, DOI: 10.1109/C3IT.2015.7060201.

[2] A. Kumar, R. K. Sharma, and A. Burnwal, “Energy Consumption Model in Wireless Ad-hoc Networks using Fuzzy Set Theory,” *Global Journal of Advanced Research*, 2015, vol. 2, no. 2, pp. 419-426.

[3] S. K. Das, S. Tripathi, and A. Burnwal, “Intelligent energy competency multipath routing in wanet,” *in Information Systems Design and Intelligent Applications*, Springer, 2015, pp. 535-543, DOI: 10.1007/978-81-322-2250-7_53.

[4] Chansu Yu, Ben Lee, and Hee Yong Youn. "Energy efficient routing protocols for mobile ad hoc networks." *Wireless communications and mobile computing* 3.8 (2003): 959-973.

[5] S. K. Das, A. K. Yadav and S. Tripathi, “IE2M: Design of intellectual energy efficient multicast routing protocol for ad-hoc network,” *Peer-to-Peer Networking and Applications*, 2016, pp. 1-18, DOI 10.1007/s12083-016-0532-6.

[6] S. K. Das, A. Kumar, B. Das, and A. Burnwal, “Ethics of E-Commerce in Information and Communications Technologies,” *International Journal of Advanced Computer Research*, 2013, vol. 3, no. 1, pp. 122-124, doi=10.1.1.300.9397.

[7] S. K. Das, S. Tripathi, and A. Burnwal, “Fuzzy based energy efficient multicast routing for ad-hoc network,” *in Computer, Communication, Control and Information Technology (C3IT), 2015 Third International Conference on, IEEE*, 2015, pp. 1-5, DOI: 10.1109/C3IT.2015.7060126.

[8] A. Kumar, A. Kumar and A. P. Burnwal, “Application of intelligent game theory approach in cognitive radio ad hoc networks”, *International Journal of Indestructible Mathematics & Computing*, 2017, vol. 1, no. 1, pp. 35-40.

[9] S. K. Das and S. Tripathi, “Intelligent energy-aware efficient routing for MANET,” *Wireless Networks*, 2016, pp. 1-21, DOI 10.1007/s11276-016-1388-7.

[10] Xiaohai Wei, Guoliang Chen, Yingyu Wan and Fred Mtenzi, "Optimized priority based energy efficient routing algorithm for mobile ad hoc networks." *Ad Hoc Networks* 2.3 (2004): 231-239.

[11] Bey-Ling Su , Ming-Shi Wang and Yueh-Ming Huang, "Fuzzy logic weighted multi-criteria of dynamic route lifetime for reliable multicast routing in ad hoc networks." *Expert Systems with Applications* 35.1 (2008): 476-484.
[12] Matthew J. Miller and Nitin H. Vaidya "Ad hoc routing for multilevel power save protocols." *Ad Hoc Networks* 6.2 (2008): 210-225.
[13] R. Zheng, R. Kravets, On-demand power management for ad hoc networks, *in: IEEE Infocom 2003*, April 2003.
[14] C. Sengul, R. Kravets, TITAN: On-demand topology management in ad hoc networks, *ACM Mobile Computing and Communications Review (MC2R)* 9 (1) (2005) 77–82.
[15] B. Chen, K. Jamieson, H. Balakrishnan, R. Morris, Span: An energy-efficient coordination algorithm for topology maintenance in ad hoc wireless networks, *in: ACM Mobi-Com 2001*, July 2001.
[16] Y. Xu, J. Heidemann, D. Estrin, Geography-informed energy conservation for ad hoc routing, *in: ACM MobiCom 2001*, July 2001.
[17] Zhihao Guo , Shahdi Malakooti, Shaya Sheikh, Camelia Al-Najjar and Behnam Malakooti, "Multi-objective OLSR for proactive routing in MANET with delay, energy, and link lifetime predictions." *Applied Mathematical Modelling* 35.3 (2011): 1413-1426.
[18] [18] Samira Kalantari, Mohsen Amiri besheli, Zeinab Sam Daliri, Shahaboddin Shamshirband and Liang Shing Ng, "Routing in wireless sensor network based on soft computing technique." *Scientific Research and Essays* 6.21 (2011): 432-4441.
[19] R.Vadivel and V. Murali Bhaskaran, "Energy efficient with secured reliable routing protocol (EESRRP) for mobile ad-hoc networks." *Procedia Technology* 4 (2012): 703-707.
[20] S. K. Das, A. Kumar, B. Das, and A. Burnwal, "Ethics of reducing power consumption in wireless sensor networks using soft computing techniques," *International Journal of Advanced Computer Research*, 2013, vol. 3, no. 1, pp. 301-304.
[21] S. K. Das, B. Das, and A. Burnwal, "Intelligent energy competency routing scheme for wireless sensor networks", *International Journal of Research in Computer Applications and Robotics*, 2014, vol. 2, no. 3, pp. 79–84.
[22] S. K. Das and S. Tripathi, "Energy efficient routing protocol for manet based on vague set measurement technique," *Procedia Computer Science*, 2015, vol. 58, pp. 348-355, doi:10.1016/j.procs.2015.08.030.
[23] S. K. Das and S. Tripathi, "Energy Efficient Routing Protocol for MANET Using Vague Set," *in Proceedings of Fifth International Conference on Soft Computing for Problem Solving*, Springer, 2016, pp. 235-245, DOI: 10.1007/978-981-10-0448-3_19.
[24] [24] A. Burnwal, A. Kumar, and S. K. Das, "Survey on application of artificial intelligence techniques," *International Journal of Engineering Research & Management*, 2014, vol. 1, no. 5, pp. 215–219.
[25] A. Kumar, A. Kumar and A. P. Burnwal, "Correlation of artificial intelligence techniques with soft computing in various areas", *International Journal of Indestructible Mathematics & Computing*, 2017, vol. 1, no. 1, pp. 27-34.
[26] S. K. Das, A. Kumar, B. Das, and A. Burnwal, "On soft computing techniques in various areas," *Computer Science & Information Technology (CS & IT)*, 2013, vol. 3, pp. 59-68, DOI : 10.5121/csit.2013.3206.
[27] S. K. Das, S. Tripathi, and A. Burnwal, "Some relevance fields of soft computing methodology," *International Journal of Research in Computer Applications and Robotics*, 2014, vol. 2, pp. 1-6.
[28] A. Burnwal, A. Kumar, and S. K. Das, "Assessment of fuzzy set theory in different paradigm," *International Journal of Advanced Technology & Engineering Research*, 2013, vol. 3, no. 3, pp. 16–22.
[29] B. K. Mishra, B. Yadav, S. Jha, and A. Burnwal, "Fuzzy set theory approach to model super abrasive grinding process using weighted compensatory operator," *International Journal of Research in Computer Applications and Robotics*, 2015, Vol. 3, no. 5, pp. 62-68.
[30] A. Burnwal, A. Kumar, and S. K. Das, "Assessment of mathematical modeling in different areas," *International Journal of Advanced Technology & Engineering Research*, 2013, vol. 3, no. 3, pp. 23–26.
[31] N. Kumari and A. P. Burnwal, "Interactive fuzzy programming model in multi-objective inventory control", *International Journal of Indestructible Mathematics & Computing*, 2017, vol. 1, no. 1, pp. 38-26.
[32] S. Murmu, S. Jha, A. Burnwal, and V. Kumar, "A proposed fuzzy logic based system for predicting surface roughness when turning hard faced components," *International Journal of Computer Applications*, 2015, vol. 125, no. 4.
[33] A. Burnwal, S. Mukherjee, and D. Singh, "An additive model of fuzzy geometric programming," *Mathematics Education India*, 2000, vol. 34, no. 1, pp. 25-29.