

# Survey of Fuzzy and Cross Layer Routing Protocols in Manet

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**Abstract** -MANET is an infrastructure less, a self-configuring network of mobile hosts connected by wireless links which forms an arbitrary topology. Due to dynamic network topology and infrastructure less network multihop communication making the unstable route in MANET is challenging than the infrastructure based networks. Several protocols for stable routing in an ad-hoc network have been proposed using the fuzzy and cross-layer in literature. But due to their limitations, there is a need to make them very robust and more stable so that they can go well with the demanding requirements of mobile ad hoc networks. This paper presents a survey of fuzzy and cross-layer based routing protocols for mobile ad hoc networks. Different fuzzy and cross-layer based routing protocols are discussed and analyzed in the paper along with their approach, their metrics and simulation results.

**Index Terms**— Fuzzy logic, cross layer, Routing Protocols,Fuzzification,Defuzzification and MANET

## 1 INTRODUCTION

IN Manet wireless mobile nodes that are making infrastructure-less network consisting of numbers of mobile hosts, communicating with one another [1]. The mobile nodes of MANET can join and leave or change their position inside the network. In such kind of situation, it may be crucial for one node to enroll other hosts in forwarding a packet to its destination due to the limited transmission range of wireless network interfaces. Every node in the network may not be in direct transmission range with other nodes. Each node in the network operates not only as a host but also as the router by forwarding packets to other mobile nodes in the network. In addition to the routing protocols in MANETs have to cope with problems like the exposed and hidden terminal problem or the usage of a shared medium, which can lead to frame collisions. MANET requires multiple constraints to select an optimal route. The constraints are battery power, energy, path stability, signal to noise ratio, bandwidth, the number of hops, mobile speed, buffer occupancy rate, queue length, and data rate. The challenges in MANET are unicast routing, multicast routing, dynamic network topology, velocity, frequency of updates or network overhead, scalability, mobile agent-based routing, quality of service, energy efficient/power aware routing, secure routing[2].

## 2 ROUTING PROTOCOLS IN MANET

To improve the performance of MANET transmission, various types of routing protocols used. They divided into flat routing protocol; hierarchical routing protocol and geographic position assisted routing protocol. In flat routing approaches adopt a flat addressing scheme. Each node participating in routing plays an equal role. Hierarchical routing usually assigns different roles to network nodes. Routing with assistance from geographic location information requires each node to be equipped with the Global Positioning System (GPS).

### 2.1 Routing in a Flat Network Structure

The protocols are fall into two categories: proactive and on-demand routing. Proactive routing protocols share the information periodically between nodes, sharing of information creates overheads to nodes. It increases the power consumption, memory wastage and reduces the lifetime of the node. Many proactive routing protocols have proposed for efficiency and scalability.

### 2.2 On-Demand Routing Protocols

An on-demand routing protocol is a category for wireless ad hoc routing. The design follows the idea that each node tries to reduce routing overhead by only sending routing packets when a communication is needed.

### 2.3 Hierarchical Routing Protocols

Hierarchical routing is the idea of organizing nodes in groups and then assigning nodes different functionalities inside and outside a group. Both routing table size and update packet size are reduced by including in them only part of the network. Thus, control overhead is reduced.

### 2.4 Zone Routing Protocol

The Zone Routing Protocol (ZRP) is a hybrid routing protocol that combines both proactive and on-demand routing strategies. The basic idea is that each node has a predefined *zone* centered itself in terms of some hops. For nodes within the zone, it uses proactive routing protocols to maintain routing information. For those nodes outside of its zone, it does not maintain routing information in a permanent base. Instead, on-demand routing strategy is adopted when inter-zone connections required [3].

To improve the performance of MANET Cross-layer based routing introduced. MANET KnowledgePlane (MANKOP) that collects all layers protocol information and all nodes in-

formation. It has two levels, networking level knowledge plane and application level knowledge plane, to collect the network information [4].

### 3 CROSS-LAYER DESIGN

Traditional Layered architectures are not suitable for the wireless network; because the seven layers open system interconnection model divides the overall networking task into layers and defines a hierarchy of services to be provided by separate layers. The OSI model forbids direct communication between nonadjacent layers; contact between adjacent layers limited to procedure calls and responses. Architecture violations introduced by cross-layer design based on three reasons, the unique problems created by wireless links, the possibility of opportunistic communication on wireless links, and the new modalities of communication offered by the wireless medium. In various ways layered architecture is violated, they are the creation of new interfaces, merging of adjacent layers, design coupling without new interfaces and vertical calibration across layers.

Creation of new interfaces category is divided into subcategories depending upon the direction of information flow they are upward information flow, downward information flow and back and forth information flow. Merging of adjacent layers creates a super layer; the service provided by super layer is the union of service provided by adjacent layers. Design coupling without new interfaces category of cross-layer design involves coupling two or more layers without creating any extra interfaces for information sharing at runtime. Vertical calibration across layers collects various parameters across layers. The cross-layer interactions divided into three categories direct communication between layers, a common database across layers and entirely new abstractions [5][6]. A cross-layer approach to MANET design enhances the performance of a system by jointly designing multiple protocol layers [7].

## 4 FUZZY LOGIC IN MANET

### 2.1 Fuzzy Controller

Route selection is a very sensitive activity for the mobile ad-hoc network (MANET). Ranking of multiple paths from the source node to the destination node can result in efficient route selection and can provide many other benefits for better performance of MANET [8]. MANETs are power constrained since nodes operate with limited battery energy. To maximize the lifetime of these networks, transactions through mobile nodes must be controlled [9]. In MANET fuzzy logic is used to make the accurate decision in route selection using available parameters. It minimizes the overall setup time required for establishing connection [10]. The fuzzy control system consists of fuzzifier, fuzzy knowledge base, rule-based decision and defuzzifier for determining control actions using fuzzy logic reasoning. Since the inputs and outputs of the systems are

commonly crisp value in nature, fuzzification and defuzzification process is used to translate them to and from fuzzy representation.

### 4.2 Fuzzification

It is a procedure where crisp input values are represented in terms of the membership function, of the fuzzy sets.

### 4.3 Fuzzy Inference Engine

Following the fuzzification process, the inference engine determines the fuzzy output using fuzzy rules that are in the form of if-then rules.

### 4.4 De-fuzzification

Defuzzification is then used to translate the fuzzy output into a crisp value. It is a mathematical process used to convert the fuzzy output into a crisp value

In this paper, we discussed various fuzzy and cross-layer routing protocols in MANET.

## 5 FUZZY AND CROSS-LAYER BASED ROUTING PROTOCOLS

### 5.1 Service Aware Multi Constraint Routing Protocol with QoS Guarantee Based On Fuzzy Logic

JING, Z et al [11] proposed a multi-constraint routing protocol based on fuzzy logic. This protocol requires three fuzzy logic subsystems namely FLS1, FLS2 and FLS3. Fuzzy Logic System 1 gets the number of nodes and mobile speeds as the parameters to find the stable route. FLS1 output route stability and Bandwidth feeds to FLS2 to calculate end to end delay and adjust the rate of packets. In FLS3 packet loss ratio is calculated based on packet buffer occupancy rate and route stability. In this protocol, various parameters taken to find the stable route is not adequate, and more systems were making delay. It reduces packet loss rate and end to end delay.

### 5.2 Reliable Routing Algorithm based on Fuzzy Logic for Mobile Adhoc Network

Golnoosh Ghalanvund et al. [12] proposed a reliable routing algorithm based on fuzzy logic to find the reliable route in MANET. During route discovery, the node with more trust value and maximum energy capacity is selected as a parameter. Trust value of each node evaluated based on the parameters length of association, ratio of a number of packets forwarded successfully by the neighbors, to the total number of packets sent and average time taken to respond to a route request and energy determined for every node. Fuzzy Logic applied to calculate reliability based on six rules. Destination node calculates the reliability for all the paths from the source and sends a maximum reliable value through route reply. In this protocol, packet delivery ratio is improved but the end to end delay is increased.

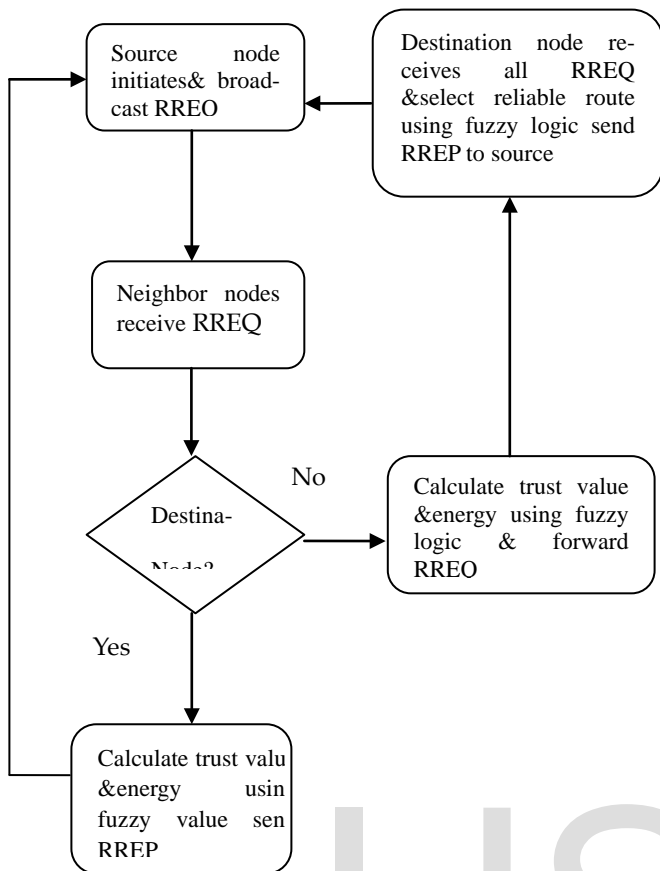


Fig1. Route selection process in RRAF

### 5.3 Fuzzy Ant Colony based Routing Protocol for Mobile Ad Hoc Network

Goswami, M.M et al. [13] proposed a fuzzy ant colony based routing protocol using fuzzy logic and swarm intelligence algorithm for selecting a route in MANET. Source node generates forward ant to create a stack for holding fuzzy cost calculated at each intermediate nodes based on the parameters buffer occupancy rate, energy consumption ratio, and signal strength. At the destination, a backward ant is generated which carry the ANT\_FUZZY\_COST in a reverse path. Intermediate nodes subtract the fuzzy cost from the ANT\_FUZZY\_COST and follow the route in reverse. Pheromone table corresponding to the forward ant's destination is updated. When it reaches the source node, it will be killed after updating the pheromone and probability table of the origin node. In this protocol packet, loss ratio and delay is minimized. This contract motivates use of fuzzy logic in swarm intelligence based routing protocol to explore other areas of routing in MANET.

### 5.4 Cross-Layer Based Routing and Rate Control Using Fuzzy Decision System in MANET

Narayanan, S and Rani Thottungal [14] have proposed cross-layer based routing and rate control using fuzzy decision sys-

tems in MANET. This protocol uses fuzzy logic system1 to select a route in source and fuzzy logic system2 in a destination to monitor the data packet transmission. For a selection of the route, source node performs the fuzzy-based optimal route selection process by considering the parameters such as path stability and bandwidth. The path stability is estimated based on available battery power, distance and link quality. Source node uses nine fuzzy rules to select an optimal path from two parameters. To adjust a data rate from the destination node, it uses fuzzy logic system2 and takes the parameters end to end delay and packet loss ratio. Destination node uses nine fuzzy rules to adjust the data transmission rate of the source. This result minimizes the end to end delay and packet loss rate.

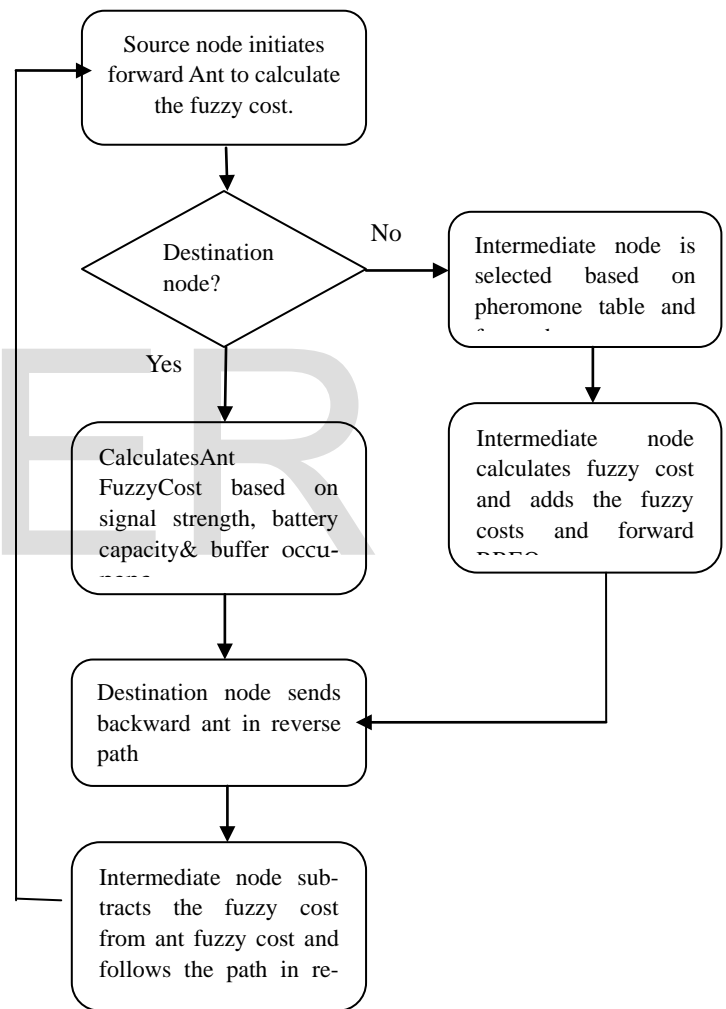


Fig2. Route selection process in FACO

### 5.5 Cross-Layer Based Routing and Power Aware Rate Adjustment(CBR\_PARA) protocol for MANET

Narayanan, S, and Rani Thottungal [15] have proposed a cross-layer based routing with power aware rate adjustment that is an extension of their previous work. This protocol is also uses two fuzzy logic systems FLS1 and FLS2. Fuzzy logic system1 is applied in source node to select the best path based on the

parameters path stability, residual bandwidth, and residual energy. It uses fifteen fuzzy rules to select an optimal path. After selecting the path, source node estimates the initial transmission power, physical data rate, and power consumption ratio to construct a transmission power and rate table. Fuzzy logic system<sup>2</sup> is applied in destination node to adjust a data rate based on an end to end delay and packet loss ratio. The physical data rate of the source is adjusted by comparing the transmission power and rate table. This protocol minimizes the energy consumption and maximizes the throughput.

energy efficient routing mechanism for mobile ad hoc network (EER). The proposed mechanism creates a fuzzy rule in each node to develop a new route during route discovery phase. Fuzzy rules help the node to take appropriate decisions for energy efficient route by considering remaining battery energy and queue status. The proposed mechanism consumes less energy and provides higher life longevity of the mobile nodes and also increases the throughput and minimizes delay.

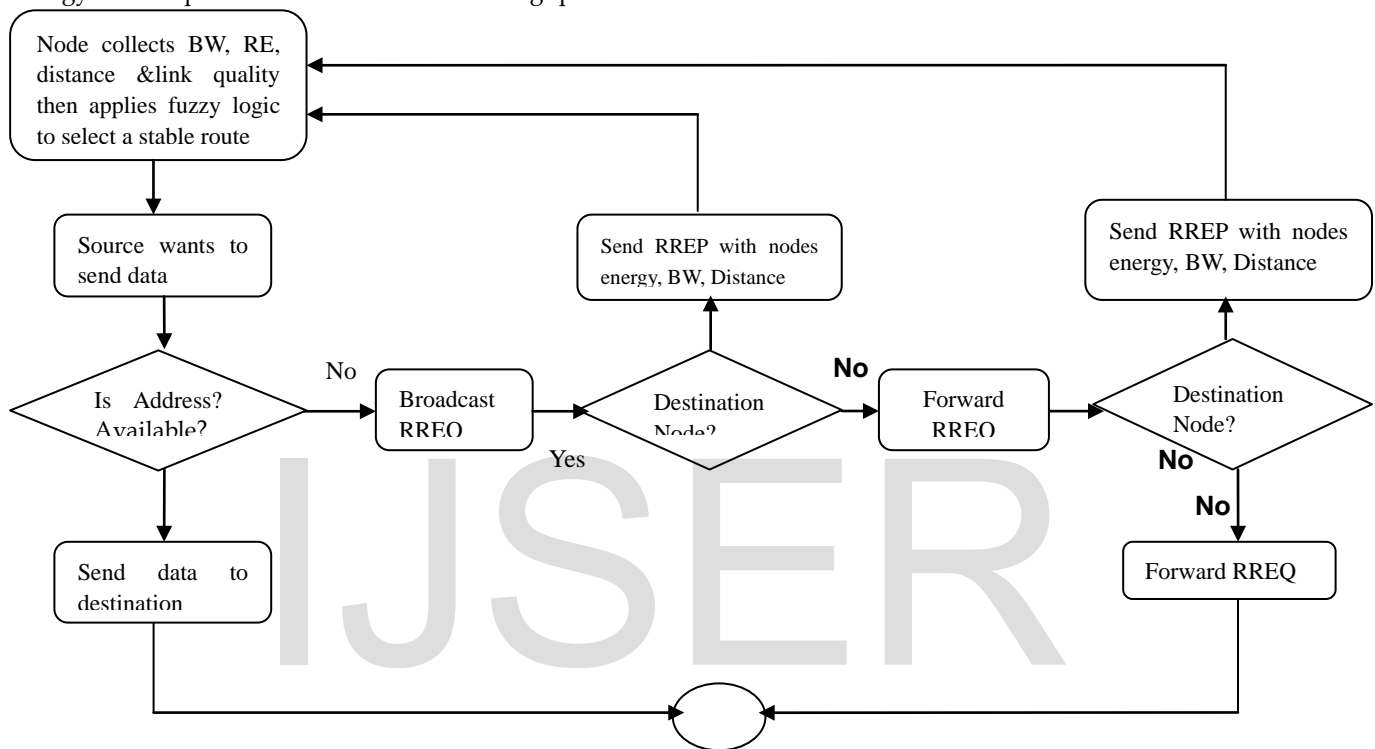


Fig 3. Route selection process in CBRRC AND CBR-PARA

### 5.6 Routing for Wireless Mesh Networks with Multiple Constraints Using Fuzzy Logic

Mala Chelliah et al. [16] have proposed fuzzy multi-constraint AODV routing technique to make a routing decision based on more than one constraint. Source node to discover a new route sends RREQ packets. Intermediate nodes on the path measure the constraints buffer occupancy, residual energy and hop count to apply fuzzy logic. Source node collects all RREP, then compares the value of fuzzy grade that is available in the routing table, then decides the route. If the current path is better updates the routing table, otherwise simply dropped. This technique minimizes the routing overhead and maximizes the throughput.

### 5.7 Energy Efficient Routing Mechanism for Mobile Ad Hoc Network

MD.Manowrul Islam et al. [17] proposed a routing approach

### 5.8 A Fuzzy Based Stable Routing Algorithm for MANET

Arashdana and Mohamed Hadibabaei[18] have proposed a fuzzy based stable routing algorithm to increase the reliability during route selection and for route maintenance before breaking packet transmitted path. In route discovery process source node calculates the link stability coefficient between nodes based on the parameters node position and velocity information. Fuzzy logic applied to calculate the link stability coefficient (LSC) and calculates the route stability coefficient (RSC) between source and destination using all link stability coefficients in RREP message. In route maintenance, the degree of route stability is calculated based on neighbor nodes distance and relative velocity. When destination receives breaking warning it broadcast the RREC message. Source node calculates RSC and compares the RSCs and change the data transmit packet path, it reducing initiate route recovery time. In the protocol, all routes LSCs and RSCs calculated and updated in the route table, the alternate route taken from the table. This algorithm improves the route stability and network per-

formance effectively.

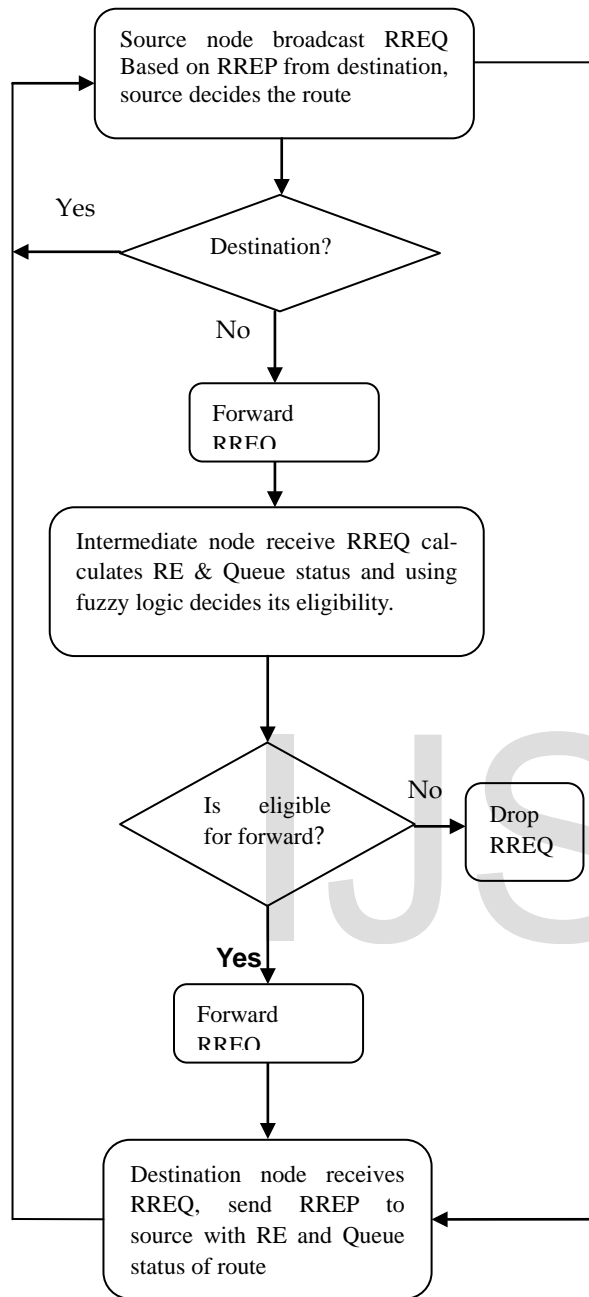


Fig4. Route selection process in EER

### 5.9 LSLP: Link Stability and Lifetime Prediction Based QoS Aware Routing Protocol

Md. Mamun-Or-Rashid and ChoongSeon Hong [19] have proposed link stability and lifetime prediction based QoS aware routing protocol to save the energy and to prolong the lifetime of the network. To achieve the QoS along with a prolonging lifetime of network and to reduce packet loss they calculated three parameters path stability, lifetime predictions and ratio of QoS and requirements for a path. To identify the path stability, calculated link stability between nodes based on link experi-

mentation time. For a lifetime prediction of path lifetime of all nodes along the path is calculated. In the final route choice requirement of minimum bandwidth is considered by traffic will be taken. In this protocol path selection link, stability and lifetime of the network are maximized.

### 5.10 A Fuzzy Energy-based Extension to AODV Routing

NiaziTorshiz, M et al. [20] have proposed a technique fuzzy-energy based AODV. This technique is used to select the optimal path based on minimum bandwidth, hop count, and battery lifetime. Destination node collects the minimum bandwidth, minimum battery lifetime and hop count to all routes from the RREQ packet. It sets the timer to get RREQ from various routes. Then these values are applied to fuzzy inference system to get the selection probability of each route. Finally, the route with the highest selection probability is chosen, and the RREP packet forwarded to the source from this route. This protocol simulation results shows that it increases the network lifetime, lower path failure than the traditional AODV and in the overhead analysis this protocol produces more control packets.

### 5.11 Cross-Layer based Congestion Control Technique for Reliable and Energy Aware Routing in MANET

Thilagavathe, V and Duraisamy, K[21] have proposed the protocol Cross-layer Congestion Aware Reliable and Energy Aware QoS Routing Protocol. Routing information collected from the transport layer and MAC layer. Transport layer monitors the data delivery ratio, and MAC layer monitors signal interference in all the nodes. If the received data packet rate exceeds the predefined threshold, then source decrements the data rate. If the estimated received power at a current time is beyond an average, exponential power of received signal, signal interference is identified by MAC layer and assumed congestion has occurred, the new alternate route is selected. If source node receives congestion status information from the both layers simultaneously for the same route, then congestion free route established. In Transport layer additive increase and multiplicative decrease (AIMD) is applied for rate-based congestion control. This protocol attains the less packet drop and reduced delay.

### 5.12 A Novel Routing Algorithm for MANET

Mamoun Hussein Mamoun[22] proposed a protocol novel routing algorithm for MANET. This technique objective is to enhance the quality of service of DSR protocol. Intermediate nodes will update the SNR value to source node if its link values of SNR lower than the existing recorded values through route reply packet when it receive the route request packet. If the SNR value is greater than the recorded value, intermediate node will not update the value. All nodes in all the routes update the SNR Value to the source node. Based on the SNR Value source node selects the path to the destination. In this protocol, simulation result shows that delivery rate and throughput are increased.

### 5.13 QoS Aware Routing based on Bandwidth Estimation for Mobile Ad Hoc Networks

Lei Chen et al. [23] have proposed a QoS aware routing protocol that incorporates an admission control scheme and a feedback scheme to meet the QoS in MANET's real-time applications. This protocol calculates the residual bandwidth in two methods, Listen to bandwidth estimation and Hello bandwidth estimation. In listening bandwidth estimation, hosts estimates its available bandwidth for new data transmission as the channel bandwidth times the ratio of free time to overall time, divided by weighing factor. In Hello bandwidth estimation, each host estimates its available bandwidth based on the information provided in the hello message. In route discovery process, the host compares its residual bandwidth with the requested bandwidth. Based on the available bandwidth, host update or discards the RREQ. Route maintenance utilizes hello message, immediate hello message, and error message.

imum fuzzy cost and maximum link expiration time. Minimum fuzzy cost is calculated using the parameters bandwidth, end to end delay, the number of hops, and energy. Fuzzification process applied in a fuzzy control system to find a minimum fuzzy cost. Based on minimum fuzzy cost fuzzy logic rules and defuzzification process determines the optimal path cost. Link expiration time is calculated using geographical positioning system, it calculated based on node location, direction, and speed .the path satisfying minimum cost and maximum link expiration time in selected to transmit data. Maximum expiration time determines the high path stability is selected, and a node with minimum energy cost is not selected. This protocol increases the throughput, delivery ratio and decreases delay.

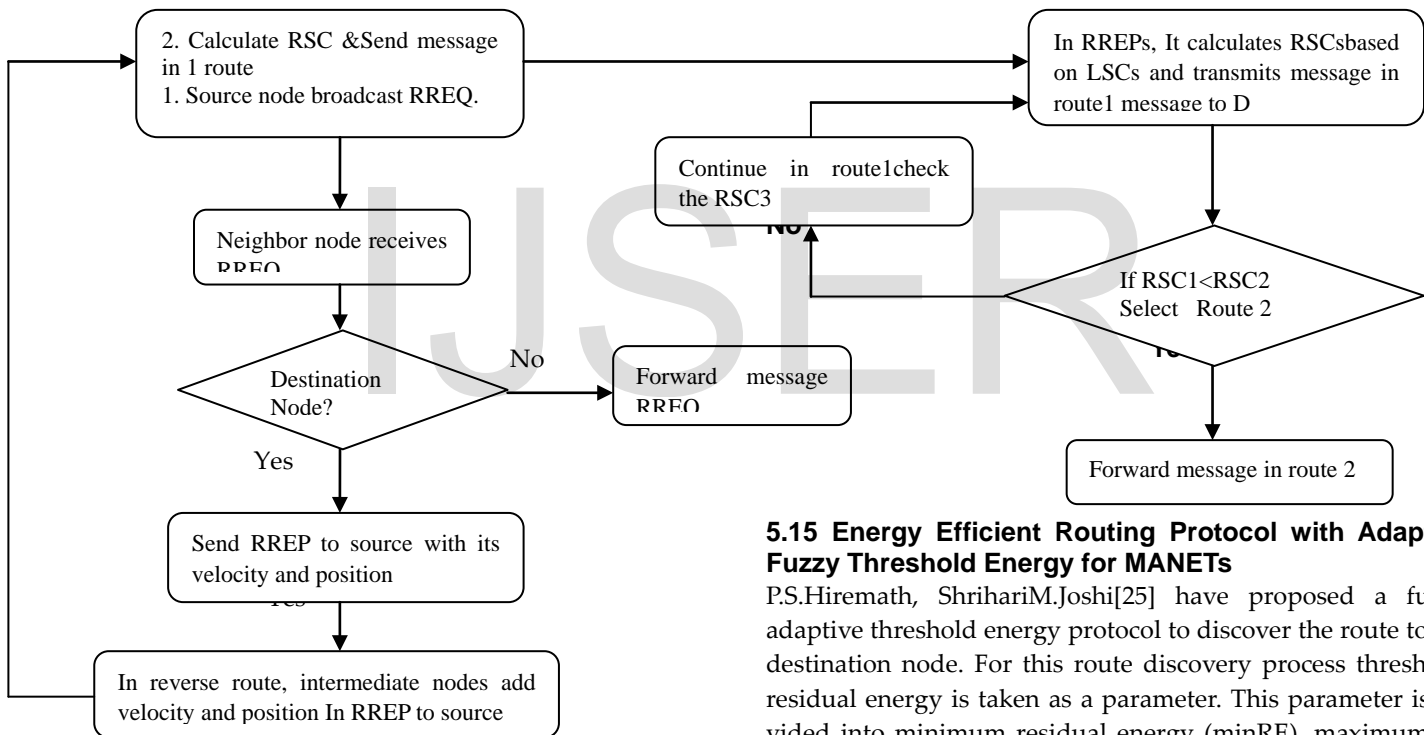


Fig5. Route selection process in SRA

This proposed scheme was providing information to the application about the network status using cross-layer approach. It increases the packet delivery ratio and decreasing the packet delay and energy consumption.

### 5.14 Energy Aware Fuzzy Based Multi-Constrained Single Path QoS Routing Protocol in Manets

V. Jayanthi and M. Sundarambal[24] have proposed Energy Aware Fuzzy based Multi Constrained Single path QoS Routing protocol to find the optimal route in MANET. The optimal path selected between the source to destination based on min-

### 5.15 Energy Efficient Routing Protocol with Adaptive Fuzzy Threshold Energy for MANETs

P.S.Hiremath, Shrihari M.Joshi[25] have proposed a fuzzy adaptive threshold energy protocol to discover the route to the destination node. For this route discovery process threshold, residual energy is taken as a parameter. This parameter is divided into minimum residual energy (minRE), maximum residual (maxRE) and medium residual energy (midRE). These values are received from all the neighbor nodes of the transmitter node. Fuzzification and defuzzification process decides the residual threshold energy to send RREQ. Source node transmits RREQ with residual threshold energy (RE<sub>TH</sub>), if the received nodes residual energy is greater than transmitted threshold residual energy then forward RREQ packet and sends RREP to neighbor nodes, otherwise simply drop the packet does not participate in route selection. This protocol consumed less energy and increased network lifetime.

**TABLE 1**  
**COMPARISON OF PROTOCOLS**

Protocol Name	Approach	Implemented protocol	Purpose	Parameters	Simulation Results
5.1Fuzzy	Fuzzy logic	DSR	Path selection	1.Speed 2.Number of nodes	Reduce delay and packet loss
5.2RRAF	Fuzzy logic	AODV	Reliable routing	1.Trust 2.Energy	Packet delivery ratio is maximum
5.3FACO	Fuzzy logic &swarm intel- ligence	Ant Colony Routing Pro- tocol	Optimal path	1.Buffer occupancy 2.Remaining battery power 3.Signal stability	Decrease the route fail- ures
5.4CBRRC	Fuzzy logic & Cross layer design	AODV	Optimal path Rate control	1.Path stability 2.bandwidth	Minimizes end to end delay And packet loss ratio
5.5CBR_PAR A	Fuzzy logic & Cross layer design	AODV	Optimal path Rate control	1.Path stability 2.Residual bandwidth 3.Residual energy	Minimizes energy con- sumption Increases throughput
5.6Route Selection	Fuzzy logic	AODV	Route Selection	1.Buffer Occupancy 2.Residual Energy 3.Hop Count	Maximizes Throughput Minimizes Congestion
5.7 EER	Fuzzy logic	AODV	Energy efficient route	1.Nodal energy 2.Current queue status	Higher throughput Higher life time for node
5.8SRA	Fuzzy logic	DSR	Stable route	1.Node position 2.Velocity	Increases stability and throughput
5.9LSLP	Traditional Layer	CLPR	More stable path	1.Link stability(motion parameters) 2.Lifetime prediction 3.Ratio of QoS support and requirements	Maximize the link stabil- ity
5.10FE-ODV	Fuzzy logic	AODV	Optimal Route	Bandwidth Hop count Battery	Path lifetime increased
5.11AOMP- REQR	Cross layer	AOMDV	Rate control	Data rate Receiving power	Minimum packet drop,delay
5.12NRA	Traditional layer	DSR	Route Selection	Signal to Noise Ratio	Maximize delivery ratio and throughput
5.13QoS Aware Rout- ing	Traditional layer	AODV	QoS Aware Routing	Bandwidth estimation Listen and Hello	Increases Packet deliv- ery ratio Minimizes delay and energy dissipation
5.14E-MSQR	Fuzzy logic	AODV	Optimal path	1.Bandwidth,2.end to end de- lay,3.energy,4.no of hops 5.link expiration time	Maximum throughput Minimum delay
5.15 AFTE	Fuzzy logic	AODV	Route selection	Residual energy	Maximize life time of network

## 6 CONCLUSION

This paper discusses the different fuzzy and cross-layer based routing protocols. The protocols proposed in [19], [22], [23] traditional layers to improve the performance is not utilizing fuzzy and cross-layer techniques. The protocols proposed in [11], [12], [16], [17], [18], [20], [24], [25] requires cross-layer network design, increases packet delivery ratio, throughput and reduces delay and congestion but does not control the data rate based on feedback from the source node. The protocol proposed in [21] uses cross-layer design and minimizes packet drop. Protocols proposed in [14], [15] implemented using fuzzy and cross-layer network design. Fuzzy logic applied in both route selection and rate control. These protocols minimize end to end delay, energy consumption and maximize throughput. So there is a need to design a routing protocol with fuzzy and cross-layer design to maximize the throughput and rate control with multiple constraints.

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