Fuzzy Based Efficient Routing Protocol For Route Recovery In MANET

Ritu Dahiya[1], Ajay Dureja[2]

[1]M.Tech Scholar (CSE), PDMCEW
Bahadurgarh, Haryana, India.
ritu.dahiya11379@gmail.com

[2]Assistant Professor (CSE), PDMCEW
Bahadurgarh, Haryana, India.
ajaydureja@gmail.com

Abstract:*A Mobile Ad-Hoc Network (MANET) is a collection of wireless mobile hosts that are arbitrarily located and lack any infrastructure and centralized administration. In MANET, routing protocols are used to provide the specific path for sending the data packets. By growing the use of real-time application on mobile devices, there is a constant challenge to provide reliable and high quality routing algorithm among these devices. Due to the mobile nature of MANET, all the routing protocols have some route errors. In addition to limited energy resources, failure of the nodes is a constraint to provide a reliable communication in wireless mobile networks. The failure of a node may have many reasons like mobility of the node and node or link failure. In this paper, we propose a technique to improve routing protocols by considering both energy and failure constraints and managing them. By using the proposed protocol, the routing protocols dynamically adapt to node's failure. In this paper, we propose a fuzzy based efficient routing protocol (FBERP) for large scale mobile ad-hoc networks that aims to minimize the packet loss rate. Each node in the network is characterized by its communication parameters. We develop a fuzzy logic controller that combines these parameters, Packet Loss Rate, Communication Rate, Energy and Delay Parameters. The value obtained, indicates the priority of a node and it is used in route formation. Our simulation shows that our proposed protocol outperforms the standard AOMDV routing protocol in minimizing the packet loss.*

Keywords:MANET, Fuzzy Logic, Route Recovery, Route Discovery, Node Failure, Routing Protocol, AOMDV, FBERP

1. Introduction

Wireless networking is a technology that enables two or more computers to communicate using standard network protocols, but without network cabling. We can categorize wireless network in primarily following two categories:

- **Infrastructured network:** A network with fixed and wired gateways.
- **Infrastructureless (ad hoc) network:** All nodes of these networks behave as routers and take part in discovery and maintenance of routes to other nodes.

A mobile ad hoc network (MANET) is a collection of mobile devices that can communicate with each other without the use of a predefined infrastructure or centralized administration. MANET is a wireless, infrastructureless and self-configuring network of mobile nodes [1]. A MANET can be constructed quickly at a low cost. Due to mobility of nodes, it becomes difficult to perform routing in a MANET as compared to a conventional wired network. MANET is having mobile nodes and thus it has a continuously changing network topology [2]. This feature makes it difficult to perform routing in a MANET compared with a conventional wired network. Ad-hoc networks have various typical features such as unreliability of wireless links between nodes, constantly changing topology, lack of incorporation of security features in statistically
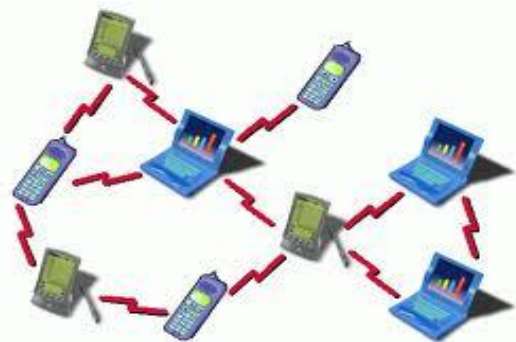
configured wireless routing protocol not meant for ad-hoc environments.

Figure 1: Mobile Ad-Hoc Network

1.1 Routing in MANET

Efficient routing of packets is a primary MANET challenge. MANETs use multi-hop rather than single-hop routing to deliver packets to their destination. The goal of routing in a MANET is to discover the most recent topology of a continuously changing network to find a correct route to a specific node. At network layer, routing protocols are used to find route for transmission of packets. Routing is the most fundamental research issue in ad hoc networking. Many routing protocols have been proposed for MANETs with the goal of making the route selection efficient. Dynamically

changing topology and lack of centralized control make the design of a routing protocol challenging. Routing Protocols used in Mobile Ad Hoc Networks must automatically adjust to environments that can vary between the extreme high mobility with low bandwidth and low mobility with high bandwidth. The routing protocols in MANET are classified as follows:
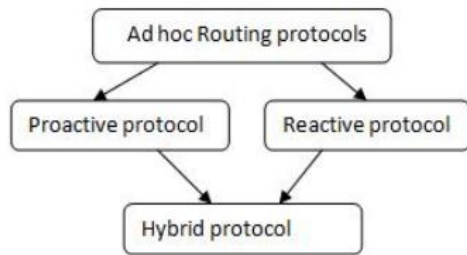

Figure 2: Classification of Routing Protocols

1.1.1 Table-Driven (Proactive) Routing Protocols

These types of protocols are called table driven protocols in which fresh lists of destinations and their routes are maintained by periodic distribution of routing tables throughout the network and this category of protocol always strives to maintain consistent and updated routing information at each node. Packets are transferred over the predefined route specified in the routing table. The proactive routing protocols use link-state routing algorithms which frequently flood the link information about its neighbors and the main drawback of proactive routing protocol isthat all the nodes in the network always maintain an updated table. Proactive protocols have lower latency in comparison to reactive protocols. Example Protocols: DSDV, OLSR (Optimized Link State Routing).

1.1.2 On-Demand (Reactive) Routing Protocols

These types of protocols are also called as On Demand Routing Protocols where the routes are not predefined for routing. Reactive protocols establish a route to a destination on demand. The route discovery mechanism is based on flooding algorithm which employs on the technique that a node just broadcasts the packet to all of its neighbors and intermediate nodes just forward that packet to their neighbors. Reactive protocols have higher latency and smaller routing overheads as compared to proactive protocols. Example Protocols: DSR, AODV.

1.1.3 Hybrid Routing Protocols

Hybrid protocols are the combinations of reactive and proactive protocols and takes advantages of these two protocols and thus combines the advantages of both. Example Protocol: ZRP (Zone Routing Protocol).

1.1.4 Unipath Routing Protocols

These protocols provide a single unique path between the source and destination by establishing wireless links between the mobile nodes and each mobile node behaves like a router for discovering and maintaining the routes.

1.1.5 Multipath Routing Protocols

These protocols provide multiple paths between the source and destination. These protocols outperform the unipath routing protocols in that they provide alternate routes in case of route failure or any other fault.

1.2 Issues Related to MANET Routing

Various issues related to MANET routing are: Mobility of Nodes, Bad Condition of Channels, Unpredictability of Environment, Unreliability of Wireless Medium, Packet Collision, Limited Energy Resources and Dynamic Topology. These issues may result in faults such as: Failure of Packet Delivery, Route Breakages, Transmission Errors, Node Failures, Link Failures, Congested Nodes or Congested Links.

1.3 Features of Routing Protocols

- Exchanging Route Information
- Gathering Route Breaks Information
- Route Recovery
- Load Balancing

1.4 Route Maintenance and Route Recovery

In MANET, data transmission starts immediately after establishing the primary route. But due to various issues of routing in MANET discussed above, there may be a route failure in primary route. To handle this problem, route maintenance is done to eliminate the broken link and to provide the uninterrupted transmission between source and the destination. Route recovery is a part of route maintenance.

1.5 Fuzzy Concept in MANET

The membership functions were introduced by Zadeh in the first paper on fuzzy sets (1965). Fuzzy logic implements human experiences and preferences via membership functions and fuzzy rules. A membership function is a mathematical formation of representing a fuzzy set. A fuzzy number is a quantity whose value is imprecise, rather than exact as is the case with "ordinary" (single-valued) numbers.

For any set X, a membership function on X is any function from X to the real unit interval [0, 1]. Membership functions on X represent fuzzy subset of X. The membership function set is usually denoted by μ_A. For an element x of X, the value $\mu_A(x)$ is called the membership degree of x in the fuzzy set. $\mu_A(x)$ quantifies the grade of membership of the element x to the fuzzy set.

- $\mu_A(x) = 0$ means that x is not a member of fuzzy set.
- $\mu_A(x) = 1$ means that x is fully member of fuzzy set.
- $\mu_A(x)$ between 0 and 1 characterize fuzzy members, which belong to set partially.

1.6 Problem Statement

Traditional on demand routing produces heavy routing traffic by blindly flooding the entire network with RREQ packets during route discovery. The routing overhead associated with dissemination of routing packets is quite huge especially when topology changes. Multipath routing protocols cache multiple routes to a destination in a single route discovery. However, due to mobility in wireless mobile networks, multiple path protocols endure additional packet drops and delay. Multipath routing protocols involving multipath discovery and local route recovery at the time of node mobility creates additional burden and heavy traffic load on the network by selecting recovery node as random overhearing node. So we propose a fuzzybased efficient routing protocol which provides multipath discovery and efficient route recovery at the time of node failure. Whenever a link or a route break is occurring, a route recovery is performed which in turn invokes the alternate route selection from the available nodes on the basis of the neighboring node which is first to send feedback acknowledgement packet from destination. In case of more than one node sending packet at same time then node with higher available throughput will be selected. The proposed routing protocol has the following advantages:

- Prioritizes the next node with maximum throughput at the time of node failure

- Minimized packet loss rate

- Provide optimal routes

- Loop-free and disjoint path

2. Related Work

This section focuses on the existing work in literature pertaining to the topic of this paper. We have briefly examined various route recovery schemes for MANETs.

Dongkyun Kim et.al introduced a power-aware route maintenance protocol to increase the network lifetime, for on-demand reactive routing protocols without periodic route recovery. It is achieved by using two threshold power levels to evenly distribute power dissipation among nodes [3].Wasim El-Hajj et.al proposed a fuzzy-based hierarchical energy efficient routing scheme (FEER) for large scale mobile ad-hoc networks which maximizes the lifetime of the network. Each node in the network is characterized by its residual energy, traffic, and mobility. A fuzzy logic controller is used to combine these parameters and the value thus obtained, indicates the importance of a node and it is used in network formation and maintenance [4].Justin Yacoski et.al proposed cross-layer approach and used enhanced channel reservation messages which allows alternate nodes to self-elect themselves by using only inferred neighbor information. This self-election avoids the dependence on individual links and minimizes failure in links [5].A. Naga Raju and Dr. S. Rmachandram introduced Fuzzy cost based approach to select the effective paths among from existing multi paths. The proposed protocol is more helpful if there is a problem of redundancy of traffic load and there is same rank for several paths, as the fuzzy cost is determined uniquely for each path [6].ShahramNourizadeh et.al proposed a technique to improve routing protocols by considering both energy and failure constraints and managing them. A fuzzy logic based failure management algorithm was proposed by them. By using this technique, the routing protocols dynamically adapt to node's failure. The simulations results show the efficiency of this technique in two sample routing protocols. Stable route recovery and high data delivery ratio are the main characteristics that the proposed protocol adds to the routing algorithms [7].Dhirendra Kumar Sharma et.al enhanced the performance of Split Multipath Routing protocols by using route update mechanism. The broken route is repaired by using route update mechanism and delay through new updated path. It increase the performance of MANET and reduced the delay metric [8].TaqwaOday and Prof. Dr. Abduladhem A. Ali used a fuzzy controller to obtain the routes cost depending on the intermediate nodes, packet queue occupancy, and internode distances. And this fuzzy cost is used to predict the lifetime of the selected routes using another fuzzy controller. Simulation shows that it enhances packet delivery ratio and end-to-end delay [9].Khalid Zahedi et.al proposed a route maintenance approach for prediction of link breakage. In this approach, the link availability is predicted and a warning message is issued if there is a chance of soon link breakage. It had been implemented on the existing Dynamic Source Routing protocol (DSR). This approach reduces the packet loss and delay that occur in original DSR protocol [10].ArashDana et.al proposed a reliable routing algorithm based on fuzzy-logic (RRAF) for finding a reliable path in Mobile Ad Hoc Networks. Two parameters are calculated for each node, trust value and energy value, to calculate the lifetime of routes. A new parameter called "Reliability Value" is generated for each route using fuzzy logic. This reliability value decides the stable route to be followed for transmission between source and destination. Simulation shows that RRAF has reliability improvement in comparison to AODV [11].S. B. Wankhade and M. S. Ali described route failure management technique for ant based routing in Mobile Ad Hoc Network, inspired by Ant colony Optimization and enhanced by Fuzzy logic technique as failure management. Transmission & processing delay, available bandwidth and number of hops visited are used by the ant agents for route discovery. A route with highest preference probability is established. Node mobility and link disconnection are predicted for failure management using fuzzy logic and based on predicted results, route or node failure is identified. Simulation results show that the routing protocol attains good packet delivery ratio with less packet drop and delay [12].D. Jagadeesan et.al proposed Multipath routing protocol for effective local route recovery in Mobile Ad hoc Networks. Multiple paths between the source and the destination are established and they are cached in there route cache at the time of route failure. The overhearing node sends recovery route and the detecting node selects recovery route on the basis of route with higher available bandwidth [13].Devi M. et.al proposed Fuzzy Based Route Recovery Technique which performs two functions: Proactive failure discovery and Route failure recovery. The metrics estimated are: Link Expiration Time (LET), Received Signal Strength (RSS), Available Bandwidth (ABW) and Residual Energy (RE) and based on these metrics, node is classified as weak, normal or strong using fuzzy logic [14].NarendraBabujiYadla et.al proposed a distributed routing protocol i.e., TORA. It provides three functions: Creation of routes, Maintenance of routes and Erasing of routes. The protocol uses three different packets for these functions [15].Pooja and Ajay Dureja proposed Enhancement of Multipath Routing Protocol for Route Recovery. It provides multipath discovery, efficient utilization of bandwidth and route recovery in case of failure. This proposed protocol overcomes the problem of stale routes in multipath routing protocols. It also shows significant improvement in packet delivery ratio and reduced end to end delay [16].Devi M. and V. R. Uthariaraj proposed a congestion detection and recovery technique. The congestion status of the nodes was calculated by using the parameters such as queue length, data rate, and medium access control (MAC) contention and it is compared with the upper and lower limit of these parameters and the node is assigned the congestion status as normal, medium or high level. Simulation results show that the proposed congestion detection based route recovery technique minimizes the packet drop and delay while increasing the packet delivery ratio in presence of high traffic loads [17].Sara Aliabadi et.al added Triangular Fuzzy Numbers to prediction of route errors and make route recovery as parallel of packet sending. Any node in this project used a route error counter and an error prediction based on Fuzzy algorithm to recover its routes before an exact route error on its route discovery has been happened [18].

3. Proposed Work

3.1 Protocol Overview

We propose a fuzzy based efficient routing protocol (FBERP) for large scale mobile ad-hoc networks that aims to minimize the packet loss rate. Each node in the network is characterized by its communication parameters. We develop a fuzzy logic

controller that combines these parameters, Packet Loss Rate, Communication Rate, Energy and Delay Parameters. The value obtained, indicates the priority of a node; a node with maximum throughput is selected and it is used in route formation. Our simulation shows that our proposed protocol outperforms the standard AOMDV routing protocol as the packet loss rate is minimized in our proposed work.In future, work can be done to lower down the packet delay and any other communication parameters may be used to further improve the protocol.Our proposed protocol FBERP uses the following algorithm for its route discovery and it also maintains its route by dynamically changing the route in case of node failure.

3.2 Algorithm

Algorithm(Src,Dst)

/*Set the Network with N nodes with Src and Dst Node Specification*/

{

1. Set CurNode=Src
   [Set Src Node As Current Node]
2. While SurNode<>Dst
   [Repeat Process till Destination Node not arrived]
   {
3. Generate the Neighbor List of Src Node called NNodeList
4. For j=1 to Length(NNodeList)
   [Analyze All Neighbor Nodes]
5. {
6. Identify LossRate,CommunicationRate and Delay Parameters for NNodeList(j)
7. Apply High, Medium and Low Fuzzy Operators on These Communication Parameters for NNodeList(j)
8. If (Low(LossRate) And High(CommunicationRate) and Low(Delay))
9. {
10. Set NNodeList(j).Priority=High
11. }
12. If (Medium(LossRate) And Medium(CommunicationRate) and Medium(Delay))
13. {
14. Set NNodeList(j).Priority=Medium
15. }
16.
17. If (HIgh(LossRate) Or Low(CommunicationRate) Or High(Delay))
18. {
19. Set NNodeList(j).Priority=Low
20. }
21.
22. Analyze the Energy Parameter for Each Node Pair and if apply Fuzzy on Energy Vector
23. If (Low(NNodeList(j))
24. {
25. Set NNodeList(j).Priority=Low
26. }
27. }
28. if (Priority(AnyNode(NNodelist))=High)
   {
   Set High Priority Node as CurNode
29. }
30. Else if(CommunicationRate<Threshold And EnergyLoss>Threshold And Throughput<Threshold)
   {

31. Increase Priority of other Remaining Nodes by 1
   }
32. Else
   {
33. Find the node with MaxThroughput and Set it as CurNode
   }
   }
}

4. Results and Discussion

4.1 Simulation Model and Parameters

We used NS2 to simulate our proposed protocol. In our simulation, the packet interval is set to be 0.0008sec. We use IEEE 802.11 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage. In our simulation, 25 mobile nodes move in a 500×500 m region for 10 seconds simulation time. We assume each node moves independently with the same average speed. In our simulation, the simulated traffic is TCP (ftp).Our simulation settings and parameters are summarized in Table 1.

Table 1: Simulation Parameters

Parameter	Value
Simulator	NS 2.35
MAC Type	802.11
Routing Protocol	FBERP
Channel Type	Wireless Channel
Antenna Model	Omni Antenna
No. of Nodes	25
Area Size	500*500
Simulation Time	10 sec
Traffic Source	TCP(ftp)
Packet Interval	0.0008 sec
Radio Propagation Model	Two way ground
Interface Queue Type	Droptail/priqueue
Max packet in queue	50

4.2 Performance Metrics

Performance Metrics are quantitative measures that can be used to evaluate any MANET routing protocol.We compare our FBERP protocol with the AOMDV protocol. We evaluate mainly the performance according to the following metrics.

4.2.1 Packet Transmission Analysis

It is the number of transmitted packets from the source to arrive at the destination.

Table 2: Shows Time vs Packet Transmission values of AOMDV and FBERP

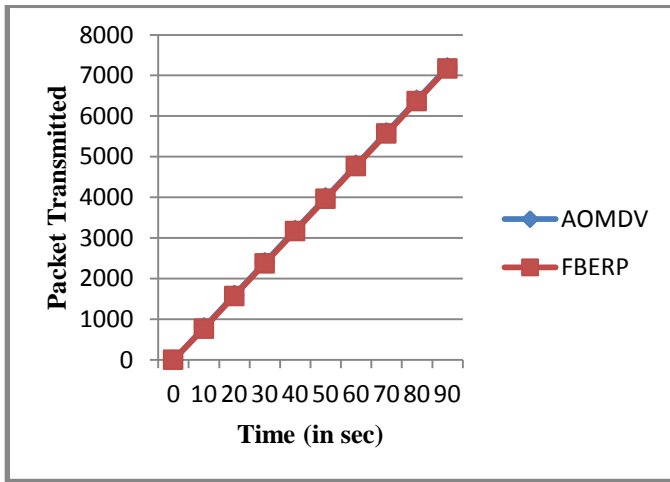| Time	AOMDV	FBERP
0	0	0
10	795	771
20	1597	1573
30	2395	2372
40	3197	3169
50	3997	3970
60	4799	4770
70	5600	5570
80	6401	6373

90	7200	7173

Figure 3: Packet Transmitted

4.2.2 Packet Loss Analysis

It is the failure of one or more transmitted packets to arrive at their destination.

Table 3: Shows Time vs Packet Loss values of AOMDV and FBERP

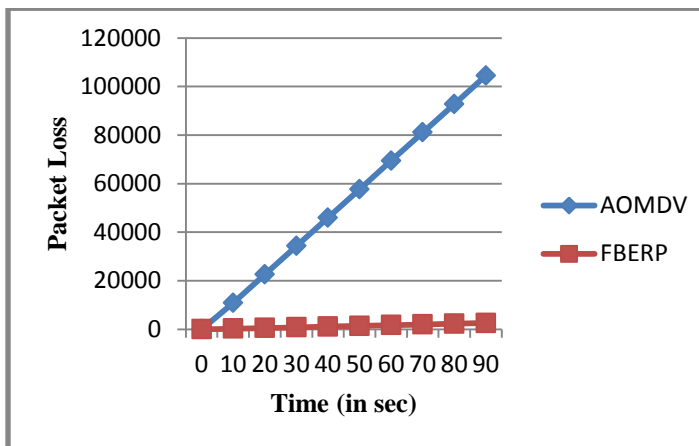| Time	AOMDV	FBERP
0	0	0
10	10890	254
20	22605	547
30	34282	840
40	45980	1137
50	57675	1430
60	69396	1724
70	81090	2016
80	92768	2310
90	104476	2602

Figure 4: Packet Loss

4.2.3 Packet Delay Analysis

It is the time between start of the packet being transmitted at the source and start of the packet being received at the destination.

Table 4: Shows Time vs Packet Delay values of AOMDV and FBERP

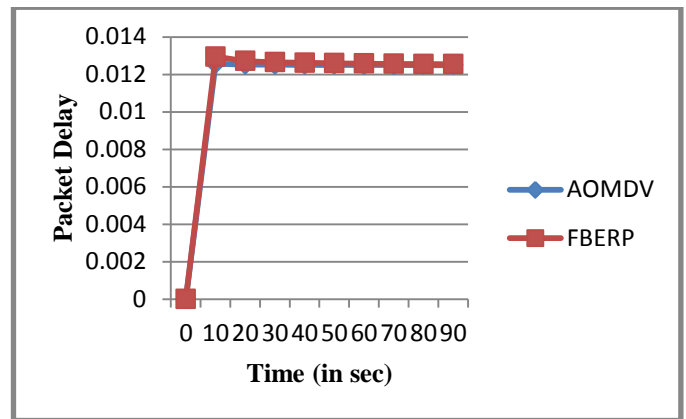| Time	AOMDV	FBERP
0	0	0
10	0.012568	0.012947
20	0.012516	0.012712
30	0.012516	0.012642
40	0.012507	0.012619
50	0.012507	0.012594
60	0.012498	0.012575
70	0.012497	0.012561
80	0.012496	0.012553
90	0.012495	0.012547

Figure 5: Packet Delay

4.2.4 Bytes Communicated Analysis

It is the number of bytes that can be transmitted along a network.

Table 5: Shows Time vs Bytes Communicated values of AOMDV and FBERP

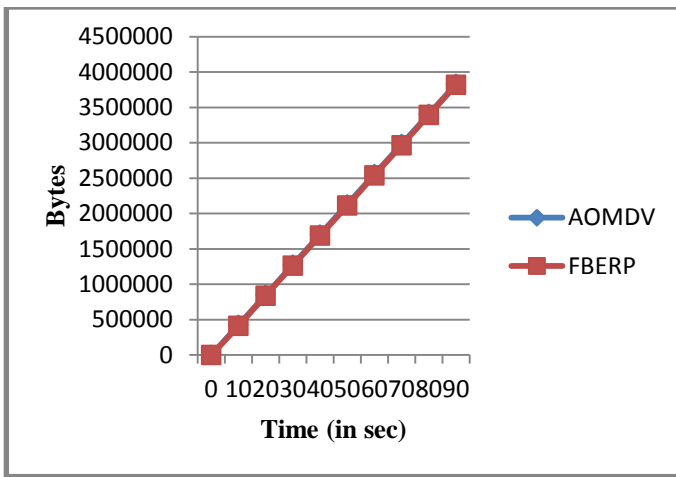| Time	AOMDV	FBERP
0	0	0
10	422940	410172
20	849604	836836
30	1274140	1261904
40	1700804	1685908
50	2126404	2112040
60	2553068	2537640
70	2979200	2963240
80	3405332	3390436
90	3830400	3816036

Figure 6: Bytes Communicated

Results

In the initial experiment, we compare our proposed protocol FBERP and AOMDV with varying time. From Figure 5.5, we can see that the number of packets transmitted in the proposed FBERP protocol is nearly same when compared to the AOMDV protocol. From Figure 5.6, we can see that the packet loss for FBERP is greatly reduced as compared to AOMDV. From Figure 5.7, we can see that the packet delay for FBERP is slightly more when compared to AOMDV. From Figure 5.8, we can see that the bytes communicated for FBERP is almost same as AOMDV.

5. Conclusion and Future Work

MANET is a wireless, infrastructureless and self-configuring network of mobile nodes. Efficient routing of packets is a primary MANET challenge. Many routing protocols have been proposed for MANETs with the goal of making the route selection efficient. But due to various issues of routing in MANET such as Mobility of Nodes, Bad Condition of Channels, Packet Collision,Unpredictability of Environment, Unreliability of Wireless Medium, Limited Energy Resources and Dynamic Topology, there may be a route failure in primary route. To handle this problem, route maintenance is done to eliminate the broken link and to provide the uninterrupted transmission between source and the destination. Various route recovery schemes have been proposed to handle the problem of route or node failures. In this paper, we propose a fuzzy based efficient routing protocol (FBERP) for large scale mobile ad-hoc networks that aims to minimize the packet loss rate. Each node in the network is characterized by its communication parameters. We develop a fuzzy logic controller that combines these parameters, Packet Loss Rate, Communication Rate, Energy and Delay Parameters. The value obtained, indicates the priority of a node; a node with maximum throughput is selected and it is used in route formation. Our simulation shows that our proposed protocol outperforms the standard AOMDV routing protocol as the packet loss rate is minimized in our proposed work.In future, work can be done to lower down the packet delay and any other communication parameters may be used to further improve the protocol.

6. References

[1] Mobile Ad Hoc Network, en.wikipedia.org/wiki/Mobile_ad_hoc_network.

[2] Marco Conti, Body, Personal, "Local Ad Hoc Wireless Networks", in the Book "The Handbook of Ad Hoc Wireless Networks" (Chapter 1), CRC Press LLC, 2003.

[3] Dongkyun Kim, Jaewoo Park, C-K. Toh, Yanghee Choi, Power-aware Route Maintenance Protocol for Mobie Ad Hoc Networks, 0-7803-7661-7/03/(c)2003 IEEE, 2003.

[4] Wasim El-Hajj, DionysiosKountanis, Ala Al-Fuqaha, Mohsen Guizani, A Fuzzy-Based Hierarchical Energy Efficient Routing Protocol for Large Scale Mobile Ad Hoc Networks (FEER), IEEE ICC 2006 proceedings, PP 3585-3590, 2006.

[5] Justin Yackoski, Chien-Chung Shen, Cross-layer Inference-based Fast Link Error Recovery for MANETs, WCNC 2006 proceedings, 1-4244-0270-0/06/(c)2006 IEEE, PP 715-722, 2006.

[6] A Naga Raju, Dr. S Rmachandram, Fuzzy Cost Based Multipath Routing for Mobile Ad-Hoc Networks, Journal of Theoretical and Applied Information Technology, PP 319-326, 2008.

[7] ShahramNourizadeh, Y.Q. Song, J.P. Thomesse, A Distributed Fuzzy-based Failure Management for Wireless Sensor Networks, The Second International Conference on Communication Theory, Reliability, and Quality of Service- CTRQ 2009, version 1, Nov 2009.

[8] Dhirendra K.S., S. Kumar and C. Kumar, Enhancement of Split Multipath Routing Protocol in MANET, International Journal on Computer Science and Engineering, Vol. 02, No. 03, PP 679-685, 2010.

[9] TaqwaOdey, Prof. Dr. Abduladhem A. Ali, Fuzzy Controller Based Stable Routes with Lifetime Prediction in MANETs, International Journal of Computer Networks (IJCN), Volume (3): Issue (1), PP 37-42, 2011.

[10] Khalid Zahedi, Abdul Samad Ismail, Route Maintenance Approach for Link Breakage Predicttion in Mobile Ad Hoc Networks, International Journal of Advanced Computer Science and Applications, Vol. 2, No. 10, PP 23-30, 2011.

[11] Arash Dana, GolnooshGhalavand, AzadehGhalavand, FardadFarokhi, A Reliable routing algorithm for Mobile Adhoc Networks based on fuzzy logic, IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 3, No. 1, ISSN (Online): 1694-0814, PP 128-133, May 2011.

[12] S.B.Wankhade, M.S.Ali, Route Failure Management Technique for Ant Based Routing in MANET, International Journal of Scientific & Engineering Research Volume 2, Issue 9, ISSN 2229-5518, PP 1-5, September 2011.

[13] D. Jagadeesan, S.K. Srivatsa, Multipath Routing Protocol for Effective Local Route Recovery in Mobile Ad hoc Network, Journal of Computer Science 8 (7): 1143-1149, ISSN 1549-3636, PP 1143-1149, 2012.

[14] Devi M., V. RhymendUthariaraj, Fuzzy Based Route Recovery Technique for Mobile Ad Hoc Networks, European Journal of Scientific Research, ISSN 1450-216X Vol.83 No.1, PP 129-143, 2012.

[15] NarendraBabujiYadla, Ch. Suresh Babu, Route Recovery Schemes for Efficient MANET, International Journal for Development of Computer Science & Technology, Volume-1, Issue-1, January 2013.

[16] Pooja, Ajay Dureja, Enhancement of Multipath Routing Protocol for Route Recovery in MANET, European Scientific Journal, ISSN: 1857-7881 (Print) e-ISSN 1857-7431, edition vol.9, No.18, PP 270-281, June 2013.

[17] Devi M., V. RhymendUthariaraj, Congestion Based Route Recovery Technique for MANET, Journal of Theoretical and Applied Information Technology, ISSN: 1992-8645, E-ISSN: 1817-3195, Vol. 54 No.1, PP 73-81, August 2013.

[18] Sara Aliabadi, Mehdi Agha Sarram, An Improvement on Route Recovery by Using Triangular Fuzzy Numbers on Route Errors in MANET, IOSR Journal of Computer Engineering (IOSR-JCE), e-ISSN: 2278-0661, p- ISSN: 2278-8727, Volume 16, Issue 1, Ver. II, PP 75-79, January 2014.

[19] Prashant Kumar Maurya, Gaurav Sharma, VaishaliSahu, Ashish Roberts, Mahendra Srivastava, An Overview of AODV Routing Protocol, International Journal of Modern Engineering Research (IJMER), ISSN: 2249-6645, Vol.2, Issue.3, PP 728-732, May-June 2012.

[20] Mahesh K. Marina, Samir R. Das, Ad hoc on-demand multipath distance vector routing, Wirel. Commun. Mob. Comput. 2006; 6: PP 969-988, Wiley InterScience, DOI: 10.1002/wcm.432.

[21] Manveen Singh Chadha, RambirJoon, Sandeep, Simulation and Comparison of AODV, DSR and AOMDV Routing Protocols in MANETs, International Journal of Soft Computing and Engineering (IJSCE), ISSN: 2231-2307, Volume-2, Issue-3, July 2012.

[22] P. Periyasam, Dr. E. Karthikeyan, Performance Evaluation of AOMDV Protocol based on Various Scenario and Traffic Patterns, International Journal ofComputer Science, Engineering and Applications (IJCSEA), Vol.1, No.6, PP 33-48, December 2011.