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Fuzzy Logic Based Path Stability Forecasting Scheme for Improving Data Dissemination in MANETs

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Abstract: Path stability of the mobile nodes in MANET plays a vital role in effective data dissemination as it depends on factors such as mobility, energy, signal strength. Several studies reveal that the prediction of path stability might provide solutions thereby routing performance can be increased. In most of the protocols route selection is based on metrics namely hop count, energy, etc. The metric namely mobility factor "MF" is used in some of the protocols. These protocols include nodes with less energy or nodes with high mobility which results in loss of path in a short period of time. Since it preserves the neighbor's history, more control overhead and maintenance complexity exist. Hence, a new metric namely Active Interactive new Neighbor Rate (AINR) has been considered for optimum path selection. In scenarios of path loss, there is an immediate need for alternative paths for continuous data transfer. From literature it is evident that fuzzy logic is more significant in exploring different possible states under path stability determination. Hence a new prediction mechanism based on fuzzy logic has been proposed by considering the Residual Energy (RE), Hop count (Hop) and proposed metric Active Interactive new Neighbor Rate (AINR) as the factors for the prediction of the optimal path. This prediction mechanism is leveraged in MANET scenarios where alternate paths should be available on hand in situations such as battlefield and natural disaster. From the simulation, it has been proved that fuzzy logic prediction model provides better results in terms of various performance metrics such as Throughput, Packet delivery ratio, End-to-end delay, Energy consumption and routing overhead than the existing protocols.

Keywords: Active interactive new Neighbor rate, Energy, Fuzzy logic, Mobile Ad hoc Networks, Path Stability.

I. INTRODUCTION

Infrastructure less network with dynamic topology makes routing in mobile ad hoc networks as a difficult task. All the nodes are highly mobile in nature which results in a dynamic topology. But they act both as a host as well as a router. The nodes in the network can organize themselves when they are within the transmission range. Due to this transmission limitation, the nodes may not connect to the destination directly. Selection of the intermediate node has a great impact on path stability. There are many influential factors which affects the stability of the path such as mobility, battery power of the node, Received signal strength,, security, fault tolerance and so on. In the applications such as military tactical networks, emergency networks, etc. connectivity is an essential factor. Many routing protocols have been proposed to solve this issue. However, the hop count metric [1] is used in many of them to select the shortest path which includes lossy links or slow nodes and hence results in poor performance in data transmission. Hence, a new metric, namely Average Encounter Rate [2] has been proposed to predict the node mobility. Multi objective routing protocols provide more better results than single objective or bi-objective protocols [3]. To avoid the packet loss due to the breakage in the path and to minimize discovery of new routes latency, multipath routing is used. In order to predict the path before it expires either due to node's energy depletion or node mobility, a prediction technique is essential. It has been found that there are many time series prediction techniques such as Bayesian theorem, Markov chain, grey prediction model, Fuzzy logic etc. to predict the stability of the path [19-20]. In this paper, fuzzy logic is used to predict the path stability for effective data transmission. In this work, section II analyses about the related work, section III about the proposed work, section IV algorithm, section V simulation results and evaluation and in section VI conclusion and future enhancements.

II. RELATED WORK

The existing problems in MANET such as the available energy of the node after the consumption in terms of transmission power, receiving power, over hearing power, idle power, link breakage due to node mobility makes data transmission as a challenging task. Most of the researchers are dealing with the issues to identify the optimal route, maintenance of the route etc. In the following section idea of the work done in optimization of energy and stability of the nodes along the path in data transmission in MANET.

In Paper [2] a new metric namely Average Encounter Rate (AER) is used instead of hop count to find a reliable path. This metric identifies nodes which has lesser in mobility or which lies in lesser dense area. These are not considered while hop count is used as a metric. During the selection of optimal node, AER^2 value has been taken instead of AER to minimize the least mean square error. However, energy is not included in this paper. In paper [3] a bi-objective optimization model is used to find the link stability and energy of the node. Single path is determined for data transmission.

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Since path stability is not considered when there is a path loss it requires more computation time to find the alternate path. In paper [4] the congestion is taken as a parameter for energy consumption. According to the author, in many existing energy efficient routing protocols, idle power and sleep power are considered for energy consumption. However, these techniques are not providing more accurate results since congestion is not considered. The nodes are classified based on their current energy level using fuzzy logic. Then load distribution for the rich energy nodes is carried on minimizing the consumption of energy. MAC layer retransmission has been done for local level traffic. However, the node mobility has not been taken into account. In paper [5], a fuzzy based controller has been used for path selection. The parameters used for path selection are length of the queue, average mobility and the distance between the two mobile nodes. The energy factor is not included for path selection. In paper [6] Path selection is based on the parameters namely delay, hop count, signal strength, congestion control and radio metric cost. This protocol uses wireless mesh path protocol (HWMP), which is a combination of both proactive and reactive protocol. However, the energy is not considered.

In paper [7] the author proposed a new routing protocol for energy reduction in MANET. The communication is done by changing the recoil off time depends on their geographical position which in turn reduces the number of retransmissions. Hence the lifetime of the network has been improved. The routing overhead is reduced by maintaining the routes in the local level. Loss of packets in the network has been decreased by forecasting lifetime of the link between the nodes. There are three parts: first one is the optimal route finding, second one is amalgamation in the remaining energy and the third one is the distance of the nodes in the path from the source and destination line. Node mobility is not considered in this paper. In paper [8] a new protocol namely 'Ad hoc on demand multipath routing with lifetime maximization (AOMR-LM)' has been proposed in which residual energy of the node is used for path selection. Two thresholds are used to classify the nodes, namely energy threshold Beta and coefficient Alpha. The selection of the optimal path is based on path class, the class in which the nodes of the path belongs. The nodes are classified as low energy, middle energy and high energy nodes. Path selection is based on high energy nodes. If high energy node is not available then the protocol will select the next higher energy node. Due to multipath selection load balancing is attained and hence network lifetime has been increased. However, the node mobility is not considered in this work.

In paper [9] the author proposed an energy efficient stable routing in which various link related metrics like "link expiration time (LET), probabilistic reliable time of the link (PLRT), link packet error rate (LPER), link received signal strength (LRSS) and remaining batter power (RBP)" are considered as input parameters. Fuzzy logic is used to calculate the probability for the route selection. In the paper [10] the author propounded the relationship between the end to end delay, previous delay and path length. A regression equation is obtained for path length and end to end delay. By using fuzzy time series and regression equation current delay is predicted. The various mobility patterns are taken as input and various prediction techniques such as RMSE, IOE are used for prediction. However, the energy factor is not considered for routing.

In paper [11] the author proposed a new fuzzy logic-based routing protocol namely FBORP to select the optimal path based on the bandwidth, mobility and the residual energy of the nodes. It is proven that the protocol performs well in a high mobility scenario when compared to the benchmark AODV routing protocol. In this protocol based on the weightage given to the parameters different routes are selected. In paper [12] the author proposed a fuzzy based multicasting routing protocol. The Fuzzy rule base depends upon the number of hop counts, sent controlled packets and the energies of the nodes on the routes. The enhancement of FMAR protocol was implemented to quickly maintain and repair the routes with the dynamic lifetime of the routing table before they crashed. In Paper [13] Fuzzy based protocol Fuzzy-AODV is used in which the parameters used are hop count, energy and mobility and the path stability is found using crisp value. However, it provides only single optimal path. In papers [14] the author proposed load balancing ad hoc on-demand multipath distance vector (LBAOMDV) protocol. The energy of the node and channel bandwidth are taken as parameters for load balancing which results in effective data transmission through multiple paths. However, the mobility of the node is not considered for path selection.

In FCMQR protocol [15] path selection is based on end-to-end delay, number of intermediate nodes and bandwidth. Nevertheless, the energy and mobility of the nodes are not considered. In paper [16] The author proposed DFES-AODV protocol in which the best path selection is based on fuzzy logic system in which the parameters used are residual battery power and energy drain rate. In paper [17] The author proposed IAOMDV-F protocol in which the best path selection is based on queue length, distance between the neighbor nodes and mobility. Then it uses path selection index to select the best path. However, the energy of the node is not considered. In paper [18] a new multipath FMRM protocol has been designed in which the fuzzy controllers are used to reduce the route reformation. In paper [19] path stability prediction is based on grey prediction model namely GM (1,1) with energy and active interactive rate as parameters. In paper [20] the path stability prediction has been done based on Markov chain prediction model in which energy is used as parameter to find the stability of the path in each time slot. However, the node mobility is not considered.

From the literature survey it has been found that the mobility prediction of the nodes based on AINR and residual energy using Fuzzy logic has not been done so far.

III. PROPOSED WORK

Initially, the path stability of each path is estimated for facilitating reliable data dissemination between the source and destination through five significant steps namely i) Estimation of Active Interactive new Neighbor Rate, ii) Identification of available energy of the path, iii) Computation of hop count iv) Normalized multi-objective optimization, v) Path stability determination and vi) Forecasting of path stability using fuzzy logic. This Fuzzy based Path Stability Forecasting Scheme (FPSFS) integrates the characteristic functionality of ideal solution techniques and fuzzy for forecasting and deciding the stability of the path which can be appropriately used for reliable data routing. The optimal path for data dissemination is chosen based on ideal solution technique by using fuzzy logic for each factor that contribute towards the stability of the path under routing. This ideal solution approach of generating fuzzy aims in investigating the positive and negative influence of each factor that could be derived during the presence and absence of any possible imposable constraints. Finally, the forecasting of reliable path for data routing is achieved depending on the analysis of feasible alternative paths in routing.

A. Estimation of Active Interactive new Neighbor Rate

In FPSFS, AINR is used for determining the mobility of the node that could be optimally used for data routing. To estimate the mobility of node, appropriate knowledge about the number of new neighbor nodes of each interacting mobile nodes under routing must be determined. AINR refers to the total number of new neighbors that has direct interaction with each specific mobile node under activity in an interval of time T [t-1, t]. This count is extracted using periodic broadcasting of hello packets that determine the degree of connectivity which pertains to the exact information of new neighbors under robust connectivity. Each node store and designates the information regarding the set of new neighbors represented using "1".

$$AINR = |Ni| / T \quad (1)$$

where $|Ni|$ represent the set of new neighbors interacting with a mobile node i.e. Encounters in an interval of time T. The neighbor set of each and every node is periodically refreshed and stored in all the mobile nodes for decision analysis. For Instance, if a mobile node 'A' is intractable with mobile nodes at time 't-1' is {B, C, E, F} and 't' is {B,G,H} then the value of AINR is 2 since B resides there at time 't-1' it is not counted twice. When the value of AINR is low then it implies that either the mobility of the node is low since it resides in the same place or the density may be low. PAINR for the path is given by "2".

$$PAINR = \sum_{i=1}^{m}(AINR_i - MAINR)^2 \quad (2)$$

B. Identification of available energy of the node

Further, energy of the mobile node under interaction in turn contributing towards the energy of the link acts as another factor that potentially influences the stability of the network. The energy of the mobile nodes that establishes a connectivity node is also collected like the AINR parameter of the network which is specific for each participating node under activity. The energy required for transmitting a packet from source node '*i*' is given by "3".

$$E_{tx}(p,i) = i.v.t_p \quad (3)$$

where *i*, *v* and t_p represents the current (i), voltage (v) and time (t_p) that is essential for transmitting a packet in the network. Further, the total amount of energy required for transmitting a packet from sender node '*i*' to another node '*j*' is computed based on "4".

$$E(p,i) = E_{tx}(p,i) + E_{rx}(p,j) + (H-1)E_o(p,o) \quad (4)$$

where, E_{tx}, E_{rx}, E_o refers to the amount of energy spent for transmitting a packet from sender node '*i*', the energy required for reception of a packet at node '*j*' and energy spent for overhearing the packet by neighbor node respectively. The value of '*H*' highlights the average number of neighbor nodes, which are closely located in the communication range from node i to node j. It is noted that the energy spent on overhearing the packet is considerably very high in the case of dense network.

Furthermore, the drain rate of a mobile node calculated using exponential weighted moving average method for a time interval '*T*' by averaging the amount of energy consumption and energy dissipation estimated during the same time period '*T*' is represented based on "5".

$$E_{Dr(i,t)} = ϒE_{Dr(i,t-1)} + (1-ϒ)E_{Dr(i,t)} \quad (5)$$

where, 'ϒ' is the exponentially distributed mean parameter that takes a value between 0 and 1. $E_{Dr(i,t-1)}$ and $E_{Dr(i,t)}$ represents the energy drain rate of a mobile node at time (t-1) and t of the node respectively. Then, the residual energy of the node $E_{Re(i)}$ is determined based on "6".

$$E_{Re(i)} = E_{Or(i)} - E_{Dr(i)} \quad (6)$$

where, $E_{Or(i)}$ is the initial energy possessed by each mobile node of the network. Finally, the Path Residual Energy factor 'PRE' is calculated using residual energy and the initial energy of the nodes along the path as defined in "7".

$$PRE = \sum_{i=1}^{n} \frac{E_{Re(i)}}{E_{Or(i)}} \quad (7)$$

C. Computation of hop count

The hop count relates to the number of hops travelled by the packet at a specific point of time when it is initiated from the source node to travel along different links of the network in order to reach the destination. This hop count parameter is gathered by each mobile nodes of the network by incorporating the transmission of specially designated control packet that aids in determining the exact number of intermediate nodes existing between the source and destination of the network. Hop count is the indirect parameter that influences the stability of the path under transmission as its increase leads to greater latency time in the network. Thus, the latency of packet transmission is represented using "8" as

$$PKT_{latency} \propto Hopcnt \tag{8}$$

At this junction, the PAINR need to be moderate, the available energy needs to be high and hop count need to be minimum for portraying path stability under routing.

D. Normalized multi-objective optimization

The factors considered for investigating path stability is found to be conflicting with one another. These factors of influence cannot be satisfied with low, moderate and high value in a specific instant of routing. Multi-objective optimization is necessary for handling these conflicts of influential parameters responsible for ensuring path stability in the network. Thus, Multi-objective optimization performs the mapping of three factors such as Active interactive neighbor rate, hop count and available energy into a single factor based on weights that determine the enforcement of the factors with constraints and without constraints. The weight inspired sum technique fails to handle the limitations in the integration process as the domination of one impactful parameter may reduce the influence of the other factors under consideration. The method of normalization is proved to eliminate the dominance of one influential factor over the other. Hence lower and upper threshold of normalization technique used for equalizing the impacts of factors that contribute to path stability is represented using "9" as

$$Norm_{LUT} = \frac{f_{c(i)} - f_{c(\min)}}{f_{c(\max)} - f_{c(\min)}} \tag{9}$$

In this lower and upper threshold of normalization technique, the range of 0 and 1 are considered in order to reduce the dominance of one impactful factor over the other influential factors of path stability.

E. Path Stability Parameter (PSP) Calculation

The calculation of Path Stability Parameter (PSP) is achieved using "10".

$$PSP = \frac{PRE_{(norm)}}{Hopcnt_{(norm)}} - PAINR_{(norm)} \tag{10}$$

The path with maximum PSP value is optimally chosen for packet forwarding with the possibility that it could provide stable route for data dissemination.

F. Forecasting of path stability using fuzzy logic

A fuzzy set A is a non-empty set of uncertain data measured by its membership functions defined as "11".

$$\mu A\ (p):\ p \rightarrow [0,1] \tag{11}$$

where the values in the range of 0 to 1 represents the membership degree. Fuzzy logic has been developed from fuzzy set. Fuzzy control system is an application of fuzzy logic.

The main objective of using fuzzy logic is to develop a technique to formulate the problem and then find the solution with higher accuracy where there is an uncertainty in the data. There are three modules in Fuzzy control system namely fuzzification, inference engine and defuzzification. Initially crisp inputs are normalized for fuzzification. Then based on the rules of fuzzy inference system the fuzzy output is obtained. Using defuzzification single crisp output is generated from fuzzy output as shown in Fig 1.

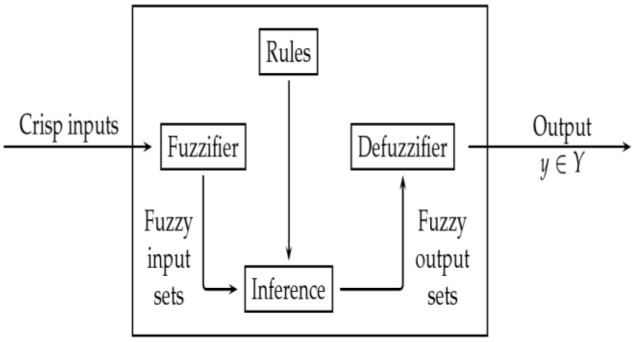

Fig 1. Fuzzy logic system

i) Fuzzification: In this module the input variables are converted into linguistic values to calculate the membership degree. The triangular member ship functions are defined as in "12".

$$\mu_A(p) = triangular(p, l, m, n) = \begin{cases} 0, & p \le l \\ p - l/m - l, & l \le p \le m \\ n - p/n - m, & m \le p \le n \\ 0, & n \le p \end{cases} \tag{12}$$

The membership functions of PAINR, PRE and Hop cnt are defined as low, medium, high as shown in Fig 2.

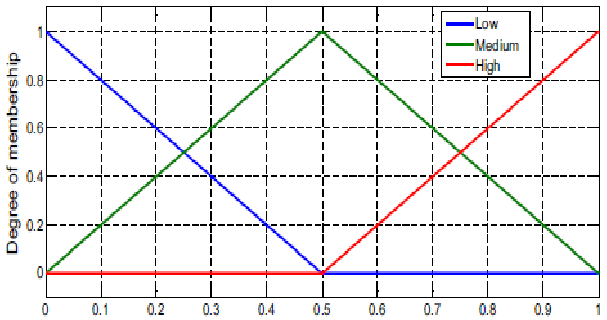

Fig 2. Membership function of PAINR, PRE and Hopcnt

ii) Inference Engine: It calculates the fuzzy output using predefined fuzzy rules. It is Mamdani type system. All inputs are normalized between 0 and 1 before applying them to fuzzy inference system (FIS). There are totally 3*3*3 = 27 rules and the output are classified as Vlow, Rather Low, Low, Low Medium, Medium, High Medium, High, Rather High, Vhigh as shown in Fig 3. Some of the rules are in table I.

iii) Defuzzification: There are many techniques used to convert the fuzzy output from inference engine into crisp value in the defuzzification module. In this paper, defuzzification is done by using the centroid formula as given by

$$P_{cop} = \frac{\int \mu_A(P) p dp}{\int \mu_A(P) dp} \tag{13}$$

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Table I: Some Rules for Fuzzification

PRE	PAINR	HOPCNT	PSP
Low	Low	Low	Low
Low	Low	Medium	Rather Low
Low	High	High	VLow
Medium	Low	High	L Medium
Medium	Low	Medium	High Medium
Medium	Medium	Medium	Medium
High	Medium	Low	High
High	Low	Low	Vhigh
High	High	Low	Rather high

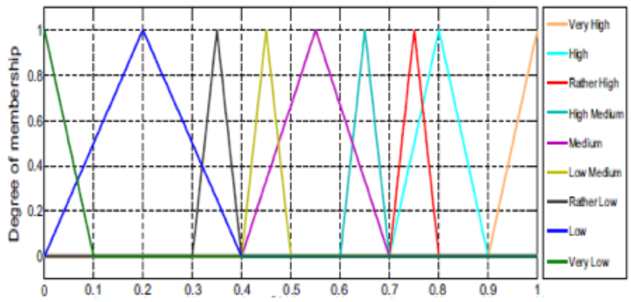

Fig 3. Membership function of path stability

Fig 4 represents the sample screen shot for given input values of PAINR, PRE, hopcnt and fuzzy output for path stability.

Fig 4. Some fuzzy rules

The following section provides the algorithm used for predicting the path stability using fuzzy logic.

IV. ALGORITHM - FPSFS

PAINR - Path Active Interactive new Neighbor Rate
PRE - Path Residual Energy factor
Hop count - No of hops in the path
PSP - Path Stability Parameter
n - Number of time slots
m - Number of paths

1. Start
2. For each path in each time session 't'
3. Calculate PAINR of mobile nodes in the path.
4. Calculate the remaining energy factor PRE of the nodes in the path.
5. Calculate no. of hops in the path.
6. Compute normalized value of PAINR, PRE and hop count.
7. Compute path stability parameter PSP of each path.
8. //Let PSP (1), PSP (2),…, PSP(m) be the PSP for m no of paths.
9. Data transmission through the Optimal path // In time slot 1
10. Opt (path)= max (PSP (1), PSP (2),…, PSP(m)).
11. For each path p where 1<p<m // for time slots 2 to n
12. Calculate the membership function for all the parameters PAINR, PRE, Hop count for each path using Mamdani function.
13. Fuzzify each input using triangular equation.
14. Using fuzzy rules and parameters compute fuzzy output.
15. Defuzzify the fuzzy output to get the crisp output.
16. End for
17. // Let PSP(1), PSP(2) ,…, PSP(m) be the crisp set of PSP for m no of paths
18. Choose the optimal path from the crisp set of candidate paths for data transmission
19. Opt(path)= max(PSP(1), PSP(2) ,…, PSP(m)).
20. End For
21. End

In this protocol initially PAINR, PRE and number of hops for each path are calculated and normalized. In the first time slot data transmission is through the optimal path. From second time slot they are given as inputs to fuzzification. Then based on the rules of fuzzy inference system the fuzzy output is obtained. Using defuzzification single crisp output is generated from fuzzy output. The optimal path will be selected with the path which is having maximum PSP value.

V. SIMULATION RESULTS AND DISCUSSION

The proposed protocol is evaluated by comparing with various existing protocols. Simulation is focused on different mobility for a fixed no of nodes 100. NS-2.35 has been used as the simulator to analyze the performance. The simulation is done 5 times and the average values are taken as measurement using Random way point mobility model. Since the nodes are in random motion, the topology of the network will go for indiscriminate change. The simulation area is 1000 * 1000 square meters. The initial energy level of each node was set to 20 joules. Table 1 presents all the simulation parameters.

Table II: Simulation parameters

Parameters	Values
Simulation tool	NS-2.35
Network nodes	100
Density of nodes	15 square meters
Transmission Range	250 meters
CBR data rate	24 Mbps
Interval of hello packets	1 second
Mobility speed	5-50 m/sec
Traffic type	CBR
Radio type	802.11 a/g

Scenario 1: The mobility of the nodes has been modified from 5 to 50 m/s and the performance has been evaluated using various metrics such as Packet delivery ratio, Throughput, Average end to end delay, routing overhead and energy consumption. Since multiple paths are maintained, there is no route rediscovery process when path loss occurs. Hence loss of packets has been reduced which results in increase in the PDR and throughput compare to other existing protocols in terms of 15%, 6%, 7% and 33%,18% and 14% than AODV [21], Fuzzy-AODV and LB-AOMDV protocols as in Fig 5 and 6.

It is also noted that in terms of congestion, as the proposed protocol gives preference for the node with less PAINR, it reduces the interaction flow between the nodes thus overhead is decreased by 29%, 24% and 17% and end-to-end delay is reduced by 46% ,37% and 22 % as in Fig 7 and 8.

As minimum number of neighbor nodes are selected all along the path the amount of energy consumption is also reduced since the over hearing power of the neighbor nodes has been reduced. Energy consumption is decreased by 36%, 30% and 16% than the above-mentioned existing protocols as shown in Fig 9. Table III provides the performance details of various protocols by increasing the speed of mobility of the nodes.

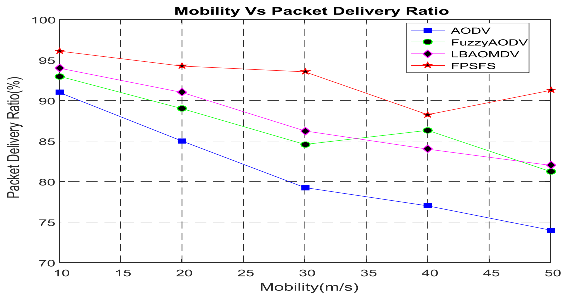

Fig 5. Mobility vs Packet Delivery Ratio

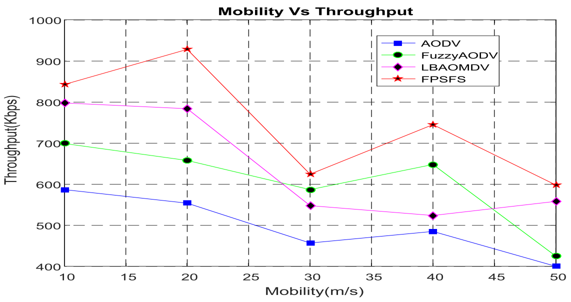

Fig 6. Mobility vs Throughput

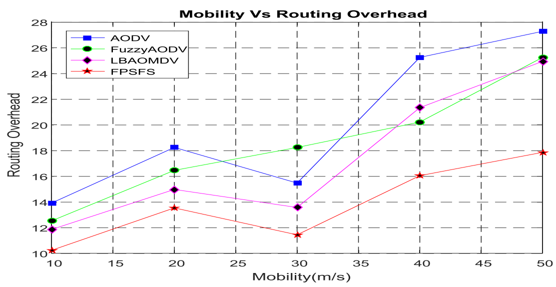

Fig 7. Mobility vs Routing Overhead

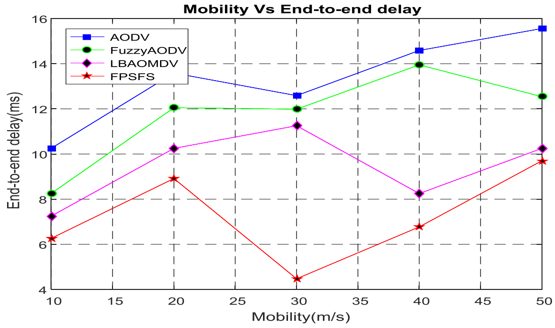

Fig 8. Mobility vs End-to-end-delay

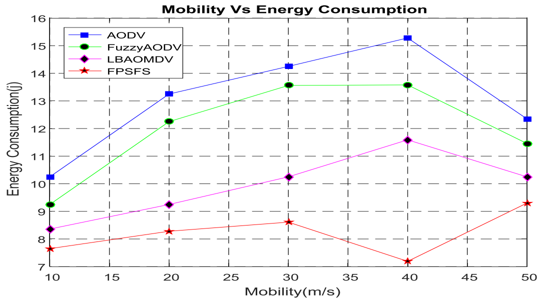

Fig 9. Mobility vs Energy Consumption

Table III: Mobility vs Performance Metrics

	Mobility	AODV	Fuzzy-AODV	LB-AOMDV	FPSFS
PDR	10	91	93	94	96.1
	20	85	89	91	94.25
	30	79.25	84.58	86.25	93.54
	40	77	86.32	84	88.25
	50	74	81.23	82	91.25
Throughput	10	587	699.25	798	843
	20	554	658	784	928.45
	30	457	587	548	624.58
	40	485.24	648.23	524	745.25
	50	400.25	425.12	558.4	598.25
Delay	10	10.254	8.254	7.25	6.265
	20	13.587	12.05	10.25	8.914
	30	12.587	1.985	11.254	4.474
	40	14.587	13.95	8.25	6.772
	50	15.56	12.54	10.25	9.701
Energy	10	10.25	9.25	8.359	7.65
	20	13.25	12.25	9.25	8.28
	30	14.25	13.56	10.25	8.61
	40	15.28	13.58	11.59	7.19
	50	12.35	11.458	10.25	9.3
Routing O	10	13.925	12.54	11.87	10.25
	20	18.254	16.47	14.985	13.547
	30	15.48	18.25	13.58	11.452

	40	25.26	20.23	21.35	16.057
	50	27.29	25.26	24.95	17.87

Scenario 2: The number of nodes for the simulation are varied from 10 to 100 in scenario 2. It has been found that increase in the PDF and throughput compare to other existing protocols in terms of 15%, 7%, 4% and 44%,17% and 6% than AODV [19], Fuzzy-AODV and LB-AOMDV protocols as in Fig 10 and 11. It is also noted that in terms of congestion, as the proposed protocol gives preference for the node with less AINR, it reduces the interaction flow between the nodes thus overhead is decreased by 41%,32% and 19% and end-to-end delay is reduced by 55% ,43% and 28% as shown in Fig 12 and 13. As minimum number of neighbor nodes are selected all along the path the amount of energy consumption is also reduced since the over hearing power of the neighbor nodes has been reduced. From Fig 14 it has been found that energy consumption is decreased by 15%, 7% and 5% than the above-mentioned existing protocol. Table IV provides the performance details of various protocols by increasing the number of nodes.

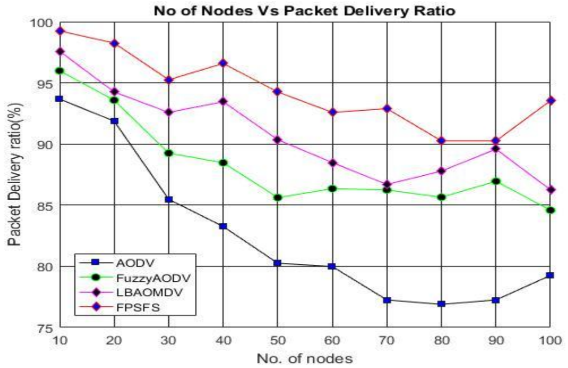

Fig 10. Number of nodes vs Packet Delivery Ratio

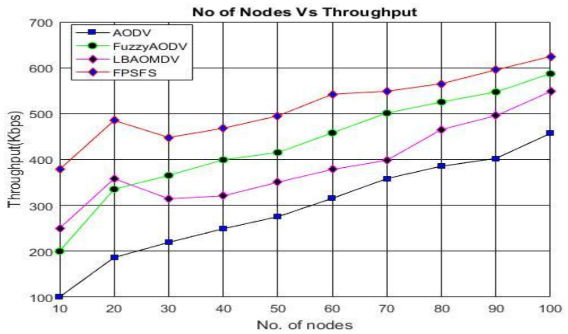

Fig 11. Number of nodes vs Throughput

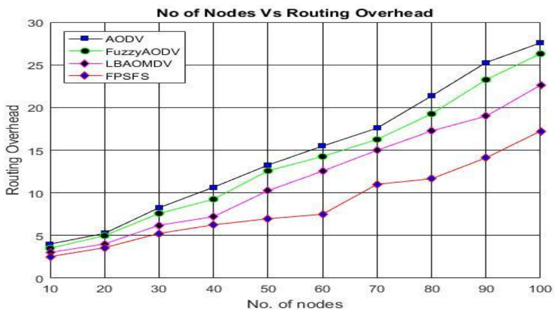

Fig 12. Number of nodes vs Routing overhead

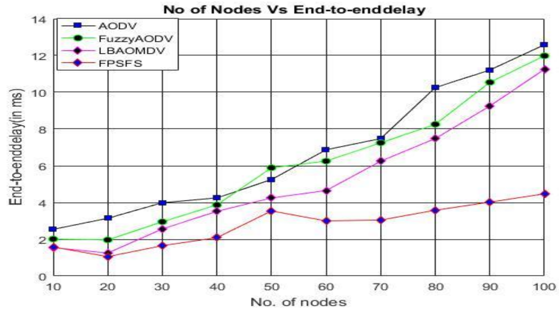

Fig 13. Number of nodes vs End-to-end-delay

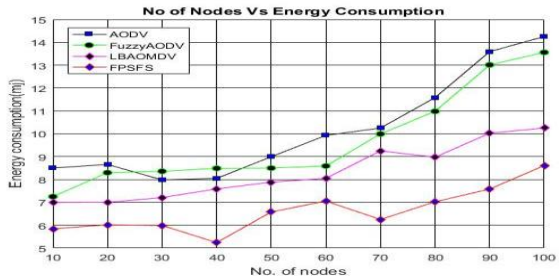

Fig 14. Number of nodes vs Energy consumption

Table IV: Number of nodes vs Performance Metrics

	No of nodes	AODV	Fuzzy-aodv	Lb-aomdv	Fpsfs
PDR	20	91.87	93.58	94.25	98.25
	40	83.25	88.47	93.45	96.58
	60	79.98	86.35	88.48	92.58
	80	76.89	85.65	87.78	90.254
	100	79.256	84.58	86.25	93.541
Throughput	20	186.32	335.21	358	485
	40	248.98	399.25	320.54	468
	60	315.24	458	378.25	542.25
	80	385.36	525.36	465.25	565.21
	100	457	587	548	624.58
Delay	20	3.14	1.965	1.25	1.054
	40	4.25	3.87	3.52	2.087
	60	6.87	6.254	4.65	2.998
	80	10.254	8.254	7.48	3.58
	100	12.587	11.985	11.254	4.474
Energy	20	8.656	8.298	7	6.02
	40	8.047	8.487	7.587	5.24
	60	9.9265	8.589	8.05	7.054
	80	11.58	10.98	8.974	7.024
	100	14.25	13.56	10.25	8.61
Routing	20	5.25	4.98	4.01	3.57

	40	10.65	9.25	7.21	6.25
	60	15.48	14.25	12.54	7.49
	80	21.35	19.25	17.25	11.65
	100	27.58	26.3	22.61	17.23

Implementation of prediction using fuzzy logic provides multiple path selection. The output of 5 candidate paths given in table V in which the path with max stability is path P4. Data transmission will be through P4. If it expires due to some reason then path P2 will be selected.

Table V : Experimental Results

PATH	FUZZY INPUT			FUZZY OUTPUT
	PRE	PAINR	HOPCNT	
P1	0.608	0.584	0.392	0.569
P2	0.62	0.235	0.38	0.664
P3	0.729	0.404	0.416	0.637
P4	0.693	0.307	0.283	0.684
P5	0.235	0.259	0.257	0.416

VI. CONCLUSION

In MANET path loss is a major issue due to dynamic nature of the nodes. Hence for effective data communication rapid change of alternate paths is required. Several path prediction mechanisms are prevailing based on various prediction models. Consistent packet delivery is achieved when multiple paths are identified by means of fuzzy logic-based prediction protocol. The simulation study shows that the performance of the new protocol FPSFS provides better results than the existing protocols in terms of routing overhead, energy, throughput, end to end delay and packet delivery ratio. This protocol can be extended by the inclusion of other metrics such as security, RSS and other QOS related factors.

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