F-EEAODV: Fuzzy Based Energy Efficient Reactive Routing Protocol in Wireless Ad-hoc Networks

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***Abstract* —**Wireless ad-hoc networks are the self organizable, self-maintained and ad-hoc by nature. Due to high mobility of nodes, the energy of a node is most important parameter in respect of network lifetime.. Routing in such a network is a big challenge.In this paper, we have proposed a fuzzy based scheme for enhancing the efficiency of AODV in wireless ad-hoc networks. Next hop selection is performed on the basis of node energy, its neighbour node enrgy, node degree. Thus next hop selection is taken by considering a number of parameters including number of hops. As we are considering energy based parameters for next hop selection, the lifetime of nodes and network is improved. Each node is embedded with a fuzzy controller system through which output parameter chance is calculated. Based on this chance value next hop selection is carried out.We have compared the proposed routing protocol F-EEAODV with AODV, DSR, and DSDV routing protocols. Simulation work is carried out using NS-2. The simulation results taken by NS-2 shows that our proposed scheme outperforms as compared to AODV in respect of throughput, end-to-end delay, propagation delay.

Index Terms—F-EEAODV, DSDV, AODV, Node degree, NN Energy, fuzzy rules, E2E delay, propagation delay.

I. INTRODUCTION

Wireless mesh networks, wireless sensor networks, mobile ad-hoc networks, vehicular ad-hoc networks are the example of ad-hoc nerwks[1]. In all these networks , routing is a big challenging task. There are so many issues (like mobility of nodes, power of nodes, signal strength)when network performance degradesA number of enhancing schemes for AODV. DSDV, and DSR routing protocols have been proposed. Also comparison type analysis for these protocols has been discussed in [2][3]. in reactive protocols like DSR(dynamic source routing) and AODV(ad-hoc on demand distance vector) routing protocols, mostly at the time of next hop selction, only one parameter named number of hopes is considered. But on the basis of varying the network conditions like size, mobility, life time of node and network, the performance degrades. Also in ssuch conditions, cost of routing is effected. Therefore it is suggested that more metrics must be considered at the time of next hop selction during a route preparing between the source and destination. AODV routing protocol is a well familiar protocol on which many research work has been completed. In some research papers, signal strength is only considered while in other papers, ssome other parameters like link stability, battery power etc. were considered. some research papers were based on computational intelligence systems. In this paper, we have proposed a fuzzy based technique F-EEAODV(Fuzzy based energy efficient AODV) to enhance the routing performance of the traditional AODV routing protocol in wireless ad-hoc networks. The proposed protocol is based on enegy parameters so that the life time of the network and routing cost would be affordable.

This paper is constituted into 5 sections. Section2 descibes about the related work of enhancement of routing protocols. In section 3, we present the proposed fuzzy based techniques, overview of tradtional AODV, fuzzy based AODV routing protocols, and fuzzy inference rules. simulation parameters, performance metrics, and results discussion is depicted in section 4. This paper is concluded by section 5.

II. RELATED WORK

In [4] Mohammad Masoud Javidi *et al*. proposed a selfish node detection reactive routing protocol. A fuzzy based mechanism has been applied with AODV to enhance the security and efficiency of the network. Based on energy level and alpha value the trust value is calculated for each node. Energy level is determined using the parameters as initial energy, transmission power, reception power, and remainder energy. Simulation and results are evaluated using MATLab. At last of this work, a comparison is carried out on the basis of packet delivery ratio, throughput, packet dropped ratio, effect on network performance.

Aldabbagh *et al*. [5] presented a fuzzy based approach for enhancing the efficiency of AOMDV in wireless mesh network. An output parameter called link status is calculated by taking input variables as RSSI(Received packet Signal Strength Indicator), BER(Bit Error Rate), velocity, and distance. Based on the output value link status, next hop decision is carried out. The metrics like end-to-end delay, route discovery frequency, and service disruption delay are used to evaluate the performance of the proposed technique. NS-2.34 simulator was used for evaluating the proposed idea. At the end of this presented work, a comparison of AODV, AOMDV, and proposed scheme is performed. It has been identified that proposed scheme could significantly reduce the service disruption delay, end-to-end delay and number of loss packets as compared to AODV, and AOMDV routing protocols.

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Marcus Okunlola Johnson et al. described a wormhole attack detection technique for AODV routing protocol in wireless sensor network [6]. By implementing this proposed technique in AODV, security features can be enhanced. Wormhole path for data transmission and neighbor's information are taken as input variables for calculating output variable wormhole detection. Simulation work is conducted using NS-2.35. Throughput, end-to-end delay, total number of delivered data packets are considered as performance metrics. A comparison work for AODV, TRM-AODV, and APS-AODV (Alternate path Selection-AODV) is conducted.by the simulation results, it is identified that proposed method provides best results.

For enhancing the stability, a fuzzy based routing mechanism for the AODV was suggested by Abbas *et al*. [7]. An output variable trust value was calculated by taking input variables (residual energy, speed, hop count). Trust value is identified for each intermediate node during making a route between source and destination. NS-2.35 simulator was used for analysis of proposed fuzzy AODV routing protocol. A comparison of AODV, fuzzy AODV, and MBCR routing protocols was conducted. From the simulation results, it was identified that proposed fuzzy AODV performs best in terms of throughput, packet delivery ratio, average end-to-end delay, average routing load. Even though at highly mobility environment, fuzzy AODV gives the outstanding performance.

To find the optimal route, a new scheme for AODV named as AAODV (Adaptive Neural Fuzzy Inference System-AODV) routing protocol was suggested by vivek sharma *et al*. [8]. ANFIS takes three input parameters: hop count, energy, and delay, and produces one output parameter. Based on the value of output parameter, routing decision is taken. ANFIS was implemented in MATLab. Simulation results were carried out using NS-2.35 simulator. Performance evaluation was conducted in terms of throughput, packet delivery ratio, and routing load. The proposed routing protocol AAODV shows better improved results.

Kishor Singh *et al*. [9] investigated an energy-efficient protocol named as energy-efficient and robust multipath routing(ERMR)protocol for ad-hoc networks. The proposed ERMR was evaluated by NS-2.31. Performance metrics like average network throughput, packet delivery ratio, and average energy consumption per bit were considered at the time of evaluation. ERMR was outperformed the conventional protocol significantly in terms of network throughput.

Mueen Uddin *et al*. [10] referred a new design and performance evaluation scheme for improving the performance of AODV routing protocol for mobile ad-hoc networks. A query localization technique was used to reduce the routing overhead. The proposed algorithm named TAODV (Tactical Algorithm on demand distance vector) was an improvement over AODV in terms of flooding of packets. Results were generated using NS-2 simulator. The comparison was conducted in terms of packet delivery rate and average end-to-end delay. This work was focused on military applications such as tactical networks.

Abderezak Touzene *et al*. anticipated a new modified AODV routing protocol named EGBB-AODV (Extended Grid-Based Broadcast AODV) for mobile ad-hoc network. In this protocol, it is assumed that each node knows only its own position in the network. Simulation is conducted for EGBB-AODV by the NS-2. A comparison work is performed for AODV, EGBB-AODV and PCB-AODV (Position-aware Counter-Based -AODV) routing protocols. The performance of all these protocols is analyzed in terms of the metrics as: the average end-to-end delay, the average time spent to complete one routing operation, the average reachability ratio, the power consumed by a node, total number of packet (data and control packet) transmitted by a node per second [11].

Md. Shohidul Islam *et al*. presented a comparison of AODV, DSDV, and DSR routing protocols in mobile ad-hoc networks [12]. The performance was evaluated in terms of throughput, packet dropped, and propagation delay in respect of number of nodes. DSR was declared as the best routing protocol in respect of receiving packets.

Jayashree Agarkhed studied the security issues for AODV routing protocol. Also a number of detection and prevention schemes were discussed. It was defined that security is the main issue during highly mobility networks [13]. In order to provide trusted and secure transmission among nodes, security issues must be considered.

A modified scheme for M-AODV was suggested by Anil Kumar *et al*. [14]. On the basis of relative mobility and the throughput of the link, the routing decision is taken. The link on which mobility of nodes is least and having higher throughput was selected for routing. The proposed scheme was evaluated using NS-2.35. A comparison work was performed in terms of throughput, PDR, and remaining energy.

Geeta Pattun *et al*. proposed a security aware scheme for AODV routing protocol. In this work, attacks in MANET were described initially and after that overview of AODV, and concept of black hole attack was presented [15]. Performance evaluation for proposed scheme was carried out in terms of packet delivery ratio, routing overhead, and packet drop. A lot of research work has been proposed for routing protocols in various fields [16], [17] to enhance the performance.

III. Proposed Fuzzy Based Technique

This section describes the modification of the classical AODV routing protocol to improve the next route selection process to enhance the network performance by applying a fuzzy based routing scheme.

A. Overview of AODV Routing Protocol

- AODV refers for ad-hoc on-demand distance vector.
- It considers only one metric i.e. number of hops.
- RREQ (route request), RREP (route reply), and RERR (route error) are three messages through which routing process is performed.
- A route request packet (RREQ) i.e. control packet ID is the combination of broadcast ID and source IP address.
- All nodes regularly exchange HELLO message.
- Unicast and multicast routing is supported by AODV.
- AODV is a reactive routing protocol i.e. routes are established only when needed. Unnecessary routes are discarded when no data is to be needed to transfer.
- Each node maintains its routing table. Routing entries in this table are deleted when no data has to be transferred. Also entries in the routing tables are updated as the routes are updated.
- During routing request process, each intermediate node maintains its reverse routing entry. Source IP address, number of hopes to source node, source sequence number, and IP address of node from which RREQ was received.
- Sequence numbers are used to prevent the formation of loops and to avoid using old/broken routes.
- When a source node wants to send the data to a specific destination node, first of all it broadcast a route request message (RREQ). When this message is received by its neighbours; they verify the message and if it is not a destination then further they broadcast the RREQ message. When a source node receives this message, it doesn’t broadcast any RREQ message. Destination node generates a RREP message. A reverse route is maintained from destination to source. When a RREP message is received by the source node, it sends data to destination following the maintained reverse path. Sometimes, if link is disturbed, a route error (RERR) message is passed by the intermediate node and finally received by the destination node then if needed again route request is made.

B. Proposed Fuzzy Based AODV Routing Protocol

The proposed technique uses fuzzy logic to calculate a node’s choice value by combining the node energy, node degree, and near node energy of each node in the wireless ad-hoc network. The nodes with the best choice values are selected to make the best route to the destination node in the network. Each intermediate node calculates its choice value whenever it receives the route request.

Each node is embedded with FIS system;

Chance (%) value can be calculated for each node in the network.

1. Node receive RREQ packet.
2. Input parameters (Node degree, Node Energy, Near Node Energy)
3. Calculate *Chance (%)* Value using FIS.

Case-I: if the source node is Source then create new reverse route entry table.

Case-II: Node is destination node then send the RREP packet to source node.

Case-III: if node is intermediate node then compare the FIS *chance (%)* value with previous store *chance (%)* value.

Subcase-I: if new value is high then update the reverse route entry table then go to case-II.

Subcase-II: if new value of *chance (%)* is less than then previous value of *chance (%)* then discard the packet.

C. Fuzzy-based Choice Value Computations

Fuzzy techniques have been extensively used in various fields of computer science and engineering research and provide a very effective approach in routing protocols in wireless networks. The concept of fuzzy logic (FL) was conceived by Lotfi Zadeh(1965), as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership. Fuzzy logic provides a single way to arrive at a definite conclusion based upon vague, ambiguous, imprecise noisy or missing input information. Fuzzy Logic (FL) incorporates a simple rule-based IF X AND Y THEN Z approach to solving a control problem rather than attempting to model a system mathematically. A fuzzy system consists of three parts: fuzzification, inference, composition, defuzzification, and a fuzzy inference engine with IF-THEN-based rules.

- **Fuzzification**

  First, it identifies the input and output of the system. Fuzzification then defines appropriate IF THEN rules and uses row data to derive a membership function.

- **Inference:**

  As inputs are received by the system, inference evaluates all IF THEN rules and determines their truth values.

- **Composition:**

  Combines fuzzy conclusions obtained by inference into a single conclusion.

- **Defuzzification:**

  Converts the fuzzy value obtained from composition into a ‘crisp’ value.

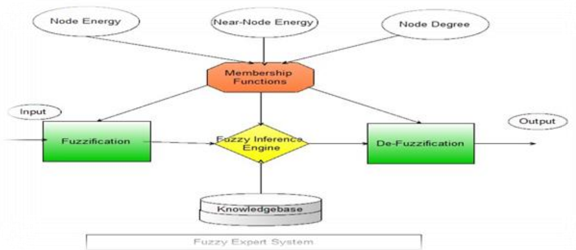

Fig. 1. Fuzzy rule based Inference system

Fuzzification is responsible for representing decisive input variables in terms of fuzzy set membership functions, as shown in Fig. 5. Defuzzification converts the fuzzy output to decisive values using a mathematical formula, while the inference engine calculates the fuzzy output depending on the IF-THEN-based rules provided in Table 1. Because of the correlation between the nodes' parameters, which have a range of values, the fuzzy logic system describes the effects of the different parameter interactions. Hence, to develop a fuzzy inference system, the input and output variables should be defined as membership functions. Fuzzy rules (IF-THEN) that connect the input memberships with the output membership are then suggested [18], [19]. The membership function is a graphical interpretation of the input and output linguistic variables. The inputs in our case are node residual energy, speed, and hop-count value, and the output represent the node trust value (node quality). Triangular and trapezoid membership functions described by equations 1 and 2 below are used to describe the input and output membership degrees of the input and output variables for fuzzy inference.

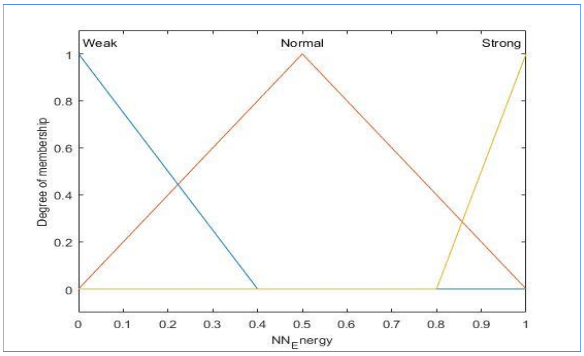

Fig. 2. Membership function for NN_Energy

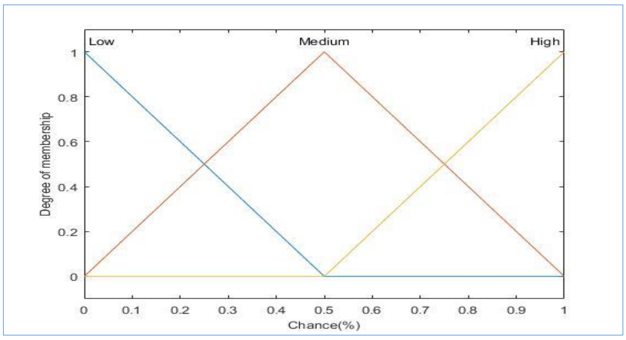

Fig. 3. membership function for 'Chance (%)'

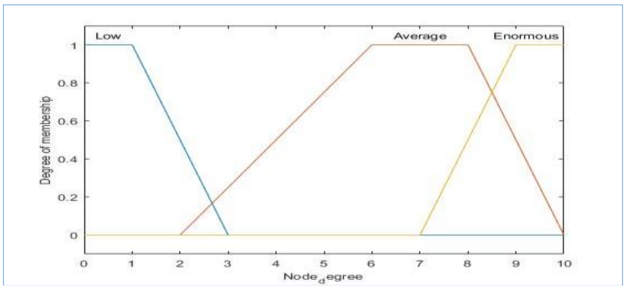

Fig. 4. membership function for Node_degree

Trapezoidal Membership Function:

$$\mu_F(x,a,b,c,d) = \begin{cases} 0, \text{ if } x<a \\ (x-a)(b-a), \text{ if } a\leq x\leq b \\ 1, \text{ if } b\leq x\leq c \\ (d-x)(d-c), \text{ if } c<x\leq d \\ 0, \text{ if } d<x \end{cases}$$

Triangular membership Function:

$$\mu_F(x,a,b,c) = \begin{cases} 0, \text{ if } x<a \\ (x-a), \quad \text{if } a\leq x\leq b \\ (c-x)(c-b), \text{ if } b<a\leq c \\ 0 \text{ if } c<x \end{cases}$$

There are different approaches used to find the crisp output. The centroid method of defuzzification is used in this proposed model. The mathematical expression for the centroid defuzzification method is as follows.

Centroid method:

Also known as the center of gravity or the center of area method, it obtains the center of area (X^*) occupied by the fuzzy set.

$$X^* = \frac{\int \mu(x)x\,dx}{\int \mu(x)\,dx}$$

D. Fuzzy IF-THEN-based Rules

Fuzzy Inference Rules

We have prepared total 27 fuzzy rules for our proposed fuzzy based technique.

1. If (Node_Energy is low) and (Node_Degree is low) and (NN_Energy is weak) then (Chance (%) is low.
2. If (Node_Energy is low) and (Node_Degree is low) and (NN_Energy is normal) then (Chance (%) is low.
3. If (Node_Energy is low) and (Node_Degree is low) and (NN_Energy is strong) then (Chance (%) is low.
4. If (Node_Energy is low) and (Node_Degree is average) and (NN_Energy is weak) then (Chance (%) is low.
5. If (Node_Energy is low) and (Node_Degree is average) and (NN_Energy is normal) then (Chance (%) is medium.
6. If (Node_Energy is low) and (Node_Degree is average) and (NN_Energy is strong) then (Chance (%) is low.
7. If (Node_Energy is low) and (Node_Degree is enormous) and (NN_Energy is weak) then (Chance (%) is low.
8. If (Node_Energy is low) and (Node_Degree is enormous) and (NN_Energy is normal) then (Chance (%) is low.

9. If (Node_Energy is low) and (Node_Degree is enormous) and (NN_Energy is strong) then (Chance (%) is low.

We tested these fuzzy rules at different values of the input parameters and got the respected output values as depicted in Table I. The figure shows the output 'chance (%)' in respect of input values 'NN_Energy' and Node_Energy.

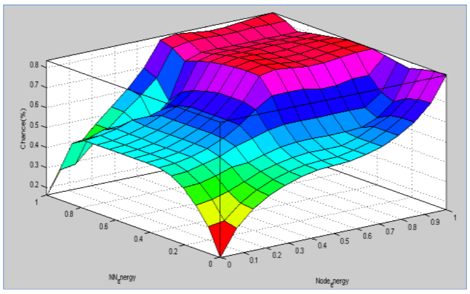

Fig. 5. Chance (%) output w.r.t. NN_Energy and Node_Energy

TABLE I: TEST CASES

Test Case No.	N. Energy	N. Degree	NN. Energy	Chance (%)
1.	0.898	0.341	0.097	0.603
2.	0.938	.092	.933	.51
3.	.938	.261	.933	.568
4.	.938	.47	.933	.757
5.	.938	.55	.933	.723
6.	.938	.799	.933	.695
7.	.938	.948	.933	.705
8.	.505	.515	.0871	.508
9.	.505	.515	.216	.553
10.	.505	.515	.346	.716
11.	.505	.515	.535	.803
12.	.505	.515	.664	.788
13.	.505	.515	.828	.742
14.	.505	.515	.928	.784
15.	.505	.515	.978	.801
16.	.0572	.515	.53	.503
17.	.311	.515	.53	.596
18.	.52	.515	.53	.804
19.	.664	.515	.53	.788
20.	.794	.515	.53	.779
21.	.873	.515	.53	.794
22.	.948	.515	.53	.802
23.	.978	.515	.53	.804
24.	.993	.515	.53	.819
25.	.993	.973	.968	.816
26.	.5	.5	.5	.822
27.	.0373	.0473	.0721	.252
28.	.943	.0473	.0724	0.499
29.	.983	.473	.0721	.502

Analysis of fuzzy rules based on results

Based on these inputs and their respective output values we have analyzed the fuzzy rules as given as below:

1. At higher level of node energy, low level node degree, and at very low level of near node energy, chance/probability is average.
2. Keeping constant node energy at high level, as node degree is increased; the chance varies from low to high. But high at higher level of node energy and near node energy, at medium level of node degree, the chance is higher (as shown in Fig. 5).

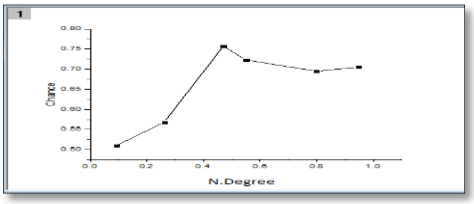

Fig. 6. N.degree Vs Chance

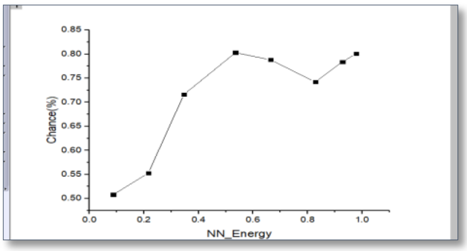

Fig. 7. NN_Energy Vs Chance (%)

Keeping node energy and node degree at medium level, increasing the near node energy, the chance (%) is also increased. But at medium level of three parameters, the chance value is highest.

3. Keeping the node degree and near node energy at medium level, at increasing the node energy, the chance (%) value also increased. But up to the medium level, after that it varies low to high. At last, height value of node energy, chance (%) is at highest level.

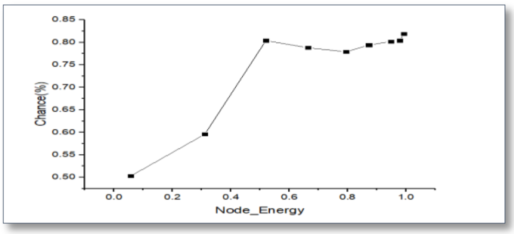

Fig. 8. N_Energy Vs Chance (%)

At highest level of node energy, near node energy, and node degree, chance (%) value is high. While lowest value of three parameters, the chance (%) value is low.

4. Highest value of node energy and lowest value of node degree and near node energy, the chance (%) value is medium.

IV. SIMULATION ENVIRONMENT AND RESULTS DISCUSSION

For AODV, F-EEAODV, DSR, and DSDV, four tcl script files were simulated in NS-2.35 simulator at different network parameters. Sometimes, few parameters were kept constant while other was updated. Simulation parameters which were used are depicted in table. Awk scripts were written to calculate the performance parameters from executed files at NS-2.35. All results were analyzed in different scenarios of the network and comparison work is represented in tables and figures.

TABLE II: SIMULATION PARAMETERS

Parameters	Description
Protocols:	AODV, F-EEAODV, DSR, DSDV
Simulation time:	10, 20, 30,40,50,60.70
Propagation delay:	10, 20,30,40,50
Simulator:	NS-2.35
Number of Nodes:	5, 10, 15, 20
Pause time:	10
Traffic type:	CBR
Number of connections:	8
UDP packet size:	1500 bytes
Channel type:	wireless channel
Radio propagation model:	TwoRay Ground
Queue type:	Drop Tail PriQueue
Link Layer type:	LL
Antenna type:	Omni Antenna
Maximum packet in queue:	50
Bandwidth:	11 Mb
Data rate:	11 Mb
Mac type:	802.11
Network area:	980×567
Node layout type:	random

For performance evaluation, we have considered some performance metrics: Throughput, End-to-End delay, Packet received, Propagation delay, Simulation time, Number of nodes.

A comparison of AODV, F-EEAODV, DSR, and DSDV has been evaluated as below:

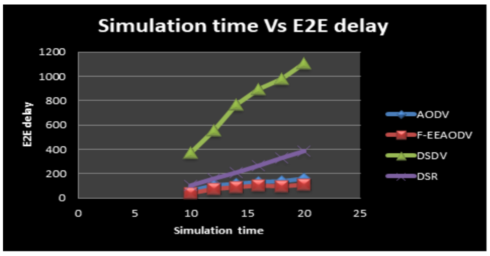

Fig. 9. Simulation Vs E2E delay

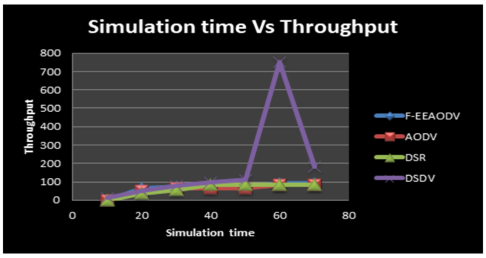

Fig. 10. Simulation time Vs throughput

End to End delay in respect of simulation times, F-EEAODV routing protocol gives the best results and DSDV performance is poor. For AODV routing protocol, end to end delay is better as compared to DSDV and DSR as simulation times are increased. For all the simulation times, F-EEAODV gives the best performance. When we compare simulation time Vs throughput for all four protocols, the throughput of DSDV gives the best performance as compared to F-EEAODV, AODV, and DSR. AODV and DSR give the approximately same throughput. But F-EEAODV gives the better throughput as compared to AODV and DSR.

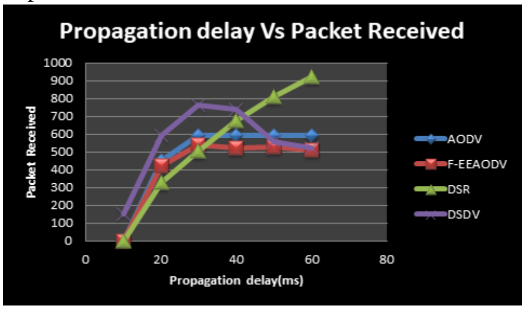

Fig. 11. Propagation delay Vs Pckt received

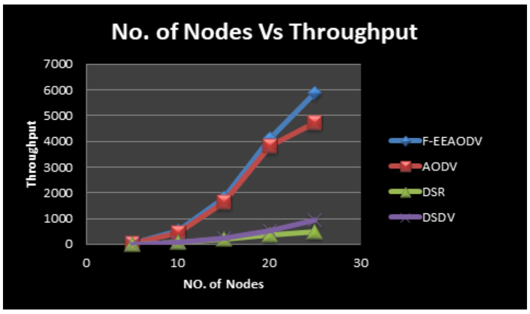

Fig. 12. No. of Nodes Vs throughput

When we analyse the packet receiving performance with respect to the different propagation delays, the DSR gives the best performance as compared to AODV, F-EEAODV, and DSDV routing protocols. Packet receiving rate is constant at increasing the propagation delays. But this goes to down stage by the F-EEAODV, DSDV routing protocols. At last as increasing the propagation delays, the best performance is given by the DSR.

When we take analytical analysis status for throughput as numbers of nodes are increased, F-EEAODV gives the best throughput with respect of number of nodes. But DSR gives the poor throughput as numbers of nodes are increased. Throughput of AODV routing protocol is best as compared to DSR and DSDV.

V. CONCLUSION

We have proposed a fuzzy based scheme for improving the routing capacity of AODV routing protocol in wireless ad-hoc networks. After simulating the new scheme at the platform of NS-2, we compared the results with AODV, DSR, and DSDV routing protocols. F-EEAODV outperforms when simulation time is increased with respect to E2E delays as compared to AODV, DSDV, and DSR routing protocols. DSDV gives superior throughput results with respect simulation time as compared to other three protocols. Numbers of packets received by DSR are highest with respect propagation delays as compared to AODV, F-EEAODV, and DSDV. When we analysed the number of nodes with respect of throughput, the F-EEAODV gives the best results. When numbers of nodes are increased, AODV is better as compared to DSR and DSDV. At last, F-EEAODV outperforms as compared to AODV in all cases.

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