Efficient Fuzzy Logic Based Probabilistic Broadcasting for Mobile Ad hoc Network

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Abstract

In Mobile Ad hoc networks broadcasting is the one of the most important and crucial phenomenon. Broadcasting can be taken up in many ways and the simplest method of broadcasting is simple flooding which can significantly increase the overheads and can result in redundant messages which can further cause the Broadcasting Strom problem. In this paper, we propose an efficient fuzzy logic based probabilistic broadcasting for AODV protocol in order to reduce overheads. The fuzzy based logic criteria make decisions which are based on some of the important parameters affecting broadcasting like number of neighbors, bandwidth available and remaining energy. The simulation result shows that the proposed algorithm is efficient and reliable with respect to the consumed power, throughput, overhead, collision rate and it also maintains low normalized routing load as compared to AODV and other routing protocols proposed in the literature in which simple flooding or fixed probability broadcasting is used.

Keywords: Fuzzy, Broadcasting, overhead, AODV, DSR, DSDV, OLSR

1. Introduction

Mobile Ad hoc Networks (MANETs) is a group of wireless mobile nodes which converse with one another with no dependence on a common central fixed infrastructure in the network. As the character of MANETs is self-configuring and distributed, it opens a wide scope of different kinds of applications for them. The prospective application of MANETs includes real time operations such as military war, disaster recovery, rescuing operations in natural calamities and tasks of law enforcement. Even nowadays MANETs find applications in creating a virtual classroom, data collection from war enemies and creating an impermanent LAN[1-4]. When in a network, the same message is sent by the source node to the rest of the nodes, then it is a broadcast communication which is very effective while sending collective information. So as broadcasting is widely used procedure in MANETs, its efficiency becomes very important with respect to the network performance. Procedure of broadcasting includes a simple route discovery from source to destination, transmission of data and controlling a network. As broadcasting is important for the design of major communication phases such as gossiping, gathering data and synchronization of data so broadcasting further becomes an important design block for controlling and route maintenance functionality. Therefore for the scalable realization of a wide variety of applications in a network there is need of a well-organized design for broadcast communication. The decimation of messages to all nodes in a network is performed through the basic operation known as broadcasting. Basically, there are two types of transmission, one is one to all model in which message is transmitted to all nodes within the transmission range

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and the second one is one to one model in which message is transmitted to single neighboring node through narrow beam directional antennas or by using different frequencies for different nodes.

One to all model of broadcasting is used frequently[5]. Also in literature survey one - to - many models are there for reaching more than one neighbor at a time[6] for which angular beam antennas can be used. There are many other usage of broadcasting, but many protocols in MANETs assume broadcast as a fundamental service[8,9].

Broadcasting can be used both in reactive as well as in proactive protocols. In proactive protocols[8] it is used for setting up a unicast route for LAN emulation, sending an alarm signal and paging a particular node where as it can used for route discovery in reactive networks. For example, many routing protocols like Dynamic Source Routing (DSR)[9], Ad Hoc on Demand Distance Vector (AODV)[9], Zone Routing Protocol (ZRP)[10,11]and location aided routing (LAR)[12] employ broadcasting for route discovery and setting up routes. Broadcasting also helps in other group communication protocol operations like multicast.

There are many broadcasting techniques proposed in literature. Initially a simple or "blind" flooding[9] technique was employed where every node that receives the packet rebroadcasts to all other nodes. The modification done in this technique[14] is that nodes carried information regarding that they don't have to receive duplicate copies of identical messages.

But employing blind flooding broadcasting seriously degrades the network performance and results Broadcast Storm problem which due to contention and collision of broadcast packets and opened a new window on research issues [5,6,14]. Many researchers have recognized this problem by showing network performance through analysis and simulations[5, 6,14] .

A different kind of broadcasting approach is recommended[5, 13, 15] which is known as probabilistic approach. This approach reduces the number of redundant messages; contention and collision hence keep away the Broadcast Strom problem.

After receiving a message for the first time by a node, it rebroadcasts the same message with a preset probability p and even all other nodes broadcast the message with the same probability. If the probability of the broadcasting is taken as 100%, this scheme becomes a simple flooding broadcasting. In probabilistic approach drastically decrease in packet overhead is seen[13, 15] at the same time sustaining a high grade of transmission of broadcast messages as compared to blind flooding.

But there are many other parameters of probabilistic broadcasting which can significantly affect the network performance. They have not been taken into consideration while analyzing these studies. These factors include the remaining energy of a node, network density and bandwidth available.

This paper proposes a new algorithm for broadcasting strategy in which fuzzy logic concept[16-21] is used with node density, i.e. Number of neighbors, available bandwidth and remaining energy of node as input and broadcasting probability P of RREQ packets is calculated as an output. To evaluate the validity of fuzzy logic based algorithm, it has been embedded in the AODV broadcasting algorithm. The rest of the paper is organized as follows.

Section 2 provides an overview of previous work on broadcasting in MANETs. Section 3 briefly describes the fuzzy logic based probabilistic broadcasting method with a simulation model and the parameters. Section 4 discusses the effects EFPB protocol on network performance with simulation results, followed by conclusions and future work in Section 5.

2. Related Work

Flooding is one of the basic broadcasting techniques used for both wired as well as wireless networks in which each node in the network broadcasts messages to all neighboring nodes after receiving its first time.

Though flooding is straightforward and uncomplicated to put into operation, but it can be expensive due to degradation of network performance, which may be a severe problem, often named as the broadcast storm problem[5-7] that is accomplished by very high redundant message retransmissions, network bandwidth contention as well as a collision. Authors[5] have considered the flooding protocol systematically and experimentally.

After analyzing their results it is clear that rebroadcast gives at most 61% additional coverage, whereas only 41% additional coverage in average covered by the previous broadcast effort. So they have accomplished that rebroadcast is very expensive and should be done with prudence. Moreover, after their analysis, broadcasting can be categorized as probabilistic, counter-based, distance-based, location-based and cluster-based broadcasting.

Probabilistic scheme

Instead of blind flooding rebroadcast messages without any probability, if nodes rebroadcasts with a predetermined probability p then this scheme, is known as Probabilistic broadcasting[13]. So in other words, we can say that if p becomes 1 this scheme is no longer probabilistic and becomes blind or simple flooding.

Counter-based scheme

In this scheme a node has to count how many similar messages is received by that node during an arbitrary time and on the basis of that, node has to decide whether to rebroadcast or not. At the same time in this scheme, it is assumed that additional coverage is very small and rebroadcast will be fruitless even when the quantity of received broadcast messages goes beyond a certain threshold limit.

Distance-based scheme/Area Based Scheme

This scheme is based on the relative distance between previous sender and present node to decide whether message should be rebroadcasted or not. Similarly in location based scheme the rebroadcast decision is taken through addition, coverage model[5]. So broadcasting nodes must be employing geographical knowledge of MANET[5] for obtaining additional coverage. Also in area based techniques a node takes decisions based on calculation of additional coverage area[5].

Cluster-based scheme

In this the whole network is divided into small groups or clusters of mobile nodes. Within a cluster there is a cluster head with many gateways. Representation of all broadcasts to all other nodes within that cluster is covered by the cluster head. The gateways function is to converse with cluster head as well as to transmit packets to other clusters within a network[22].

The techniques discussed above lacks in deciding the values of the parameters such as highest and lowest values of probability and threshold value. Some authors give a procedure to calculate or tune them, but optimization is missing, which further depends on various parameters. In this paper, we propose a fuzzy logic based probabilistic broadcasting optimization technique with following input parameters:

- The available bandwidth
- Remaining energy
- Node density of nodes

Employing these three parameters we can optimize our broadcasting which will further help us to design a self regulating protocol depending upon the different network environments. In this paper our main aim is to illustrate a methodology to recognize the best possible parameters and for the same we have employed fuzzy logic based algorithm to investigate the feasible settings. Then taking all these set of parameters into account, the performance of the network is analyzed using a network simulator. So our goal is to reduce broadcast storm problem knowing the network environment parameters i.e. network density, available bandwidth and remaining energy of nodes.

Zadeh was first to introduce the fuzzy set theory in 1965 which further produced Fuzzy Logic Control. The significant robustness of Fuzzy Logic Controller makes them better than other conventional controllers. This is because of acceptance of linguistic rule based model of Fuzzy Logic Controller rather than analytical models used by other controllers. So simply we can say that fuzzy control can be employed where knowledge can be articulated in the form of rules or formalism. Additionally FLC has the following advantages:

- FLC can be used where inputs are not so much exact or precise.
- FLC even does not require high speed processors.
- In the traditional nonlinear controllers we require more memory to store look up table, whereas in case of FLC it requires less memory as it stores data in the form of membership functions with fuzzy rules.

The proposed scheme is based on the available bandwidth, remaining energy and node density of nodes where the RREQ packets are not broadcasted at fixed probability, but broadcasting probability depends on the these three factors. So in our proposed scheme (EFPB) following are the advantages as compared to other existing protocols:

- The proposed algorithm decreases the rebroadcast figure without considerable negotiation on its reachability and at the same time with the conventional probability method that AODV employs, generates a large number of re-broadcasts.
- In EFPB scheme the RREQ packets are broadcasted after evaluating the nodes condition which depends upon three parameters which is better than the original probability schemes where fixed probability or blind flooding is used.
- By using the EFPB scheme, the nodes having more energy, available bandwidth and having less numbers of neighbors are used more which further increases the network lifetime.

3. Efficient fuzzy logic Based Probabilistic Broadcasting (EFPB)

A probabilistic broadcasting method can be designed which can additionally decrease the broadcasting overhead by using the rule base control system optimization technique known as fuzzy logic. The Fuzzy Logic based algorithm efficiently handles the inputs with uncertainty and ambiguity. The input and output membership functions of Fuzzy Logic based algorithm are not based on statistical distributions. We propose a new Efficient fuzzy logic Based Probabilistic Broadcasting algorithm in this paper to minimize the routing overheads in the broadcasting scheme of AODV. EFPB algorithm accepts three input parameters i.e. node density, available bandwidth and remaining energy of the node. The main aim of proposing this algorithm is to use Fuzzy Logic to optimize

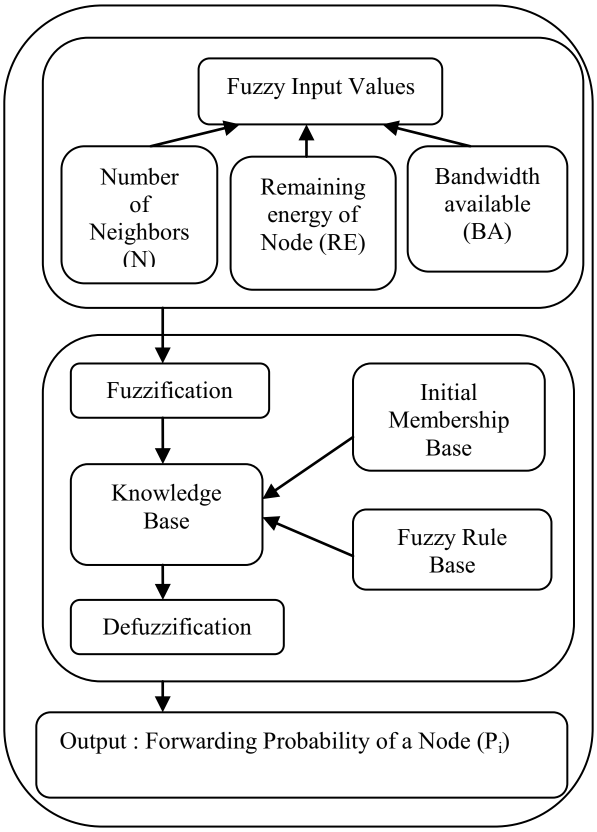

Fig. 1. Fuzzy Inference System.

broadcasting which will further result in removing broadcast storm problem. We have employed Mamdani's method in the inference process as it is more frequently used in applications. In EFPB algorithm the broadcasting probability depends upon three input parameters:

Number of Neighbors (N)

Number of neighbors of any node *i* can be known at physical layer by sending HELLO packets at regular interval.

Bandwidth Available (BA)

In our EFPB algorithm, each node is responsible for calculating the available bandwidth within a path. Let β be the bandwidth available as well as C be the link capacity related with single-hop neighbor[23] for any node *i* .A_R is the collective allocated rates for all incoming as well outgoing flows of packets. Therefore, the summation of the allocated incoming as well outgoing flow rates of packets and the available bandwidth on the route must be equivalent to the link Capacity C_i which can be articulated by following equation:

$$A_{Rij} + \beta_i = C_i \quad (1)$$

Knowing the link capacity C_i the bandwidth available is calculated from the following equation:

$$\beta_i = \max \{0, C_i - A_{Rij}\} \quad (2)$$

Remaining energy of the node (RE)

We employ the energy utilization rate as the factor to illustrate the remaining energy of any node *i*. Energy utilization rate is represented as EU_i. As the energy utilization of any node is because of the transmission, reception as well as overhearing of a packet for a node, which can be calculated by using the following equation

$$EU_i = \frac{P_r \times N_r + P_s \times N_s + P_o \times N_o}{T} \quad (3)$$

where P_r ,P_s and P_o are the energy utilized by node *i* when node *i* is receiving, sending or overhearing a packet ; N_r ,N_s and N_o are the number of the three types of packets respectively; T is the time spend by the node *i* while consuming its energy. Thus, EU_i is the average energy utilization rate of the node *i*. Then the remaining time (RTi) of the node *i* to utilize its energy, can be calculated using the following equation:

$$RT_i = \frac{RE_i}{EU_i} \quad (4)$$

where RE_i indicate the remaining battery energy of the node i and can be calculated from its physical layer.

There are five steps as shown in Figure 1 to get the crisp value from our FIS system.

(i) Every rule of antecedent in Table 1 is evaluated in the first step.
(ii) Then in second step rule conclusion is achieved.
(iii) Aggregation of conclusions is done in the third step.
(iv) And the fourth step is defuzzfication where the defuzzifier calculates the crisp value of output variable i.e. probability of broadcasting (P_i) depending upon its membership function by using "Eq. (5)" i.e. Center Of Gravity (COG) method.

$$P_i = \frac{\int_V y \times \mu(y) d(y)}{\int_V \mu(y) d(y)} \quad (5)$$

(v) In the fifth step defuzzified output is considered as input to the RREQ probabilistic broadcasting module of the AODV. In this work fuzzy logic is rooted in the NS2 simulator to analyze the network performance with different input parameters which are dynamic in nature.

Figure 2 shows the algorithm for EFPB. A membership function can be designed in three ways: (i) Interview those who are familiar with the underlying concept and later adjust it based on a tuning strategy (ii) Construct it automatically from data (iii) learn it based on feedback from the system performance. Additionally use of parameterizable functions that can be defined by a small

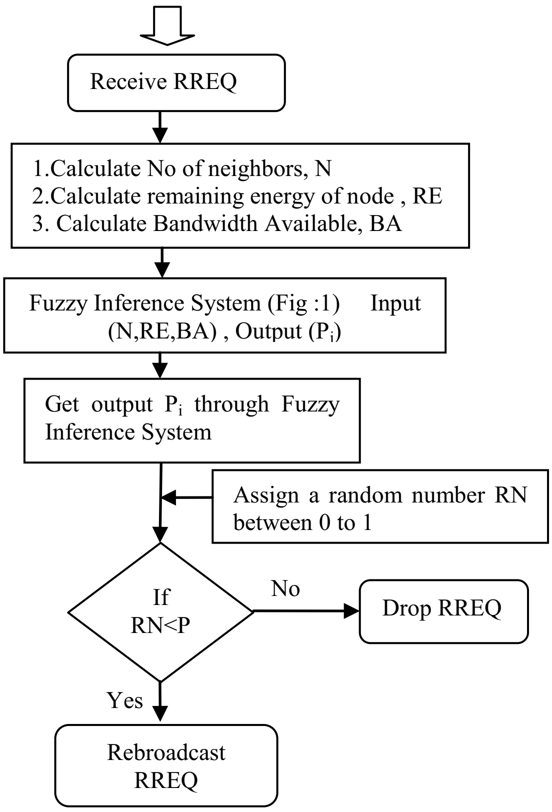

Fig. 2. Description of EFPB Algorithm.

number of parameters. The parameterizable membership functions most commonly used in practice are the triangular membership function and trapezoid membership function. The former has three parameters and later has four. Simplicity is the main advantage of triangular and trapezoidal membership functions. That's why we have used both triangular as well as trapezoidal membership function. As well as the design of the fuzzy rule base consists of setting the linguistic rules and determining the membership functions of linguistic variables. So as to design the rule base, we have selected the trial and error method. In this method, based on the information obtained from the experiment, a set of if-then fuzzy rules are designed and then the system is tested. If the preferred performance is not observed, rules are again changed. This procedure is sustained till the functionality of the system is fulfilled.

Table 1 below shows the membership value of the inputs (N,BA,RE) and Fuzzy Logic system rules .Figure 3(a), Figure 3(b) and Figure 3(c) shows the input Membership Function for inputs (N,BA,RE) and Figure 3(d) shows the output membership function(P_i). In Figure 3(a) N_{avg} is the average number of neighbors of a network and if the number of neighbors is less than 0.5 N_{avg} then it is considered as small otherwise it is large. In Figure 3(b) similarly if the available bandwidth is less than 0.8 is considered as less otherwise it is high. In Figure 3(c) also in Remaining energy membership function, th1 is the threshold of the battery being empty, and th2 is the threshold of the battery being full.

Table. 1. Fuzzy Logic system rules

	Input			Output
S.No	N	RE	BA	P
1	Large	Less	Less	Low
2	Large	Less	High	High
3	Large	High	Less	Low
4	Large	High	High	High
5	Small	Less	Less	Low
6	Small	Less	High	High
7	Small	High	Less	High
8	Small	High	High	Extreme High

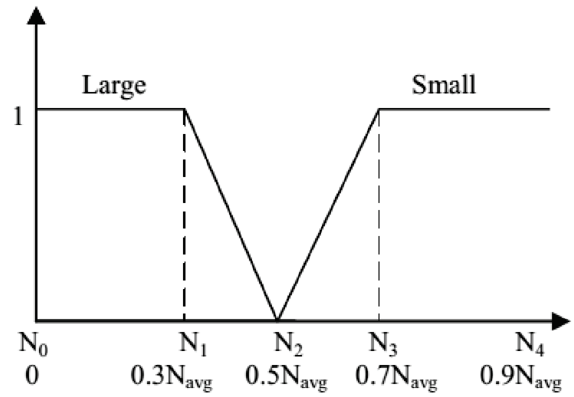

Fig. 3(a). Membership function for Number of neighbors (N).

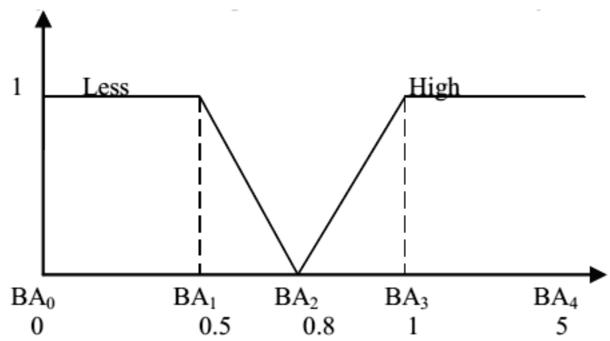

Fig. 3(b). Membership function for bandwidth Available (BA)

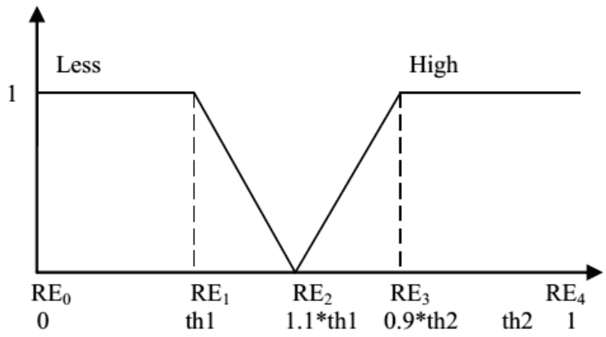

Fig. 3(c). Membership function for Remaining energy (RE)

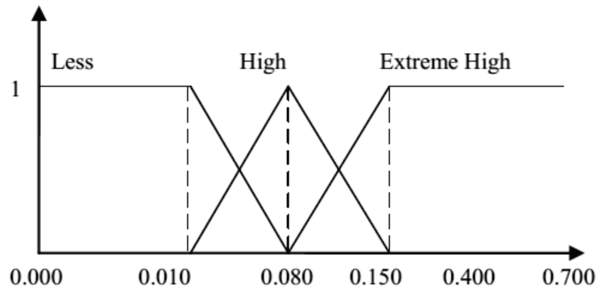

Fig. 3(d). Membership function for output probability (P)

4. Performance Analysis

In this section we evaluate and compare the performance of proposed Efficient Fuzzy logic based Probabilistic Broadcasting (EFPB) algorithm with the performance of the following protocols: traditional AODV with fixed probability, AODV_EAPB, Destination Sequenced Distance Vector (DSDV) routing, dynamic source routing (DSR) and Optimized Link State Routing (OLSR). Network simulator, NS2[24-27] has been employed to assess the modified AODV using Efficient fuzzy logic based probabilistic broadcasting scheme (EFPB).Many network simulators are available for each educational and business uses for example NS2, GloMoSim , OPNET , QualNet and OMNeT++ . Ns-2 is the most accepted one and most of the prevailing works on MANETs mentioned during this paper use NS-2 for the performance analysis. Hence, it is employed in this work to assess the performance of the proposed broadcasting scheme. It is an open source tool designed by researchers at Berkeley University, and enforced supported C++. It provides substantial support for simulation of communications protocol, routing, and multicast protocols over wired and wireless networks. Ns-2 is employed beside OTCL script to regulate network parameters and topology.

The mobility approach that has been employed in the entire simulations was the random way point. Also the IEEE 802.11 DCF (Distributed Coordination Function) is used as the MAC layer protocol in this set up. In all the cases, the nodes send a constant bit rate (CBR) data traffic between source and destination over UDP (User Datagram Protocol). The transmission range of mobile nodes is set to 100 meters. The 100 nodes are located evenly in grid form initially over the region of 1500m x 1500m. The initial energy for each node is set to be 100 J. The node density is varied from 0 to maximum 10,20,30,40,50,60,70,80,90 and 100 to evaluate the performance of efficient fuzzy logic based probabilistic broadcasting scheme implemented on AODV routing protocol. The simulation parameters are shown in Table 2. The screenshot for routing using AODV_EFPB is shown in Figure 4.

Table. 2. Summary of the parameters used in simulations

Parameter	Value
Transmitter Range	100 m
Simulation time	400 s
Scenario Simulation repetitions	10
Interface queue length	50 messages
Pause time	0 s
Topology size	1500 x 1500 m^2
Packet Size	512 bytes
Mobility	1-30 m/s
Number of nodes	100
Data traffic	CBR
Initial energy of the nodes	100 J
Mobility model	Random Way-Point

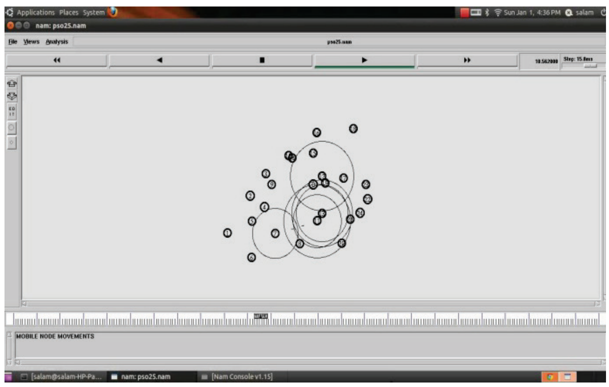

Fig. 4. Screenshot for routing using AODV_EFPB Protocol

The parameters that have been taken to analyze the network performance and protocols are as follows[28]:

- **Consumed power:** This is defined as average of power consumed by all nodes of the network.

- **Throughput:** It provides the network consistency in providing information to the destination. So throughput can be defined as the number of packets incoming at the sink in one millisecond.
- **MAC Load:** It can be defined as the number of MAC layer packets transmitted by each node within the network divided by the total number of data packets effectively reached at each and every destination node.
- **Routing overhead:** Within a network each and every control messages like RREQ, broadcasted and received is actually known as routing overhead.
- **Collision Rate:** The average number of data packets that are unsuccessful to reach the destination is known as collision rate.

4.1 *Consumed power*

As seen in the Figure 5 AODV_EFPB use less energy per node as compared with other four standard protocols. Mainly the battery usage of AODV_EFPB gets better in contrast to that of AODV_EAPB[29] and traditional AODV with fixed flooding. The AODV_EFPB performs best at each and every point of the node density range. The DSR protocol uses additional battery in contrast to AODV_EAPB and AODV_EFPB. Other than this it performs exceptionally well in contrast to AODV as the node number within the network is near about 100 nodes. In contrast, the energy usage within any network implemented with DSDV as well as OLSR increases rapidly starting from quite elevated levels. As the number of nodes increases, the energy consumption of OLSR implemented networks enhances as compared to all protocols taken into consideration. Also OLSR protocol employs a method that regularly revises knowledge about neighboring nodes and as a result spends further energy. As we increase the density of the node within a network, necessary updates increases, and therefore for proactive protocols, performance degrades, particularly when network mobility is present.

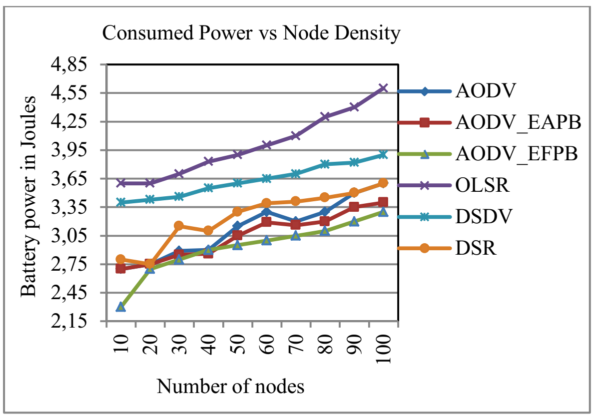

Fig. 5. Consumed Power vs. node density.

4.2 *Throughput*

Data throughput of all six protocols is shown in Figure 6. DSR presents appreciable performance. Also, AODV_EFPB performs well with average dense networks till the network size remains within 50 nodes. Among AODV_EFPB, AODV_EAPB and traditional AODV protocols, nodes are not required to have information about the route between two nodes, which decreases the total control packets required for the route discovery process. OLSR as well as the DSDV perform badly in contrast with the other protocols. This is for the reason that these are proactive protocols, and table revision is required, which create comparatively more packet overhead, which can create an obstruction in big networks, particularly in mobile networks as well as it decreases the bandwidth of the network. Though, these protocols are superior for low data rate communication as their self revising helps in maintaining the connectivity to a certain extent as compared to the accessibility of bandwidth on behalf of application data. Also in this scenario the AODV_EFPB execute similarly to the OLSR and DSDV routing protocol.

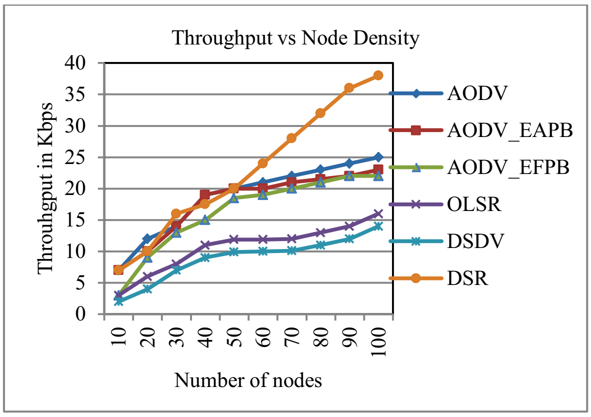

Fig. 6. Throughput vs. Node density.

4.3 *MAC Load*

MAC loading is shown for all six protocols in Figure 7. And from the figure it is clear that for bigger networks, a comparative number of messages are produced by OLSR as well as DSR implemented networks. That clarifies why the number of successful data packet delivery is extremely less which further enhances packets re-transmissions. Also DSDV as well as AODV show just a fair increase in the number of retransmissions. The figure also shows that the employment of Efficient fuzzy logic based probabilistic technique as used in AODV_EFPB considerably decreases the quantity of overhead messages within the network. Because we have information of node neighbors as well as the battery of each node and the probability of broadcasting control packets depends upon the node's battery which is input to the fuzzy logic so the path failure due to battery of nodes occurrence is very low which further decreases MAC Load significantly in our AODV_EFPB . In our proposed scheme the quantity of messages rebroadcasted is reduced considerably in all parts of the network density; the improvement is 45% better than the traditional AODV which is also 2% over the AODV_EAPB i.e. our previous scheme.

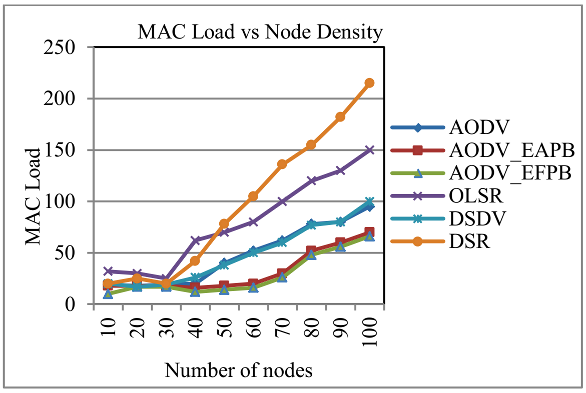

Fig. 7. MAC load vs. Node density.

4.4 *Control message overhead*

Figure 8 illustrates control message overhead of all protocols. As seen in the graph AODV_EFPB, has lower control message overhead than AODV_EAPB and the standard AODV with fixed probability protocol. Because we have information of node battery and the probability of broadcasting control packets depends upon the nodes battery as per our input to fuzzy logic so the path failure due to battery of nodes occurrence is very low which further decreases control message overhead significantly in our AODV_EFPB . Whereas DSR as well as DSDV presents a superior result because they use the least number of control packets while transmitting and receiving alternatively, OLSR protocol shows poor performance as compared to all other protocols which further worsens the situation when the number of nodes increases from 30 to 40.

4.5 *Collision Rate*

The collision rate is shown through number of dropped packets in reference to network size and is shown in Figure 9. In AODV_EFPB, it is lesser from AODV_EAPB and the traditional AODV protocol. As per our input to fuzzy logic we have used available information about available bandwidth as well as

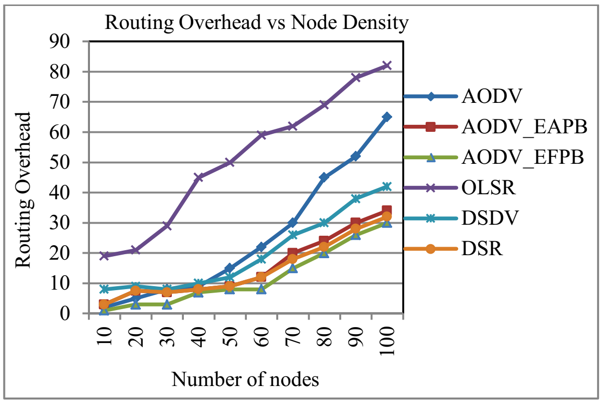

Fig. 8. Routing overhead vs. node density.

battery status. The knowledge of these two parameters it reduces collision rate in AODV_EEFB. The results of DSDV are almost same as of AODV_EFPB as in this method fuzzy optimization technique is employed in which broadcasting further depends upon nodes energy ,bandwidth available and node density which results in significant improvement in network performance in every scale of the network. Also, both OLSR as well as DSR perform superior in less node networks with node density approximate to 30 nodes subsequent to which performance degrades. The traditional AODV with fixed probability protocol presents extremely worse performance as compared to all the protocols as soon as the node number goes beyond 20.

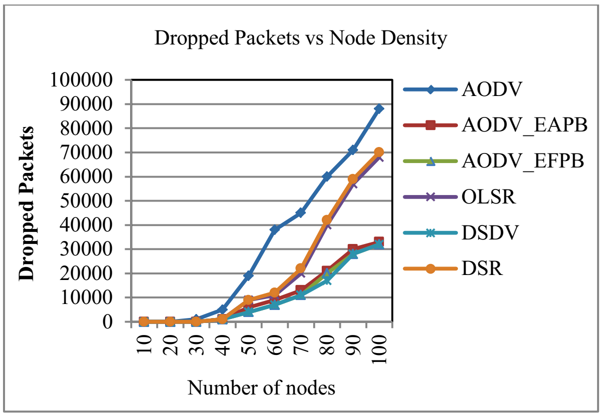

Fig. 9. Dropped Packets vs. Node density.

5. Conclusions

In this paper an Efficient fuzzy logic based probabilistic broadcasting (EFPB) technique for transmitting RREQ packets is proposed and implemented in the AODV routing protocol for mobile adhoc network which outperforms the other broadcasting techniques. In previously proposed the other probability based broadcasting techniques, every node broadcast with fixed probability without considering the node density, remaining energy and available bandwidth of the nodes. The proposed scheme in this paper decides probability of RREQ broadcast depending on the output of fuzzy controller, which depends upon node density, remaining energy and available bandwidth of the nodes. The best feature of this algorithm is that it gives an output probability of broadcasting depending on their remaining energy and available bandwidth and this information can be utilized while deciding the probability of broadcasting RREQ packets. EFPB outperforms the other broadcasting techniques which are used by traditional AODV that uses either fixed probability or blind flooding. Moreover EFPB achieves better results as compared to other routing protocols like DSDV, OLSR and DSR in all aspects. Further, the same technique can be implemented also with the other parameters such as node velocity. It can be used in the route discovery phase and it can be analyzed whether it can remove the broadcasting storm problem or not with increasing link stability.

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