Fuzzy-Logic Based Probabilistic Broadcasting Technique for Mobile Adhoc Networks

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Abstract

Broadcasting also called as flooding is one of the earliest research interests in mobile ad hoc networking. The main objective of broadcasting scheme is to avoid broadcast storm problem, provide good network performance and scalability. Existing probabilistic scheme consider only one parameter such as network density, node location or counter value in calculating probability value for broadcasting. These probability scheme cannot change their broadcasting approach even though the objectives of the system may change based on node characteristics or network conditions. There is no probabilistic broadcasting schemes which consider multiple parameters for determining the probability to broadcast. The parameters that greatly affect broadcasting is the network density, node location, etc. in this paper a new probabilistic broadcasting algorithm has been proposed that aims to utilize up to date local topological characteristics of intermediate nodes such as network density and node location. As we are using multiple values to calculate probability for broadcasting there is a need of optimization technique (such as Fuzzy Logic). With the use of fuzzy logic the proposed algorithm can keep good balance between rebroadcast efficiency, reachability and throughput.

Keywords: *Probability, fuzzy logic, network density, mobility, node location.*

1.Introduction

Traditionally, broadcasting means sending a message from one given node (the source station) to all the nodes in the network. In a multi-hop decentralized network, the broadcasted data has to be relayed by intermediate nodes in such a way that all the network graph is spanned. In MANET, simplistic broadcast schemes results in network with redundancy, contention, collision which is often called “Broadcast Storm Problem”. This can prevent broadcasts from achieving the objectives of optimal delivery ratio, energy balancing, and latency.

The main objective of broadcasting scheme is to avoid broadcast storm problem, provide good network performance and scalability. Therefore, a route discovery technique that can guarantee an efficient utilization of the limited system resources while achieving acceptable levels of other important performance metrics such as throughput and end-to-end delay is highly desirable. Till date, research on efficient broadcasting scheme in mobile ad hoc networks has proceeded along two main schemes: Deterministic and Probabilistic [1]. Deterministic schemes use network topological information to build a virtual backbone that covers all the nodes in the network. In order to build a virtual backbone, nodes exchange information, typically about their immediate or two hop neighbors. This results in a large overhead in terms of time and message complexity for building and maintaining the backbone, especially in the presence of mobility. Probabilistic schemes, in disparity, rebuild a backbone from scratch during each broadcast. Nodes make instantaneous local decisions about whether to broadcast a message or not using information derived only from overheard broadcast messages. These schemes incur a smaller overhead and demonstrate superior adaptability in changing environments when compared to deterministic schemes [2-4]. However, these schemes have poor reachability as a tradeoff against overhead.

2.Literature Review

Most probabilistic broadcast approaches that have been proposed in the literature [5, 6, 10] have considered a fixed forwarding probability at each intermediate node. This could lead to most nodes not receiving the broadcast packet when the forwarding probability is set too low or more redundant transmissions if the probability is set too high, as discussed in [7, 8]. One of the causes for this is that every node in the network has the same probability of rebroadcast, regardless of its local topological characteristics, such as neighboring node density. In a dense network, multiple nodes may share similar transmission coverage. Therefore, if some nodes, randomly, do not forward the broadcast packet, these could save resources without degrading the delivery effectiveness. On the other hand, in a sparse network, there is much less shared coverage; thus some nodes might not receive the broadcast packet unless the rebroadcast probability is set high enough. Consequently, the rebroadcast probability should be set differently from one node to another according to their local topological characteristics.

Cartigny and Simplot [9] have described a probabilistic scheme where the forwarding probability p is computed from the local density n (i.e. the number of neighbors of the node considering retransmission). The authors have also introduced a fixed value parameter k to achieve high reachability. This broadcast scheme has a drawback of being locally uniform. This is because each node in the network determines its forwarding probability based on the fixed efficiency parameter k which is not globally optimal.

The author in [12] introduces the concept of distance into the counter based scheme, in which nodes closer to the border of source has been given higher rebroadcast probability since they create better expected additional coverage area [5]. Distance threshold is taken to distinguish between interior and border nodes. Two distinct random assessment delays are applied to the border and interior nodes, with border nodes having shorter random assessment delay than the interior nodes.

Zhang and Agrawal [7] have described a dynamic probabilistic scheme using a combination of probabilistic and counter-based approaches. In this approach, the forwarding probability at a node is set based on the number of duplicate packets received at the node. But the value of a packet counter at a node does not necessarily correspond to the exact number of neighbors of the node, since some of its neighbors may have suppressed their rebroadcasts according to their local rebroadcast probability.

Whereas the author in [14] has proposed a hybrid route discovery algorithm which combine the features of fixed probability and counter based approach. The packet counter is used as density estimation. When the packet counter value is high the node is located in dense region and so the rebroadcasting is inhibited, when it is low the node is located in sparse region and packet is rebroadcasted with fixed probability p. In [13] the author has introduced neighbor knowledge scheme in the probabilistic scheme. With neighbor knowledge scheme 1 hop neighbor of a node is calculated by generating HELLO message. Then the average neighbor, minimum average neighbor and maximum average neighbor is calculated after which nodes are classified into two groups or three groups, this represent the density of nodes sparse, medium sparse, dense. Different probability value is given based on the node density for rebroadcasting.

In [15] the author has proposed the broadcasting scheme that dynamically computes the forwarding probability using a probability function. In [11], the network topology is logically partitioned into sparse and dense regions using the local neighborhood information. Each node located in a sparse region is assigned a high forwarding probability whereas the nodes located in the dense regions are assigned low forwarding probability.

In this paper, we propose fuzzy logic based probabilistic broadcasting that take advantage of the short comings of the existing probabilistic schemes. For instance, firstly by considering the location of the node that is whether it is located on the border or in the interior of the nodes transmission range, the probability value can be different so as to have a fine balance between improving the network connectivity and the retransmissions redundancy. Secondly the network density that is, in a dense network the retransmissions redundancy is relatively high and can degrade the overall performance of the network. On the other hand in a sparse network, the connectivity of the network is relatively low. Therefore, the forwarding probability should be set dynamically to reflect the local topological characteristics of a given node; e.g. whether the node is located in a sparse, medium sparse and dense network.

3.Fuzzy Logic based Probabilistic Broadcasting

The algorithm dynamically adjusts the forwarding probability at each node based on its local density, and node location with respect to source node. In this study, the local density of a node is estimated using its number of 1-hop neighbors, which is obtained by periodic exchange of “hello” packets among neighboring nodes [33] and speed of a node. Whereas the node location is classified into two category border node and interior node. Nodes lying within the transmission range (250 meter) and threshold distance (200 meter) are called border node and nodes lying within the threshold distance are called interior nodes [12].

The Fuzzy Logic Controller (FLC) is showing a better performance than conventional controllers in the form of increased robustness. Fuzzy Control is based upon practical application knowledge represented by so called linguistic rule based, rather than by analytical (either empirical or theoretical) models. Fuzzy Control can be used when there is an expertise that can be expressed in its formalism. That allows to take opportunity of available knowledge to improve processes and perform a variety of tasks.

Its wide range of applications and natural approach based on human experience makes Fuzzy Control a basic tool that should be made available to Programmable Controller users as a standard. Fuzzy Control is a multi-valued Control, no longer restricting the values of a Control proposition to "true" or "false". Fuzzy logic is used in generating the multivalued probability with multiple input values which is network density and node location. Simulation results have shown that using fuzzy logic with the three parameters neighborhood information, node location of a node to dynamically set the forwarding probability can significantly reduce the broadcasting, RREQ forwarded and routing overhead while improving network throughput for most considered network operating conditions.

3.1 *Input Parameters Of Fuzzy Logic Control*:

Two inputs are given to fuzzy logic in order to calculate probability value. The two inputs are:

1. Network Density
2. Node Location

The fuzzy controller takes two inputs, process the information and outputs the broadcasting probability. In the above two stated inputs the network density is determined by the average number of neighbors [13] in the network. Below is the formula used to calculate average number of neighbours $\bar{n}$ at a node in the network at that time instant is defined by the relation:

$$\bar{n} = \frac{\sum_{i=1}^{N} N_i}{N} \qquad (1)$$

Where N is the number of nodes in the network and N_i is the number of neighbors at a node x_i at a particular time instant.

Secondly, the maximum number of neighbors, $\bar{n}_{max}$ and minimum number of neighbors, $\bar{n}_{min}$ are determined using the average number of neighbors $\bar{n}$. Let N1, N2, . . . , N_k be the number of neighbors at nodes x1,x2, . . . ,x_k, respectively, such that Ni > $\bar{n}$, where i is a positive integer such that i ≤ k, then the expected maximum number of neighbors is defined as

$$\bar{n}_{max} = \frac{\sum_{i=1}^{k} N_i}{k} \qquad (2)$$

Also, if N1,N2, . . . , N_r are the number of neighbors at nodes y1,y2, . . . , y_r, respectively, such that Ni < $\bar{n}$, , where i is a positive integer such that i ≤ r, then the expected minimum number of neighbours is defined as

$$\bar{n}_{min} = \frac{\sum_{i=1}^{r} N_i}{r} \qquad (3)$$

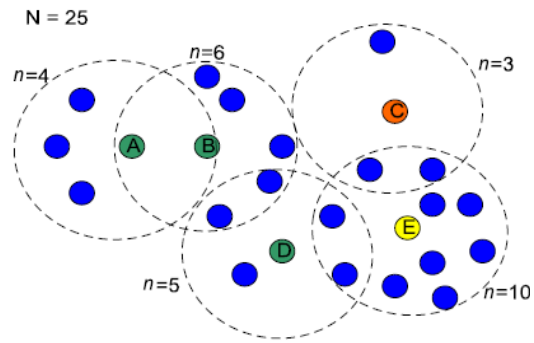

Fig 1: Illustration of 25 nodes located in low sparse, medium sparse, dense and highly dense topology

Therefore, the expected minimum, average and maximum number of neighbors for a give topology scenario are related as $\bar{n}_{min} < \bar{n} < \bar{n}_{max}$.

When the node neighbor number (Nx) is less then $\bar{n}_{min}$ then node lies in low sparse network , when Nx lies between $\bar{n}_{min}$ and $\bar{n}$ then the node belongs to medium sparse network, if node neighbor number Nx lies between $\bar{n}$ and $\bar{n}_{max}$ then the node belongs to dense network and finally the node belongs to highly dense network when it is more then $\bar{n}_{max}$. Lets take an example when number of nodes in a network is 25 then $\bar{n}_{min}$ is 3, $\bar{n}$ is 6 and $\bar{n}_{max}$is 9 as calculated from equation 1,2 and 3 as shown in Fig 1. As stated above the density is classified in four category and so the probability is categorized in high, medium, low and very low probability value. For node location as the EAC of border nodes are high so the probability for border nodes is also set to high while for interior nodes it is set to low.

The author [5] has indicated that the border nodes have a higher expected additional coverage area (EAC) than the interior nodes. Therefore in [12] author has introduced distance threshold (Dth) in the counter based scheme. As shown in Fig. 2, node A denotes the source node, and R denotes the transmission range. The nodes lying within node A's transmission range but outside the range of Dth are called border nodes (e.g. node B and C). The nodes lying within Dth are called interior nodes (e.g. node D and E) **.**

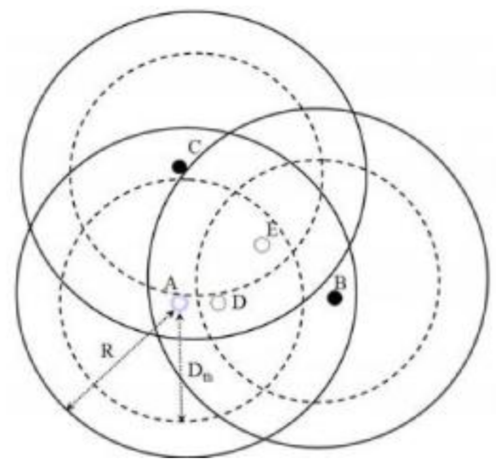

Fig 2. Illustration of EAC

3.2 *Proposed Algorithim*

Fuzzy logic based probabilistic accepts two input parameters:

A. Network Density

Let $\bar{n}$ is the average number of neighbors, $\bar{n}_{min}$ minimum number of neighbors, $\bar{n}_{max}$ maximum number of neighbors. Then, density α of the underlying network is defined in (1).

$$\alpha = \begin{Bmatrix} Low\ sparse\ if\ N_x < \bar{n}_{min} \\ Medium\ Sparse\ if\ \bar{n}_{min} < N_x \leq \bar{n} \\ Dense\ if\ \bar{n} < N_x \leq \bar{n}_{max} \\ Highly\ Dense\ if\ N_x > \bar{n}_{max} \end{Bmatrix} \quad (4)$$

B. Node Location

Let Lx be the current node location and Dth is the distance threshold. Node location is denoted by β and is given in (2):

$$\beta = \begin{Bmatrix} Interior\ if\ L_x < D_{th} \\ Border\ if\ L_x > D_{th} \end{Bmatrix} \quad (5)$$

This algorithm calculates the probability value using the fuzzy logic controller which then broadcast the route request packet in the network, thus avoiding the broadcast storm problem. The algorithm is as follows:

1) Source node broadcast RREQ packet to all neighbors.
On hearing a RREQ packet m at node X from source S
Get the number of neighbors' Nx at node X;
Calculate average number of neighbors α and node location β.

2) Each of those neighbors in turn call the fuzzy controller by setting the inputs with $\bar{n}$, $\bar{n}_{max}$, node location. While the output that is probability value is set to high, medium, low and very low.

3) Pass the Nx and Lx value to fuzzy controller

4) Fuzzy controller then generates the probability value P as an output.

The decision which the fuzzy controller makes is derived from the rules which are stored in the database equation 1 and 2. These are stored in a set of rules. Basically the rules are if-then statements that are intuitive and easy to understand.

5)Generate a random number RN over (0, 1).

6)If RN ≤ P
rebroadcast the received message;
7)Else
drop the message.

The steps involved in the Fuzzy controller are as follows:

1) FUZZIFICATION: Fuzzification converts the input data namely network density and node location into suitable linguistic variables. A scale mapping is performed using triangular and trapezoidal membership function, which transfers the range of input variables into corresponding universe of discourse.

2) KNOWLEDGE BASE: Knowledge base consists of database and rule base. Data base provides necessary definitions that are used to define linguistic control rules with a syntax, such as: IF < fuzzy proportion > THEN < fuzzy proportion > .

The 'IF' part is called the 'antecedent' and the 'THEN' part is called the 'consequent'. In control applications the antecedents are 'error' and 'change in error' and the consequent is the 'control command'.

3) DECISION MAKING LOGIC: Decision making logic infers a system of rules through the fuzzy operators namely 'AND' and 'OR' and generates a single truth value which determines the outcome of rules (inferred fuzzy control action).

4) DEFUZZIFICATION: Defuzzification yields a crisp, non-fuzzy control action from an inferred fuzzy control action. In the present work, mean of maxima method is used as the defuzzification strategy because of its simplicity and no overhead.

4.Performance Analysis

Qualnet is a discrete event simulator, used in the simulation of Mobile ad hoc networks. To evaluate the performance of the proposed scheme for route discovery algorithms, the implementation of the AODV routing protocol in the qualnet simulator has been modified and fuzzy logic control has been embedded so as to efficiently execute the proposed algorithim. The simulation parameters that have been used in our experiments are stated in table 1.

Table 1: Simulation Parameter

Parameter	Value
Transmitter range	250
Bandwidth	2 Mbit
Interface queue length	50 messages
Simulation time	900 seconds
Pause time	0 second
Packet size	512 bytes
Topology size	500 * 500 m^2
Number of Nodes	10, 20, 30, 40 nodes
Data traffic	CBR
Mobility model	Random waypoint

Extensive simulation experiments have been conducted to compare the performance of the fuzzy Probability-AODV against smart probability broadcast-AODV (SPB-AODV)[33]. Here the simulation is done by varying the number of nodes 10, 20, 30, 40: aodv, fuzzy gives the performance comparison of 10 nodes, aodv2, fuzzy2 gives the performance comparison of 20 nodes, aodv3, fuzzy3 gives the performance comparison of 30 nodes, aodv4, fuzzy4 gives the performance comparison of 40 nodes, as shown in Fig 2 to Fig 5.

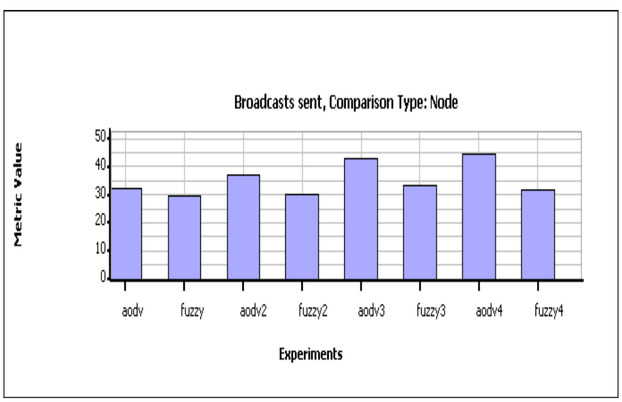

Fig 2: Comparing two probabilistic broadcast schemes in terms of Total Broadcast sent

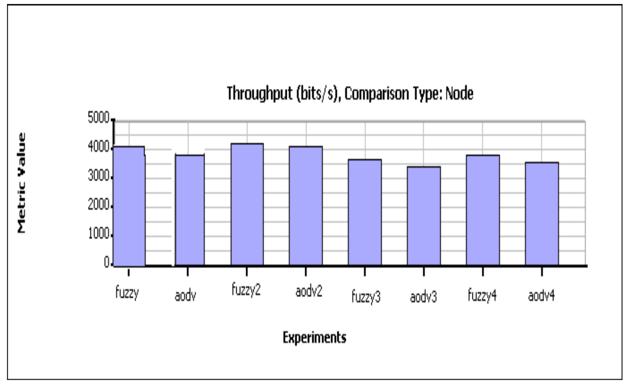

Fig 3: Comparing two probabilistic broadcast schemes in terms of Throughput

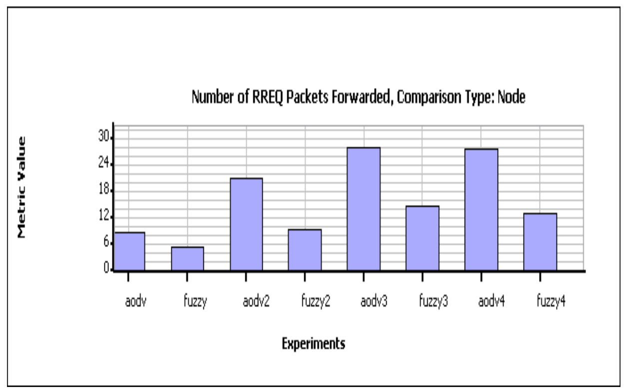

Fig 4: Comparing two probabilistic broadcast schemes in terms of No of RREQ packet forwarded

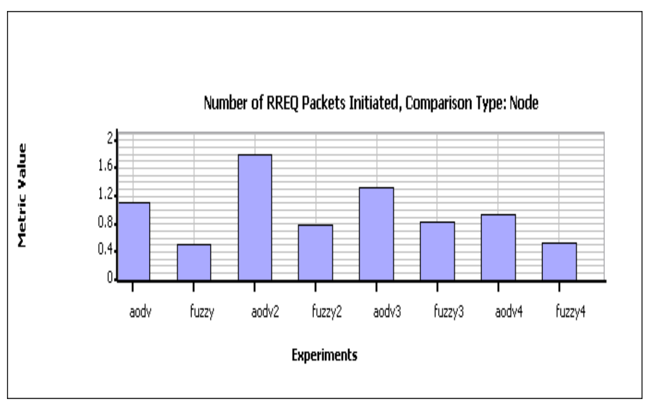

Fig 5: Comparing two probabilistic broadcast schemes in terms of No of RREQ packet initiated

Above are the four results between AODV (SPB-AODV) and fuzzy AODV that shows Total broadcast sent, throughput, no of RREQ packet forwarded, no of RREQ packet initiated. The results have revealed fuzzy Probability-AODV exhibit superior performance as compared with SPB-AODV.

5.Conclusion

This paper has evaluated the performance of fuzzy logic based probabilistic broadcasting scheme with smart probabilistic broadcasting, which uses only network density for determining the probability value. The present work brings out the potential advantages of applying Fuzzy Logic Control technique for generating dynamic probability value based on the network density and node location. Fuzzy Logic Control can therefore be an effective strategy for generating varying probability value for broadcasting in MANET. The simulation results revealed that the proposed algorithm generates much higher throughput and saved rebroadcast. The results have also shown that the degradation of the number of RREQ packet initiated and forwarded in dense network has significantly reduced. Though the analysis in this paper has been very crude, but this clearly depicts the advantage of adding the fuzzy logic controller in the conventional probabilistic broadcasting scheme. The results tend to be more broadcasting efficient. The comparisons show the superiority of Fuzzy Logic Control scheme over the smart probabilistic broadcasting schemes.

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