2016 IEEE 27th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications - (PIMRC): Mobile and Wireless Networks

A FLRBF Scheme for Optimization of Forwarding Broadcast Packets in Vehicular Ad Hoc Networks

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***Abstract*—Due to the highly dynamic network feature, Vehicular Ad Hoc Networks (VANETs) suffer from the frequent link breakage and low packet delivery rate, which pose challenges to design routing protocols. To address this issue, we propose a Fuzzy Logic Routing Based on Forwarding (FLRBF) optimization scheme depending on receiving nodes for optimizing forwarding broadcast packets. We first calculate and record the distance factor and time delay from one source node to the destination node. Via the above information, we define a forwarding probability value for each node by the proposed fuzzy logic system based on high priority routing algorithm. Motivated by the defined forwarding probability values, nodes set timers and forward packets to achieve balancing broadcast efficiency, network throughput and average end-to-end delay. In the end, we conduct simulations to verify the performance of FLRBF. Results demonstrate that the proposed protocol performs well in terms of packet delivery ratio, end-to-end delay and overhead.**

***Index Terms*—Fuzzy logic, routing protocol, optimization, VANETs.**

I. Introduction

Vehicular Ad Hoc Networks (VANETs) are burgeoning wireless communication technology [1], which is one of the most successful areas in Mobile Ad Hoc Networks (MANETs) [2]. Although many efficient broadcasting techniques have been proposed in MANETs, those techniques have considered a random waypoint mobility model which is unrealistic for VANETs. For characteristics of VANETs are patterned mobility of nodes, large-scale and highly dynamic topology, which make the network frequently partitioned and disconnected [3]. Therefore, there are several challenges for addressing intermittent-connectivity issues in VANETs.

To design an efficient reliable broadcast protocol in VANETs, the metrics of packet delivery ratio, delay and overhead should be taken into considerations. Traditionally, the routing schemes for vehicle networks are challenging for varied network environment. And most of the existing delay tolerant networks routing for vehicular mainly focus on metrics such as delay, hop count and bandwidth, etc. [4] Those prevent broadcasts from achieving objectives of optimal delivery ratio, energy balancing and low latency.

Currently, applications for Intelligent Transportation System (ITS) such as road accident calls and emergency notification require an efficient reliable broadcasting scheme that can deliver broadcast messages to all vehicles in an area of interest. In [5], Edge-aware Epidemic Protocol (EAEP) shows each car has its geographical knowledge by means of GPS. Upon the receipt of a new broadcast message, a car randomly sets a waiting timeout. When the timeout expires, the car decides whether to rebroadcast with a probabilistic function or not. Higher probability will be given to cars in the edge of circulated broadcast. However, it provides slow speed of data dissemination due to its waiting time. In [6], AckPBSM is a parameterless broadcast protocol in static to highly mobile ad hoc networks, which uses GPS to retrieve position knowledge. It employs 1-hop position information obtained by periodic beacons to construct Connected Dominating Sets (CDS) [7]. Upon the receipt of a broadcast message, nodes set waiting timeout before possible rebroadcasting. Nodes in CDS set shorter waiting time. To address intermittent connectivity issue, acknowledgements of broadcast messages are piggy backed in periodic beacons so that nodes can rebroadcast only if their neighbors have not received the broadcast messages. However, its simple flooding and speed of data dissemination are not shown compared with PBSM [8] and DV-Cast [9] in the simulation. In [10], a routing algorithm uses fuzzy logic to discover an optimal route for transmitting data packets to the destination in MANETs. Although it helps every node in MANET to choose next efficient successor node on the basis of channel parameters like environment noise and signal strength, the performance of the route is a little good by increasing network life time, reducing link failure and selecting best node for forwarding the data packet to next node. A Fuzzy-Gossip protocol using fuzzy logic is proposed in [11]. It shows an optimal routing path from source to destination by selected the best node from candidate nodes in the forwarding paths by favoring highest remaining energy and the lowest distance (minimum number of hops) to the sink. However, the Fuzzy-Gossip protocol has a bit complex mechanism due to its calculation of favoring factors.

To address these challenges, we adopt a Fuzzy Logic [12] Routing Based on Forwarding (FLRBF) optimization scheme by considering the influence of the distance factor and time delay from one source node to the destination node. We use a fuzzy logic system to calculate and gain the output fuzzy sets of forwarding probability. Then, via the above information, we define a forwarding probability value for each node based on high priority routing algorithm by the designed fuzzy logic system, which is a linguistic oriented methodology and has the fundamental ability to address the problems with imprecise knowledge. Finally, motivated by the defined forwarding probability values, nodes set the timers and forward packets to achieve balancing broadcast efficiency, network throughput

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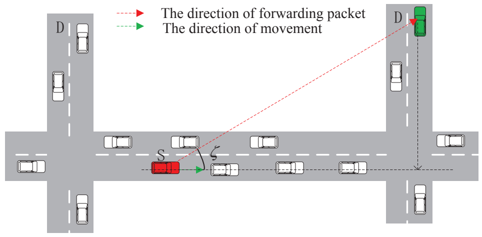

Fig. 1: Detailed schematic diagrams of the direction factor

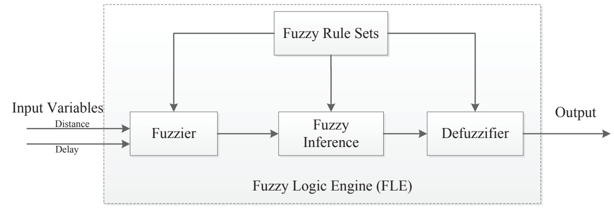

Fig. 2: Composition of fuzzy control system

and average end-to-end delay. More specifically, our main contributions can be summarized as follows:

- Based on receiving nodes for forwarding packets, FLRBF takes full advantage of characteristics of wireless communication and does not require periodic HELLO packets to collect information of neighbor nodes.
- In the process of implementation of FLRBF, we consider the execution behavior after nodes receive packets and define a forwarding probability value for each node employing high priority routing algorithm based on fuzzy logic system.
- Motivated by the local message of relay nodes, including path delay and node location, we arrange nodes to set timers and forward packets to make a balance of broadcast efficiency, network throughput and average end-to-end delay.

The rest of paper is structured as follows. Section II describes FLRBF optimization scheme. Simulation setup and analysis of results are depicted in Section III, and Section IV draws conclusions and makes a prospect.

II. FLRBF Optimization Scheme

In this section, we first assess two factors of the distance and time delay from a node to the destination, and then illustrate forwarding strategy of FLRBF optimization scheme in detail.

A. Assessment of Two Factors

In our proposal, a node decides whether to broadcast the received packet or not based on measurement of the distance and time delay from one node to the destination. When a node receives a broadcasting packet, it will identify whether it's own or not. If not, the node will evaluate the parameters of distance and delay time through the information of location and speed respectively in its upstream hop node, the destination node and itself.

1) Computation of Distance Factor: After the node receives a packet, the distance factor can be computed by equation (1).

$$df_i = \begin{cases} 1 - \frac{d_{sd} - d_{id}}{R}, d_{id} <= d_{sd} \\ 1, d_{id} > d_{sd} \end{cases} \tag{1}$$

where d_{id} is the distance from i node to the destination node, d_{sd} is the length from the upstream hop node to the destination node, R denotes communication radius of i node.

2) Computation of Time Delay:

(a) We use two unit vectors $\overrightarrow{D_i}$ and $\overrightarrow{D_p}$ to evaluate the direction factor, $\overrightarrow{D_i}$ shows the direction of moving, $\overrightarrow{D_p}$ denotes the direction of forwarding packets. Here, the angle of ζ presents the direction of motion between $\overrightarrow{D_i}$ and $\overrightarrow{D_p}$:
   - If $0 \le \zeta \le \pi/2$, the direction factor is "1".
   - If $\pi/2 < \zeta \le \pi$, the direction factor is "-1".

   The detailed schematic is shown in Fig. 1. Here, we use the following equation (2) to calculate the direction factor.

$$\begin{aligned} \zeta &= a\cos\left(\frac{\overrightarrow{D_i} \cdot \overrightarrow{D_p}}{\left|\overrightarrow{D_i}\right|\left|\overrightarrow{D_p}\right|}\right) \\ \vartheta_i &= \begin{cases} 1, 0 \le \zeta \le \pi/2 \\ -1, \pi/2 < \zeta \le \pi \end{cases} \end{aligned} \tag{2}$$

(b) We employ equation (3) to evaluate the delay time t_{id} on data packets from i node to the destination node.

$$t_{id} = \frac{d_{id}}{\vartheta_i v_i - \vartheta_d v_d} \tag{3}$$

(c) When the node receives a data packet, using equation (4) can gain the assessment of path time delay factor.

$$tf_i = \begin{cases} \frac{t_{id}}{t_{sd}}, t_{id} <= t_{sd} \\ 1, t_{id} > t_{sd} \end{cases} \tag{4}$$

B. Forwarding Strategy

1) Fuzzy Logic: Fuzzy logic is provided in a pioneering article by Lotfi A. Zadeh known as "fuzzy sets" in 1965. In this paper, "membership" and "membership function" are described differences in the process of the transition, and the human fuzzy phenomenon can be solved in which the precise mathematical language cannot depict [13]. Based on fuzzy logic, the selection of a system shown in Fig. 2 can be made through three major steps: fuzzification, fuzzy inference system, defuzzification. The fuzzy editor inputs linguistic variables changed by real number values, and fuzzy inference repository contains linguistic rules, they constitute a fuzzy logic controller decision-making behaviors. The process of making decision in fuzzy logic controller is matching the input linguistic variables with linguistic rules, and then putting input linguistic variables into output linguistic variables. Relatively,

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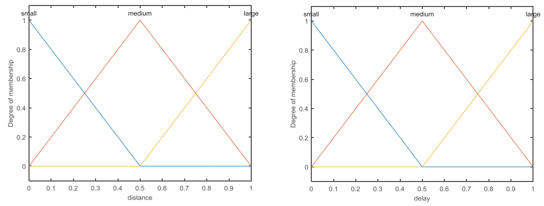

(a) The distance factor (b) The time delay factor

Fig. 3: Fuzzy membership functions

defuzzification is putting output linguistic variables into real number values, which are used in network system.

Here, we use a fuzzy system to develop node forwarding decisions and the concrete steps of fuzzy system are showed as follows:

Fuzzification: according to the distance factor and time delay and their membership functions, it is the conversion of input factors into $\{large, medium, small\}$, which can be identified by the fuzzy system.

Fuzzy inference: it is the core of fuzzy inference system, which maps input fuzzy sets into output fuzzy sets according to the fuzzy rules. Here, based on the fuzzy rules a fuzzy logic controller gains the output fuzzy sets $\{Highest, High, Medium, Low, Lowest\}$ on the probability of broadcast decisions.

Defuzzication: it converts fuzzy probability of broadcast decisions into actual values, which are used in a controller.

2) Fuzzification of Distance Factor and Time Delay: The function of fuzzification is putting actual values into fuzzy sets. The process of it is converting input values into input fuzzy sets according to the corresponding fuzzy membership functions.

In our proposed protocol, the scope of distance factor is [0, 1]. The smaller it is, the closer the distance between a node and the destination node is, otherwise, the further the distance is. The distance factor 0 denotes influence factor of the distance between a node and destination is zero, factor 1 shows that the distance between a node and destination is equal to or greater than the distance from the upstream hop node to destination. In the fuzzy logic system, we adopt fuzzy membership functions shown in Fig. 3. a, which puts actual values into input fuzzy sets $\{large, medium, small\}$.

At the same time, the scope of time delay factor is [0, 1]. The smaller it is, the shorter time delay from a node forwarding a packet to the destination is, otherwise, the longer time delay is. 0 denotes the influence factor of time delay from a node forwarding a packet to the destination is zero, 1 shows that time delay from the node forwarding a packet to the destination is equal to or greater than time delay from the upstream hop node to the destination. In the fuzzy logic system, we adopt fuzzy membership functions shown in Fig. 3. b, which puts actual values into input fuzzy sets $\{large, medium, small\}$.

3) Rules of Fuzzy Logic Controller: After calculation of input fuzzy sets on the distance factor and time delay, the receiving node will gain the output fuzzy sets on the forwarding probability using fuzzy rules in the list. The fuzzy sets of forwarding probabilities are shown in $\{Highest, High, Medium, Low, Lowest\}$. In our fuzzy system, there are nine rules in the library as described in TABLE I. And simple cases are shown as follows:

TABLE I: IF-THEN RULES BASE

Rule No.	If(AND)		THEN
	Distance	***Delay***	***Forwarding Probability***
1	small	large	Medium
2	small	medium	High
3	small	small	Highest
4	medium	large	Low
5	medium	medium	Medium
6	medium	small	High
7	large	large	Lowest
8	large	medium	Low
9	large	small	Medium

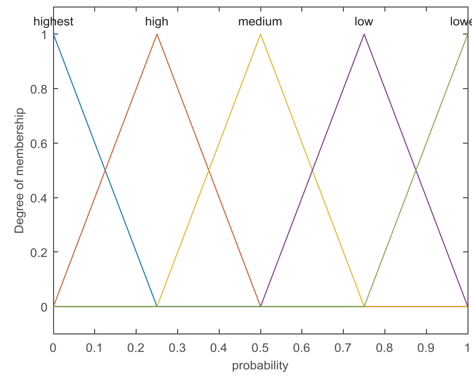

Fig. 4: The fuzzy logic membership functions

Rule 1: if the fuzzy distance is *small* and time delay is *small*, then the forwarding probability is *Highest*;

Rule 2: if the fuzzy distance is *small* and time delay is *medium*, then the forwarding probability is *High*;

4) Defuzzification: The process of defuzzification is to convert the fuzzy sets into an actual value P through using weighted average method. According to vague broadcast decisions $\{Highest, High, Medium, Low, Lowest\}$ on the probability, we use membership functions $\mu_p(x)$ of the fuzzy logic system shown in Fig. 4 to get a reasonable accurate value. And equation (5) of $\mu_p(x)$ for the actual value P is shown as follows:

$$P = \frac{\int_a^b \mu_p(x)\, x dx}{\int_a^b \mu_p(x)\, dx} \tag{5}$$

Here, we get an example to say the usage of fuzzy rules. If a value of distance factor is 0 and a value of time delay is 0.2, then the fuzzy set of the distance is $\{small = 1, medium = 0, large = 0\}$ and the fuzzy set of time delay is $\{small = 0.8, medium = 0.2, large = 0\}$. According to the fuzzy rules, we can know it matches rules 1 and 2. Due to the fuzzy distance on low membership

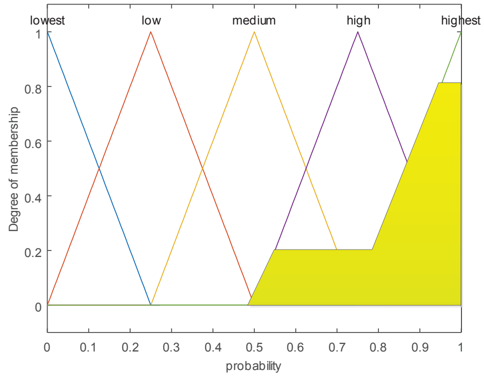

Fig. 5: Case of fuzzy system output area

degree of 1 and time delay on low membership degree of 0.8, the forwarding probability of fuzzy set on *Highest* is 0.8 based on the fuzzy rule 1 and the minimum value strategy. Similarly, according to the fuzzy rule 2, due to the fuzzy distance on low membership degree of 1 and time delay on medium membership degree of 0.2, the forwarding probability of fuzzy set on *High* is 0.2 based on the minimum value strategy. Then the forwarding probability of functions $\{Highest = 0.8, High = 0.2\}$ and $\{Medium = 0, Low = 0, Lowest = 0\}$ is yellow shown in Fig. 5, we can obtain the forwarding probability value is 0.72 by the weighted average method.

5) Packet Forwarding Strategy: We select forwarding nodes using timers. Using the competition decision to forward broadcast packets, timers are required to set a fixed time after receiving packets in nodes. Once the timer in a node is off, the node forwards the packet and shuts up the timer, besides, other nodes receiving the forwarding packet shut up the timer and give off the packet. Here according to the forwarding probability value of output fuzzy system, timers set time through the equation (6).

$$t = T * (1 - P) \tag{6}$$

where T denotes the maximum forwarding time delay, P shows the forwarding probability of fuzzy output. The larger the forwarding probability is, the smaller timers set, that is to say, the sooner nodes forward a packet.

Another method is FLRBF-p, whose basic method is the same as FLRBF optimization scheme. However, FLRBF-p adopts a p value as the forwarding probability, which is a random probability instead of the timer competition strategy after nodes receive the output forwarding probability from the above fuzzy logic system. In the process of implementation of FLRBF-p, the fuzzy logic system for FLRBF-p should be implied after nodes receive a packet. Each decision-making node randomly generates a probability value in the timer, which is used to control the packet forwarding.

III. Simulation Results and Analysis

In this section, the network simulator NS-2 is used to verify the performance of FLRBF optimization scheme. Comparisons between the proposed FLRBF and FLRBF-p are given in performance with GPSR location protocol and flooding protocol by setting and analyzing different parameters.

A. Simulation Setup

TABLE II: SIMULATION ENVIRONMENT

Setup	Freeway scenario
Map size	2500m $\times$ 2500m
Number of nodes	20, 40, 60, 80, 100, 120
Transmission range	250m
Maximum speed (km/h)	10$\sim$100
Traffic flows	30 random CBR flows, each with 32 kbps
Packet size	512 bytes
MAC	IEEE 802.11 MAC (11 Mbps)
Propagation model	Nakagami Model
Simulation time	450s

Aimed at highway scenario, the simulation environment is shown in TABLE II. We use IDM mobile model to approximate the movement behavior on roads by adopting different node density and movement speed to gain the performance through comparative analysis. We use the number of nodes to distinguish the node density, here adopting 20, 40, 60, 80, 100 and 120. Each vehicle moves along the road at an expected speed varying from 10 to 100 km/h. The transmission range of each node is 250m. The wireless signal attenuation model is used in ground launch model (Two Ray Ground), the sending power is 0.25W, and the signal frequency is set to 914MHZ, etc. In each simulation for each scenario, the source node and destination node are randomly selected as a pair of nodes. The CBR traffic model is adopted by sending node to generate data grouping, here adopting 32Byte as the size of groups and 512b/s as the rate of data. In general, data flow produces in 100 seconds at the beginning of the simulation, here the time of simulations is set to 450s.

B. Results and Analysis

As presented in Fig. 6, the packet delivery ratio of FLRBF is nearly 1.6 times better than that of GPSR, while number of nodes is changing. As the increase of nodes, the delivery ratio rises. That is to say, with the increase of network node density, the rising number of alternative forwarding nodes is advantageous to packets forwarding. As for the number of nodes increasing, the packet delivery ratio of flooding rises due to the increasing of conflicts on node broadcasting, and the delivery ratio is declining. Due to the FLRBF considering both the distance factor and conflicts caused by controlling redundancy broadcasting, the delivery ratio of the proposed FLRBF is better than other protocols. However, the packet delivery ratio of FLRBF-p is worse than that of FLRBF due to the p value as the forwarding probability. For p value is a random probability instead of the timer competition strategy after nodes receive the output forwarding probability from the fuzzy logic system.

As it is shown in Fig. 7, there are results of end-to-end delay with the change of amount of nodes, where the end-to-end delay of FLRBF is roughly the same with that of GPSR

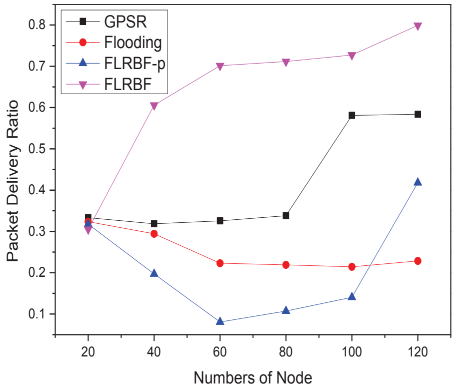

Fig. 6: Packet delivery ratio with different number of nodes

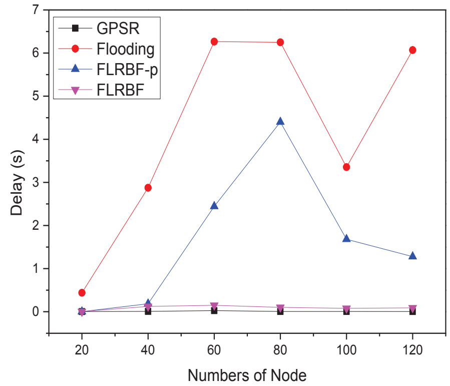

Fig. 7: Results of end-to-end delay

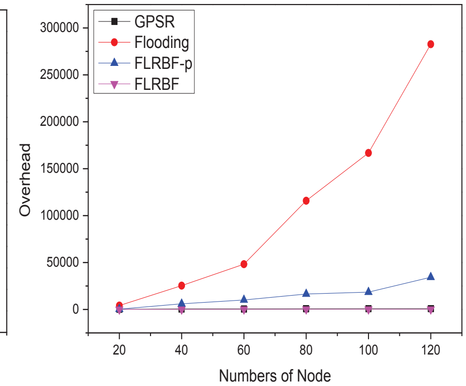

Fig. 8: Network overhead with different number of nodes

protocol. But FLRBF can provide more realistic calculation than GPSP protocol according to the packet statistics on time of successful transmission from a source node to the destination. Meanwhile, using simulations with different number of nodes, we have shown that the proposed protocol can decrease around 58.6% of the average end-to-end delay compared with that of flooding in the simulated scenario. The reason is that FLRBF-p adopts competition mechanism based on the timer, which makes that time delay is oppositely bigger, but is still acceptable.

As it is described in Fig. 8, the network overhead of FLRBF is just the same as that of GPSR protocol with different realistic calculation, when the network overhead changes with different number of nodes. However, we have found that the proposed protocol can decrease around 76.1% of the average overhead compared with that of flooding in the simulated scenario. The reason is that FLRBF-p uses forwarding strategy based on receiving nodes by the calculation of probability through fuzzy logic system without periodic HELLO packets. Then the timers ensure nodes forwarding broadcast, which achieves reduced overhead greatly.

IV. Conclusion

In this paper, we propose a FLRBF optimization scheme by considering the influence of the distance factor and time delay. We use fuzzy logic system to calculate and gain output fuzzy sets of forwarding probability. Then, depending on the above information, we define a forwarding probability value for each node based on high priority routing algorithm. Motivated by the defined forwarding probability values, nodes set timers and forward packets. Based on reasonable performance criteria, using simulations with different number of nodes, the proposed protocol can decrease around 58.6% of the average end-to-end delay compared with that of flooding protocol. Meanwhile, in another simulated scenario with different number of nodes, our protocol can decrease around 76.1% of the average overhead compared with that of flooding. According to simulations, it is proved that our proposed protocol clearly performed better in achieving balancing broadcast efficiency, network throughput and average end-to-end delay.

Acknowledgment

This work was supported by the National Natural Science Foundation of China under Grant No. 61271176, No. 61401334 and No. 61571350, the Fundamental Research Funds for the Central Universities (BDY021403, XJS16013, JB160112), and the 111 Project (B08038).

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