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Fuzzy Logic Based Geocast Routing in Vehicular Ad Hoc Network

Akhtar Husain[1], Santar Pal Singh[2]* and S C Sharma[3]

[1]Department of CS & IT, Faculty of Engineering &Technology, MJP Rohilkhand University, Bareilly 243 006, India

[2*]Department of Computer Science & Engineering, Thapar Institute of Engineering and Technology, Patiala 147 004, India

[3]Wireless Network and Cloud Computing Lab, Electronics & Computer Discipline, DPT, IIT Roorkee 247 667, India

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The purpose of vehicular ad hoc network (VANET) is timely, effectively and efficiently transmission of urgent messages from source to destination. These objectives can be solved effectively with geocast routing approaches in VANETs as the most of the intelligent transportation system (ITS) applications require sending information to the vehicles belonging to a particular geographic region. In this paper an attempt has been made to develop the geocast routing protocols using fuzzy logic. The fuzzy logic routing (FLR) approach is used to implement the protocols. Three membership functions for each input distance, direction, speed and five membership functions for output (chance) with Mamdani fuzzy inference system (FIS) are used. MATLAB R2015a has been used to analyze the performance of developed protocols and compared with other fuzzy routing protocols in terms of PDR and delay. It has been observed that fuzzified geocast protocols developed with FLR approach outperform fuzzy based unicast protocols reported by other authors.

Keywords: FIS, FLR, Geocast, ITS, PDR, VANET

Introduction

The moving vehicles that form the vehicular ad hoc network (VANET) on the road aid to safety and provide comfort services to passengers as well as drivers. Safety messages have to be transmitted from source to geocast region within a particular time period.[1,2] Many researchers such as in[1] incorporated fuzzy logic to take appropriate forwarding decisions. Therefore, to take the decision to disseminate safety and comfort messages with minimum delay; we have used fuzzy logic (FL) for geocast routing protocols in VANET. To select approximate best next forwarding node, we wrote a fuzzy logic approach. We have applied fuzzy logic on geocast routing protocols to develop three fuzzy logic based geocast routing protocols named as GeoLAR_FL, GeoDREAM_FL, GeoZRP_FL. The applied fuzzy logic (FL) based approach helps in tacking the best decision. FL deals with the values that are approximate instead of exact and the range of values of FL variables is between 0 and 1. When decision criteria are uncertain, the fuzzy logic inference system (FIS) becomes very much valuable. The motivation for using the fuzzy system is to help better selection of forwarding node during the route establishment phase of the routing protocols. To evaluate and analyze the performance of our developed protocols MATLAB15a is used. Various metrics like speed, distance, direction taken as inputs to the FL system. The node with max distance, speed and less direction towards destination geocast region from current forwarding node is considered as the best next hop node. This paper is arranged in 5 sections. Section 1, illustrates the introduction. Related work is expressed in section 2. Fuzzy logic system, model and approach are illustrated in section 3. In section 4, we have analyzed the result of developed protocols. In the last, section 5 covers the conclusion and future directions.

Related Work

Fuzzy logic approach has been applied by several authors in various routing protocols to enhance the performance of VANET with different inputs (direction, speed, distance, location, degree, etc.), outputs (fuzzy cost, chance, optimum route, priority, range, etc.), membership functions, and defuzzification methods as shown in Table 1. As observed from this table that mostly authors proposed fuzzy based routing protocols for the networks in which messages are transferred from one source to single destination. Some situations such as accident,

*Author for Correspondence
E-mail: spsingh78@gmail.com

Table 1 — Related works on fuzzy based routing protocols in Vehicular Ad Hoc Network

S. No.	Author	Protocol	Parameter	Inputs	Output	Software Tool	Year
1.	R H Khokhar, *et al.*[1]	Fuzzy-assisted social-based routing for urban environments	PDR, delay	Friends, indirect friends, non-friends	Fuzzy cost	MATLAB	2011
2.	KZ Ghafoor, *et al.*[2]	Fuzzy logic-assisted geographical routing VANETs	PDR, delay, control overhead	Relative direction, distance	Fuzzy cost	MATLAB	2012
3.	S Agarwal, *et al.* [3]	FL based Greedy Routing (FLGR)	Delay	Distance, speed, direction, pos	Optimum function	MATLAB	2015
4.	JCD Angeles, *et al.*[4]	Fuzzy Logic-Based Multi-hop Routing for VANETs	Congestion, Link quality	Vector distance, buffer occupancy	Fuzzy score	VEINS, SUMO	2015
5.	Wu C, *et al.*[5]	VANET Broadcast Protocol Based on Fuzzy Logic and Lightweight Retransmission	PDR, Messages per packet	Distance, node mobility, signal strength	Rank	NS-2, SUMO	2012
6.	C Sonmez, *et al.* [6]	Fuzzy-based congestion control for WMSNs	Latency, Frame loss	Node degree, queue length, data arrival rate	Fuzzy output	OPNET	2014
7.	M Chelliah, *et al.* [7]	Routing for WMNs with Multiple Constraints Using Fuzzy Logic	Delay, throughput	Buffer, hop count	Fuzzy output	NS2	2012
8.	Gu, *et al.* [8]	A Social-Aware Routing Protocol Based on Fuzzy Logic in VANETs	Delivery ratio, delay	Centrality, similarity, activeness	Priority	NS2 and VanetMobiSim	2014
9.	Z Ghafoor, *et al.*[9]	A FL approach for beaconing in VANETs	PDR, throughput, delay	Vehicle status, direction	Range	JIST/SWANs	2013
10.	P Mittal , *et al.*[10]	A Throughput and Spectrum conscious FL based Routing Scheme for CRNs	Delivery ratio, throughput	Distance, position	Optimum route	MATLAB	2016
11.	N Geetha, *et al.* [11]	A Multi Criterion FL based Energy Efficient Routing for Ad Hoc Networks	Energy	Buffer occupancy, hop count	Route selection grade	NS-2	2017
12.	G Li, *et al.* [12]	Adaptive fuzzy multiple attribute decision routing in VANETs	PDR, delay	distance, direction, density, location	Fuzzy performance	MATLAB	2015
13.	M Hussein, *et al.* [13]	Location Aided Hybrid Routing Protocol for (LAHRP)	PDR, NRL, Delay	Distanced, battery life, density	Cost Value	GloMoSim	2011
14.	N Raju, *et al.*[14]	ODMRP based on DREAM	Throughput, Mobility	Bandwidth, traffic load	Cost	GloMoSim	2008
15.	O A Awad, *et al.*[15]	CHFL-ZRP	PDR, Throughput, Delay	Energy, Concentration, centrality	Chance	NS-2	2016

jam on the road requires to communicate urgent messages to vehicles' group belonging to a particular area, so that the vehicles coming towards the problematic point can change their routes. Therefore, we have proposed geocast routing protocols that would help to send the urgent messages timely and efficiently.

Fuzzy Logic System and Approach

Fuzzy logic deals with approximate values instead of exact or fixed values. It is of great use when it is not possible to make a precise decision. Systems using fuzzy logic are capable to provide solutions of imprecise problems very efficiently. It includes a set of fuzzy rules for describe the mobility of vehicular nodes in an adaptable way with different environments such as dense or sparse. In fuzzy system, values of vague input data are specified in a wide range in order to get the most accurate possible optimum values.[13] To find out the output from imprecise input data, the fuzzy system uses three modules fuzzification, fuzzy inference system (FIS), defuzzification.

Fuzzification transforms crisp or exact data into fuzzy inputs. Each crisp data input has set of values to which it can be transformed. The transformation is done with help of membership functions (MFs)[16] cached in knowledge base (KB) of FL. The group of MFs exists in the universe of disclosure that holds all possible values or concepts to a crisp system variable.

The MF is associated with a set of inference rules to fuzzy outputs.[17,18] There are two general forms of FIS known as Mamdani and Sugeno. Here we used Mamdani model.

Defuzzification process translates the fuzzy output of inference system to a crisp or exact value with some MFs. There are diverse defuzzification methods for producing optimum outputs. The major defuzzification schemes include centroid of area (COA), middle of maximum (MOM), largest (highest) of maximum (LOM), smallest of maximum (SOM), fuzzy mean (FM), bisector, etc.[19,20] In this work COA method is used for defuzzification.

Fuzzy Logic based Routing (FLR) Approach

In fuzzy logic-based routing (FLR), a "hello" packet is broadcasted by all the network nodes periodically. When a node receives the "hello" packet, it becomes aware of the other neighbouring nodes within its transmission range R. The node that is at highest distance from the source, is elected by the FLR as the next-hop node as illustrated in Fig. 1.

The next-hop node forms a minimum angle amid itself, current forwarding nodes, and the destination. It moves at exceedingly fast pace towards destination having maximum progress from current forwarding node towards the destination.[21,22] Such a scenario is shown in the Fig 2. A source node designated as S is the current forwarding node having seven neighbours named as A to H, covered by its transmission range. The transmission range is given by R and represented by a circle of radius R in the figures.

All the nodes within the circles are called internal nodes. Other nodes that reside outside the circle (or transmission range) are known as external nodes. The external nodes can be used as intermediate node. According to the proposed approach, nodes E, F, G, H are discarded because they aren't in the way of target node as well as they are far away from the target. As a result, we considered only those neighbours that lie in the right half of the circle. Node A is placed at largest dist from source as compared to B (d1>d2) as well as C (d1>SC). Therefore, node A is chosen as the next-hop forwarding one. The node A also makes the smallest angle (α<β and α <χ) between itself, source nodes S and destination node D. It is assumed that node A is moving with a faster speed as compared to nodes B and C. It has shown largest progress towards node D from node S in comparison to B and C.

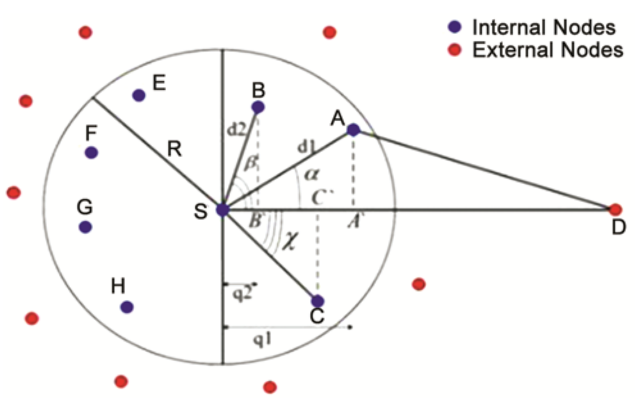

Fig. 1 — Procedure for the selection of next hop using fuzzy logic[3]

Implementation of Fuzzy Logic based Routing (FLR) Approach

Notations

Notations used in FLR approach be as

SN	Source node
PFN	Present forwarding node
N	Number of neighbours of PFN
SNHN	Selected Next-Hop Node
BNHN	Best Next-Hop Node
C_MAX	Counter
VID	Vehicle' Identifier

Conceptual Description of FLR Approach

Step 1: Initialize PFN= SN
Step 2: Define fuzzy input/output variables with their MFs for all the parameters.
Step 3: Derive fuzzy rules (IF-THEN from) using routing parameters considered.
Step 4: Put C_MAX= 0
Step 5: Exit when destination is inside maximum range of PFN.

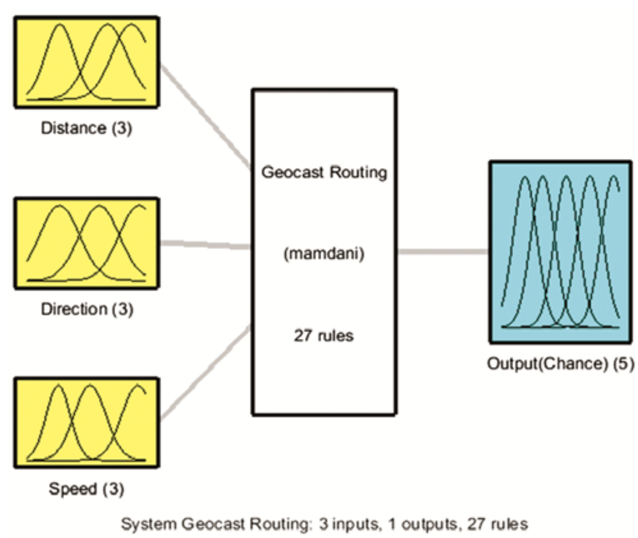

Fig. 2 — Fuzzy Inference Systems (FIS) for Geocast Routing in VANET

Step 6: For (i=1, VID=1; i<=N; i++, VID ++)
Step 7: Calculate the crisp (numerical) data values for the neighbour vehicular node means distance, relative direction w.r.t PFN, speed, progress towards objective.
Step 8: Provide calculated data values calculated as input to the fuzzy system.
Step 9: Calculate fuzzy values using MFs described in step2 for all the input parameter.
Step 10: Provide calculated fuzzy values to FIS.
Step 11: Using IF-THEN rules prepared during step 3, map the fuzzy values to get fuzzy linguistic output that provides the best next-hop forwarding node.
Step 12: Using defuzzification method and output MF, defuzzify the linguistic result into a crisp value(c-value).
Step 13: if (c-value>= C_MAX)
{
C_MAX = c-value;
SNHN = VID;
}
Step 14: Set BNHN = SNHN
Step 15: Update PFN = BNHN
Step 16: Repeat the steps 4 to 15.
Step 17: Stop

Implementation of GEOLAR_FL, GEODREAM_FL and GEOZRP_FL using FLR

Most of the researchers applied fuzzy logic on routing protocol considering the destination as single node. In this work, Fuzzy logic based routing (FLR) algorithm is applied on geocast routing algorithms namely GeoDREAM-DF, GeoLAR_DF, GeoZRP-DF and fuzzified geocast protocols are developed named as GeoLAR_FL, GeoDREAM_FL and GeoZRP_FL.

To know the behaviour of developed fuzzified geocast routing protocols a fuzzy inference system (FIS) with three input metrics distance, angular direction, speed and one output metric (chance) is shown in Fig. 2 with Mamdani method of fuzzification.

System Model

Vehicular ad hoc network scenario has been setup using a traffic simulator VanetMobiSim and generated traces of vehicles are used as an input file to MATLAB 15a. The simulation has been carried out 20 times and average value of these runs is calculated for vehicles from 10 to 80. The parameters used in simulation are given in Table 2.

Fuzzification of Input and Output Variables

A routing process using fuzzification is developed that has four input parameters: speed, direction, position, and distance. The MATLAB fuzzy toolbox has been used for the implementation of the system. The optimum fuzzy value is calculated to decide the best next-hop node. The Gaussian MF is preferred in the fuzzification as it better suits to the highly dynamic nature of the VANETs.

Distance: The distance is divided into five linguistic variables as described in Table 3.

$$Gaussian(l,m,w) = e^{-\frac{1}{2}\left(\frac{l-m}{w}\right)^2} \quad \ldots (1)$$

Where, *l,m,w* are linguistic variable, MF's middle and MF's width respect.

For distance metric, Gaussian membership function (MF) defined in Eq.1 is used and five MFs for fuzzy sets in terms of distance are defined as given below.

(i) $\mu_{Near(l)} = \exp^{-\frac{1}{2}\left(\frac{l-70}{70}\right)^2}$

(ii) $\mu_{medium(l)} = \exp^{-\frac{1}{2}\left(\frac{l-170}{100}\right)^2}$

(iii) $\mu_{Far(l)} = \exp^{-\frac{1}{2}\left(\frac{l-250}{80}\right)^2}$

Table 2 — Simulation parameters

Parameters	Value
Network area	(2500×2500) m^2
No. of nodes	10,20,30,40,50,60,70,80
Packet size	512 Bytes
Mobility Generator and Evaluation tools	VanetMobiSim, MATLAB
MAC Protocol	IEEE802.11p
Propagation Model	Nakagami model
Simulation Time	600 seconds
Geocast Routing Protocols	GeoLAR_FL, GeoDREAM_FL and GeoZRP_FL

Table 3 — Linguistic variables for distance/direction metric

Near	(0 to 70 meters)
Medium	(70 to 170 meters)
Far	(170 to 250 meters)
SlightD	(0 to 25 degrees)
MidD	(25 to 55 degrees)
LargeD	(55 to 90 degrees)

The Gaussian curves of MFs for different distance metrics are illustrated in Fig. 3(a). The MFs are used to determine the degree of the distance factor to which it belongs i.e. near, medium and far.

Direction: The MFs are also defined for the metrics direction. The range of cosα is considered to be between 0 and 1 as only the nodes in right half of the circle is taken as neighbors as revealed in Fig. 3(a). The direction metric is categorized into 3 fuzzy sets as given in Table 3. The MFs for the different variants of the direction are shown in the Fig. 3(b).

(i) $\mu_{SlightD(l)} = \exp^{-\frac{1}{2}\left(\frac{l-25}{25}\right)^2}$

(ii) $\mu_{MidD(l)} = \exp^{-\frac{1}{2}\left(\frac{l-55}{30}\right)^2}$

(iii) $\mu_{LargeD(l)} = \exp^{-\frac{1}{2}\left(\frac{l-90}{35}\right)^2}$

Speed: Another metric that is considered in the analysis is speed. With high speed the network topology changes very frequently make the VANETs highly dynamic. The vehicular nodes move at different speeds in different scenarios. Therefore, the speed is classified into different categories as given in Table 4. Like other metrics, the MFs for these are defined as shown in the Fig. 3(c).

(i) $\mu_{Slow(l)} = \exp^{-\frac{1}{2}\left(\frac{l-40}{40}\right)^2}$

(ii) $\mu_{Medium(l)} = \exp^{-\frac{1}{2}\left(\frac{l-80}{40}\right)^2}$

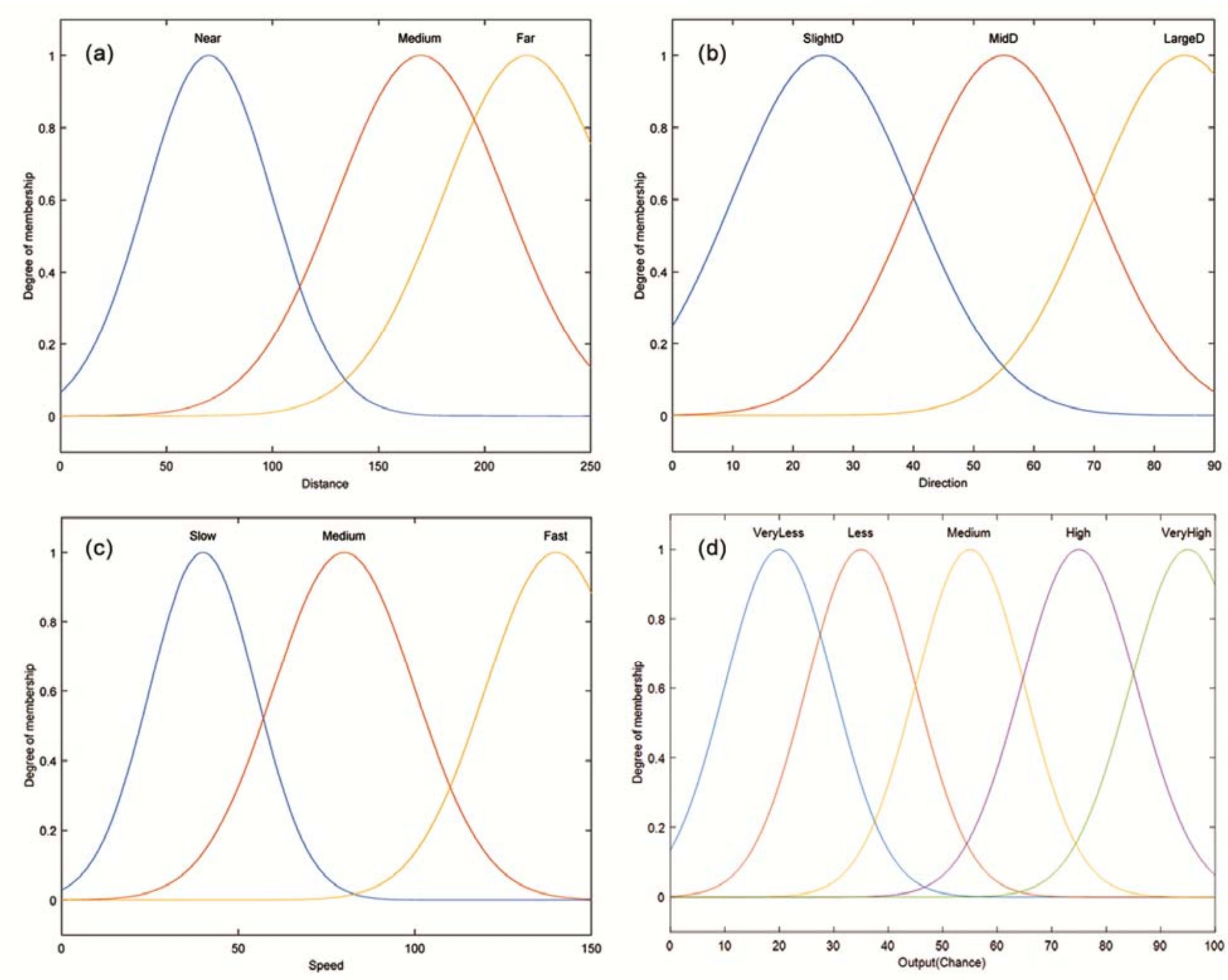

Fig. 3 — (a) Graphical representation of distance membership function, (b) Graphical representation of direction MFs, (c) Graphical representation of speed MFs and (d) Graphical representation of output MFs

(iii) $\mu_{Fast(l)} = \exp^{-\frac{1}{2}\left(\frac{l-150}{70}\right)^2}$

Output variable: The next-hop node in the routing process is decided with the help of output of the routing metrics. The output of metric is provided by the MFs in the form of a "chance" value. The chance value lies between 0 and 100. These values are categories as very less, less, medium, high, very high like given in Table 4. It indicates the chances of a node getting selected as next-hop. The higher chance values represent the greater chances of getting selected.

The MFs corresponding to this classification are defined as follows and their graphical representations are shown in the Fig. 3(d).

(i) $\mu_{Verynear(l)} = \exp^{-\frac{1}{2}\left(\frac{l-20}{20}\right)^2}$

(ii) $\mu_{Near(l)} = \exp^{-\frac{1}{2}\left(\frac{l-35}{15}\right)^2}$

(iii) $\mu_{Medium(l)} = \exp^{-\frac{1}{2}\left(\frac{l-55}{20}\right)^2}$

(iv) $\mu_{L\arg e(l)} = \exp^{-\frac{1}{2}\left(\frac{l-75}{20}\right)^2}$

(v) $\mu_{Veryl\arg e(l)} = \exp^{-\frac{1}{2}\left(\frac{l-100}{25}\right)^2}$

Rule based FIS for Metrics

In FIS, a set of IF-THEN rules is used to represent the knowledge. The IF-THEN rules work on a set of input/output variables. The general form of fuzzy IF-THEN rule is given as:

IF <fuzzy preposition>, THEN<fuzzy preposition>

Table 4 — Linguistic variable for speed metric/ output variable "chance"

Slow	(0 to 40 Kilometer per hour)
Medium	(40 to 80 Kilometer per hour)
Fast	(80 to 150 Kilometer per hour)
Very less	(0 to 20)
Less	(20 to 35)
Medium	(35 to 55)
High	(55 to 75)
Very high	(75 to 100)

The IF branch of above is called as antecedent (premise) while THEN branch is called as consequent (conclusion). A number of fuzzy based rules are given Table 5. If rule 1 is considered, it can be interpreted as follows: if distance between nodes is "very large", the position is "very long" and speed is "very fast" with direction "slight angular directed" then fuzzy output is "very high".

It is desirable to choose a node as next-hop that is farthest from the source node (nearer to target) and moving towards the destination. In such cases, the number of intermediate nodes would be smaller. If the speed of the node is very fast, the node bears a risk to walk off the communication range quickly but at the same time, it increases the chances of reaching out. For such case, the output of fuzzy system is classified as very high like shown in Table 5. Considering all these factors, 27 rules are defined in this work. A randomly selected twenty rules are given Table 5 for simplicity

Table 5 — Fuzzy inference rules

Rules	Distance	Direction	Speed	Fuzzy output "chance"
Rule 1	Near	SlightD	Slow	Less
Rule 2	Near	SlightD	Medium	Medium
Rule 3	Near	SlightD	Fast	High
Rule 4	Near	MidD	Slow	Very Less
Rule 5	Near	MidD	Medium	Less
Rule 6	Near	MidD	Fast	Medium
Rule 7	Near	LargeD	Slow	Very Less
Rule 8	Near	LargeD	Medium	Less
Rule 9	Near	LargeD	Fast	Medium
Rule 10	Medium	SlightD	Slow	Less
Rule 11	Medium	SlightD	Medium	High
Rule 12	Medium	SlightD	Fast	Very High
Rule 13	Medium	MidD	Slow	Less
Rule 14	Medium	MidD	Medium	Medium
Rule 15	Medium	MidD	Fast	High
Rule 16	Medium	LargeD	Slow	Medium
Rule 17	Medium	LargeD	Medium	Less
Rule 18	Medium	LargeD	Fast	Medium
Rule 19	Far	SlightD	Slow	Medium
Rule 20	Far	SlightD	Medium	High
Rule 21	Far	SlightD	Fast	Very High
Rule 22	Far	MidD	Slow	Medium
Rule 23	Far	MidD	Medium	High
Rule 24	Far	MidD	Fast	Very High
Rule 25	Far	LargeD	Slow	Less
Rule 26	Far	LargeD	Medium	Medium
Rule 27	Far	LargeD	Fast	High

Defuzzification

The defuzzification is the process that produces numerical results from the linguistic form in fuzzy logic system. The linguistic results cannot be used in the real world systems. With the help of the rules in a fuzzy logic system a decision is made. An aggregation process is used before defuzzification to combine the outputs of different rules in a fuzzy set. The fuzzy set so obtained is provided as input to the defuzzification process. A number of defuzzification methods are available there. In this work, we have considered the centroid scheme, which is one of the extensively used defuzzification method defined as follows

$$COA = \frac{\int \mu(x)xdx}{\int \mu(x)dx}$$

Wherever, x is a fuzzy var as well as $\mu(x)$ is the MF. An example is illustrated in Fig. 4 where the defuzzified value is shown with the help of a red line.

Fuzzy System Scenario

In this work, a candidate node with a distance of 153 meters from the current forwarding node is considered that is moving with a speed of 115 kmph and angular direction of 72.3 degree. Under these conditions, the output of the fuzzy system will be 60.1. The node with this optimal value to be elected as a next-hop forwarding one. It is observed from the results that the optimal function rises as the distance and velocity of neighbouring node increases with minimized direction and more progress. It helps to choose the best next-hop forwarding node leading to lower delays.

The FIS with input/output values is shown in Fig. 4 where Fig. 4(a) and 4(b) shows the behaviour correlation among inputs distance, direction and corresponding fuzzy output chance. The output value increases with the increasing distance and direction of neighbour node from the source.

Results and Discussions

In this manuscript, we have designed and implemented 3 fuzzified geocast protocols named as GeoDREAM_FL, GeoLAR_FL GeoZRP_FL by applying FLR fuzzgy logic approach on the geocast routing GeoDREAM-DF, GeoLAR-DF, GeoZRP-DF. The developed protocols are analyzed by MATLAB R2015a and results analyzed using parameters such as PDR and delay in VANET. We have considered number vehicular nodes varying from 10 to 80 for analysis of geocast protocols with and without fuzzy logic. The results are compared for above parameters.

Packet Delivery Ratio (PDR)

It is attained by the division of the quantity of the packets effectively delivered with the quantity of total pkts. It is symbolized as:

$$PDR = TPD / TPG \quad \ldots (2)$$

Here, TPD is the total amount of packets successfully delivered and TPG is the total packets generated.

As observed from the graph in Fig. 5 that in the beginning PDR increases as the no. of nodes

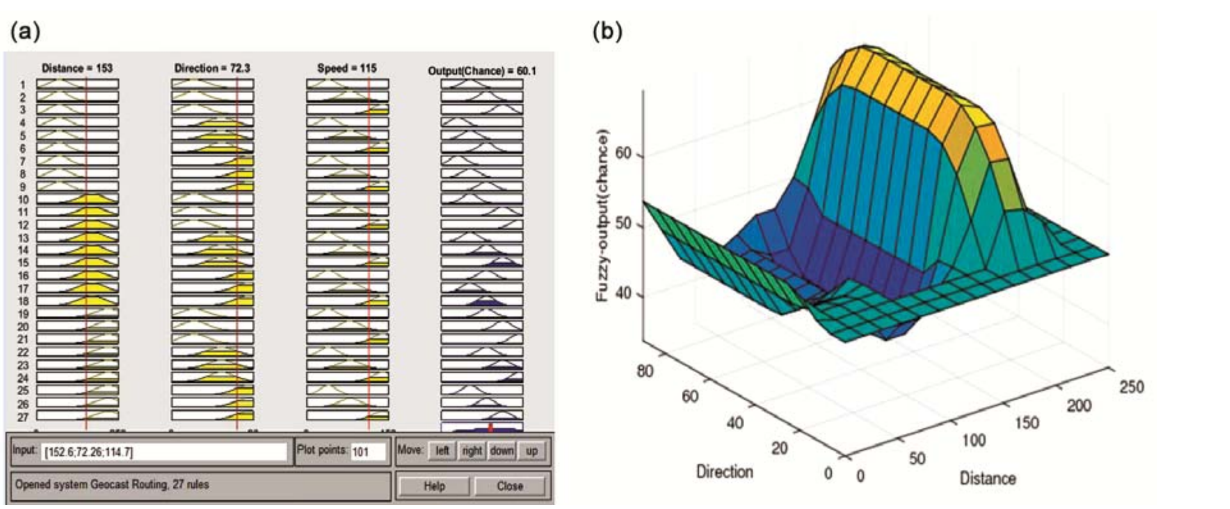

Fig. 4 — (a) FIS with input/output values (defuzzified value is shown with red line) and (b) Fuzzy output for various distances and angular direction

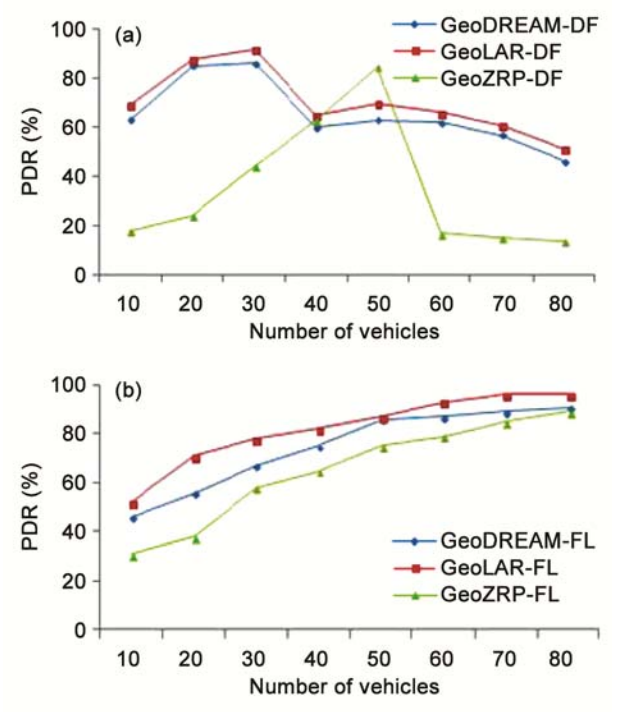

Fig. 5 — Packet delivery ratio of geocast routing without and with fuzzy logic

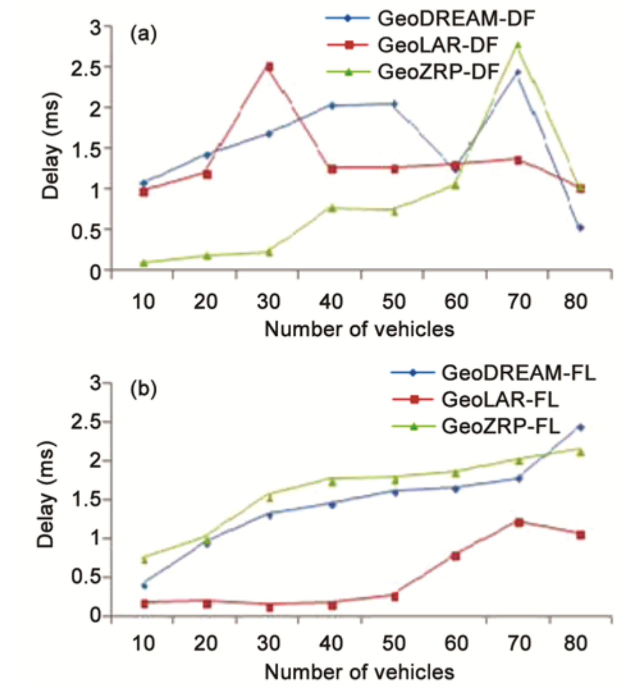

Fig. 6 — Delay of geocast routing without and with fuzzy logic

increases. With lesser no. of nodes, link is not established between source and destination. Once density rises, the transmission link is established and preserved for the long span. Because of that, routing protocols demonstrate good performance as depicted in the graphs.

Since the number of nodes is augmented further, packet delivery ratio starts to go down, because lot of vehicles uses the wireless link. It is clear from the graph that LAR performs comparatively better than DREAM, while the ZRP' performance is the lowest in both one i.e. optimized and without optimized one. As shown by graphical depiction in Fig. 6(a) and 6(b), it came to our knowledge that packet delivery ratio is improved when FLR approach is applied on the geocast routing. Therefore we can say that our fuzzified geocast routing algorithms named as GeoDREAM_FL, GeoLAR_FL and GeoZRP_FL by applying fuzzy logic approach performs better comparative to GeoDREAM-DF, GeoLAR-DF, GeoZRP-DF.

Delay

It is attained as the overall time in use by the network in memory buffer, waiting queue, packet retransmission and circulation of packets. In other words, delay specifies the latency for a bit of data to go across the network from one communication endpoint to other one.

Conclusions

This work centres on the implication of FLR approach to elect the best next-hop forwarding node for further communication on geocast routing in VANETs. Here in this work, we developed three fuzzified routing protocols named as GeoDREAM_FL, GeoLAR_FL, GeoZRP_FL. The adaptive feature of the FLR approach makes developed protocols appropriate for quick acceptance and transmission characteristics of vehicular networks. FLR considers a group of vehicles travelling in the same direction in particular geocast region and vehicles' status as inputs of the system for fine tuning and optimizing the membership functions of the proposed FIS in accordance with the vehicular traffic traits. The developed protocols have been devised effectively and derived from three routing metrics of neighbouring nodes to choose the BNHN (best next-hop node) in addition to get the optimal route from source to destination region. In future, the work can be extended for two way movement of vehicles.

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