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Pandian Vasant
Ivan Zelinka
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Improving the Route Selection for Geographic Routing Using Fuzzy-Logic in VANET

Israa A. Aljabry(✉) and Ghaida A. Al-Suhail

Department of Computer Engineering, University of Basrah, Basrah, Iraq
ghaida.suhail@uobasrah.edu.iq

Abstract. The ability to design a routing protocol capable of constructing adaptive and efficient channels for delivering data packets is an important factor in the successful evolution of VANET networks. Because they contain a GPS unit, most VANETs use position-based routing protocols. Greedy Perimeter Stateless Routing (GPSR), which has been widely implemented, is one solution to VANET's difficulties. The FL-NS GPSR routing protocol is proposed in this study as an effective intelligent fuzzy logic control system. To detect the appropriate next-hop node for packet forwarding, the proposed routing protocol integrates two metrics: neighbor node and vehicle speed. It also alters the format of the hello message by adding the direction field. The OMNeT++ and SUMO simulation tools are used in parallel to examine the VANET environment. The obtained results are made in an urban environment indicate substantial improvements in the network performance compared to the traditional GPSR concerning the QoS parameters.

Keywords: FL-NS GPSR · Fuzzy logic · OMNeT++ · SUMO · QoS · VANET

1 Introduction

VANET is a wireless network of automobiles that functions independently, while it may use network infrastructure access points such as roadside devices. These devices are often put in fixed sites to permit long-distance communications between vehicles and transportation infrastructure or among vehicles, and they can also serve as an internet gateway [1–3]. In particular, VANET is classified as a category of Mobile Ad-Hoc Network (MANET). It offers a potential notion for informing consumers about real-time information such as accident scenarios, weather updates, road conditions, and so on [4, 5].

Notably,position-based routing protocols route messages depending on the geographic location of the nodes. The position is normally known from the vehicle's Global Positioning System (GPS) information. In this protocol, the source node must be alert of its own position as well as the site of the target node. The performance of a position-based routing protocol is affected by driving conditions. For VANETs, numerous position-based routing protocols have been suggested, such as Greedy Perimeter Stateless Routing (GPSR) [6, 7]. The GPSR routing protocol routes the packet to the nearest node to the destination. When it comes to real-time traffic, throughput, and higher mobility models, the position-based Greedy Perimeter Stateless

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Routing protocol is said to be more suited for VANETs. Many routing protocols created recently take the core principle of GPSR and alter it as needed [8–10].

The local maximum issue, also known as the problem of picking an unusual node for sending data, is one of the fundamental tests with classical geographic routing methods. The local maximum arises in the basic greedy algorithm when the distance between the source and target nodes is less than the distance between surrounding nodes and the destination or when there is no node near the destination other than the source node. The state of the routing algorithm is altered when the local maximum problem occurs. As a result, packet lifetime decreases, increasing the likelihood of packet loss [11, 12].

Many parameters can influence the GPSR performance such as obstacles, the link quality, the network size, and so on. Therefore, in this paper, the main contribution focuses here on two parameters, namely the vehicle speed and the neighbor node. Specifically, the vehicle speed has a very important role in the data routing among vehicles since moving too fast makes the probability of a link breakage is very high so it is very crucial to select the vehicle with a low-speed probability and ensure the arrival of the packet to the destination. And, we need also to determine the neighbor node probability being close to the source, in consequence, this factor would allow the node being in closeness for a good delivery of the data. These two factors are applied using a fuzzy logic approach to achieve the best next-hop selection to enhance performance. It is accomplished in Infrastructure-to-Vehicle (I2V) mode because it minimizes the packet loss and delay as well. The fuzzy logic controller is integrated into all vehicles and also the RUS to pick the best next-hop based on the two metrics. The simulation is applied in an urban area.

The arrangement of the paper is as follows: Sect. 2 demonstrates the related work; Sect. 3 goes in-depth to show the process of enhancing the GPSR using fuzzy logic. In Sect. 4, the proposed FL-NS GPSR algorithm is introduced. Section 5 reveals the simulation tools and the obtained results. Finally, Sect. 6 summarizes the conclusions.

2 Related Work

Several strategies have recently been offered to mitigate GPSR problems in the associated literature; some researches are devoted to the mathematical model while the others are based on intelligent techniques. In this section, some of the famous strategies are been demonstrated as follows. The authors in [13] offered an innovative greedy forwarding approach utilized to develop a novel routing protocol grounded on vehicle position, to prevent link breakages, and provide a fixed route that enhances PDR and throughput. The recommended Density and Velocity (Speed, Direction) Aware Greedy Perimeter Stateless Routing protocol (DVA-GPSR) is grounded on the proposed greedy forwarding technique, which uses vehicle density, speed, and direction to identify the most feasible relaying node candidate. On the other hand, in [14] the data congestion problem has been considered via a data transfer routing method for real-time data transmission. Such a problem is caused by heavy traffic on the main roads and consequently leads to an increase in the data stream and package loss. In addition, the connection partition problem is also produced by insufficient traffic movement, and this issue will lead to increasing the transmission delay. The suggested protocol has two phases: next-hop selection in the chosen path between the current and future intersections and next-intersection selection. Zhou et al. in [15] suggested a unique data delivery strategy for urban vehicle networks that can increase the performance of the route without depending on GPS. A fuzzy-rule-based wireless transmission method is proposed to improve relay choice while taking into account multiple factors such as hop count, driving direction, connection time, and vehicle speed. Both wired transmissions among RSUs and wireless V2V transmission are used. Every RSU is outfitted with a machine learning system. In [16], the authors introduce a new routing protocol based on fuzzy logic systems that might aid in the coordination and analysis of contradictory metrics. To pick the best next-hop for packet forwarding, the proposed routing protocol integrates numerous variables such as achievable throughput, direction, vehicle position, and link quality.

Finally, in [17] the weight-aware greedy perimeter stateless routing protocol (WA-GPSR) is given. Based on many routing factors, the upgraded GPSR protocol computes the reliable communication area and determines the next forwarding vehicle.

3 The Enhancement of GPSR Using a Fuzzy Logic Controller

A famous model named fuzzy logic scheme with a strong academic foundation that would brightly incorporate approximate, vague, and ambiguous knowledge [18–20]. This section, suggests a fuzzy logic-based enhancement to geographic routing. Our suggested scheme aims to integrate fuzzy logic decision-making in the selection of next-hop nodes by taking into account several metrics linked to vehicle speed and neighbor node.

The architecture of VANET may differ among areas, as may the protocols and interfaces. The presentation and session layers are omitted in VANET, and a specific layer can be additionally divided or separated into sub-layers in the VANET design, as shown in Fig. 1.

The parameters of vehicle speed and neighbor node are preprocessed and fed into the network layer where the fuzzy system is installed, after that the output is passed to the other layers for further processing. The position and direction are fed from the MAC and physical layers.

The Fuzzy Logic Decision System (FL-DS) is in charge of determining the fuzzy score of every nominee forwarding based on the vehicle speed and neighbor node. These two factors work together to pick the best next-hop that is close to the destination and has a high link quality.

We use the minimum deduction approach for the Mamdani system. Due to its simplicity, we employ the triangle membership for the following input/output (Table 1).

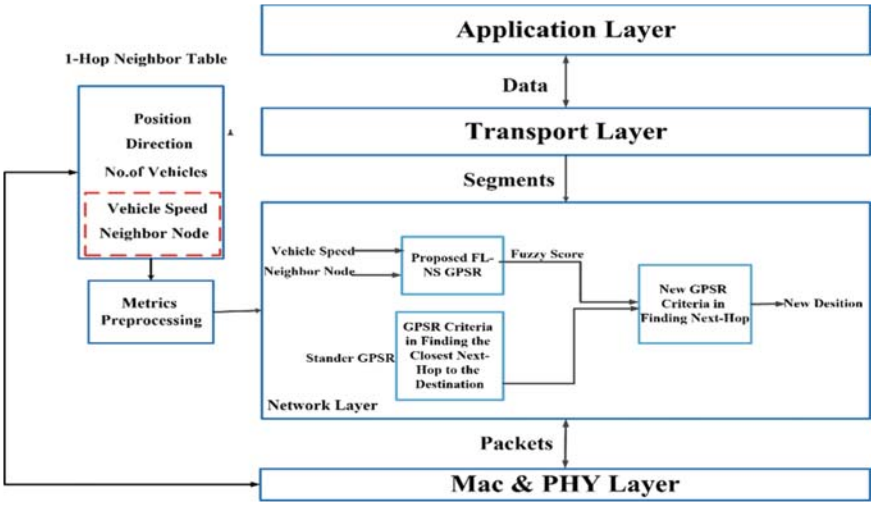


Fig. 1. FL-NS GPSR system architecture.

Table 1. Input/output fuzzy rules.

Input		Output
Link quality	Neighbor node	Fuzzy score
Low	Low	Low
Low	Medium	High
Low	High	Very-high
Medium	Low	High
Medium	Medium	Medium
Medium	High	High
High	Low	Very-low
High	Medium	Low
High	High	Medium

In the proposed protocol, we consider the GPSR beacon frame, which includes the following extra fields: a) The vehicle direction (b) The vehicle speed, and (c) The neighbor node. Figure 2 depicts our suggested scheme's redesigned beacon structure.

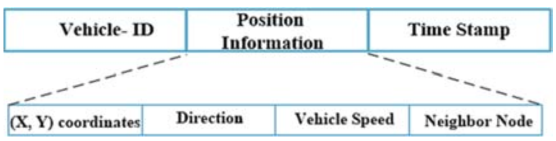


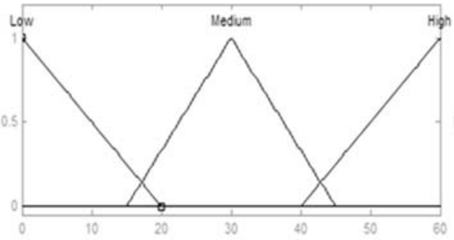
Fig. 2. The modified beacon structure.

The nodes use the hello packet data to generate a new item in the neighbor table or to update that table. By default, each neighbor has one entry in the GPSR neighbor table. Each item provides the neighbor's (ID) IP address, the time-stamp of the last hello packet received, and the X, Y coordinate. The neighbor table in our method now includes two new fields: vehicle speed and neighbor node. Each vehicle has a Neighbors' Table (NT) that stores information received from the hello beacon as illustrated in Table 2.

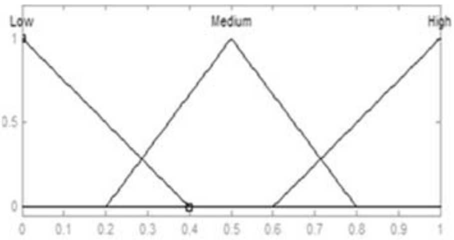
Now, to generate a clear numerical value, the center of gravity (COG) method is chosen because it is the most used defuzzification methodology in many real-world applications. Figure 3 illustrates the fuzzy score performance membership function and illustrates the relationship between the input and the output variables.

Table 2. Neighbor table format.

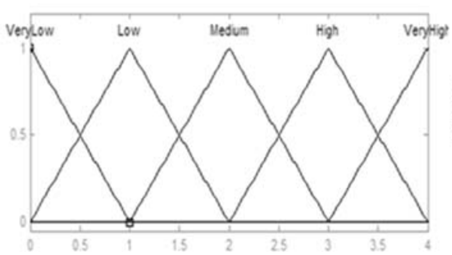
Neighbor's ID
Position (X, Y)
Direction
Vehicle speed
Neighbor node
Last packet sequence number
Last HELLO message timestamp



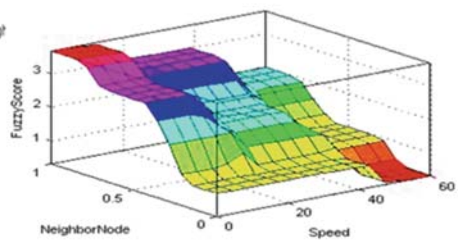
(a) MFs of Input Variable for Vehicle Speed.



(b) MFs of Input Variable for Neighbor node.



(c) Output of MF(Membership Function).



(d) 3D Graph of FIS.

Fig. 3. Fuzzy inference system of proposed FLC model FL-NS GPSR.

4 The Proposed FL-NS GPSR Algorithm

The proposed algorithm is mentioned below including the effect of the two parameters of vehicle speed and neighbor node. It is developed to enhance the routing performance when these parameters are taken into consideration of route selection. Note that this improvement will increase the processer time but also has a positive impact on improving the performance by controlling these parameters which in the traditional protocol will have an undesirable effect on the performance. Hence, the pseudo-steps of the proposed algorithm is termed as follows:

The Proposed FL-NS Algorithm

Theory: All Nodes has a GPS
Input: Nodes, Communication Range, Network Map
Output: Best Neighbor Node as next-hop
Stage 1: Characteristics Calculation
1- **For each** node N_i **do**
2- Calculate the position of N_i: (X_i, Y_i)
3- Calculate the Speed of N_i (Si)
4- Calculate the Distance of each N_i (D_i)
5- Calculate direction of N_i: (Dir_i)
6- **End for**
Stage 2: Add Fuzzy Logic Controller
7- **If** Node i is Destination
8- Forward the packet to the Destination
9- **Criteria 1:** Find Closest Distance to Destination
10- Calculate and Compare the Distance between Destination & all Neighbor Ni (Using Euclidean Formula);
11- **Criteria 2:** Use FLC to Find and Tune the Next-Hop using two parameters: Vehicle Speed & Neighbor Node.
12- Fuzzy_output = Calculate_Fuzzy_Score;
13- Establish the New Neighbors' Table ➲ Adding Fuzzy_Score_Values of All N_i and Distances of Destination & all Neighbor N_i to Neighbor Table.
14- Search: **if** $Rank_i$ with Highest Fuzzy Score && Closest Distance to Destination
15- Set Node i as the Next-hop
16- End **if**

5 Performance Evaluation

We analyze the effectiveness and efficiency of FL-NS GPSR and compare it to the traditional GPSR. The tools that are used to perform this simulation is the network simulator OMNeT++ with the help of two frameworks the INET, and Veins. In addition, to make the simulation more realistic, the traffic simulator SUMO is used in conjunction with OMNeT++. Figure 4 depicts the road network for an urban environment constructed using a 3×6 Manhattan grid.

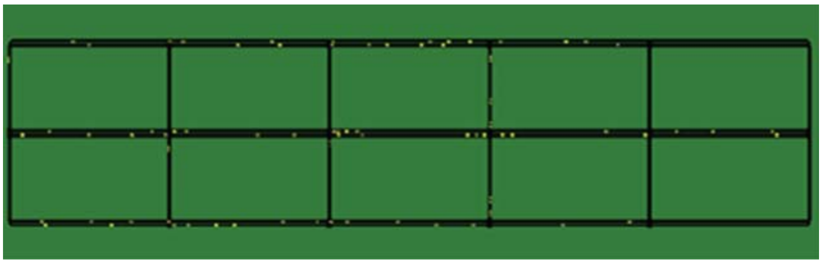


Fig. 4. 3 × 6 Manhattan grid.

The parameters implemented in this scenario are revealed in Table 3.

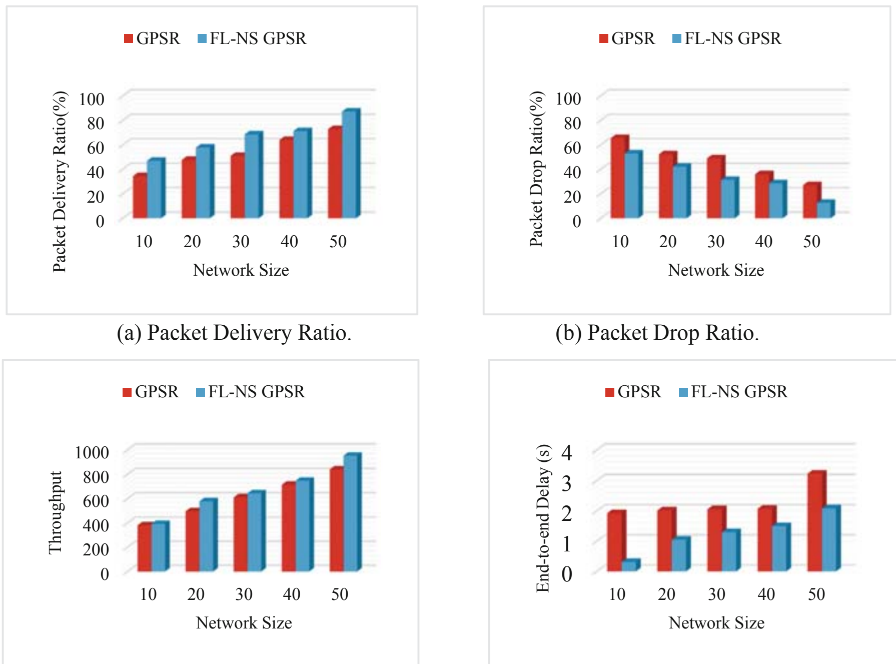
Table 3. Simulation parameter.

Parameter	Value or protocol
OMNeT++ version	OMNeT++ V 5.5.1
SUMO version	SUMO 1.6.0
INET version	INET 4.2.1
Veins version	Veins 5.0
Simulation area	2500 × 2500 m
MAC protocol	IEEE802.11p
Layer 3 addressing	IPv4
Routing protocol	GPSR & FL-NS GPSR
Communication mode	I2 V
Number of vehicles	10, 20, 30, 40, 50
Vehicle speed	40 km/h
Beacon interval	1 s
Simulation time	600 s
Transmission range	250 m

Figure 5 explains the scenario with a different number of vehicles in terms of the maximum allowable network size. Notice that Fig. 5(a) displays the packet delivery ratios of the two routing protocols; the traditional GPSR and the proposed FL-NS GPSR in various density cases. It can be seen that the packet delivery ratio of FL-NS becomes higher in all density variations as compared to standard GPSR. In fact, it is well-known that the degradation in the GPSR performance is justified by the use of simply distance as a single measure for the routing process. Using only distance metrics is incapable of avoiding unstable links that may break owing to congestion or outdated neighbors. Therefore, our FL-NS GPSR uses a sophisticated routing decision process that allows the best and most stable next hop to be selected.

Figure 5(b) demonstrates the packet drop ratio which shows that the FL-NS has lower values compared to the GPSR protocol since it considers many parameters these parameters can help in improving the performance and reducing the number of lost data. The network throughput is an important indicator for demonstrating the network's scalability as in Fig. 5(c). A network's capacity would rise linearly alongside the number of nodes to ensure scalability as shown the FL-NS outperforms the traditional routing protocol.

Figure 5(d) depicts the end-to-end delay result. It might be said that as the number of nodes in the network grows, so does the end-to-end delay. Data packets are sent to the destination in less time in the proposed protocol because nodes with a higher possibility of being greedy are chosen. As a result, the end-to-end delay is decreased. The suggested FL-NS uses fuzzy theory to choose nodes with reduced mobility and traveling in the way of the target node as the next forwarding nodes. The proposed Fuzzy GPSR can provide good and reasonable results compared to existing works, such as a mathematical model in [13] and fuzzy logic-based model as in [16].



(a) Packet Delivery Ratio. (b) Packet Drop Ratio.

(c) Throughput. (b) End-to-End Delay.

Fig. 5. GPSR and FL-NS GPSR vs the network size.

6 Conclusion

One of the most challenges in vehicular ad hoc networks is building routing protocols for active topologies. In position-based routing protocols, the use of GPS in vehicles provides the facility to detect their own geographic location as well as the geographic location of their neighbors. In this study, the GPSR routing protocol was developed to produce a new FL-NS GPSR based on the fuzzy logic controller (FLC). To determine the fittest next-hop node, the proposed FL-NS GPSR routing protocol relies on vehicle speed and neighbor node in order to reduce the delay and enhance the packet delivery ratio. In Addition, to improve the network performance, a new field called “Direction field” was also introduced within the beacon message. The simulation results reveal that our proposed algorithm FL-NS GPSR outperforms the standard GPSR protocol and other existing works due to the significant enhancements in the E2E delay and network throughput. As a result, one can conclude that such an approach makes this protocol resistant to the changes in the environment; in particular when the number of vehicles increases. For future work, the proposed protocol can be extended using other intelligent techniques of optimization algorithms like PSO or ABC.

References

1. Tripp-Barba, C., Zaldívar-Colado, A., Urquiza-Aguiar, L., Aguilar-Calderón, J.A.: Survey on routing protocols for vehicular ad Hoc networks based on multimetrics. Electronics **8**(10), 1–32 (2019)
2. Aljabry, I.A., Al-Suhail, G.A.: A survey on network simulators for vehicular Ad-hoc networks (VANETS). Int. J. Comput. Appl. **174**(11), 1–9 (2021)
3. Ayoob, A.A., Su, G., Mohammed, M.N.: Vehicular Ad Hoc network: an intensive review. In: International Conference on Intelligent Computing and Optimization, pp. 158–167 (2018)
4. Yu, S., Choi, L., Cho, G.: A new recovery method for greedy routing protocols in high mobile vehicular communications. In: Proceedings of the 2008 IEEE International Conference on Vehicular Electronics and Safety, ICVES 2008, no. October, pp. 45–50, (2008)
5. Ghafoor, H., Koo, I., Gohar, N.U.D.: Neighboring and connectivity-aware routing in VANETs. Sci. World J. **2014** (2014)
6. Kazi, A.K., Khan, M.: DyTE: an effective routing protocol for VANET in urban scenarios. Eng. Technol. Appl. Sci. Res. **11**(2), 6979–6985 (2021)
7. Aljabry, I.A., Al-Suhail, G.A.: A simulation of AODV and GPSR routing protocols in VANET based on multimetrices. Iraqi J. Electric. Electr. Eng. **17**(2), 66–72 (2021)
8. Rahimi, S., Jabraeil Jamali, M.A.: A hybrid geographic-DTN routing protocol based on fuzzy logic in vehicular ad hoc networks. Peer-to-Peer Netw. Appl. **12**(1), 88–101 (2018). https://doi.org/10.1007/s12083-018-0642-4
9. Houssaini, Z.S., Zaimi, I., Drissi, M., Oumsis, M., Ouatik, A.: Trade-off between accuracy, cost, and QoS using a beacon-on-demand strategy and Kalman filtering over a VANET. Digital Commun. Netw. **4**(1), 13–26 (2018)
10. Bala, R., Krishna, C.R.: Scenario based performance analysis of AODV and GPSR routing protocols in a VANET. In: Proceedings - 2015 IEEE International Conference on Computational Intelligence and Communication Technology, CICT 2015, pp. 432–437, (2015)

11. Houmer, M., Hasnaoui, M.L.: An enhancement of greedy perimeter stateless routing protocol in VANET. Proc. Comput. Sci. **160**, 101–108 (2019)
12. Kumar, S., Verma, A.K.: Position based routing protocols in VANET: a survey. Wireless Pers. Commun. **83**(4), 2747–2772 (2015). https://doi.org/10.1007/s11277-015-2567-z
13. Bengag, A., Bengag, A., Elboukhari, M.: A novel greedy forwarding mechanism based on density, speed and direction parameters for vanets. Int. J. Interactive Mob. Technol. **14**(8), 196–204 (2020)
14. Wu, D., Li, H., Li, X., Zhang, J.: A geographic routing protocol based on trunk line in VANETs. In: Ning, H. (ed.) CyberDI/CyberLife -2019. CCIS, vol. 1138, pp. 21–37. Springer, Singapore (2019). https://doi.org/10.1007/978-981-15-1925-3_2
15. Zhou, Y., Li, H., Shi, C., Lu, N., Cheng, N.: A fuzzy-rule based data delivery scheme in VANETs with intelligent speed prediction and relay selection. Wireless Commun. Mob. Comput. **2018**, 1–15 (2018)
16. Alzamzami, O., Mahgoub, I.: Fuzzy logic-based geographic routing for urban vehicular networks using link quality and achievable throughput estimations. IEEE Trans. Intell. Transp. Syst. **20**(6), 2289–2300 (2019)
17. Smiri, S., Abbou, A.B., Boushaba, A., Zahi, A., Abbou, R.B.: WA-GPSR : weight-aware GPSR-based routing protocol for VANET. Int. J. Interactive Mob. Technol. **15**(17), 69–83 (2021)
18. Zaimi, I., Boushaba, A., Squalli Houssaini, Z., Oumsis, M.: A fuzzy geographical routing approach to support real-time multimedia transmission for vehicular ad hoc networks. Wireless Netw. **25**(3), 1289–1311 (2018). https://doi.org/10.1007/s11276-018-1729-9
19. Mishra, P., Gandhi, C., Singh, B.: Link quality and energy aware geographical routing in manets using fuzzy logics. J. Telecommun. Inf. Technol. (2016)
20. Limouchi, E., Mahgoub, I., Alwakeel, A.: Fuzzy logic-based broadcast in vehicular ad hoc networks. In: 2016 IEEE 84th Vehicular Technology Conference (2016)