Unstable Connectivity Aware Protocol for Dependable Messages Delivery for Future Internet of Vehicles

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Research Article

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Posted Date: April 21st, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1535145/v1

Unstable Connectivity Aware Protocol for Dependable Messages Delivery for Future Internet of Vehicles

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Abstract. In the near future, Internet of Vehicles (IoV) enabling the Intelligent Transportation System paradigm swill undergo a significant change when integrating autonomous vehicles as intelligent and powerfully platform systems. All this would generate huge traffic messages that should be rigorously taken into account in order to ensure dependable message delivery in a real-time manner. Therefore, Timely useful information acquisition in an unstable connectivity environment like IoV is of paramount importance when making a decision that is related to critical events. For instance, saving lives in accident occurrences greatly depends on the urgent messages sent out and received by rescue services. Furthermore, preventing accidents by alerting obstacles impeding road circulation requires stable link communications conveying surely emergency messages to their appropriate destinations. Therefore, the high velocity of vehicles affects negatively node communication links leading to frequent link disconnections. In this paper, we propose to take advantage of the IoV features to choose appropriate metrics aiming to ensure route stability according to two levels. In the first one, the best routes are discovered by using metrics such as signal strength, bandwidth, delay and node velocity. In the second level, an approach for estimating links lifetime has been used. The latter is based on speed and direction parameters in order to find the most durable route. To this end, the Fuzzy Logic method has been used to reach our objective. The performance evaluation of our proposal has been carried out through the NS-3 simulator and the obtained results outperform GICA, QoS Cluster and weight-based protocols.
Keywords: Internet of Vehicles, QoS, Links Stability, link lifetime duration, Emergency message delivery

1 Introduction

Internet of Vehicles (IoV) technology is an extended and promising emergent field of well known Vehicular Ad hoc NETwork (VANET) paradigm. This extension is the expected consequence of the transition of the traditional Internet network to the Internet of Things (IoT). IoV is dedicated to constituting a platform enabling primarily tasks managing vehicles security in roads and secondly offering passengers to get access to objects located via IoT network. IoV network is essentially formed by vehicles as nodes. In near future, these nodes will be considered as autonomous vehicles convertible into mobile offices providing work conveniences. Therefore, On-Board Units (OBU) are embedded on vehicles and terminal units, called Road Side Unit (RSU) which are installed on roads at specific locations like road intersections. Viewed from the network perspective, an IoV system is composed of three levels: Vehicle-Connection-Cloud, as shown in Figure 1. A vehicle in IoV is a smart vehicle embedding appropriate equipment. Various sensors are embedded to collect information about vehicle surroundings, and communication devices to communicate with other vehicles and/or IoT. IoV support different communication modes: Vehicle-to-Road (V2R), Vehicle-to-Vehicle (V2V), Vehicle-to-Sensor (V2S), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Human (V2H) or Vehicle-to-Personal device (V2P) [1]. This richness of interactions allows a vehicle to be able to share and gather information on other vehicles, roads and surroundings. An embedded software platform is needful to process information states and information control. Vehicles can take a dual role at the same time: as clients to consume services from IoT and as peers to participate in distributed computing inside IoV. Therefore, IoV combines peer-2-peer and client-server computing paradigms. Vehicles can cooperate and collaborate with each other using the peer-2-peer paradigm in order to realize some tasks like file-sharing or cooperative driving and on the other hand, vehicles can use resources at servers from IoT utilizing client-server distributed system [2].

A server can be an ordinary computing node or a cloud data centre. With servers and cloud computing IoV can manage much more complex applications and tasks. Servers or cloud data centres may offer various services to vehicles. Servers have powerful computing resources, storage resources, and more information/data outside vehicles; so advanced or complex IoV applications will need servers over the Internet and even will have to use the fog computing paradigm since the IoV platform may provide that because of their powerfulness. This may also contribute to relieving perturbations stemming from low connectivity. IoV applications are divided into two categories: safety applications which include: collision alerts, warning on wrong-way driving, warning on overtaking vehicle, pointing out accident occurrences or obstacles in the road, etc… and non-safety applications that comprise: infotainment activities, collaborative activities [3] and all actions rendering travels enjoyable for vehicle drivers and passengers. However, IoV applications suffer from certain problems due to their intrinsic features such as higher vehicles mobility, low signal strength and the limited stable infrastructure installed on roads. The latter may be efficiently employed as support of communication to get practical and durable access to IoT environment. These problems, in turn, are the principal cause of frequent changes of the network topology originating unstable communication links between vehicles, RSU and outside IoV network. In fact, the involved lack of connectivity may negatively impact the Quality of Service (QoS) of IoV applications, particularly when these are of real time type.

In IoV environment, the main factors that affect links communication and may impede the data transmission process may be divided into two categories: the first one includes factors that cause frequent links disconnection like +the high speed of nodes, low signal strength, opposite destination, etc. Category two contains factors leading to a long transmission time like low bandwidth, high delay, a full queue and so on.

To improve the quality of service for IoV applications by ensuring the use of better communication links despite an environment advocating a lack of connectivity, we propose a new communication protocol named: Routing Protocol based Quality of Service and Links Stability (RPQLS). The proposal is specifically adapted to IoV architecture with hierarchical communication management enabling smart connectivity. Therefore, the network is organized into clusters. A cluster includes a set of nodes (vehicles) as cluster members and each cluster is managed by a Cluster Head (CH) elected by its peers [4],[5],[6],[7]. The First Hierarchical Level (FHL) concerns the inter-cluster head communications and the Second Hierarchical Level (SHL) is dedicated to inter-cluster member communications. FHL uses the Fuzzy Logic method through two fuzzy systems. One system combines signal strength and bandwidth and

another between velocity and delay. SHL is based on links estimation lifetime which we consider a good indicator of links stability.
The rest of the paper is organized as follows: In Section 2 we present previous works proposed to guarantee the routing process in the IoV network paradigm and highlight the weak points of each one of them, Section 3 describes our proposal with its two levels modelling. Section 4 deals with carrying out simulations to evaluate the performance of the proposal. The final section concludes this work.

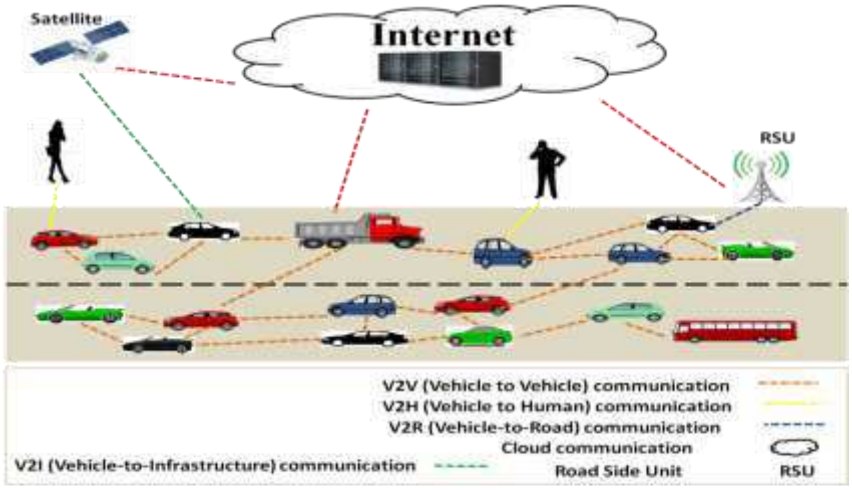


Fig.1. IoV basic Architecture

2 Related Work

Routing is one of the most challenging issues in the Internet of Vehicles, many works have been proposed to route packets from their source node to their destination.
The authors of this paper [8] propose a new weight-based clustering algorithm for vehicles environment based on three parameters namely: node safety, node density and node mobility in order to guarantee reliable network connectivity and minimize network overhead. QoS Based Clustering for Vehicular Networks (QoSCluster) [9], it is a multi-metric clustering algorithm, the authors of this work proposed two kinds of metrics to calculate the weight value such as; QoS Metrics that include average link expiration time, Average link bandwidth and average time to completion, and stability metrics that include the level of connectivity, relative mobility and the average relative distance. The authors in [10] proposed A Cluster-Based Directional Routing Protocol (CBDRP) in VANET where they divide vehicles with the same move direction into several clusters and select one Cluster Head (CH) in each cluster. During data transmission, the source node sends a packet to the CH of its own cluster and the CH forwards the packet to the CH of the destination cluster. Finally, the destination CH sends out the data packet to the destination node. The algorithm selects the best path

based on the transmission direction vector of data packets and speed vector. However, the proposed protocol did not consider any factor of quality of service in term of channel capacity like bandwidth which confirms that it is not adaptive for multimedia applications. Geographical Information based Clustering Algorithm (GICA) destinated to IoV environment is proposed in [11]. The proposed algorithm uses different metrics to select CHs in the IoV environment such as destination, position and mobility in order to calculate the weight value. The goal of this protocol is to select the stable nodes in the network based on the calculated weight value; thereafter the selected nodes will be elected as CHs. Authors in [12] suggest using a Deep Reinforcement learning algorithm to select the best cluster head. The proposed work named an experience-driven approach based on an Actor-Critic based Deep Reinforcement learning framework (AC-DRL) aims to manage the network resources by selecting the most performing nodes as CHs in an efficient manner that takes into consideration the challenges of the IoV environment. The collaborative clustering algorithm for the Internet of vehicles (CCA-IoV) proposed in [13] aims to find the most performing vehicles in terms of computing and storage capacities in order to select them as CHs. The authors of this work present a new metric called Node Score (SC) metric that is calculated based on mobility factor, link stability and node degree. In order to guarantee cluster stability architecture, CCA-IoV added Vice Cluster Head as a supplement to the CH. In [14] authors proposed a new clustering protocol called Cluster-based enhanced AODV for IoVs (AODV-CD), the proposed work added some modifications to the classical AODV protocol to support clustering structure to achieve stable and high quality of service (QoS) routing. Efficient Weight-based Clustering Algorithm using a Mobility Report (WECA-MR) [15], is a new algorithm destined for IoV environment, the main goal of this proposal is to guarantee an efficient clusters stability with a minimum number of CHs. The cluster formation process is based on nodes' weight values. The calculated weight values are based on three parameters: number of neighbors, average distance and Mobility Report (MR). The letter uses two other mobility metrics such as velocity and acceleration in order to increase clusters stability. Based on different works cited above we notice that all the proposals introduce algorithms that form and maintain clusters in vehicular networks, for our best knowledge there is no work proposed to address the quality of service and link stability in intra cluster and inter clusters communication. In this work, we propose to use clustering-based communication protocol within two different levels of communication. By using variety of node parameters and metrics such as: node speed, bandwidth, delay, signal strength, link lifetime that can guarantee the quality of service and acting in accordance with IoV architecture and requirements.

3.1 Proposed framework

Cluster-based routing protocols are shown to be more advantageous than flat routing protocols since they guarantee lower overhead, higher scalability and throughput, and better usage of the system capacity because of better performance in MAC layer context [16]. At the network layer, clustering reduces the size of routing table and decreases transmission overhead resulting from updating routing tables following frequent topological changes compared to proactive protocols [4]. Although each node stores only a fraction of the total network routing information, clustering is able to achieve topology information by aggregating current nodes information. Consequently, clustering may be considered to create more scalable and stable communication schemes [18]. Through IoV architecture, each vehicle can be connected with: an existing infrastructure, a sensor, another vehicle, a personal device, etc. The different connection types in IoV let the network to be very interactive and scalable and need a stable structure to manage it. In our proposed framework, nodes are organized into clusters. Each cluster is controlled by a Cluster Head (CH) in charge of: offering services to its cluster members, gathering information from network (mobile servers), and sharing information with others servers and so on. Cluster members can also exchange route information between them. In this proposal, we are interested to ensure a robust connection and high quality of service for network users by finding stable routes between cluster members and between clusters. So, we suppose that the clustering is already done by any clustering algorithm adaptive with IoV environment [5],[6],[7],[19]. To form the clusters on the road we used the algorithm introduced in [19] where vehicles and personal devices that share the same moving direction are divided into many clusters; each vehicle and every personal device (smart phone, tablet, etc) of passengers is considered as a node. Each ordinary node can communicate with its Cluster Head, its neighbors in the same cluster and with any close infrastructure with radio communication. The responsibility of cluster head is assigned only to vehicles in order to avoid the constraint of energy lack being caused by battery depletion. Figure 2 shows the architecture of our framework called Routing Protocol based on Quality of service and Link Stability (RPQLS).

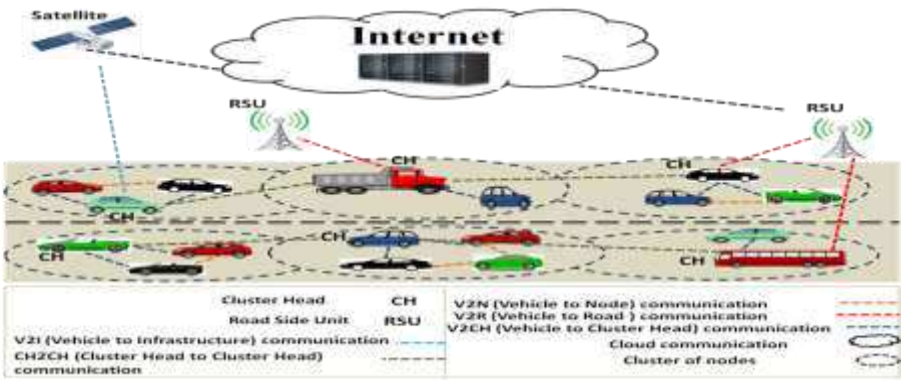


Fig.2. Clustering based RPQLS Architecture

3.2 First Routing Level (inter-clusters)

This level aims to obtain high cluster stability for guaranteeing a long duration of contact and a short response time between the cluster head source and destination. At this level, we suggest combining between four parameters to ensure more quality of service on Internet of Vehicles communication:

Signal strength: this parameter indicates if the source and destination nodes are close or not. Upon reception of Hello message from the source node, the receiver node measures the signal strength of the received packet using [34] method.
Bandwidth: is the second metric used in our proposal, it is defined as the amount of data that can be transmitted in a fixed amount of time and measured by (b/s); a high value of bandwidth leads to fast data transmission. To calculate bandwidth, we used the method presented in [33].
Delay: This indicates the time taken by a packet from the source node to the destination. It is measured in second by **eq.1**, and a low delay means a low response time.

$$D = t_r - t_s \quad (1)$$

In this context, t_s is the time when sending the packet and t_r is the time when receiving the packet.
Node speed: measured in km/h; node velocity is the main factor that causes frequent link disconnection, especially in IoV environment, is calculated by **eq.2**.

$$s = d/t \quad (2)$$

Where d denotes distance and t denotes time.

To reach the attended quality of service, we need to find the route having maximum signal strength and bandwidth and minimum Speed and delay.
Excellent signal strength and low speed mean a long connectivity; large bandwidth and low delay imply fast transmission. Nodes in IoV lack intelligence, they are unable to act according to their own initiative to decide if the route is best or not. Therefore, they need to be assisted by an intelligent system to decide on their place. Such a system may be built from Fuzzy Logic approach.
Fuzzy logic is an extension of the classical logic that allows modelling of data imperfections (Incomplete or ambiguous data) and to a certain extent, approaches the flexibility of human reasoning. Thus, in the present concept, we use Fuzzy logic in order to give vehicular nodes the ability to decide and choose the best route based on the received information. Fuzzy Logic has been advantageously used in many research and development fields, particularly in wireless networks like VANETs and IoV which concern us [20], [21], [22], [23].
In our proposal, the important parameters used are divided into two categories: the first one contains parameters that need maximization and the second one includes parameters that need minimization. We utilize two fuzzy systems using Fuzzy Logic method: the first Fuzzy System is used to combine between the signal strength and bandwidth and the second Fuzzy System is used to bring together nodes speed and delay. Before starting details of each Fuzzy System, we begin by defining Fuzzy Logic method.

2.2.1 Fuzzy Logic Approach

The concept of Fuzzy Logic (FL) [24], [25], [26] is a control system methodology implemented in systems in order to solve various problems related to an environment of imperfect information without any measurements and any computations. It includes different systems starting from small, simple, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. Our problem in this proposal and especially in this level is to find best servers in IoV according to some suitable criteria. Thus, the main reason motivating the use of Fuzzy Logic in our protocol is the large advantages provided by FL along cited previously such as: the ease to model human reasoning, its simplicity and flexibility of calculation, it covers a wider range of operating condition and so on. It is hard, in our context, to establish an accurate analytical model because of unavailable precise numerical values for certain metrics. For example, values related to: signal strength, bandwidth, node density and mainly connectivity.

2.2.2 First Fuzzy System

As mentioned above, to have more link quality, we need to select links that have more signal strength and bandwidth. The first Fuzzy System describes the three phases of Fuzzy Logic applied on both metrics namely signal strength and Bandwidth.

Fuzzification

First of all, a set of input data are gathered and converted to a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. This step is known as Fuzzification. Signal strength and bandwidth membership functions and output membership function are shown in Figures 3, 4, and 5, respectively. Membership functions can be classified into three variables as Low, Medium and High. To facilitate the calculation of membership degrees, we have transformed the real values (x-axis) of input variables to [0, 1]. The membership degrees are calculated through Table 1**.** Trapezoidal membership function is used to define each input membership function. We have chosen Trapezoidal function for its greater precision in the calculation. The fuzzy output value determines the probability of link QoS. In Figure 5, five output functions have been calculated as fuzzy output.

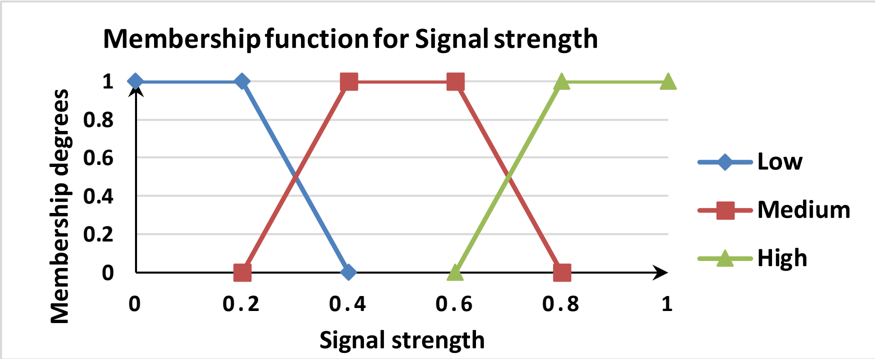


Fig.3. Membership function for signal strength

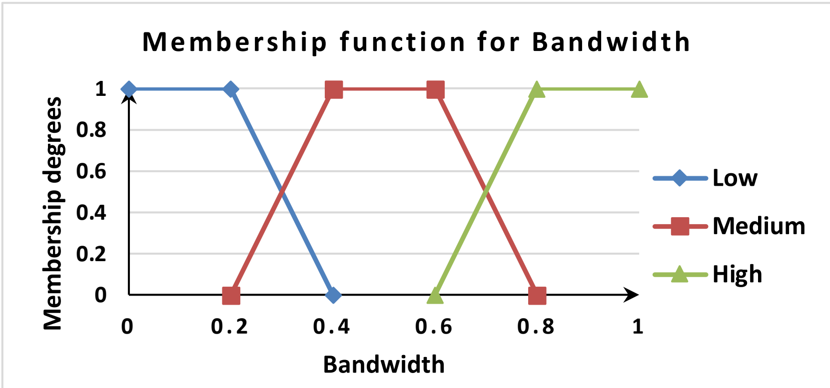


Fig. 4. Membership function for bandwidth

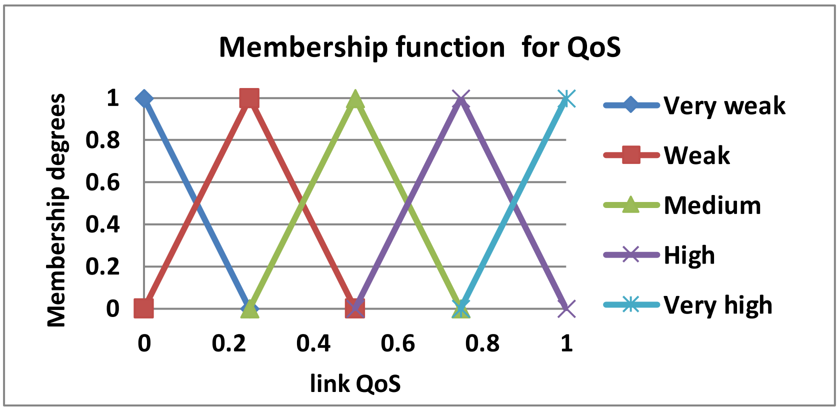


Fig. 5. Membership function for link QoS of First Fuzzy System

Table 1. Membership degrees Calculation Method

Interval	Membership degrees		
	Low	Medium	High
$0 \leq x \leq 0.2$	1	0	0
$0.2 \leq x \leq 0.4$	$u = -\frac{x - 0.4}{0.2}$	$u = \frac{x - 0.2}{0.2}$	0
$0.4 \leq x \leq 0.6$	0	1	0
$0.6 \leq x < 0.8$	0	$u = -\frac{x - 0.8}{0.2}$	$u = \frac{x - 0.6}{0.2}$
$0.8 \leq x \leq 1$	0	0	1

Fuzzy rules for first Fuzzy System

In fuzzy logic, the fuzzy rules are written based on IF-THEN rules. Each rule has two parts: part antecedent premise (condition), expressed by IF…, substantial part (conclusion) expressed by THEN. These rules are used for mapping fuzzy values and pre-defined rules, and combinations of rules are used in order to calculate link fuzzy values. These rules as shown in Table 2 are used in each node in order to calculate the link state between the sender and the receiver of the message.

Table 2. IF-THEN rules for the first fuzzy system

Rule number	**Signal strength**	**Bandwidth**	**Quality of service**
1	Low	Low	Very weak
2	Low	Medium	Weak
3	Low	High	Medium
4	Medium	Low	Weak
5	Medium	Medium	Medium
6	Medium	High	High
7	High	Low	Medium
8	High	Medium	High
9	High	High	Very high

Defuzzification

With the defuzzification process, we will be able to convert membership degrees of output linguistic variables into numerical. A Centre Of Area (COA) method is used in our proposition for the defuzzification phase; this method provides a crisp value based on the centre of gravity of the fuzzy set. The total area of the membership function distribution used to represent the combined control action is divided into a number of sub-areas. The area and the center of gravity of each sub-area are calculated and then the summation of all these sub-areas is taken to find the defuzzified value for a discrete fuzzy set. For discrete membership function, the defuzzified value is denoted by Equation 3 below.

$$FL1 = \sum_{i=1}^{n}[\,x_i * \mu(x_i)]/[\mu(x_i)] \qquad (3)$$

Where x_i is the sample element, $\mu(x_i)$ is the membership function and n represents the number of elements in the sample.

2.2.3 Second Fuzzy System

Fuzzification

As the first fuzzy system, we classified the input membership functions into three variables. Choosing a bigger number than three for membership functions variables is not a good solution. A high number of variables lead to high number of IF-THEN rules which can hamper the system work. Unlike using a lower number than three cannot satisfies all variable situations. Figure 6 illustrates the membership function for speed. Figure 7 represents the membership function for delay. Figure 8 shows the membership function for QoS. The membership degrees are calculated with the same method as mentioned above in Table 1.

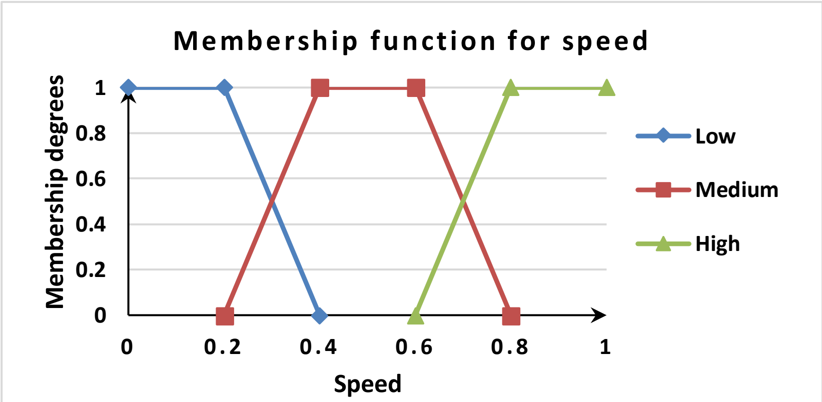


Fig. 6. Membership Function for Speed

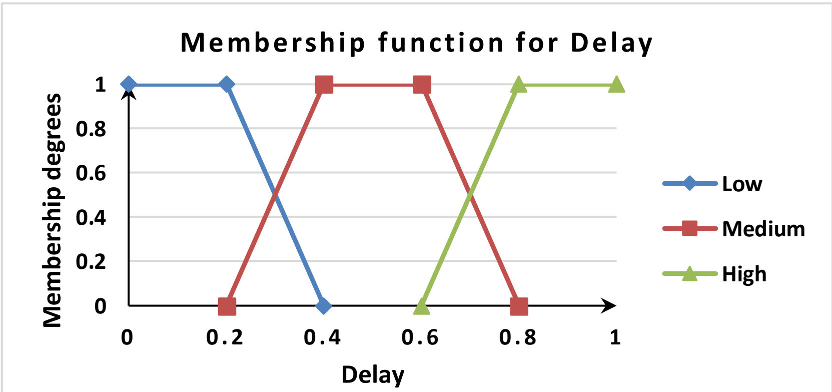


Fig. 7. Membership Function for delay

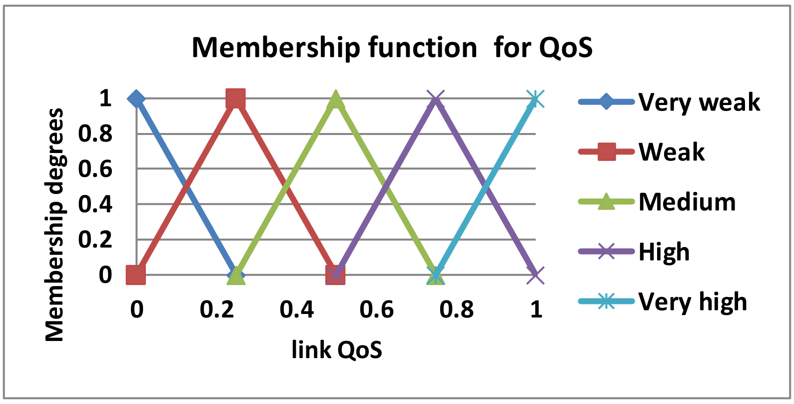


Fig. 8. Membership Function for link QoS of Second Fuzzy System

Fuzzy rules

Table.3 illustrates the IF-THEN rules of the second fuzzy system

Rule number	**Speed**	**Delay**	**Quality of service**
1	Low	Low	Very high
2	Low	Medium	High
3	Low	High	Weak
4	Medium	Low	High
5	Medium	Medium	Medium
6	Medium	High	Weak
7	High	Low	Medium
8	High	Medium	Weak
9	High	High	Very weak

Deffuzification

The second Fuzzy System defuzzification phase utilizes Equation.4 to calculate output cost value.

$$FL2 = [\sum_{all\,rules} x_i * \mu(x_i)]/[\mu(x_i)] \qquad (4)$$

2.2.4 Routing mechanism for the first proposition

In the first level of our proposal, the establishment of route is done by a request as shown in Figure 9. Each cluster head requestor initiates its route searching by broadcasting a REQuest Message (REQM). An REQM message illustrated in Figure 10 contains: IP_source (IP address of source cluster head), ID_Msg (Identification of Message), IP_Dest (IP address of destination cluster head), S (Speed of source cluster head), and T (time of sending message) in order to calculate the delay by receiver node. MFV (Minimum Fuzzy Value) takes the minimum value of all fuzzy values of previous neighbors participating in the route discovery process. It is obtained from the combination of signal strength and bandwidth. MXFV (Maximum Fuzzy Value) takes the maximum value of all fuzzy values of all previous nodes participating in the route discovery process. MXFV is a result of the combination of delay and speed parameters. The pair (IP_source, ID_Msg) identifies the REQM message, the ID_Msg is incremented each time the cluster head source broadcasts a new packet of REQM. Thus, if a vehicle has received an REQM duplicate message, the second will be dropped. The QoS of each link is represented by both MFV (min FL1) and MXFV (max FL2) values of Fuzzy System illustrated above. Each node receiving the packet REQM compares the address of destination with its address. Two possible cases can occur: if the two addresses are similar, the receiver node is the destination. Otherwise, the node checks if it has already received a REQM with the same ID (ID_Msg) and the same source cluster head address. If it is the case, the node must ignore the packet REQM. In the contrary case, the node becomes an intermediate node. Then, it saves the pair (IP_source, ID_Msg) in its cache to reject the future duplicates REQM. The receiver node calculates the delay and estimates signal strength and bandwidth and recovers speed from the received packet. Once all parameters are available, the receiver node calculates the FL1 and FL2 values and compares between the calculated and the received ones. The lowest between FL1 and MFV and the highest between FL2 and MXFV will be inserted in REQM. The key idea of taking the minimum value of FL1 during the route discovering process is to avoid the route that have weak nodes and find the best of the worst. For example, all nodes of route have high values of FL1 except one node has low value. This means that: this node can leave the route in few times because it has a low signal or can delay the time transmission because it has a low Bandwidth. As a result, the source will loss the communication with its destination as fast as possible. The same case for FL2 applies, the route that has maximum value means high speed which causes frequent link broken or high delay that leads to long transmission time. When the destination receives all packets REQM from the different routes, it calculates the ratio between MFV and MXFV using **eq.5** for each REQM packet received. The aim of the ratio value is to have a harmonization between the two FL values; then the route having the maximum value is selected. The destination inserts the max value of ratio value in the packet REPM (replay message) shown in Figure 10 (We note that REPM is unicast) and send it to the cluster head source.

$$\text{ratio\_value} = MFV / MXFV \qquad (5)$$

IP_source	ID_Msg	IP_Dest	S	T	MFV	MXFV	Seq_Id

Fig. 9. REQM (Request Message) Format

IP_source	ID_Msg	IP_Dest	Max_value	Seq_Id	Data

Fig. 10. REPM (Reply Message) Format

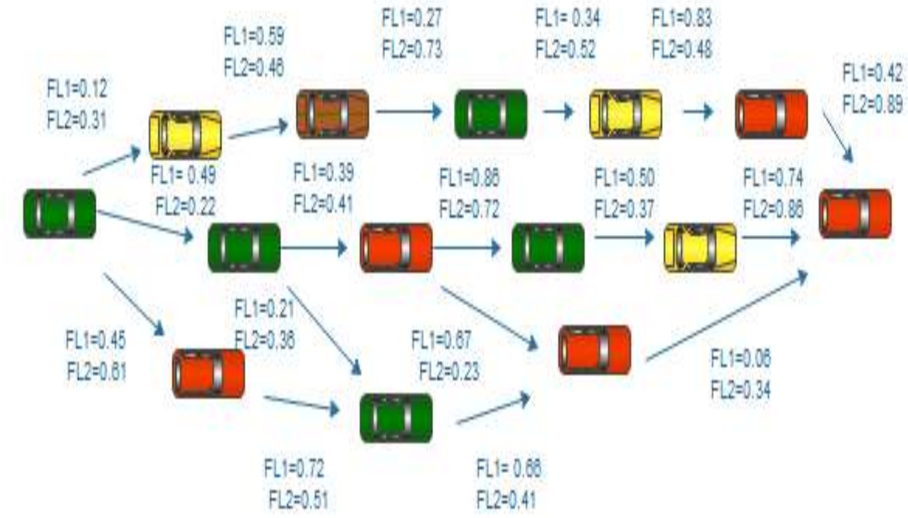


Fig. 11. REQM Broadcasting Process

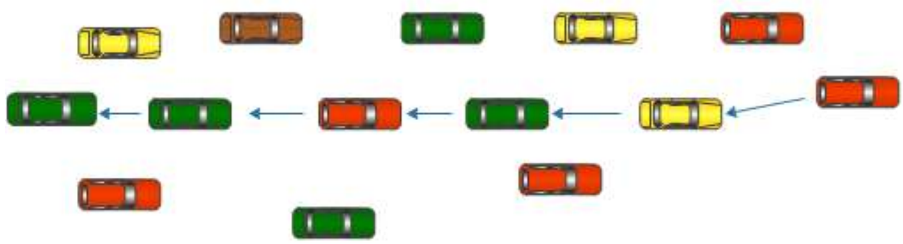
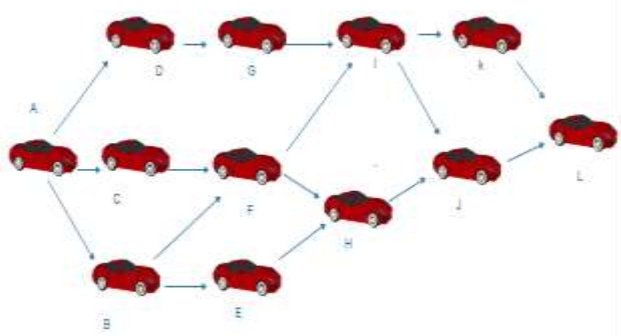


Fig. 12. REPM Sending Process

2.2.5 Routing mechanism for the second proposition

During the simulation phase, we observed that the average delay is a little bit high and the first proposition needs to be improved to comply with our needs. We suspected that the time is taken, in the destination cluster head to choose the best route between all the routes received, has a relationship with this delay. To deal with this, we proposed another solution dedicated to improving the average delay in the first level of the first proposition. The same concept of FL1 and FL2 calculation is used. In this second proposal, we give each intermediate node the possibility to take the decision on which route will be selected. The cluster head requestor broadcasts an REQM (Request Message) to all its neighbours. The criteria of node selection are based on FL1 and FL2 values discussed above and based on previous information in the route establishment process. Each node receiving the REQM, calculates FL1, and FL2 values based on received and available parameters; then it takes the ratio between FL1 and FL2. Two possibilities can happen: if the receiver node has just one neighbour sender, it calculates its FL1 and FL2 values; then it compares them with MFV and MXFV, respectively. If FL1 is the lowest, it will be inserted or/and if FL2 is the highest it will be inserted. The node receiver saves the previous path in its routing table and forwards the packet to its neighbours. In the case where the receiver has more than one sender at this time, the receiver node will compare all ratio values of packets received. The receiver chooses the path that has the maximum value; it saves it in its routing table and ignores the other received paths. Finally, when the REQM arrives in the destination cluster head, the latter resends a REPM (Reply Message) to the original cluster head sender by the best route selected. Figure 13 shows the routing mechanism of the second proposition where: SN (source node), D (a destination that receives the packet), FL1, FL2 (FL1, FL2 values between SN and D), MFV (Min FL1in REQM message), MXFV (Max FL2 in REQM message), and SP (Selected Path).Fig.13. Path Selecting Process of Second Proposal



SN	D	FL1	FL2	MFV	MXFV	SP
A	B	0.71	0.38	0.71	0.38	A
A	C	0.51	0.07	0.51	0.07	A
A	D	0.44	0.51	0.44	0.51	A
B	E	0.61	0.39	0.61	0.39	AB
B	F	0.15	0.46	0.15	0.46	AC
C	F	0.65	0.13	0.51	0.13	AC
D	G	0.44	0.51	0.32	0.51	AD
E	H	0.42	0.64	0.42	0.64	ABE
F	I	0.57	0.81	0.51	0.81	ACF
F	H	0.21	0.91	0.21	0.91	ABE
G	I	0.25	0.68	0.25	0.68	ACF
H	J	0.31	0.83	0.31	0.83	ACFI
I	J	0.61	0.11	0.51	0.81	ACFI
I	K	0.73	0.17	0.51	0.81	ACFI
J	L	0.49	0.52	0.49	0.81	ACFIK
K	L	0.58	0.67	0.51	0.81	ACFIK

Fig.13. Path Selecting Process of Second Proposal

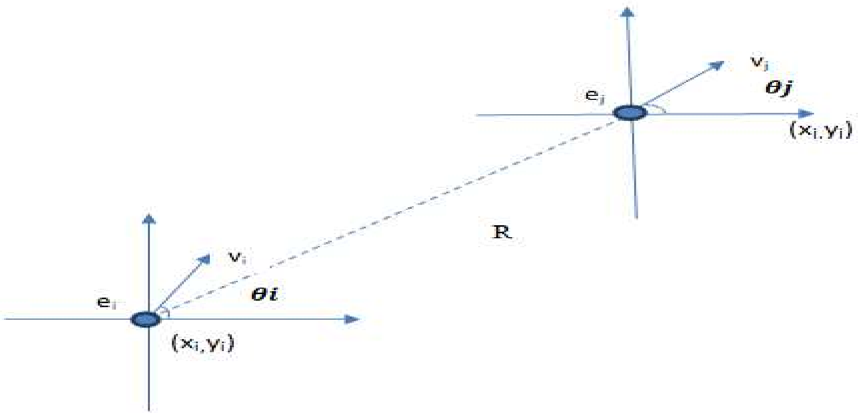


Fig.14. Parameters used to calculate *LET*

3.3 Second routing level (Intra-cluster)

In the second level of our proposed protocol, we suppose that each vehicle has at least one route to its cluster head by which it sends its service request. The goal of this level is to find the best path in terms of stability. In order to ensure robust connectivity, we use the estimation of link lifetime as an indicator of link stability which leads to the QoS in routes. Many works have been proposed to estimate the link lifetime based on different metrics [27], [28], [29], [30]. These works have been dedicated to VANETs and very few works have addressed the issue in the IoV environment. In our present work, the estimation of link lifetime is based on nodes' speed and direction. We chose this approach because it is based on the main factors generator of frequent links disconnection like velocity and direction. The same direction and close velocities mean unlimited connectivity. As a cluster head is a gateway or access point for vehicles in the cluster to have access to different services, utilization of a stable route is required. Link expiration time LET is shown in Figure 14 and it has been calculated based on velocity and direction parameters and the angle between two vehicles based on the **Eq. (6)**

$$LTE_{ij} = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \qquad (6)$$

Where, $a = v_i\cos\theta_i - v_j\cos\theta\ j$, $b = x_i - x_j$, $c = v_i \sin\theta_i - v_j \sin\theta_j$, and $d = y_i - y_j$. Vehicle velocity (v_i) and coordinates (x, y) parameters are available via GPS.

3.3.1 Routing mechanism of second level

Each node in a cluster exchanges its parameters (position, velocity) with its neighbor nodes using periodic Hello messages as shown in Figure 15. Each vehicle receives a Hello message estimates the link lifetime based on received parameters and saves the link lifetime value and source address in its route table. Each cluster member node, in each cluster, has to discover all possible routes to all its cluster vehicles including its cluster head using Hello messages. After receiving Hello messages from neighbor nodes, the source node classifies all available routes in its routing table according to the long route lifetime. If a node does not receive a Hello message from its neighbor during an interval of time t, it marks the routes used by this neighbor as disabled. Then it sends an error message ERRM to neighbors upstream of the route. In the case where the node needs a communication, the node requestor checks if the destination is in its cluster. If so, it chooses the longest link lifetime in its routing table according to the destination address and it sends a unicast request. On the contrary case, the node requests or sends a request message through the longest link lifetime path saved in its routing table to the cluster head. In turn, the cluster head sends a reply message to the node requestor via the same path. The example represented in Figure 16 and Figure 17 illustrates the node exchanges, mechanism parameters and the links establishment process with their cluster head, respectively. Flowchart of first proposition and second proposition are shown in figure 18 and figure 19, respectively.

<table>
<tr><td colspan="2">Source IP Address</td></tr>
<tr><td colspan="2">Destination IP Address</td></tr>
<tr><td colspan="2">Sequence Number</td></tr>
<tr><td>V</td><td>(x,y)</td></tr>
</table>

Fig.15. Hello Message Format

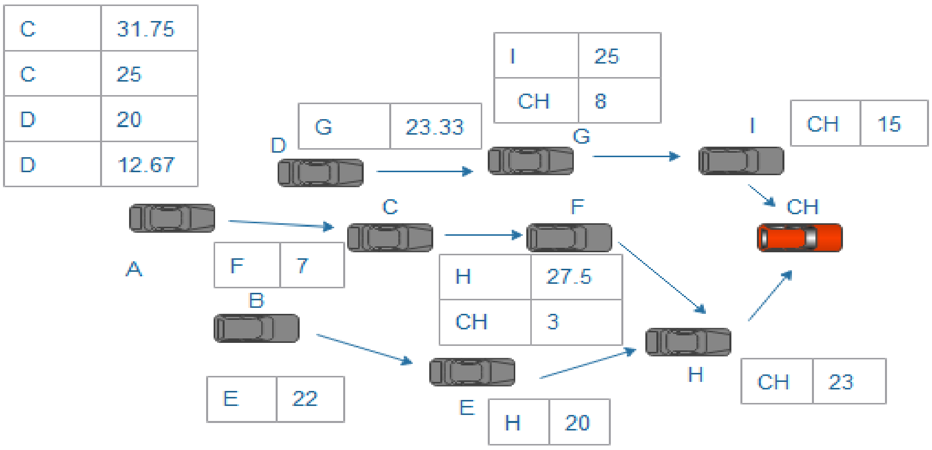


Fig. 16. Vehicle Exchanges and Mechanism Parameters

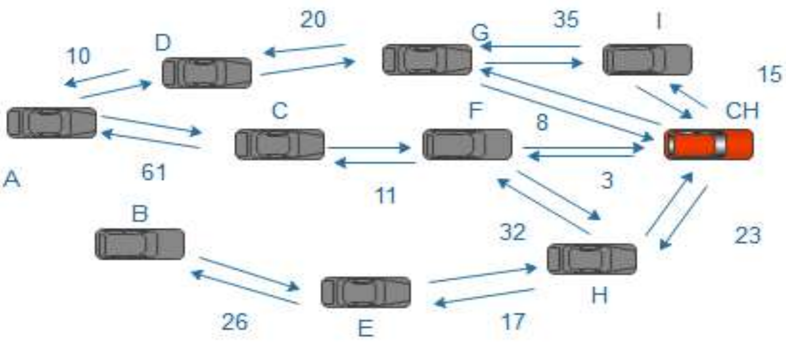


Fig.17. REQM Broadcasting Process

4. Results and Discussion

In this section, we report results generated from different simulation scenarios carried out and comparison between our proposal and referenced protocols ZRP, QoS-OLSR and CBDRP. To this end, we used the well-known NS3 network simulator [31] and we generated a realistic mobility model using the tool "Mobility Model Generator for Vehicular Networks" (MOVE) [32]. Vehicles are able to communicate with each other using the IEEE 802.11p MAC layer and 10 MHz of channel Bandwidth, other nodes like smart phones; tablets, etc. use the IEEE 802.11 MAC layer protocol. Due to the unpredictability of node velocities and network density, the vehicles are predisposed to rapid information loss. In fact, these two factors play an important role in communication link lifetime and quality of routing between vehicles. We compared the routing protocols under various node speeds and various network sizes in order to evaluate the impact of these factors on the performance of our protocol. We have generated a highway vehicular environment where we considered 60 km/h, as a minimum speed and 120 Km/h, as a maximum one. Table.4 shows the parameters used in the simulation process. A detailed analysis of the simulation results is given in the following.

Table.4. Simulation Parameters

Parameters	Value
Ns-3	version NS-3.26
Simulation time	300 s
Velocity	60–120 Km/h
Data packet size	500–3000 bytes
Source/destination	Random
Channel type	Wireless channel
MAC type communication protocol	IEEE 802.11p / IEEE 802.11
Simulation network area	3000m*100 m

4.1 Average packet delivery ratio (PDR)

PDR metric represents the percentage of data packets that reach destination compared to the total number of packets sent to the same destination. Different events may lead to loss of data packets such as: network collision, link failure, and insufficient bandwidth, overhead of buffering and nodes mobility. Speeds of vehicular nodes and network density have direct impact on various performance metrics like: PDR, delay and link disconnections (Network overhead) in IoV networks. For this reason and to study the effect of varying speed on routing protocols in the first scenario, speed changes from 60 km/h to 120 km/h with 1500 as a number of nodes. In +the second scenario, the number of nodes varies from 500 to 2000 nodes in the network with a speed of 70 km/h. The results are depicted in Figure 20.a shows the variation of Packet Delivery Ratio versus the variation of nodes speed, where the PDR decreases as the speed of nodes increases. With low mobility, proposition 1 and proposition 2 behave almost in the same manner and they exhibit better output with an average PDR of 94% and 90% respectively. As speed increases, degradation in the performance of QoSCluster is greater and PDR is reduced to 49%. The weight-based protocol has a relatively high PDR than GICA. As shown in Figure 20.b, PDR variation in different nodes number represents the dependence of routing protocols on diverse network densities. In weight-based protocol and GICA, an increased number of nodes lead to a decreased packet delivery rate. QoSCluster records the lower PDR compared to other protocols and this is due to a high number of control messages, buffer overflow and increased packet loss rate. In the proposed protocol, the PDR rate is improved according to different numbers of nodes as compared to other protocols, because the basic idea of PDR is the choice of stable routes. The stable route needs a longer link lifetime, appropriate mobility, higher bandwidth and closer distance.

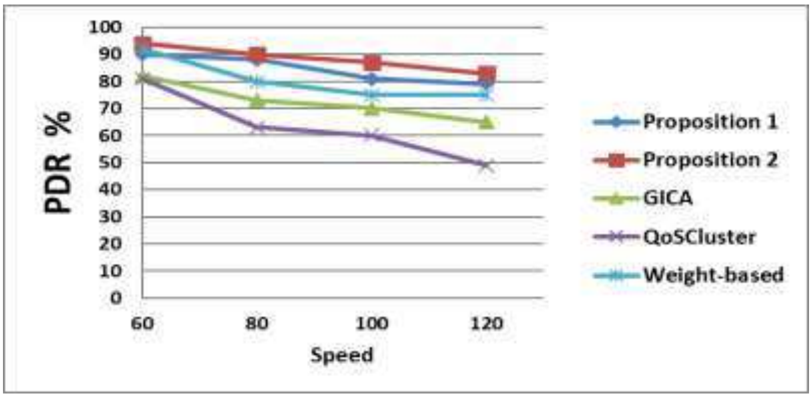


Fig 20.a Packets Delivery Ratio vs Node Velocities

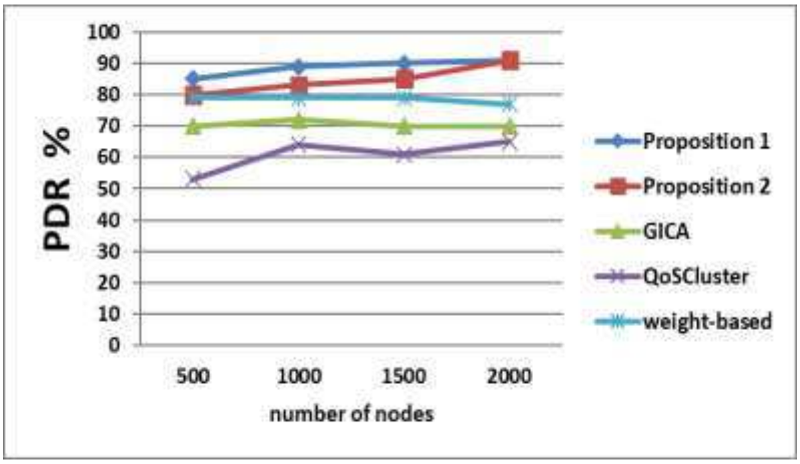


Fig 20.b Packets Delivery Ratio vs Number of Nodes

4.2 End to End Delay (EED) Metric

EED metric is the average time taken by a data packet sent from its source to arrive to its destination. In IoV networks, decreased link bandwidth and frequent link disconnections lead to increased probability of packet delay. Since the proposed approach selects stable routes for communication, there are lesser broken links during data transmission; this reduces the End to End delay. As shown in Figure 21.a, GICA protocol at high speeds exhibits greater delays because the link between two nodes is likely to be broken at high speeds. The absence of stable links selection process between Cluster Heads in GICA increases the probability of links disconnection. The QoS Cluster protocol delay is the lowest compared to GICA and weight-based, particularly at high speeds. The reason for this performance is that the route selection process between nodes in QoS Cluster is based on speed and direction vectors which minimize the probability of frequent links disconnection; this reduces the new link establishment which in turn decreases packets delay. The proposed protocols have shown high performance in terms of delays compared to other protocols. This is due to taking into account multiple parameters like speed, signal strength, bandwidth and delay when selecting a route to a destination. The probability of failure and End to End packet delay will be reduced at different speeds. As shown in Figure 21. b, when network density increases, End to End delay also increases for GICA, QoS Cluster, weight-based protocols. In the GICA protocol, the End to End delay is the highest. The main reason for this delay is that in the GICA protocol for neighboring nodes only one parameter is selected (short path), which will invariably be its closest neighbor. This problem faced in the proposed protocol was resolved using fuzzy logic and taking into account various parameters. As shown in the diagram, the average End to End delay of proposed protocols decreases in different densities.

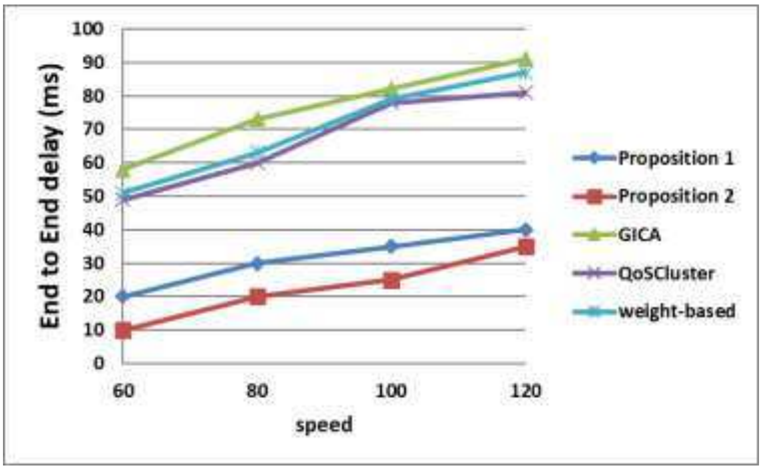


Fig 21.a End to End Delay vs Speed of Nodes

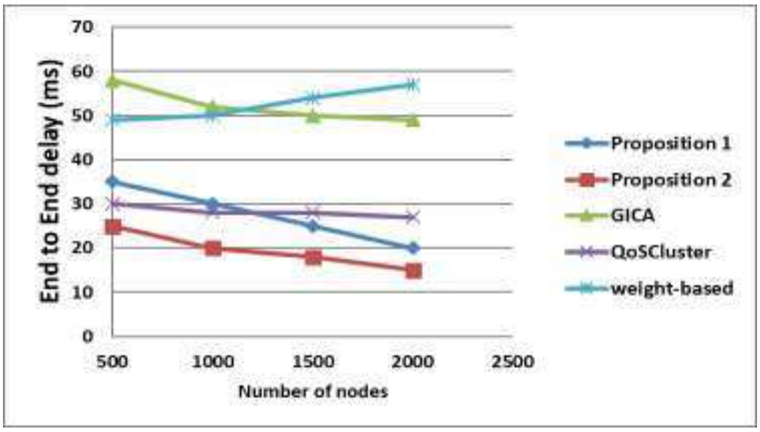


Fig 21.b End to End Delay vs Number of Nodes

4.3 Generated Overhead

This metric is measured in terms of the number of packets (Beacon messages) sent in the network. Frequent link disconnections lead nodes to resend route request messages which in turn augment network overhead, beacon messages sent to update the network and may also congest the network. Link stability could be affected by different crucial factors such as distance, direction, and speed; also decreasing the signal strength parameter leads to an increased probability of link disconnection. As shown in Figure 22. a, the number of packets sent was greater in the weight-based protocol compared to other protocols. In GICA, the increased speed of nodes leads to more link failure. In our proposed protocols, the most stable link is selected using the longest link lifetime variable and the use of fuzzy logic (With appropriate speed, higher signal strength (closer distance)) between cluster heads that may reduce link failure probability and the number of RREQ packets decreased at destination. As it is shown in Figure 22.b, in different network densities, the number of packets sent in the GICA protocol had an upward trend and was higher than that one of GICA and the weight-based protocols. In CBDRP protocol, an increase in network density leads to increased network congestion and hence, the probability of link failure was very high. The number of packets sent by proposed protocols was fixed and less than that of the QoS Cluster, GICA and weight-based protocols.

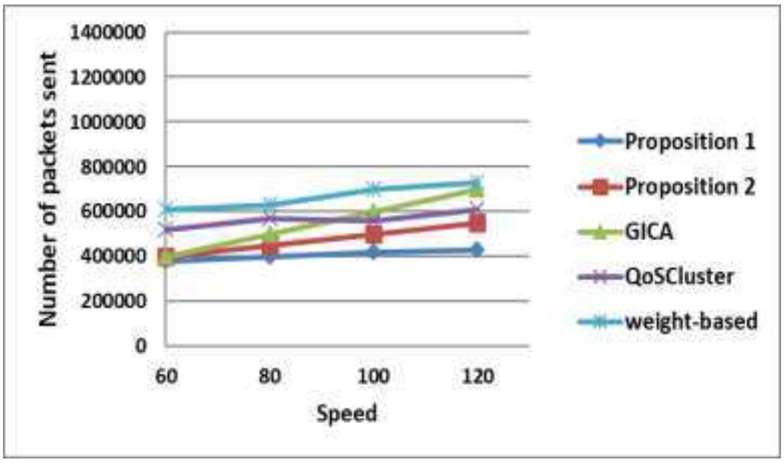


Fig 22.a Number of Packets Sent vs Node Velocities

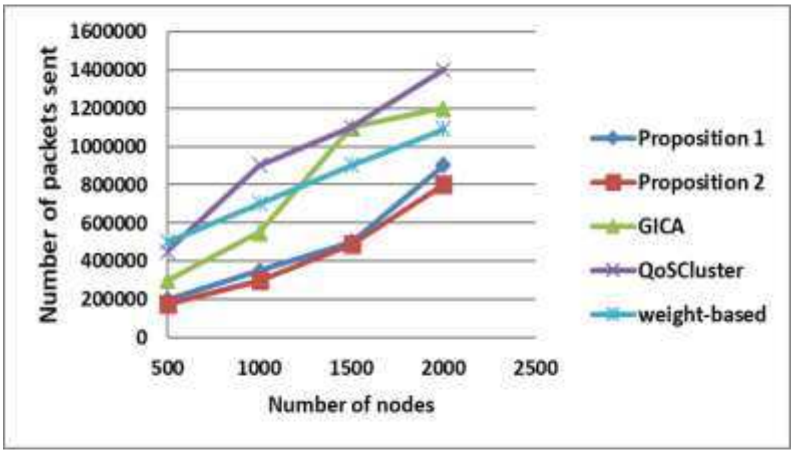


Fig 22.b Number of Packets Sent vs Number of Nodes

5 Conclusion

In an IoV environment, several types of messages are being transmitted, in particular urgent and non-urgent messages. Urgent messages convey key events which have to dependably reach their destinations in a real-time way. To achieve this objective, long-lasting communication links, stable and dependable must be available. This is what is devoted to our present work. Therefore, we proposed RPQLS: an efficient bi-level Routing Protocol based on Quality of service and Links Stability for the internet of vehicles. In the first level, we selected essential parameters like signal strength, Bandwidth, Velocity and delay as Fuzzy Logic inputs in order to determine the best routes between cluster heads. In the second level, we considered the estimation of link lifetime as a criterion of link durability in order to select stable routes between the cluster members. The performance evaluation of our proposal has been carried out through an NS3 simulator using different relevant scenarios and metrics. The results provided by our proposition outperform those of the well-known protocols namely: QoS Cluster, GICA and weight-based.

As future work, we envision enhancing our proposal by suggesting a new cluster formation algorithm based on node capacities such as computing ability, waiting queue size and delivery service time, all according to velocity variations.

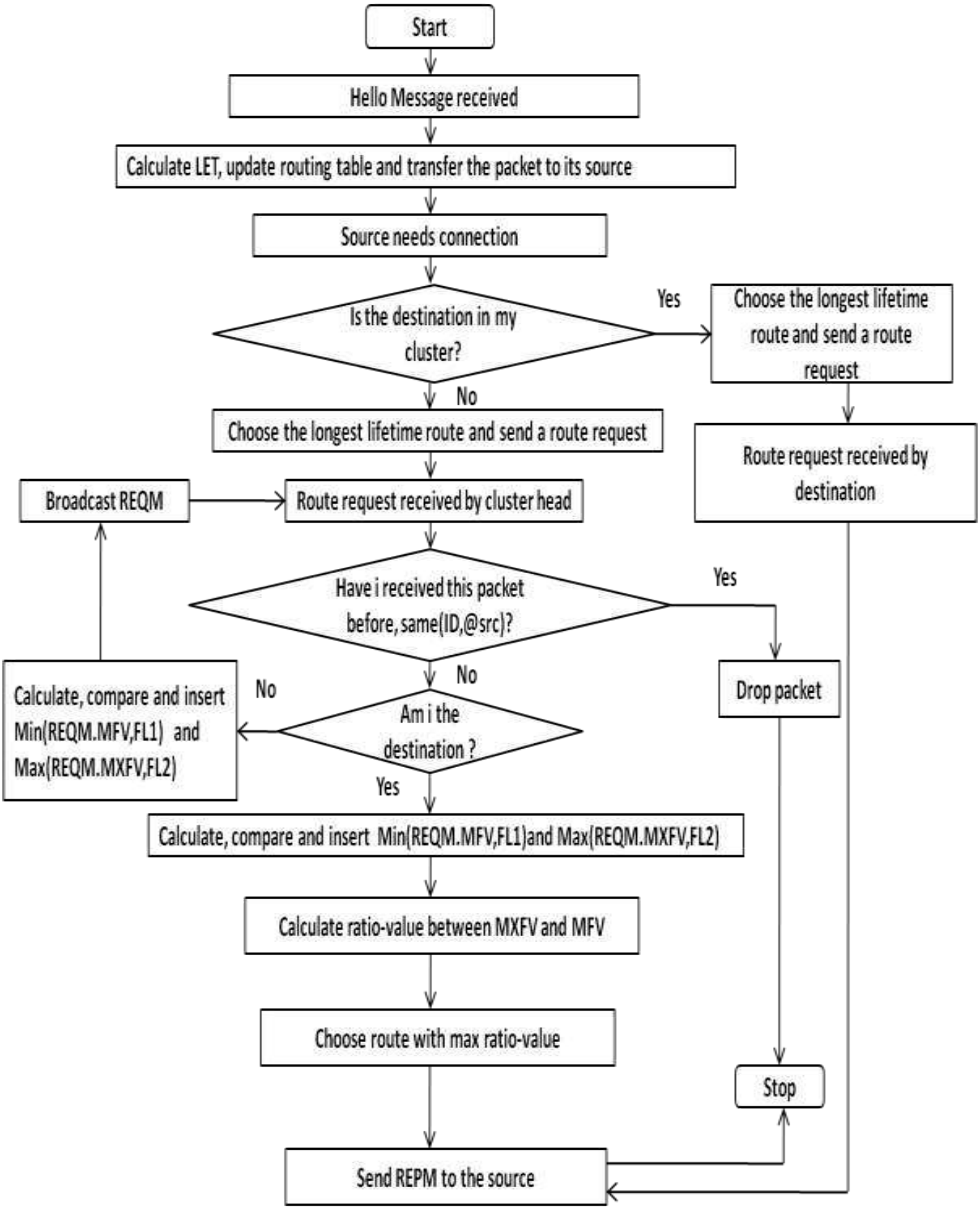


Fig.18. Flowchart for the First Proposition

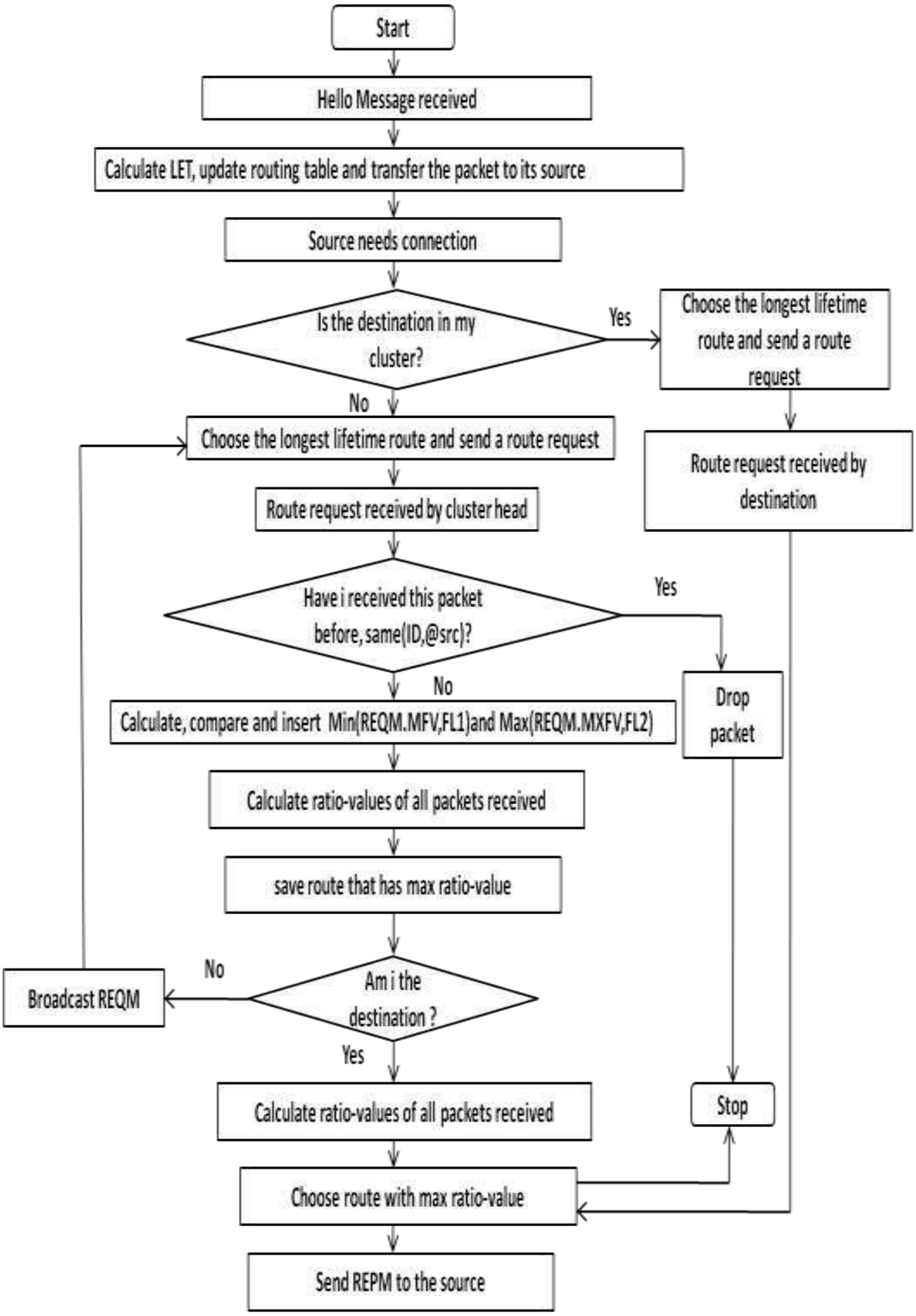


Fig.19. Second Proposition Flowchart

Declarations

Funding
This research work is supported by PHC-Tassili Grant Number 17MDU984.

Conflicts of interest/Competing interests
The Authors declare that there is no conflict of interest

Availability of data and material
All data is provided in full in the results section of this paper.

Code availability
The code source used in this study is available from the corresponding author upon reasonable request.

Authors' contributions
All authors contributed to the study conception and design. The first draft of the manuscript was written by Rim Gasmi and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

References

[1] O. Kaiwartya; A.H. Abdullah; Y. Cao; A. Altameem; M. Prasad; C. Lin; X. Liu "Internet of Vehicles: Motivation, Layered Architecture, Network Model, Challenges, and Future Aspects" in Special Section in IEEE Access: Future Networks: Architectures, Protocols, and Applications, vol.4; ISSN: 2169-3536; pp: 5356 – 5373, 2016.

[2] M. Gerla; E. Lee; G. Pau; U. Lee "Internet of vehicles: From Intelligent grid to autonomous cars and vehicular clouds" IEEE World Forum on Internet of Things (WF-IoT), 2014 Seoul, South Korea.

[3] E. Khorov ; A. Lyakhov; A. Krotov ; A. Guschin "A survey on IEEE 802.11 ah: An enabling networking technology for smart cities", Computer Communications, vol.58, no.1, pp.5369, 2014.

[4] C. Cooper, D. R. Franklin, M. Ros, M. Abolhasan. "A Comparative Survey of VANET Clustering Techniques", IEEE Communications Surveys & Tutorials pp(99):1-1, September 2016.

[5] M. Ren, L. Khoukhi, H. Labiod, J. Zhang, V. Vèque, "A mobility-based scheme for dynamic clustering in vehicular ad-hoc networks (VANETs) in Vehicular Communications, vol 9, pp. 233-241, July 2017 .

[6] F. Aadil, W. Ahsan, Z. Rehman, P. Shah, S. Rho, I. Mehmood, " Clustering algorithm for internet of vehicles (IoV) based on dragonfly optimizer (CAVDO)" in The Journal of Supercomputing, vol 74, pp 4552-4567, September 2018.

[7] M. Fahad Khan, F. Aadil, M. MAaqsood, S. H. R. Bukhari, M. Hussain, Y. Nam "Moth Flame Clustering Algorithm for Internet of Vehicle (MFCA-IoV)" in IEEE Access, pp. 11613-11629, 2019.

[8] R. Gasmi, M.Aliouat "A Weight Based Clustering Algorithm for Internet of Vehicles" Automatic Control and Computer Sciences, vol 54 ,pp 493-500, 2020.

[9] S. Bellaouar, M. Guerroumi, S. Moussaoui "QoS Based Clustering for Vehicular Networks" Smart Cities Dependability in Sensor, Cloud, and Big Data Systems and Applications, 5th International Conference, DependSys, Guangzhou, China, November 12–15, 2019.

[10] T. Song ; W. Xia ; T. Song ; L. Shen "A cluster-based directional routing protocol in VANET" IEEE 12th International Conference on Communication Technology, pp. 1172–1175, China, 2010.

[11] R. Gasmi, M.Aliouat, H. Seba "Geographical Information Based Clustering Algorithm for Internet of Vehicles" Machine Learning for Networking: Third International Conference, MLN 2020, Paris, France, November 24–26, 2020.

[12] A. Sharif, J. Ping Li, M. Asim Saleem, G. Manogran, S. Kadry, A. Basit & M. Attique Khan "A dynamic clustering technique based on deep reinforcement learning for Internet of vehicles" Journal of Intelligent Manufacturing, vol 32, pp 757–768, 2021.

[13] M. Bersali, A. Rachedi, H. Bouarfa "A New Collaborative Clustering Approach for the Internet of Vehicles (CCA-IoV)" Second International Conference on Embedded & Distributed Systems (EDiS), Algeria, 3 November 2020.

[14] S. Ebadinezhad "Design and Analysis of An Improved AODV Protocol Based on Clustering Approach for Internet of Vehicles (AODV-CD)" International journal of electronics and telecommunications, 2021, vol. 67, no. 1, pp. 13-22.

[15] O. Senouci, S. Harous, Z. Aliouat "An Efficient Weight-Based Clustering Algorithm using Mobility Report for IoV ", 9th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), 8-10 Nov. 2018.

[16] R.S. Hande; A. Muddana " Comprehensive survey on clustering-based efficient data dissemination algorithms for VANET" IEEE, International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES), Paralakhemundi, India, 2016.

[17] M. Sood; S. Kanwar "Clustering in MANET and VANET: A survey" International Conference on Circuits, Systems, Communication and Information Technology Applications (CSCITA), Mumbai, India, 2014.

[18] Y. Luo; W Zhang; Y. Hu, "A new cluster based routing protocol for VANET", IEEE International Conference on Networks Security Wireless Communications and Trusted Computing (NSWCTC), pp. 176–180, China, 2010.

[19] Z. Huang, L. Y. Por, T. F. Ang, M. H. Anisi and M. S. Adam, “Improving the Accuracy Rate of Link Quality Estimation Using Fuzzy Logic in Mobile Wireless Sensor Network” in Advances in Fuzzy Systems, vol 2019, Article ID 3478027, 13 pages, 2019.

[20] Hu X, Ma L, Ding Y, Xu J, Li Y, Ma S. Fuzzy Logic-Based Geographic Routing Protocol for Dynamic Wireless Sensor Networks. *Sensors*, 2019; 19(1):196. doi.org/10.3390/s19010196

[21] A. K. Mishra, R. Kumar, J. Singh, “A review on fuzzy logic based clustering algorithms for wireless sensor networks” in IEEE International Conference on Futuristic Trends on Computational Analysis and Knowledge Management, Noida, India, 2015.

[22] B. Balakrishnan and S. Balachandran, “FLECH: Fuzzy Logic Based Energy Efficient Clustering Hierarchy for Nonuniform Wireless Sensor Networks,” in Wireless Communications and Mobile Computing, vol. 2017, pp.13, 2017

[23] Wang, Q, Lin, D, Yang, P . Z. Zhang (2018) *A Fuzzy-logic Based Energy-efficient Clustering Algorithm for the Wireless Sensor Networks.* In: Proceedings - SoftCOM 2018: 26th International Conference on Software, Telecommunications and Computer Networks. x, Split, Croatia. IEEE . ISBN 978-9-5329-0087-3, 2015.

[24] L.A. Zadeh “Fuzzy sets*” information and control, vol.8, Issue 3, pp 338-353, June 1965.

[25] D. E. Tamir, N. D. Rishe, A. Kandel, Fifty Years of Fuzzy Logic and its Applications, Published by Springer International Publishing ISSN 1860-0808, ISBN 978-3-319-19683-1

[26] Fuzzy logic with Engineering applications, Third edition Timothy J. Ross 2010 John Wiley & sons. Ltd ISBN 978-0-470-74376-8.

[27] S. Shelly and A.V. Babu**,** Link residual lifetime-based next hop selection scheme for vehicular ad hoc networks**,** in EURASIP Journal on Wireless Communications and Networking, vol 2017, No 1, pp. 1-13, 2017.

[28] J. Huang, J. Bai, “A Novel Approach of Link Availability Estimation for Mobile Ad Hoc Networks”, in IEEE Conference: Vehicular Technology Conference, VTC Spring, June 2008

[29] N. Alsharif, K. Aldubaikhy and X. Shen. Link Duration Estimation using Neural Networks based Mobility Prediction in Vehicular Networks, in IEEE Canadian Conference on Electrical and Computer Engineering (CCECE), 2016.

[30] N. Sofra,A. Gkelias K.K. Leung. Route construction for long lifetime in VANETs in IEEE Transactions on Vehicular Technology, 60(7):3450 – 3461, October 2011.

[31] Riley G.F., Henderson T.R. The *ns-3* Network Simulator, In: Wehrle K., Güneş M., Gross J. (eds) Modeling and Tools for Network Simulation. Springer, Berlin, Heidelberg. 2010.

[32] F. K. Karnadi; Z. H. Mo; K. c. Lan. "Rapid Generation of Realistic Mobility

Models for VANET " Proc. of IEEE Wireless Communications and Networking Conference, pp. 2506-2511, Hong Kong, March 2007.

[33] A. Lakas, M. Fekair, A. Korichi, N. Lagraa “A Multiconstrained QoS-Compliant Routing Scheme for Highway-Based Vehicular Networks” Wireless Communications and Mobile Computing, vol. 2019, Article ID 4521859, 2019.

[34] D. ABADA, A. MASSAQ, A. BOULOUZ “Improving Routing Performances to Provide Internet Connectivity in VANETs over IEEE 802.11p” International Journal of Advanced Computer Science and Applications, vol. 8, No. 4, 2017