A Reliable Route Repairing Scheme for Internet of Vehicles

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Abstract: Recently, Internet of Vehicles (IoVs) have been recognized a key solution for vehicular communications. Connected vehicles, personal smart devices, and infrastructures' road side units have been shaping the underlying architecture of IoVs technology, where the conventional routing protocols cannot facilitate reliable and efficient communication for dynamic IoVs topologies. Hence, this technology is highly susceptible to frequent network fragmentations, thus expose communication channels to the regular failure problem. Reliable communication between vehicles requires adopting the existing routing strategies along with the current requirements. This paper, thus, introduces a novel routing repair strategy, referred to as Reliable Route Repairing Strategy (RRRS) to tackle routing failure problems. Repairing the operation of channel communications between the source and destination pairs is prioritized according to stability degree of the connected vehicles. The RRRS defines three zones (i.e. a high-active, a low-active and a non-active zones), and privileges repairing a broken link to the high-active zone only. These three zones are classified based on the angle's values between source, vehicles and destination. The RRRS features are combined with the traditional AOMDV protocol, and a comparison study has been conducted to compare the AOMDV, the RRRS-AOMDV and the HM-AOMDV protocols. Simulation results demonstrate that the RRRS-AOMDV achieves better performance, about 30% to 45% in terms of Packet Transmission Overhead, Packet Repairing Overhead and Average Data Packets Latency.

Keywords: IoVs, Internet of Things, AOMDV, broken links.

1. Introduction

With the emergence of Internet of Things (IoT), anywhere, anytime and anything communication paradigm will enable more than 50 billion smart devices to become connected to the internet by 2050 [1]. Indeed, this vast number of smart devices can form different types of smart applications and solutions as shown in Figure 1. For instance, Internet of Vehicles (IoVs), smart air pollution monitoring systems, smart cities and smart home systems are examples of such platforms [2]. Over the last decade, IoVs represents a groundbreaking vision of improving transport safety, reducing traffic congestion, and enhancing public transportation facilitates. A comprehensive study from U.S Department of Transportation shows that the number of vehicles is increased about 2.2 percent between 2015 and 2016 [3]. As a result, the number of accidents is reached up to 194,477 in 2014. Another study reveals that, death rates from road traffic accidents in developing countries, such as Nigeria is about 33.7 percent per 100,000 population every year [4]. The study in [5] confirms that that 60 percent of a multi-vehicle collision could be avoided if drivers informed about a crash site at least 500ms in advance, thus, making IoVs as one of the most powerful solutions to solve several problems in logistics and transportation systems. Basically, to achieve a safety factor in roads, vehicles in IoV environment are equipped with various sensors and devices to collect traffic data, including, vehicle speed and direction, safety warning messages, accident reports, traffic flow and many other important data.

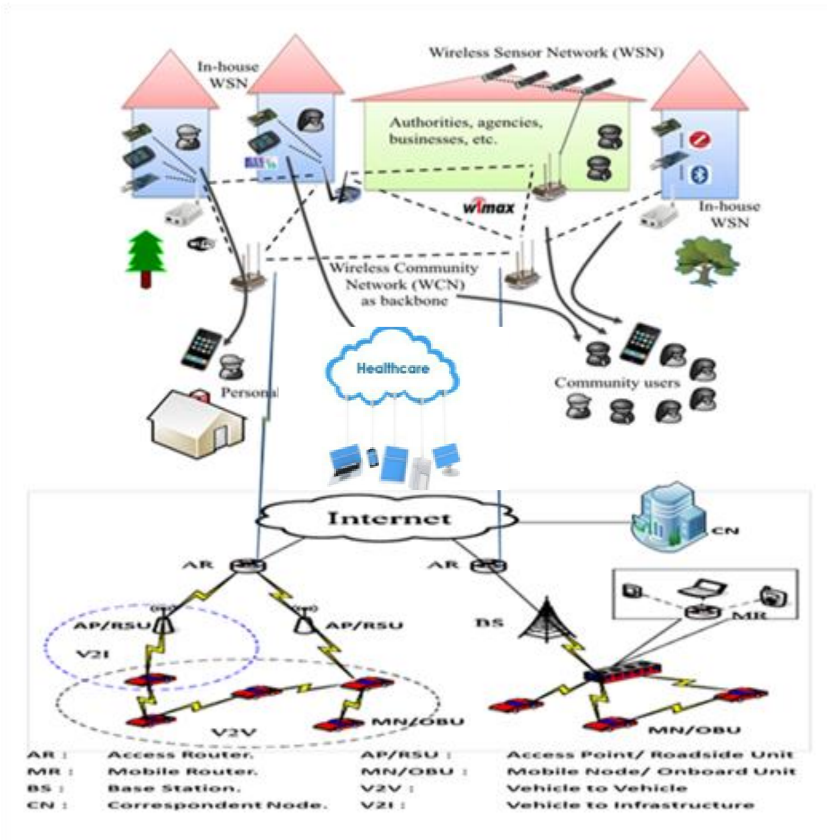

Figure 1: Vehicular communication within other smart applications

The heterogeneous network architecture of IoVs can be classified into five types of vehicular communications, namely, Vehicle-to-Vehicle (V2V),Vehicle-to-Roadside unit (V2R), Vehicle-to-Infrastructure (V2I) of mobile networks, Vehicle-to-Personal devices (V2P) and Vehicle-to-Sensors (V2S) [6]. The traditional Intelligent Transportation System (ITS) includes V2V, V2R and V2I, which form another communication network known as Vehicular Ad hoc Networks (VANETs). With the various existing types of IoVs architecture, vehicles can initiate control packets via themselves, roadside unites, or personal devices. This can eliminate the problems associated with traditional routing, where searching for a route or repairing it is handled by intermediate vehicles only. Indeed, the design of resource constrained networks such as IoVs is a challenging task. Due to the unreliable characteristics of IoVs environments coupled with different resource limitations, make the routing in IoVs a difficult operation among vehicles. In this paper, we propose the Reliable Route Repairing Strategy (RRRS) as a new routing repair strategy scheme for IoVs. It treats vehicles as active vehicles and non-active vehicles, where link failures could occur frequently. Usually, vehicles motion and speed are the main cause for the link failure phenomena, as vehicles always travel in different directions and speeds. Hence, vehicles that construct a communication channel could leave the transmission range quickly or move in a different direction arbitrarily.

Toward this ends, we suggest a new formulation of a traditional repair strategy that is based on the scenario where vehicles are moving inside relevant zones in a city environment. The novelty of this work lies in categorizing vehicles into three zones (i.e. *The high-active zone, the low-active zone, the none-active zone*), while taking accurate re-link process in order to select the most appropriate paths. It also takes into account the position of a source-destination vehicle with respect to previous vehicles within a recently expired route. Each zone is assigned a proper probabilistic value, and it is participated in route repairing process accordingly. The probabilistic value is calculated based on the angle values between the source, the vehicles and the destination. The key function of this protocol focuses on selecting the links that ensure high connectivity for packet delivery and improve the overall network performance with minimal number of control messages and lower packet transmission time. It is worth mentioning that, the probabilistic model is widely used to handle the route discovery problem as well as the broadcast storm problem in Mobile Ad hoc Networks (MANETs) and VANETs[7][8][9][10]. The remainder of the paper is organized as follows: Section II presents related work. The proposed Reliable Repair Routing Strategy(ARRS) is described in Section III. Section IV explains the experimental setup configuration and discusses the results. Section V concludes the work and provides some future directions.

2. Related work

The basic idea of Ad hoc On Demand Distance (AODV) protocol is presented in [11], and it is mainly designed for MANETs. AODV is classified as a reactive protocol, since it builds and maintains routes between source-destination pairs when it is needed. Establishing a route in AODV takes place when a source broadcast Route REquest (RREQ) packet to its neighbors. If the required destination in not located within source's transmission range, RREQ packet is flooded through the entire network until the destination is found. Once the destination is reached, it sends back Route REply (RREP) packet to inform the source that the route is established. Bujari et al. in [12] have shown that properly configured topology-based protocols such as AODV achieves acceptable performance in VANETs environment. AODV-MR with multi Rout REply (RREP) packets for VANET is proposed by Xingyun PENG et al. to maintain efficient link connectivity and to handle route repair problems. A destination vehicle in AODV-MR replies to all RREQs and correspondingly produce a series of RREPs and creates multiple reverse paths to a source vehicle. AODV-MR handles the broken link problem by means of optimal and suboptimal routes where the data is sent over the two routes at the same time. The suboptimal route can be used to route data packet when the optimal route is broken or not available instead of initiating a new route discovery phase[13]. A similar Alternate Path-AODV technique is proposed in [14], which allows each vehicle to broadcast only two RREQ packets to its neighboring vehicles. Then, the receiving vehicles can easily record two different reverse path tracks to the source. Baozhu Li et al.[15] suggested to broadcast data packets during local repair process, which helps finding a reverse path while sending data packet to a destination vehicle. An Improved AODV (I-AODV) for VANETs in city scenarios has been proposed in [16]. The I-AODV deals with route discovery phase by limiting source routing up to two hops, while modifying the route reply phase by creating a backup route between source and destination vehicles. The backup route is used when the primary route is failed. Liu Yujun et al.[17] enhanced the performance of the AODV-BR (Backup Recovery) [18] by broadcasting RREP packets only to 1-hop neighbor instead of blindly dissemination to all neighboring vehicles. It also extends the HELLO message to establish a backup route while using the Extended Routing Table and the Least Hop Count to select the best alternative vehicle, thus significantly reduces the distance between the repair vehicle and the destination. A further improvement on AODV, namely AODV+ is proposed in [19] to offer reliable transmissions and to support the Internet connectivity with V2V and V2I communication. When a direct link to a destination is not available or is expired, data packets can immediately be forwarded to an infrastructure node or to the Internet. The functionality of AODV+ is also improved in Modified-AODV+ (M-AODV) [20] to enable routing and re-routing via V2I and I2I, when single-hop or multi-hop communication of V2V cannot be established. However, such improvements fail to work with infrastructure-less environment where V2I or I2I are not available.

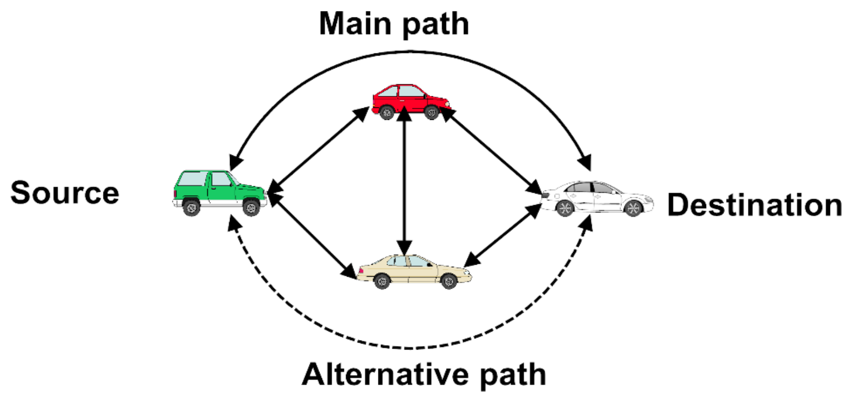

Figure 2: AOMDV uses two paths; the main path and the alternative path.

Ad hoc On demand Multiple Path Distance Vector (AOMDV)[21] protocol is an extension of AODV with no routing loop and link-disjoint path problems. The main idea of AOMDV is to find more than one path between source-destination pairs during route discovery phase as in Figure 2. The motivation behind the AOMDV is the fact that a single path cannot work effectively with high dynamic network, where links failures and route breaks may occur frequently. In order to maintain a multipath, each copy of RREQ packets arriving at a vehicle records an alternative path back to the source. When the main path is no longer available to the destination, the alternative path is used instead. Consequently, to enhance the performance of the traditional AOMDV, a High Mobility Ad hoc On demand Multiple path Distance Vector (HM-AOMDV) protocol is proposed in [21]. The HM-AOMDV uses hop counts metric and relative velocity values between vehicles to determine the best routing transmission path. The proposed protocol assumes that the vehicle nodes can maintain stable communication connection, if the relative velocity is zero between two vehicle nodes and they move on the same direction. On the other hand, if a relative velocity between two moving vehicle nodes is large, then a link lifetime is too short. The Mobility Factor (MF) is calculated for each vehicle and sent back with RREP packet to its neighbors. Every vehicle maintains MF for all its neighboring vehicles. The vehicle with the higher MF is selected as a next node for current transmission. In this paper, the HM-AOMDV is selected in the simulation comparison experiments against the new proposed solution (i.e. RRRS).

Although some related works [11-16], have confirm their ability to reduce network overhead and improve the performance, maintaining multiple paths is not cost effective and consumes network resources. In addition, such solutions are not designed to operate with the IoVs environment. Moreover, the majority of the previously mentioned studies focused on addressing the problem of finding an alternative path, however how to repair a broken path is not deeply addressed. To the best of our knowledge, this paper presents the first study that takes advantage of the multiple path solutions as in the traditional AOMDV, and probabilistic routing model and augment them to repair the broken route. Such a new combination shows superior performance in comparison to the existing solutions such as HM-AOMDV [20] and AOMDV [21].

3. Reliable Repair Routing Scheme (RRRS)

Route maintenance is a very crucial part of the overall routing mechanisms in MANETs applications. It occurs when an active route between pairs of source and destination becomes no longer available. This is due to the rapid movement of nodes, which leads to a frequent change to the network topology. In the traditional route maintenance strategies, once the active route is broken during data transmission, a local repair process takes place by an upstream node. The upstream node broadcasts RREQ packet locally to the downstream nodes if its location near to the destination node. However, if the local repair is unsuccessfully completed, a Route Error (RERR) packet is sent back to the source through an intermediate node. Once the source node received the RERR packet it should reinitiate a new route discovery phase by broadcasting RREQ packet again. Reinitiating the route discovery process might flood the network with control messages and cause a significant network overhead, especially if the case of reinitiating the route discovery process keeps arising.

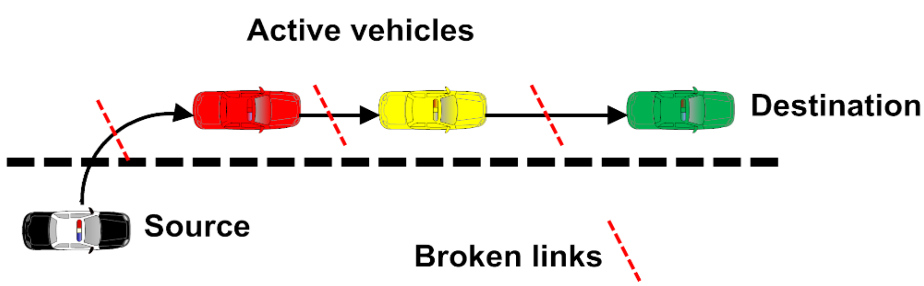

Figure 3: destination vehicle still close with active vehicles in case of broken link.

As a result, a new route maintenance strategy is needed to reduce the network overhead that mainly comes from the control packets. As illustrated in Figure 3, when a link break takes place, a destination vehicle does not move far away or fast from its recent active route. Thus, the RRRS is proposed to overcome such an issue and to tackle the network overhead problem. The RRRS defines the following three zones namely, t*he high-active zone:* $0^0 < \theta \leq 60^0$, *the low-active zone:* $60^0 < \theta \leq 90^0$, and *the non-active zone:* $\theta > 90^0$.

The above angle values θ are obtained by using the following cosine invers mathematical equation:

$$\theta = Cos^{-1}\left(\frac{X^2 + Y^2 - Z^2}{2XY}\right) \tag{1}$$

where X, Y and Z are the distances values that can be calculated using the coordinates of a source vehicle, intermediate vehicles, and a destination vehicle as in Figure 4. Based on these three zones, the RRRS defines three rules, each one refers to a specific zone, and each zone assigns a forwarding probability value for its related vehicles. The three rules are defined below and followed by detailed examples.

Rule1: *The high-active zone for source-destination pairs contains a group of high active nodes that are a part of the previous active route with their 1-hope neighbors. Active nodes should make acute angle (i.e* $0 < \theta \leq 60^0$*) between a source-destination pair, and they are assigned a high retransmission probability, which is calculated based on equation (2).*

$$Tr_{hp} = 1 - \left(\frac{\theta}{2*180^0}\right) \tag{2}$$

where Tr_{hp} is defined as a value of the high retransmission probability, which should be assigned for the vehicles of the high-active zone. Figure 5 is illustrated based on this equation.

Rule2: *The low-active zone for source-destination pairs contains a group of high active nodes that are a part of the previous active route with their 1-hope neighbors. Active nodes should make Acute angle (i.e.* $60 < \theta \leq 90^0$*) between source-destination pairs, and they are assigned a low retransmission probability, which is calculated based on equation (3)*

$$Tr_{lp} = \left(\frac{\theta}{2*180^0}\right) \tag{3}$$

Tr_{lp} represents the value of low retransmission probability, which should be assigned for the vehicles of the low-active zone. Low Tr_{lp} means all vehicles inside the low-active zone are suppressed to repair the broken link again.

Rule3: *The none-active zone for source-destination pairs contains a group of high active nodes that are a part of the previous active route with their 1-hope neighbors. None-active nodes should make obtuse angle (i.e. $90^0 < \theta < 180^0$) between source-destination pairs, and their retransmission probability is equal to zero.*

As an example, on equations number (1), (2) and (3), based on Figure 5, consider the following scenario:

- While Vehicle V_2 belongs to the high-active zone as its θ_2 value is equal to 20 *(i.e. $0 < \theta \leq 60^0$)*. The high retransmission probability Tr_{hp} for V_2 is set to 0.94 by using equation number (1). **Rule1**

  $Tr_{lp} = 1 - \left(\frac{20^{\circ}}{2*180^0}\right) = 0.94$
- Vehicle V_1 belongs to the non-active zone as its θ_1 value is larger than 90 (θ_1>90). Hence, the value of retransmission probability for V_1 is set to zero. **Rule3.**

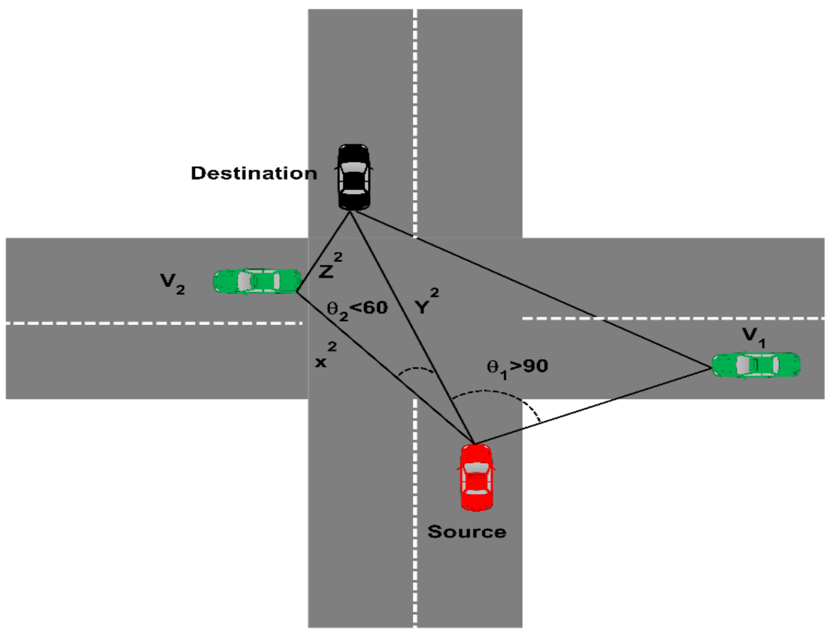

Figure 4: shows illustrative example on how to use RRRS's rules.

The proposed approach conceptual design is illustrated in Figure 5. When a source vehicle initiates a RREQ packet, it checks first if the routing history towards a requested destination exists in the routing cash table. If it is the case, the RREQ packet is marked as a route maintenance packet. Otherwise, it is marked as a new route discovery packet. When an intermediate vehicle receives the RREQ packet, it checks whether it is marked as a route maintenance or as a new route discovery packet. In case of a route maintenance, the intermediate vehicle should determine itself to which zone it belongs to, based on its angle value. Then, a forwarding opportunity is calculated by using equation (2) and (3). On the other hand, a new route discovery process is instantiated and the RREQ packet is sent over to all vehicles.

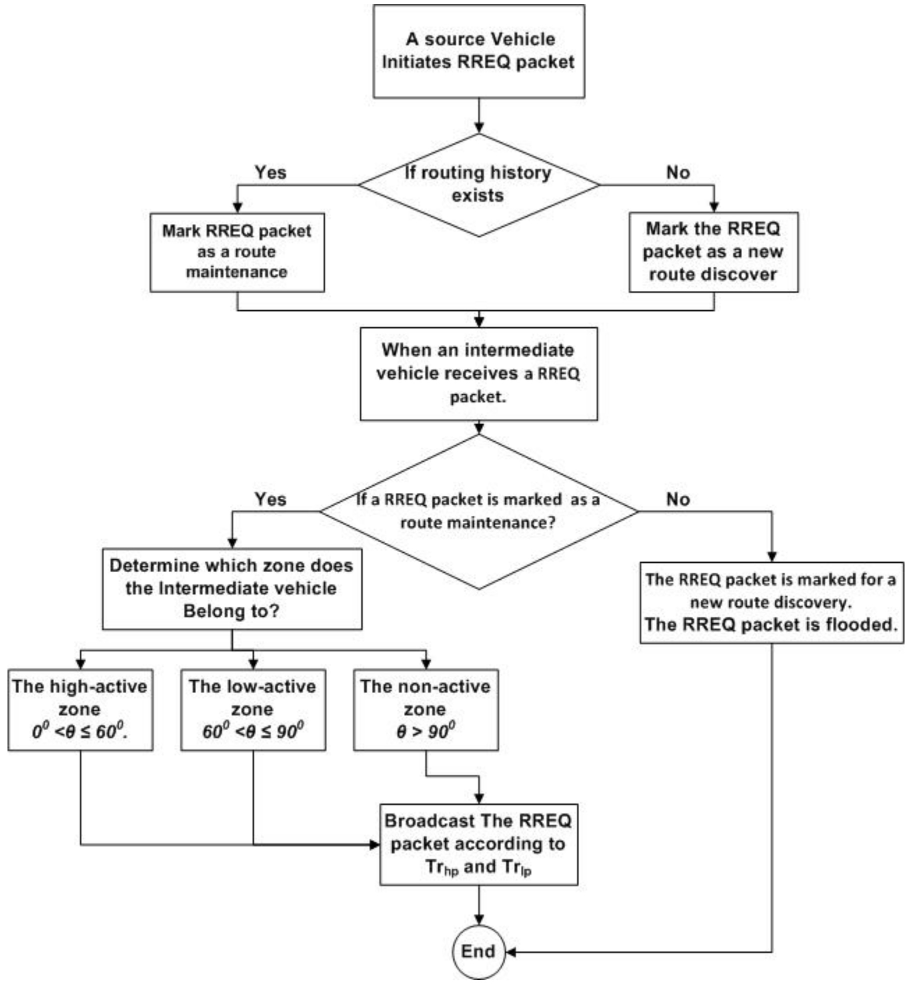

Figure 5: The main steps of the RRRS.

In Figure 6, an illustrative example is given to describe how the RREQ packet is propagated using the scheme during the route maintenance phase, when the routing history of the source-destination pairs is existing. The example consists of three types of vehicles which are identified according to their zones. In Figure 6, vehicles A, B and C forward data packets on behalf of the source-destination pairs. Each of the vehicles (i.e. A, B and C) identifies itself as active vehicles for the path by constantly updating the routing history in its cache as data, and the RREP packets are forwarded. The active nodes also identify themselves to their 1-hop neighbors, V_1, V_2, V_3, by periodically transmitting "HELLO" packets which contain their identifications.

If any of the active vehicle (e.g. node C) moves out of the transmission range of its active neighbors, or becomes unavailable, then the route between the source-destination pairs will no longer be considered as a valid route. This will trigger another round of route discovery. In this case, nodes A, B and C and their 1-hop neighbors (V_1, V_2, V_3) forward the RREQ packets using the equation (2). Vehicles V_5 and V_6 are located in the low-active zone and should forward the RREQ packets using the equation (3). Vehicles V_7 and V_8 are not allowed to transmit the RREQ packets as they are part of the none-active zone (i.e. $\theta < 90^0$).

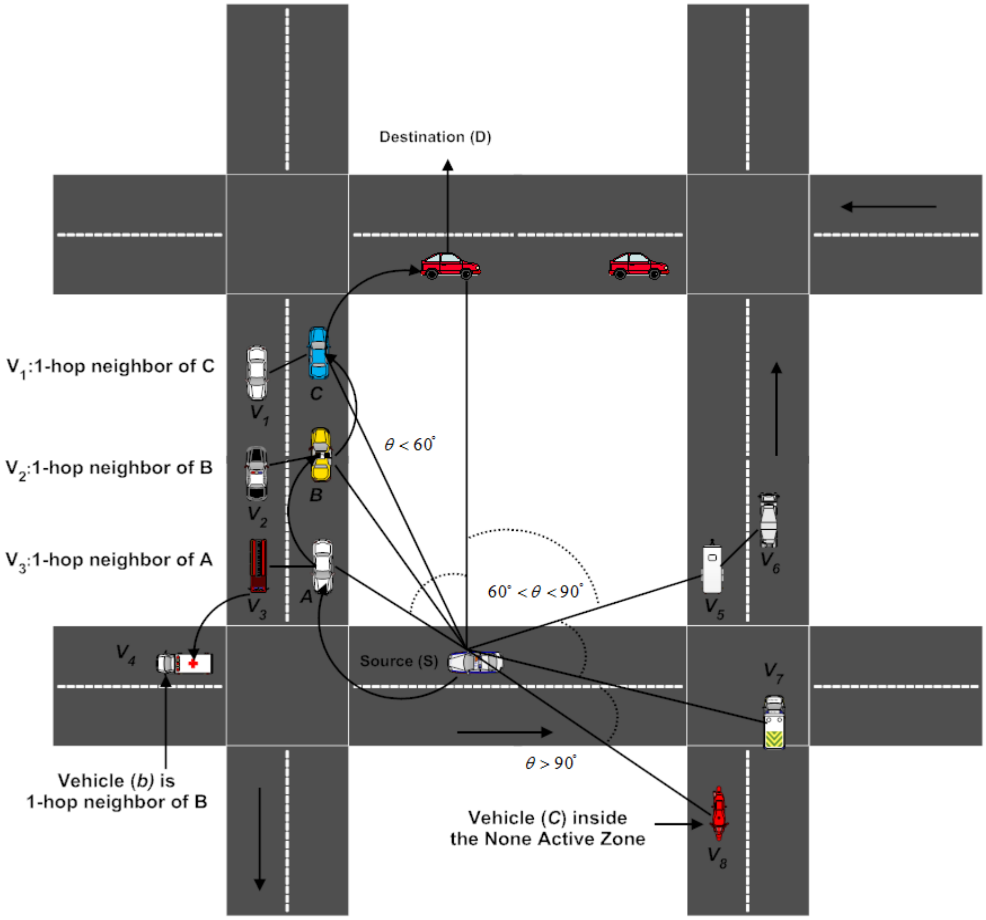

Figure 6: shows detailed example for the proposed strategy**.**

In General, if V_x is the number of high-active vehicles with their 1-hope neighbors, V_y is the number of nodes located in the low-active zone with their 1-hope neighbors, and V_z is the number of nodes located in the non-active zone. If the transmitted RREQ packet is marked as route maintenance, then the Total Number of possible retransmissions (T_n) of equations (2) and (3) are related as follows:

$$T_n = Tr_{hp} \times V_x + Tr_{lp} \times V_y + 0 \times V_z \tag{4}$$

The value of Tr_{hp} and Tr_{lp} are dynamically calculated based on the angle degree between the source-destination pair. In Figure 7, assume that the total number of vehicles at a specific period is $V_n = 40$, the number of vehicles in the high-active zone with their 1-hop neighbors is $V_x= 6$, the number of vehicles with 1-hop neighbors of low-active zone is $V_y= 2$, and the number of vehicles inside the non-active zone is $V_z=2$. Assume that approximately θ values for vehicles A, B and C with their 1-hop neighbors vehicles V_1, V_2 and V_3 are equal to 40^0, θ values for vehicles V_5 and V_6 are equal to 75^0, and for vehicles V_7 and V_8 are equal 110^0 and 120^0 respectively. Therefore, the total number of possible broadcasts of an RREQ packet is calculated as follows:

$$T_n = 1 - \left(\frac{40^{\circ}}{360^{\circ}}\right) \times 6 + \left(\frac{75^{\circ}}{360^{0}}\right) + 0 \times 2 \approx 6$$

While in a traditional repair strategy as in AOMDV, T_n is calculated as follows:

$$T_n = V_n - 2 = 40 - 2 = 38$$

From the above simple analysis, it can be concluded that the total number of possible broadcasts of an RREQ packets T_n is reduced by approximately 92% compared to a traditional repair strategy.

4. Simulation results and discussions

In this section, the performance of the proposed routing scheme (i.e. RRRS) is evaluated against the traditional routing protocol in AOMDV. NS-2 simulator [22] is used with a Simulation of Urban Mobility (SUMO) platform on Manhattan model [23], which usually used to represent the movement pattern of vehicles in a typical metropolis where streets are defined by maps. For the purpose of the evaluations, important factors were considered, such as the network traffic which was regulated from 200 flows to 1000 flows, and IEEE 802.11p [24] is used as MAC layer protocol. Number of vehicles are set to 100 vehicles; each vehicle moves at speed 20m/s with a random distribution of 10 roadside units. To simulate the fading problem in wireless channels, Nakagami propagation model is selected as it is more general applicability in practical fading channels [25]. Table 1 summarizes the simulation environment.

Table 1: list of parameters that are used in the simulation.

Parameter	**Value**
Network traffic flow	varying from 200 (low) to 1000 (high).
The communication model	802.11 p as the MAC layer
The vehicle traffic model	SUMO with Manhattan model
Number of vehicles	100 vehicles
Speed of vehicles	Up to 20m/s
Roadside units	10 RSUs
Propagation model	Nakagami propagation

Network performance is analyzed using the following important metrics: *Packet Transmission Overhead (PTO)* that represents the total number of generated control packets (i.e. RREQ packets) during the route search and route repair**;** *Packet Repairing Overhead (PRO)* which indicates stability of the proposed scheme which shows the total number of RERR packets that are generated due to broken links and *Average Data Packets Latency (ADPL)* is defined as the average delay between times at which the data packet was transmitted from the source vehicle until the time it is received at the destination vehicle.

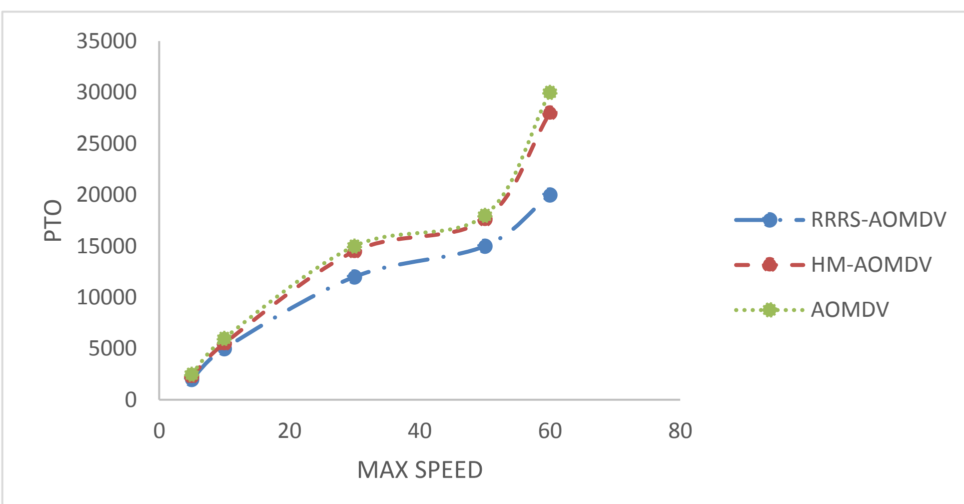

Figure 7: Packet Transmission Overhead vs. Vehicles Max Speed.

Effect of the maximum speed: Various vehicle speed values are used to evaluate the performance of RRRS-AOMDV in comparison to the typical AOMDV and the HM-AOMDV. The minimum speed was set to 5m/s and the maximum speed was set to 60m/s. The number of vehicles is set to 600 vehicles randomly distributed over a network area of 1000 m x 1000 m. The total number of connections between the source and destination pairs are set to 20. The effect of the vehicles speed over the PTO is illustrated in Figure 7. The connection stability between the source and destination is decreased, when the vehicle speed increases. This can increase the number of RREQ packets that should be generated to re-establish the invalid routes due to the vehicles speed. It is noticed from Figure 8 that the RRRS-AOMDV performs better than HM-AOMDV and AOMDV over different speed values. For instance, when the vehicles speed set to 60m/s, the RRRS-AOMDV reduces the PTO about 34% compared to AOMDV and 29% compared to the HM-AOMDV. Similarly, the effect of the vehicles speed over the PRO (i.e. Number of RERR packets) was also studied and the results are illustrated in Figure 8. The RRRS-AOMDV, the HM-AOMDV and AOMDV generate RERR packets when they detect a link failure. It is noticeable that the RRRS-AOMDV incurs smaller number of RERR packets than the AOMDV and the HM-AOMDV. This is because the RRRS-AOMDV considers active-zones only in the route repairing phase.

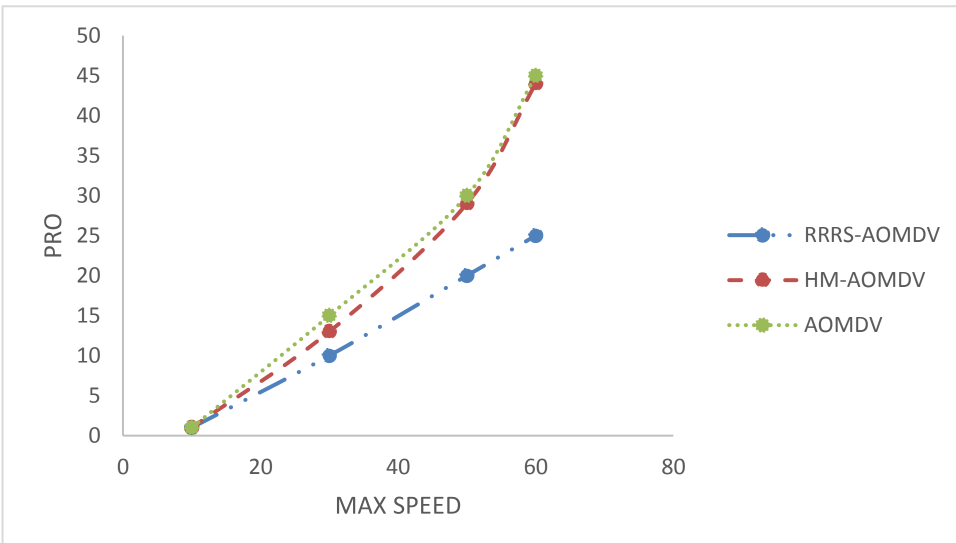

Figure 8: Packet Repairing Overhead vs. Vehicles Max Speed.

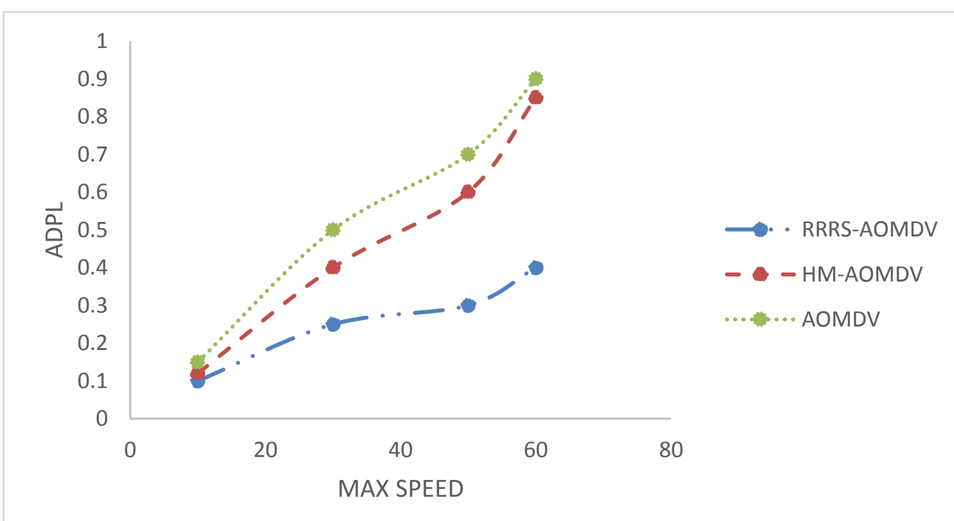

Figure 19: Average Data Packets Latency vs. Vehicles Max Speed.

For instance, RERR packets associated with RRRS-AOMDV is decreased up to 45% compared to its counterpart when maximum speed is set to 60m/s. The Average Data Packets Latency of the proposed schemes was also evaluated under different speed values of the vehicles and the results are illustrated in Figure 9. It is therefore obvious that as the vehicle speed increases, the ADPL is also increasing proportionally. This is due to the fact that routes with frequent breakages and re-establishment require longer time for the data packets in the interface queue to reach the destination. However, at all maximum node speed points RRRS-AOMDV outperform the AOMDV and the HM-AOMDV.

Effect of network connections: A communication channel is established between the source and destination pairs after a valid route is selected between them. It allows both pairs to send and receive data packets. In this simulation, each routing scheme is evaluated by using different number of connections, which varies from 10 to 70. The obtained results are shown in Figure 10 which illustrates the effect of the number of vehicle connections over the PTO (i.e. RREQ packets) generated by the RRRS-AOMDV the HM-AOMDV and the AOMDV increases with the increase in the number of connections. This is because as the number of connections between the sources and destinations increases, POT increases proportionally.

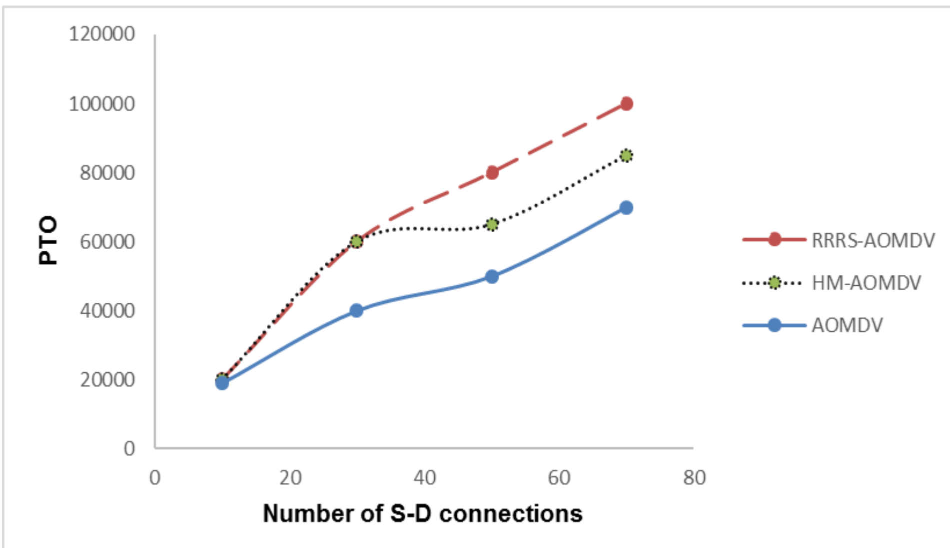

Figure 10: Packet Transmission Overhead vs. Number of connections.

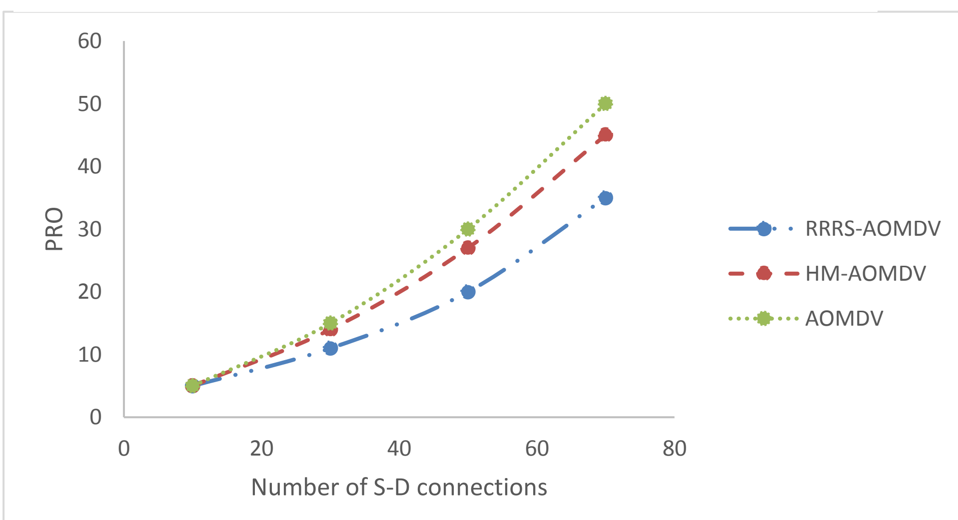

Figure 11: Packet Repairing Overhead vs. Number of connections.

In fact, opening a communication channel between the source and destination requires the source to initiate and rebroadcast the RREQ packet. However, RRRS-AOMDV shows superior performance as it reduces approximately by 30% and 18% compared to the AOMDV and the HM-AOMDV when the number of connections is set to 70 connections.

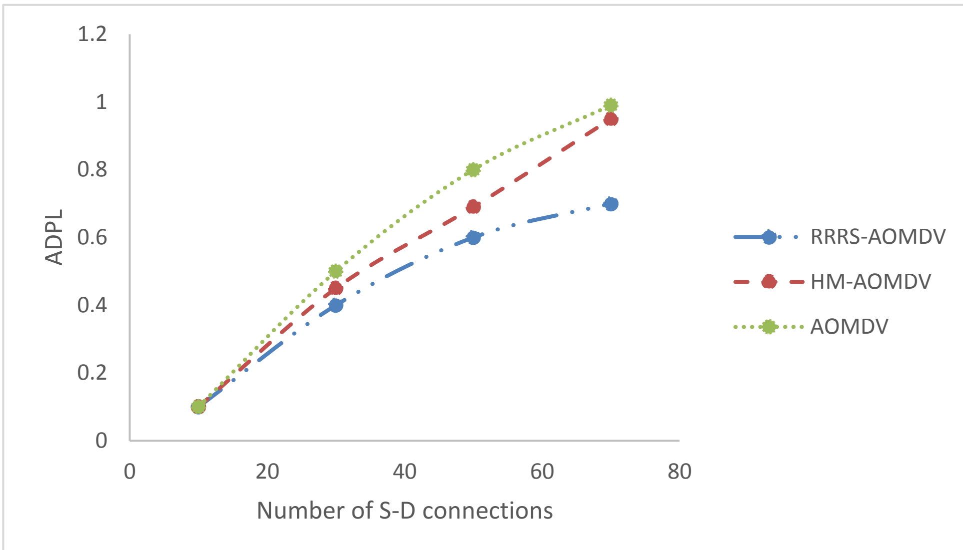

Figure 12: Average Data Packets Latency vs. Number of connections.

Similarly, Figure 11 shows the results of PRO (i.e. RERR packets) versus the number of connections. It can be noticed from Figure 11 that the PRO increases as the number of connections increases. This is due to the fact that as more channel connections are established, more paths are needed, more links could be broken and more RERR packets are generated. However, among the different number of connections, the RRRS-AOMDV performs better than the AOMDV. Finally, Figure 12 illustrates the effect of varying the number of connections on ADPL. The number of total data packets transmitted across the wireless channels depends on the number of connections between vehicles. Normally, the more connections we have the more data packets occur. This forces the data packets to be queued in the interface queue; which may cause significant delays. Clearly, ADPL dramatically increases as the number of connections increases. Figure 12 also depicts that the RRRS-AOMDV scheme incurs the lowest ADPL. For instance, when the number of connection is high, i.e. 70, ADPL for the RRRS-AOMDV, the HM-AOMDV and the AOMDV is 0.7 sec, 0.95 and 0.99 sec, respectively.

5. Conclusion and future works

In this paper, we have proposed a new reliable route repairing scheme (RRRS), which is a modified version of the AOMDV protocol with the ability to repair the broken links between vehicles in a reliable strategy. The proposed protocol suppressed vehicles that belong to the low-active zone and the non-active zone to participate in the route recovery process. A high opportunity for repairing links is given to vehicles that belong to the high-active zone. These zones are classified according to the calculated angle values between the source vehicle, history of the previous active vehicles with their one-hope neighbors, and the destination vehicles. The RRRS protocol is compared against the HM-AOMDV and the AOMDV protocol using simulations considering the Urban

Mobility (SUMO) platform. The simulation results show that the proposed protocol improves the performance in terms of packet transmission overhead, packet repairing overhead, and average data packets latency. In our future work, we will utilize the advantages of RRRS-AOMDV and the M-AODV+[20] routing protocol to support V2V communication in IoVs, by including V2I and I2I communications in routing and re-routing process. Furthermore, this proposed solution could enhance the routing protocol and link stability by including new routing metrics such as the shortest path, link expiration time and multipath fading channel statistics [26]. The RRS-AOMDV can be investigated further with more scenarios and operating conditions, such as multi-lane roads, high-speed highways and the hidden Markov model [27].

References

[1] FTC Staff Report; The Internet of Things: Privacy and Security in a Connected World. January 2015. Available online at:https://www.ftc.gov/system/files/documents/reports/federaltrade-commission-staff-report-november-2013-workshopentitled-internet-things-privacy/150127iotrpt.pdf

[2] M. A. Feki, F. Kawsar, M. Boussard and L. Trappeniers, "The Internet of Things: The Next Technological Revolution," in Computer,Feb 2013, vol. 46, no. 2, pp. 24-25.

[3] Reported road casualties in Great Britain: main results 2016 by Department for Transport. Available online at:https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/668504/reported-road-casualties-great-britain-2016-complete-report.pdf.

[4] Agbonkhese, O; Yisa, G.L; Agbonkhese, E.G; Akanbi, D.O; Aka, E.O; Mondigha, E.B.,"Road Traffic Accidents in Nigeria: Causes and Preventive Measures," IISTE Journal on Civil and Environmental Research,2013,vol.3, no.13, pp.90-99.

[5] Eze E C, Zhang S and Liu E," Vehicular ad hoc networks (VANETs): Current state, challenges, potentials and way forward,"20th International Conference onAutomation and Computing (ICAC),Cranfield, 2014, pp. 176-181.

[6] Kaiwartya O, Abdullah A H, Cao Y, Altameem A, Prasad M, Lin C T and Liu X,"Internet of Vehicles: Motivation, Layered Architecture, Network Model, Challenges, and Future Aspects," IEEE Access,2016, vol. 4, no. , pp. 5356-5373.

[7] Adarbah H Y, Ahmad S, Arafeh B and Duffy,"Efficient broadcasting for route discovery in Mobile Ad-hoc Networks,"International Symposium on Performance Evaluation of Computer and Telecommunication Systems (SPECTS), Chicago, IL, 2015, pp. 1-7.

[8] Zheng J, Tong H, Wang Z and Wu Y, "A Destination and Moving Direction Information Based Probabilistic Routing Protocol for VANETs," IEEE Global Communications Conference (GLOBECOM), Washington, DC, 2016, pp. 1-5.

[9] Chekhar M, Zine-Dine K, Bakhouya M and Aaroud,"A dynamic threshold-based probabilistic scheme for broadcasting in ad hoc networks," 15th International Conference on Intelligent Systems Design and Applications (ISDA), Marrakech, 2015, pp. 511-516.

[10] Tseng Y C, Ni S Y, Chen Y S and Sheu J P,"The Broadcast Storm Problem in a Mobile Ad Hoc Network,"Wireless Networks,March 2002, vol.8, no.2, pp 153–167

[11] C. Perkins, E. Belding-Royer and S. Das. Ad hoc On-demand Distance Vector (AODV) routing, RFC3561,2003.

[12] A. Bujari and O. Gaggi and C. E. Palazzi and D. Ronzani," Would Current Ad-Hoc Routing Protocols be Adequate for the Internet of Vehicles? A Comparative Study," IEEE Internet of Things Journal, March 2018, no.99,pp 1-9.

[13] Peng X, Wu Y, Xu Z and Lin X,"AODV-MR: AODV with multi-RREP for VANET," The 7th IEEE/International Conference on Advanced Infocomm Technology, Fuzhou, 2014, pp. 172-176.

[14] Mittal S, Kaur R and Purohit K C,"Enhancing the data transfer rate by creating alternative path for AODV routing protocol in VANET," 2nd International Conference on Advances in Computing, Communication, & Automation (ICACCA), Bareilly, 2016, pp. 1-5.

[15] Baozhu Li, Yue Liu and Guoxin Chu, "Improved AODV routing protocol for vehicular Ad hoc networks," 3rd International Conference on Advanced Computer Theory and Engineering(ICACTE), Chengdu, 2010, pp. V4-337-V4-340.

[16] D. Sutariya and S. Pradhan, "An improved AODV routing protocol for VANETs in city scenarios," IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM -2012), Nagapattinam, Tamil Nadu, 2012, pp. 575-581.

[17] Liu Yujun and Han Lincheng, "The research on an AODV-BRL to increase reliability and reduce routing overhead in MANET," International Conference on Computer Application and System Modeling (ICCASM), Taiyuan, 2010, pp. V12-526-V12-530.

[18] S. J. Lee and M. Gerla, "AODV-BR: backup routing in ad hoc networks," 2000 IEEE Wireless Communications and Networking Conference, Chicago, IL, 2000, vol.3, pp. 1311-1316.

[19] Hamidian, A.: A Study of Internet Connectivity for Mobile Ad Hoc Networks in NS 2. Master's thesis. Department of Communication Systems, Lund Institute of Technology, Lund University (January 2003).

[20] J. Wantoro and I. W. Mustika, "M-AODV+: An extension of AODV+ routing protocol for supporting vehicle-to-vehicle communication in vehicular ad hoc networks," IEEE International Conference on Communication, Networks and Satellite (COMNETSAT), Jakarta, 2014, pp. 39-44.

[21] W. I. Lee, S. I. Chowdhury, G. Y. Kee, W. S. Baek and J. Y. Pyun, "Velocity Aware Multipath Distance Vector Routing Protocol for High Mobility over Vehicular Ad-Hoc Networks," The 5th FTRA International Conference on Multimedia and Ubiquitous Engineering, Loutraki, 2011, pp. 189-194.

[22] McCanne, S., Floyd, S.: The Network Simulator - ns-2, http://www.isi.edu/nsnam/ns/; Fall, K., Varadhan, K.: The ns Manual.

[23] M. Behrisch, L. Bieker, J. Erdmann, and D. Krajzewicz, "SUMO - Simulation of Urban MObility - an Overview," The 3th International Conference on Advances in System Simulation (SIMUL),2011, pp. 63-68.

[24] Vandana Jayaraj, Hemanth C., Sangeetha R.G.," A survey on Hybrid MAC Protocols for Vehicular Ad-hoc Networks", Vehicular Communications, vol.6, pp. 29-36, 2016.

[25] M. Nakagami, "The m-distribution - A General Formula of Intensity Distribution of Rapid Fading," Stat. Methods Radio Wave Propag, pp.3-36, 1960.

[26] D. Abada, A. Massaq and A. Boulouz, "Connecting VANETs to Internet over IEEE 80211p in a Nakagami Fading Channel," International Conference on Wireless Technologies, Embedded and Intelligent Systems (WITS), pp. 1-6, 2017.

[27] L. Yao, J. Wang, X. Wang, A. Chen and Y. Wang, "V2X Routing in a VANET Based on the Hidden Markov Model," IEEE Transactions on Intelligent Transportation Systems, March 2018, vol. 19, no. 3, pp. 889-899.