[15] D.B. Johnson, D. Maltz, Y. Hu, "Dynamic source routing protocol for mobile ad hoc networks (DSR)", IETF Internet Draft, April 2003, available at http://www3.ietf.org/proceedings/04mar/I-D/draftietf-manet-dsr-09.txt.
[16] M. Takai, J. Martin, R. Bagrodia, "Effects of wireless physical layer modeling in mobile ad hoc networking", In Proceedings of the 2001 ACM International Symposium on Mobile Ad Hoc Networking & Computing (MobiHoc 2001), pp.87-94, Oct. 2001.
[17] Y. Lin, Y. Chen, S. Lee, "Routing protocols in vehicular ad hoc networks: a survey and future perspective", Journal of Information Science and Engineering, Vol.26, No.1, pp.913-932, Jan. 2010.
[18] J. Garcia-Nieto, J. Toutouh, E. Alba, "Automatic tuning of communication protocols for vehicular ad hoc networks using metaheuristics", Journal of Engineering Applications of Artificial Intelligence, Vol.23, No.5, pp.795–805, Aug. 2010.
[19] H. Cheng, S. Yang, "Genetic algorithms with immigrant schemes for dynamic multicast problems in mobile ad hoc networks", Journal of Engineering Applications of Artificial Intelligence, Vol.23, No.5, pp.806–819, Aug. 2010.
[20] J. Toutouh, J. Garcia-Nieto, E. Alba, "Intelligent OLSR routing protocol optimization for VANETs", IEEE Transactions on Vehicular Technology, Vol.61, No.4, pp.1884-1894, May 2012.

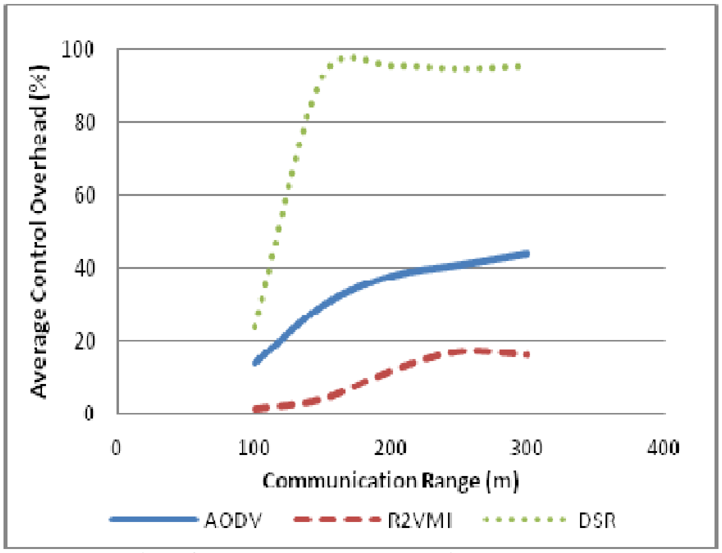

Fig. (12): Average control overhead percentage vs. communication range (speed = 5m/s).

5. Conclusions and Future Work

In this paper, a two-step AODV-based routing protocol is proposed for VANET networks. At first, node-grouping is done using their mobility information such as speed and movement direction. If the first step cannot respond efficiently, the algorithm enters the second step which uses LET in grouping process. The goal of the proposed protocol is increasing the stability of routing algorithm by selecting long-lived routes and decreasing link breakages. The comparison of the proposed algorithm with AODV and DSR protocols using NS-2 shown that the proposed algorithm increases the packet delivery ratio while reducing the routing control overhead. Implementing this algorithm in other popular routing protocols and providing a suitable medium access control (MAC) protocol for it are our future works.

References

[1] H. Hartenstein, K.P. Laberteauxhristos, "A tutorial survey on vehicular ad hoc networks", IEEE Communications Magazine, Vol.46, No.6, pp.164-171, Jun. 2008.

[2] F. Li, Y. Wang, "Routing in vehicular ad hoc networks: a survey", IEEE Vehicular Technology Magazine, Vol.2, No.2, pp.12-22, Jun. 2007.

[3] T. Taleb, E. Sakhaee, A. Jamalipour, K. Hashimoto, N. Kato, Y. Nemoto, "A stable routing protocol to support ITS services in VANET networks", IEEE Transaction on Vehicular Technology, Vol.56, No.6, pp.3337-3347, Nov. 2007.

[4] E. Sakhaee, T. Taleb, A. Jamalipour, N. Kato, Y. Nemoto, "A novel scheme to reduce control overhead and increase link duration in highly mobile ad hoc networks", In Proceedings of IEEE Wireless Communications and Networking Conference (WCNC 2007), pp.3975-3980, Mar. 2007.

[5] E.M. Royer, C. Toh, "A review of current routing protocols for ad hoc mobile wireless networks", IEEE Personal Communications, Vol.6, No.2, pp.46-55, Apr. 1999.

[6] CarLink, http://carlink.lcc.uma.es/ (2008).

[7] M. Heddebaut, J. Rioult, J.P. Ghys, C. Gransart, S. Ambellouis, "Broadband vehicle-to-vehicle communication using an extended autonomous cruise control sensor", Journal of Measurement Science and Technology, Vol.16, No.6, pp.1363–1373, Jun. 2005.

[8] M. Shulman, R. Deering, "Third annual report of the crash avoidance metrics partnership April 2003–March 2004", National Highway Traffic Safety Administration (NHTSA), Washington, DC, Jan. 2005.

[9] L. Andreone, C. Ricerche, "Activities and applications of the vehicle to vehicle and vehicle to infrastructure communication to enhance road safety", In Proceedings of the 5th European Congress and Exhibition on ITS, Jun. 2005.

[10] R. Kruger, H. Fuler, M. Torrent-Moreno, M. Transier, H. Hartenstein, W. Effelsberg, "Statistical analysis of the FleetNet highway movement patterns", University of Mannheim, Mannheim, Germany, Technical Report, TR-2005-004, Jul. 2005.

[11] W.B. Zhang, H.S. Tan, A. Steinfeld, B. Bougler, D. Empey, K. Zhou, M. Tomizuka, "Implementing advanced vehicle control and safety systems (AVCSS) for highway maintenance operations", In Proceedings of the 6th Annual World Congress on ITS, Nov. 1999.

[12] D. Jiang et al., "Design of 5.9 GHz DSRC-based vehicular safety communication", IEEE Wireless Communication, Vol.13, No.5, pp.36–43, Oct. 2006.

[13] C.K. Toh, "Associativity based routing for ad hoc mobile networks", Journal of Wireless Personal Communications-Special Issue on Mobile Networking Computing Systems, Vol.4, No.2, pp.103–139, Mar. 1997.

[14] C.E. Perkins, E.M. Royer, "Ad-hoc on demand distance vector routing", In Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, pp.90–100, Feb. 1999.

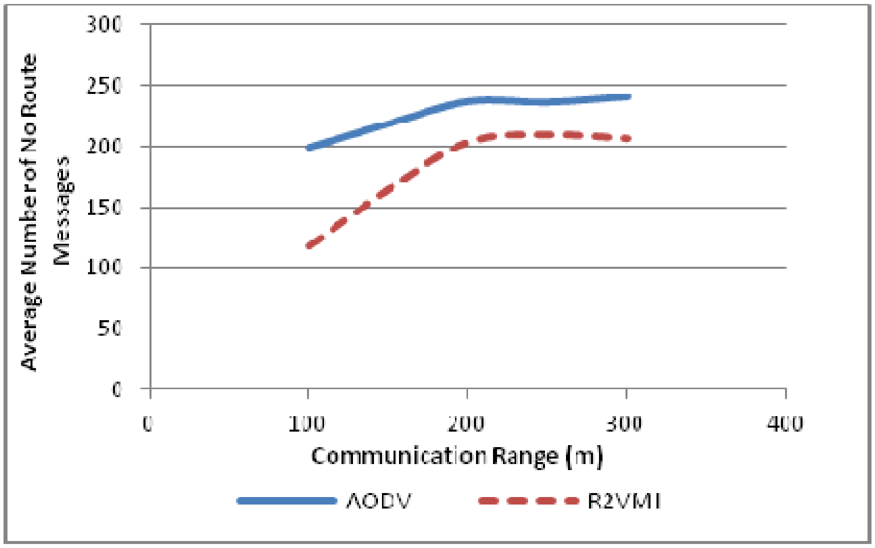

Fig. (10): Average number of no route messages vs.

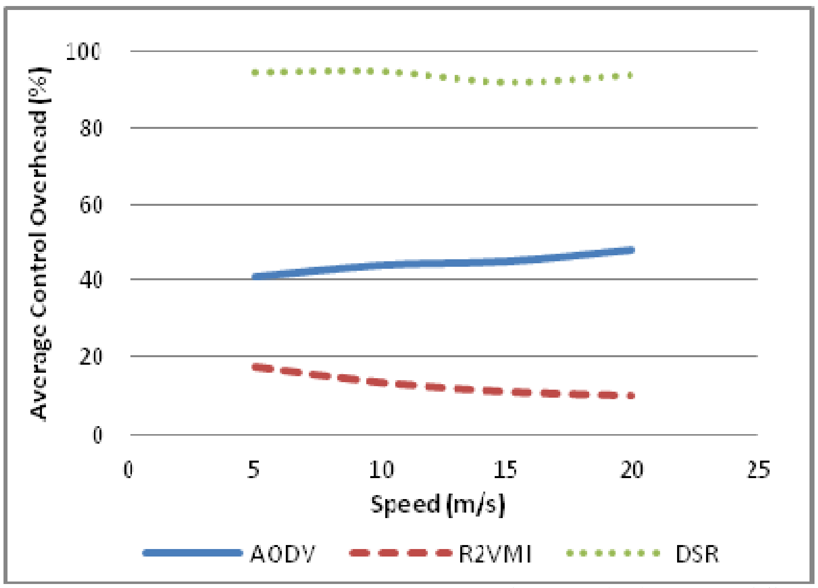

Fig. (11): Average control overhead percentage vs. speed (communication range = 250m).

Figure 10 illustrates the total number of RREQs with respect to the communication range. As expected, R2VMI has lower RREQ's due to the less route

Communication Range (speed=5m/s).

Flooding is the most fundamental method for the route discovery process in reactive (on-demand) routing protocols. Network performance can be affected by the number of flooded requests and the flooding occurrence frequency which imposes extra network traffic in the system and increases the delay in data transmission. The frequency of route discovery and its flooded request packets is related to path stability which is an essential issue in mobile adhoc networks. Figures 11 and 12 represent the average routing control overhead in different speeds and communication ranges, respectively. As it can be seen, the control overhead is degraded using R2VMI compared to DSR and AODV protocols. R2VMI protocol can control the number of request broadcasts. In first step, only the nodes which are in the same groups with the source node and in the second step, only the nodes which can make the link with LET more than the threshold LET are allowed to rebroadcast the RREQ packets. Moreover, the number of path breakages is degraded according to higher rout stability, resulting in the lower number of RREQ and RERR packets.

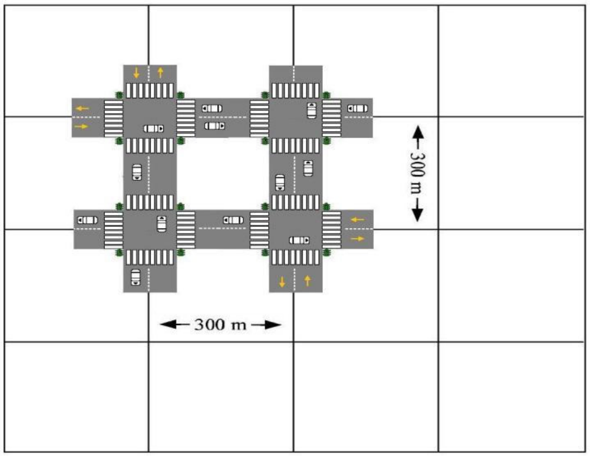

Fig. (7): The simulation environment.

The overhead of control messages and the delivery ratio of the algorithms are obtained by averaging between 20 iterations. Figures 8 and 9 show the average delivery ratio versus speed and communication range, respectively. The delivery ratio metric indicates the number of delivered data packets to the destination nodes divide by the total number of data packets sent by the source nodes. Both figures show the higher delivery ratio of R2VMI compared to AODV and DSR protocols due to the two proposed mechanisms. R2VMI improves the rout-stability by selecting the longer-lived routes.

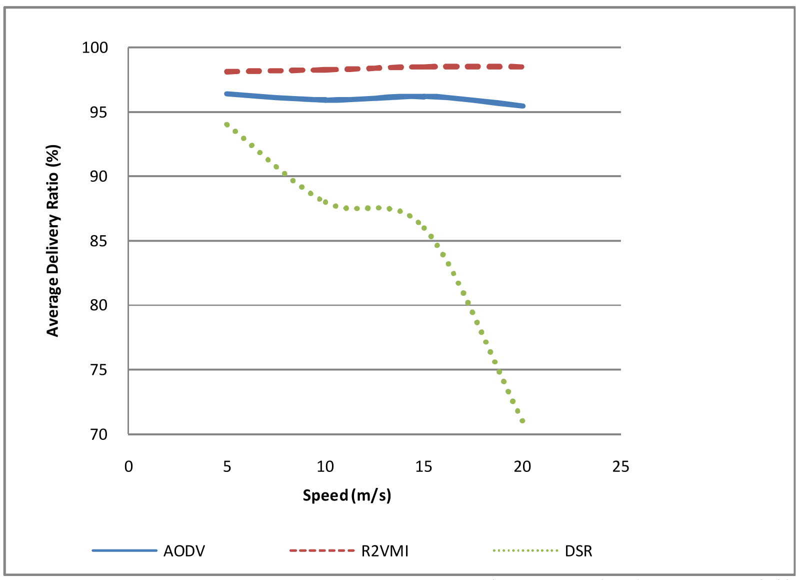

Fig. (8): Average delivery ratio percentage vs. speed (communication range = 250m).

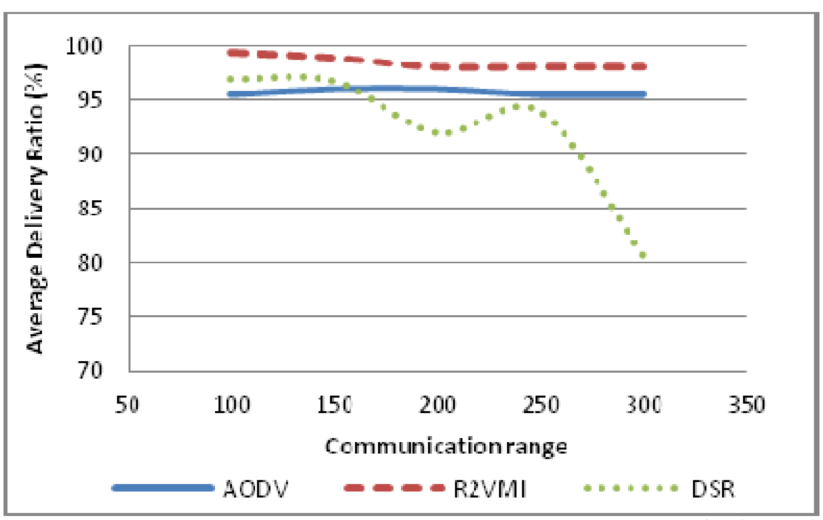

Fig. (9): Average delivery ratio percentage vs. communication range (speed = 5m/s).

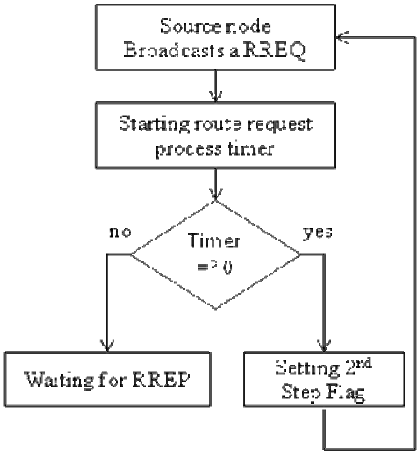

Fig. (3): Source node's flowchart of broadcasting RREQ.

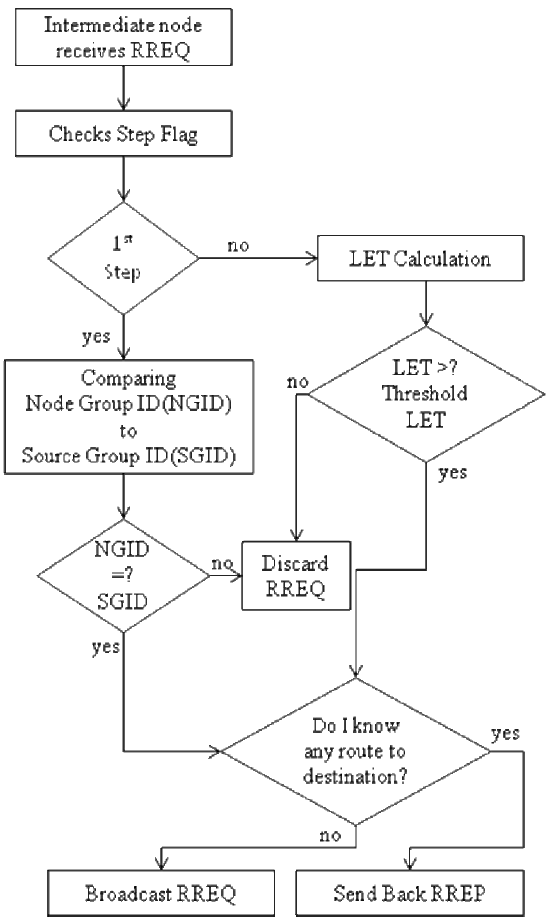

Fig. (4): Intermediate node's flowchart receiving a RREQ.

3.3. Packet Format

According to the modifications made to the AODV protocol, the following fields should be added to the RREQ frame. Figure 5 display the RREQ fields in R2VMI protocol.

AODV RREQ	Group ID	Mobility Information	Threshold LET	Minimum LET	Step

Fig. (5): R2VMI RREQ packet format.

Group ID shows the movement direction of the source node. Mobility information consists of GPS retrieved information such as position and speed of the node. The receiver node needs this information to calculate its LET. In case of rebroadcasting the RREQ, its mobility information will be replaced in this field.

RREP packet is created to send if a route to the destination is found in the intermediate nodes or the route request reaches the destination node. According to our modifications to AODV protocol, the following fields should be added to the AODV RREP frame. Figure 6 displays the RREQ fields in th
e R2VMI protocol.

AODV RREP	Mobility Information	Bottleneck LET on reverse path

Fig. (6): R2VMI RREP packet format.

The Mobility Information field is used to calculate the LET by providing position and velocity information of prior node when RREP is travelled back. The bottleneck LET field represents the shortest link duration in the reverse path. As the RREP is forwarded back to the source node, it is updated by the intermediate nodes. They compare this field with their own LET and put the shortest one in the field. Therefore the source node will be aware of the minimum LET of the links to restart a new route discovery process before link breakage.

4. Simulation Results

Network Simulator 2 (NS2) is used for simulating the proposed algorithm. Figure 7 shows the simulation environment. The simulation area and the distance between intersections set to 1200*1200 square meters and 300 meters, respectively. . The nodes reaching the boundaries will enter again form the other side. The roads are considered two-way. In each simulation iteration, 270 nodes, including 14 source nodes and 14 destination nodes are spread in the roads The vehicle speeds are selected between 5 to 20 meters per second and the communication range of nodes are chosen between 100 to 300 meters. Nodes move along the two-way roads until they reach to an intersection. They continue straight, turn back, turn right or turn left with equal probabilities of 0.25. All these parameters are chosen randomly in a uniform distribution.

paths on the map. Each node which is going to send a RREQ packet for finding a path, puts its mobility information (location and velocity vectors) and group ID in its RREQ packet and broadcast it to its neighbors.

Each node which receives the RREQ packet checks its sequence number to avoid replying to redundant requests and if the request is new then checks its group ID. If the receiving node has the same group ID and also it currently has a route to the destination, it will send the RREP in response to the RREQ but if it has no route to the destination, this intermediate node adds its mobility information to the RREQ and rebroadcasts it. The process will continue till the RREQ responded by the destination or an intermediate node which has a route to the destination. The new route discovery process will begin just before breakage of the existing path. The existing path break time is estimated using Link Expiration Time (LET). LET can be calculated using Global Positioning System (GPS) information or Doppler shift [4]. Considering figure 1,

$$\mathrm{LET} = \frac{(-(ab+cd)+\sqrt{(a^2+c^2)R^2-(ad-bc)}}{(a^2+c^2)} \qquad (1)$$

in which

$$a = \nu_i \cos\theta_i - \nu_j \cos\theta_j$$

$$b = x_i - x_j$$

$$c = \nu_i \sin\theta_i - \nu_j \sin\theta_j$$

$$d = y_i - y_j$$

These parameters refer to positions, speeds and velocity angles of node j and node i.

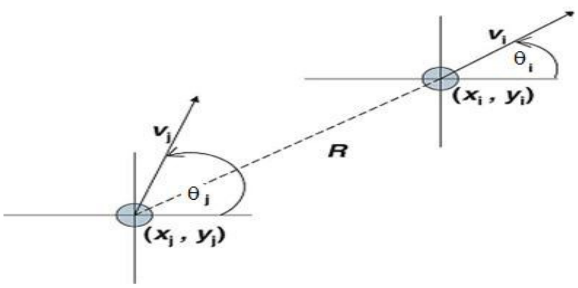

Fig. (1): LET calculation.

3.2. Step two

Route establishment using the same group ID results in more stable routs and discarding the RREQ with different group IDs will reduce the overhead of the network at the expense of reducing the routing efficiency in some situations.

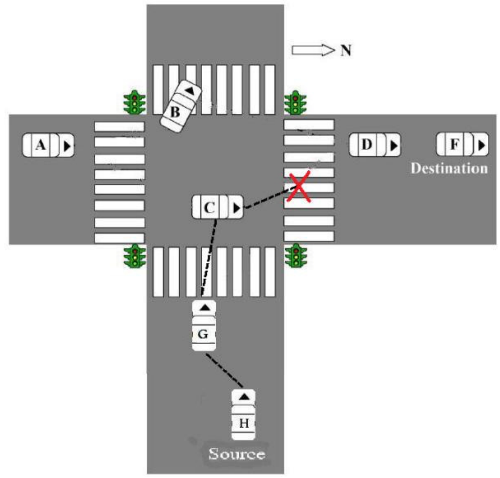

Fig. (2): RREQ between H and F; Node C is not permitted to rebroadcast the RREQ.

For example in the situation of figure 2 which node H is interested to send data packets to the node F, It begins the route discovery process. In this scenario when the RREQ is received by Node C, as it is in different group, the RREQ is not rebroadcasted and no rout can be discovered.

In the R2VMI, the second step is designed to deal with such a situation which source node does not receive any RREP message and its timer is expired. In this step, node H sends another RREQ with a flag that informs the intermediate nodes to replace the group ID comparison with the threshold LET mechanism. In this method, each node rebroadcasts the RREQ if it has a higher LET value than a threshold value. I.e. the link should be connected more than this threshold value.

Figure 3 shows the flowchart of the source node RREQ, when it has no routes to the destination available in its routing table. It broadcasts the RREQ packet and waits for the corresponding RREP. If it does not receive any RREP packet till a specific time, it begins the second step by setting the flag and rebroadcasts the new RREQ. Figure 4 illustrates the flowchart of the intermediate nodes receiving a RREQ. It checks the step flag. In the first step, this node compares its group with group ID field in RREQ but If the routing algorithm is in second step, this node calculates the LET of its link and rebroadcast the RREQ if its LET is greater than the threshold LET in the packet.

The remainder of this paper is organized as follows; related works are reviewed in section 2. Section 3 describes the proposed routing algorithm. The simulation results are presented in section 4 and the paper is concluded in Section 5.

2. Related Works

The ad hoc routing protocols which are designed for MANETs are categorized into three types: reactive (such as ABR (Associativity-Based Routing), DSR (Dynamic Source Routing), AODV (Ad-hoc On-demand Distance Vector)), proactive (such as DSDV (Destination-Sequenced Distance Vector), WRP (Wireless Routing Protocol)) and hybrid (such as ZRP (Zone Routing Protocol)). However, they are not suitable for efficient V2V communications because the control messages in reactive protocols and route update timers in proactive protocols are not used to predict path breakages and are needed to be modified. Due to the highly dynamic nature of the VANETs, proactive and hybrid routings are not practical.

ABR [13] broadcasts associativity "ticks" messages periodically in order to calculate the duration of the links. The degree of stability is considered high, if a node has high associativity ticks with its neighbor node. The nodes with high degree of associativity are selected by the destination node. If we assume ABR in a highly mobile network, such as a VANET, all nodes within a time range regardless of their direction and speed would receive equal associativity ticks. In this case, high associativity means that the neighbor node has been within communication range for a substantial period of time, while the mobile node may already be close to the edge of the communication boundary, so it does not ensure that the mobile node will continue to remain within range. On the other hand, a suitable node which provides a more stable link may have just come into the range of the target node and due to having a lower associativity value is not chosen. Thus, ABR would not be suitable for the considered VANET network.

DSR [16] is an on-demand protocol and is based on source routing. It utilizes a route cache where routes it has learned so far are cached. Therefore, a source first checks its route cache to determine the route to the destination. In route discovery, the source floods a request packet through the ad hoc network, and the reply is returned by either the destination or another host, which can complete the request from its route cache. Each query packet has a unique ID and an initially empty list. When receiving a query packet, if a node has already seen this ID or it finds its own address already recorded in the list, it discards the copy and stops flooding; otherwise, it appends its own address in the list and broadcasts the query to its neighbors. If a node can complete the query from its route cache, it may send a reply packet to the source without propagating the query packet further. DSR is suitable for the environments where only a few sources communicate with infrequently accessed destinations, so it may result in large delay and large communication overhead in highly dynamic environment with frequent communication requirement.

AODV [14] is an on-demand routing protocol that builds routes only when needed. When a source has a packet to send but does not have a route to the destination, it broadcasts a Route Request (RREQ) message. Nodes that do not have the route to the destination, upon the reception of a unique RREQ message, forward it to their neighbors and update their route tables to set up a reverse route back to the source. Intermediate nodes that have a fresh route to the destination respond by means of a Route Reply (RREP) message directed to the originating source. As the RREP propagates back to the source, intermediate nodes set up forward pointers to the destination. Once the source receives the RREP, it starts the transmission of packet. In AODV, a sequence number is used to prevent routing loops and nodes must use the information with the most up-to-date sequence number while making routing decisions. When a link along the active route breaks, the node upstream of the broken link propagates a Route Error (RERR) message towards the source to inform the source of the link failure. Considering VANET characteristics, AODV seems to be the best choice as a basis for improvement.

Different routing strategies have been defined based on prior ad hoc network architectures by targeting the specific VANET needs of scenarios and applications, and some literature have focused on protocol parameter optimizations to improve the QoS [18-20]. There are several surveys about VANET routing protocols (e.g. [2] and [17]). ROMSGP (Receive On Most Stable Group-Path) [3] is one of the well-known AODV-based routing protocols designed for VANETs. It uses the vehicles' movement information (e.g., position, direction, speed, and digital mapping of the roads) to predict a possible link-breakage event prior to its occurrence. Vehicles are grouped according to their velocity vectors. This kind of grouping ensures that vehicles, belonging to the same group, are more likely to establish stable single and multihop paths as they are moving together. The frequency of flood requests is reduced by elongating the link duration of the selected paths. This protocol works well if the source and the destination are in the same group (direction) but faces problems if they are in different groups (directions). In our proposed algorithm, called "Reliable Routing protocol based on Vehicle Movement Information" (R2VMI), we use node grouping idea and resolve the ROMSGP problem introducing a two steps routing algorithm.

3. The Proposed Routing Algorithm (R2VMI)

The proposed routing algorithm named R2VMI is based on the AODV routing protocol which is one of the most popular algorithms in MANETs. R2VMI works in two basic steps.

3.1. Step one

In this step, similar to the ROMSGP protocol [3], routing paths are selected based on the nodes' direction. The direction of the vehicle is estimated in 4 basic orthogonal

A Reliable Routing Protocol for Wireless Vehicular Networks

Mohsen Maadani(1) - Seyed Ahmad Motamedi(2) - Mostafa Mohammadi Noshari(3)

(1) Ph.D Condidate - Department of Electrical Engineering, Shahr-e-Qods Branch, Islamic Azad University
(2) Proffesor - Department of Electrical Engineering, Amirkabir University of Technology
(3) Ms.A - Department of Electrical Engineering, Amirkabir University of Technology

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Recently, much attention has been paid to Vehicular Ad hoc Network (VANET). VANETs address direct communication between vehicle-to-vehicle and vehicles to roadside units (RSUs). They are similar to the Mobile and Ad hoc Networks (MANET) in their rapid and dynamic network topology changes due to the fast motion of nodes. High mobility of nodes and network resources limitations have made the routing, one of the most important challenges in VANET researches. Therefore, guaranteeing a stable and reliable routing algorithm over VANET is one of the main steps to realize an effective vehicular communications. In this paper, a two-step AODV-based routing protocol is proposed for VANET networks. At first, node-grouping is done using their mobility information such as speed and movement direction. If the first step cannot respond efficiently, the algorithm enters the second step which uses link expiration time (LET) information in the formation of the groups. The goal of the proposed protocol is increasing the stability of routing algorithm by selecting long-lived routes and decreasing link breakages. The comparison of proposed algorithm with AODV and DSR protocols is performed via the Network Simulator NS-2. It is shown that the proposed algorithm increases the delivery ratio and also decreases the routing control overhead.

Index Terms: Inter-Vehicular Communications (IVC); link breakage; mobility information; stability; Vehicular Ad hoc Networks (VANET).

1. Introduction

A Mobile Ad hoc Network (MANET) is a set of mobile nodes that can move dynamically and arbitrarily. The popularity and low-price of IEEE 802.11 standard has lead the vehicle manufacturers to improve their products' safety and comfort using a short range communication between vehicle-to-vehicle (V2V) and vehicle to roadside unit (RSU) on the streets [1]: Vehicular Ad hoc Network (VANET). They are a special case of MANETs with the motions and velocities of the nodes constrained by the predefined streets, speed limits, level of congestion in the streets, and traffic control mechanisms. Moreover, processing power and storage capacity are not a problem in VANETs [3]. At present, the IEEE group is completing the IEEE 802.11p and IEEE 1609 final drafts, known as "Standard Wireless Access in Vehicular Environments" (WAVE), specifically designed for VANETs [17]. The primary application of these networks is the Intelligent Transportation Systems (ITS), which aims to increase road safety and transportation efficiency through traffic monitoring, traffic flow control, collision avoidance, and real-time diversion routes computation [2]. Navigational devices such as Global Positioning System (GPS) can provide the required mobility information such as position, direction and speed of the vehicle. Other applications include internet connectivity, location-specific advertisements, etc. CarLink [6], ADASE2 [7], CAMP [8], CarTALK2000 [9], FleetNet [10], California PATH [11] are a few examples of ITS. Dedicated Short Range Communications (DSRC) are one-way or two-way short to medium range wireless communication channels in the 5.9GHz licensed band specifically assigned for ITS use. Currently its main use in Europe and Japan is in electronic toll collection. DSRC systems in Europe, Japan and U.S. are not, at present, compatible.

Due to the dynamic nature of the mobile nodes in the network such as highly dynamic topology, frequently disconnected links, discovering and maintaining reliable communication routes are the most important challenges in VANETs [1]. The main goal of a routing protocol is to establish a correct and efficient route between a pair of nodes to deliver messages in a timely manner with a minimum overhead [5]. In this paper, we consider a VANET network made of a number of mobile nodes dispersed over a geographical area where only Inter-Vehicular Communications (IVC) exists. The goals of the proposed algorithm are increasing path stability and delivery ratio while reducing control overhead. This method uses the movement direction of the nodes as the clustering criteria, and link expiration time (LET) parameter in the route discovery process to find more stable routes.