A Stable Route and the Remaining Time Prediction to Send a Data Packet in Highway Environment

Mohamed Nabil[1(✉)], Abdelmajid Hajami[2], and Abdelkrim Haqiq[1]

[1] Computer, Networks, Mobility and Modeling Laboratory, FST, Hassan 1st University, Settat, Morocco
nabilmed77@gmail.com, ahaqiq@gmail.com
[2] LAVETE Laboratory, FST, Hassan 1st University, Settat, Morocco
abdelmajidhajami@gmail.com

Abstract. There are numerous research challenges to develop safety or non-safety applications in vehicular ad hoc networks (VANETs). One of the critical issues consists in designing a scheme that solves the local maximum problem, reduces contention phase, increases the route lifetime and reduces the frequent path disruptions caused by high mobility of vehicles. Existing schemes do not take into consideration all these issues. For this reason, this paper addresses these issues for non-safety applications in a highway environment. We propose a scheme that strives to find a stable route, minimize contention phase and predict the route lifetime and the average transmission time of the data packets. Our scheme increases the percentage of packets delivery, reduces the control overhead and decreases number of error messages generated during transmission of data packets as function of vehicles density.

Keywords: Stable route · Prediction the route lifetime · Stable neighbor · IDM_LC · Highway scenario · VANET · NS2

1 Introduction

A Vehicular Ad hoc Network (VANETs) is a case of MANET where nodes are vehicles. VANETs provide a wireless communication between vehicles, using a dedicated short range communication. Each vehicle can communicate with other vehicles directly through the device On Board Unit (OBU) forming vehicle to vehicle communication (V2 V) or communicate with fixed equipment beside the road, referred to as Road Side Unit (RSU) forming vehicle to infrastructure communication (V2I). These types of communications allow vehicles to share different sorts of information. The aim behind sharing this information is to provide a safety message to warn drivers about expected hazards in order to decrease the number of accidents by enabling a set of safety applications and to provide passengers comfort by enabling a set of non-safety applications. These applications can provide drivers or passengers with weather and traffic information and detail the location of the nearest restaurant, petrol station or hotel. They can allow passengers to play online games, access the internet and check their emails while the vehicle is connected to the infrastructure network [1].

A. Abraham et al. (eds.), *Proceedings of the 16th International Conference on Hybrid Intelligent Systems (HIS 2016)*, Advances in Intelligent Systems and Computing 552,
DOI 10.1007/978-3-319-52941-7_2

Several challenges await researchers to develop these applications. Among these challenges is to design an efficient routing protocol that can increase the route lifetime duration, deliver a packet in a minimum period of time and be suitable for high density of vehicles. Hence, this protocol will increase the percentage of packets delivery with few dropped packets and will reduce the control overhead and the increasing throughput.

Numerous schemes were proposed to address this issue. Among them the ones are based on the reactive approach in which the next forwarder is chose on real time. Schemes of this approach aim to reduce the number of hops, to increase the route lifetime and to select the stable route and the shortest distance path between source and destination. A contention phase will be created whenever selecting the next forwarder. This contention phase introduces few units of delay which will be substantial in multi-hop communication in dense environment. Selecting the stable routes can lead to the local maximum problem. These schemes still suffer from frequent breaking of the route during the data transmission. Hence, several data packets will be lost.

To overcome these limitations, we propose a routing protocol through which the choice of the route is based on selecting the most stable neighbor with the transmitter of route request message giving priority to neighbor that travels in the same direction of the transmitter movement. This protocol also allows predicting the lifetime of the route and the transmission average time of the data packets; hence, it allows predicting the left time of route to send a data packet to minimize the number of errors and the number of the lost data packets. To minimize contention phase, each vehicle periodically determines two most stable neighbors (one of them is in the front and the other is in the back of vehicle) as well as their stability time.

The rest of the paper is organized as follows. Section 2 presents related work. Section 3 shows our scheme. Section 4 presents simulation and results. Finally, we give a conclusion in Sect. 5.

2 Related Work and Motivations

One of the well-known schemes is GPSR [2]; it uses the greedy forwarding method whereby next hop is chosen based on node that is closer to the destination node. When the local maximum problem happens, GPSR switches to a perimeter routing algorithm. In a highway environment, this protocol does not select the most stable route that decreases the frequency of breaking route; hence the increase of the number of error messages because it does not take in consideration the route stability at forwarding packets. The authors in [3] studied LAR [4] in highway scenario. The protocol was tested against vehicles density for various metric (throughput, packets delivery ratio, end to end delay, and overload) with a high speed. The protocol has good performance in a communication environment and it is sensitive to the density of vehicles and the number of lanes. D-LAR [5, 6] is a greedy approach that combines LAR with DIR [7] to forward packets in the request zone to the direct neighbor having direction closest to the line drawn between source and destination. This protocol does not take into consideration the direction of movement of the forwarder vehicle. Hence, it cannot choose the most stable route in the case where there are two neighbors of the sender, one of them travels in opposite direction and it is the closest to the line drawn between source and destination. MOPR [8] uses the moving information of vehicles to predict future positions of vehicles and to estimate the time needed for the transmission of data to decide whether a route is likely to be broken or not during the transmission time. MOPR allows avoiding link broken by high mobility of vehicles during data transmission. The performance of this algorithm depends on the used transmission protocols. In [9], the authors have grouped vehicles according to their direction of movement. The stability of the communication is ensured by the choice of the most stable path using the ROMSGP scheme. This choice is made based on the calculation of LET of each path. The longest LET path is considered to be the most stable. The authors did not take into consideration the case where vehicles travel in opposite direction if there is no vehicle travelling in the same direction of group movement. RBVT-R [10] is a reactive source routing protocol for VANETs that creates routes on demand by using "connected" road segments. A connected road segment is a segment between two adjacent intersections with enough vehicular traffic to ensure network connectivity. When a node receives a new Route Discovery (RD), it holds the packet for a period of time inversely proportional to the distance between itself and the sending node. After the waiting period, a node rebroadcasts the RD packet only if it did not notice that this packet was rebroadcast by nodes that are located further on the same road segment. The waiting period becomes substantial in multi-hop communication in highway. Besides, the protocol not takes into count the route stability because the RD packet will be rebroadcasted by the vehicles that are located further on the same road segment. SCRP [11] is a distributed routing protocol that builds stable backbones on road segments using connected dominating sets (CDS). The vehicle with the lowest SF (vehicle's stability factor) is added to the backbone. The latter chooses the neighbor with the lowest SF as the next forwarder; hence, it becomes a backbone vehicle. Then, it selects the next vehicle to be included in the backbone. This procedure is repeated until the all of road segment is covered. In highway environment, this scheme builds one path only on long of road in a proactive manner. Hence, all source vehicles share the same path or part of path. While the number of source vehicles increases, the performance of protocol decreases (throughput, packets delivery ratio, end to end delay).

Besides of these above issues of these routing protocols, most of them are focused to improve the urban environment. They do not take into count the highway environment which characterized by high speed vehicle mobility. This constraint makes routing very challenging in highway. Our scheme strives to minimize contention phase, avoid route break before of its apparition, by predicting the remaining time of route to send a data packet. Also, it allows finding stable route by selecting the most stable neighbor of the transmitter of route request message giving priority to the neighbor that travels in the same direction of the movement of this transmitter.

3 Stable Route and Remaining Time Prediction (SRRTP)

SRRTP is designed for non-safety applications in highway environment. It is on demand routing protocol, it is similar to LAR [4] and AODV [12] protocols.

The network model consists of one road ended by two intersections in highway environment or in urban environment for roads segments. This road has the same characteristics such as length, width, number of lanes. Each lane has a distinctive traffic density (see Fig. 1). Each vehicle is equipped with a global positioning system (GPS) that provides information about its location, speed, and direction. Finally, each source node knows the location of the destination by using a location service such as RLSMP [13].

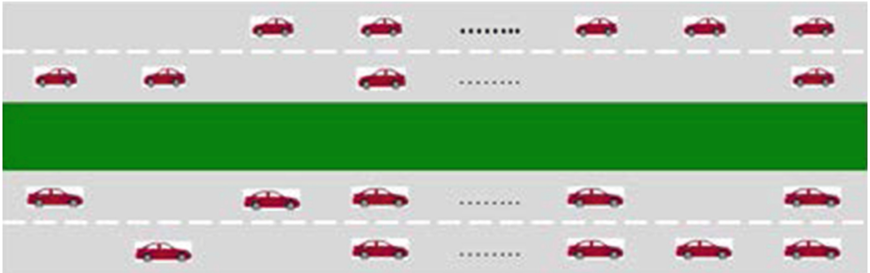

Fig. 1. Bi-directional highway model

SRRTP is based on the following considerations: most-stable neighbor, minimization contention phase, route lifetime prediction, transmission time prediction of the data packet and route construction.

3.1 Most-Stable Neighbor

This section is presented in our work [14] and extended in our works [15, 16]. There are four cases to calculate the time (t) of each neighbor.

First case: The vehicles I and A have the same direction of movement and do not have the same velocity at time t0 [15, 16]:

$$t = \frac{X_I - X_A}{V_A - V_I} + \frac{\sqrt{R^2 - (Y_I - Y_A)^2}}{|V_A - V_I|} \tag{1}$$

Second case: The vehicles I and A have the same direction of movement and they have the same velocity at time t0 [16]: In this case, the transmitting vehicle calculates the distance d between itself and each neighbor which has the same speed by this formula:

$$d(A, I) = \sqrt{(X_A - X_I)^2 + (Y_A - Y_I)^2} \tag{2}$$

The vehicle which has the closest distance from the R/2 will receive and transmit the route request message.

Third case: The forwarding vehicle has an opposite direction of its neighbor at time t0 and they are approaching each other [11].

$$t = \frac{R + d(A, I)}{|V_A + V_I|} \tag{3}$$

Fourth case: The forwarding vehicle has an opposite direction of its neighbor at time t0 and they are moving away from each other [11].

$$t = \frac{R - d(A, I)}{|V_A + V_I|} \tag{4}$$

3.2 Minimization of Contention Phase

If each vehicle which has a route request message will perform operations to select the vehicle that will receive and retransmit the message, the accumulation time of these operations of all participating vehicles in route becomes substantial. Therefore, these operations increase the route request time between sources and destinations. Hence, decreasing the route lifetime at transmission of data packet and a new route request message can be triggered in entire network. To avoid this contention phase, each node periodically determines the most stable neighbor onward and the most stable neighbor backward; at the same time, it determines the time of stability of each of these neighbors. Each vehicle seeks these most stable neighbors (onward and backward) among those traveling in the same direction of its movement. If there are no neighbors that have the same direction of its motion, then it searches among those traveling in the opposite direction. Hence, we give priority to the neighbors that travel in the same direction of the transmitter movement to receive and forward the route request message.

The vehicle which has the route request message chooses (among its neighbors in the half-circle of its coverage area in the side closing to the destination) that has the longest time for receive and forward this message.

3.3 Route Lifetime Prediction

To predict the lifetime of the route established between sources and destinations, each source adds the stability time (TS) (it is calculated and determined in Sects. 3.1 and 3.2) of the next transmitter relative to the current transmitter in the route request packet. Each vehicle receives this route request packet compares the stability time of the next hop to the one in the request packet. The shortest stability time will put in the route request packet instead of the other.

TS = min (E ($TS_{i,j}$)) where E is the set of links between vehicles that build the route between source and destination. E ($TS_{i,j}$) is the set of lifetimes of these links between i and j vehicles that build the route between source and destination.

When the destination receives the route discovery packet, it copies the TS, its current location, its current speed and current time in the route reply packet and it sends this packet back downstream at source.

3.4 Transmission Time Prediction of the Data Packet

Transmission time of a data packet between the source and destination get changed according to the density of vehicles in highway (see Fig. 2). Therefore, it is hard to predict a constant value during the time of the simulation. To solve this problem, each time the destination receives a data packet, calculates and stores the average time of data packet transmission. When a route request reaches to the destination, the latter sends the average time in the route reply message that will be sent back downstream to source. The latter calculates the remaining time of route between itself and the destination, if it wants to send a data packet. If time left of route is less than the average transmission time of a data packet, the source launches a new route request; otherwise, it sends the data packet.

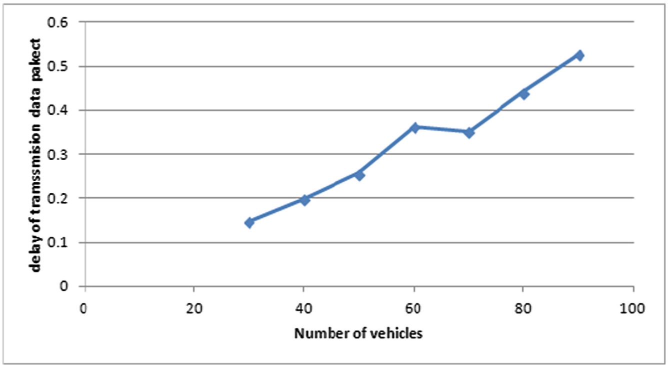

Fig. 2. Average transmission time of a data packet versus vehicles density

3.5 Route Construction

When the source S wants to send a data packet to the destination D, it checks its routing table. If there is a route to the destination (enabled route), S calculates the remaining time of route between itself and the destination.

If this time of route is strictly greater than the average transmission time of a data packet, the source sends the data packet; otherwise, S checks its list of neighbors to the destination. If D is listed then S updates the route to the destination and sends the data packet; otherwise, S generates a new route request message. If D is located towards the direction of S movement, S sends the route request to the neighbor that is onward (the neighbor onward that remains the longest time in the S coverage area); otherwise, S sends the route request to the neighbor that is backward (the neighbor backward that remains the longest time in the S coverage area). Each vehicle (I) receives a route request message it will forward the message to its onward vehicle if it received the message from its back vehicle, otherwise it will forward the message to its back vehicle. This operation will be repeated until arrival to destination. When the destination receives the route discovery packet, it copies the stability time (TS), average time of data packet transmission, its current location, its current speed and current time of speed in the route reply message and sends it downstream toward the source.

4 Simulation and Results

We have used the pattern IDM-LC that is a microscopic mobility model in the tool Vehicular Ad Hoc Networks Mobility Simulator (VanetMobiSim) [17, 18] and we have used NS2 [19] to implement our protocol. Vehicles are deployed in a 4000 m × 100 m area. This area is a highway with four lanes bidirectional; its ends are set by traffic lights. Vehicles are able to communicate with each other using the IEEE 802.11 MAC layer. The vehicles' speed fluctuates between 0 m/s and 27 m/s. We have considered packet size of 512 bytes, Simulation Time of 400 s, hello interval of 1 s and packet rate of 4 packets per second. We setup ten multi-hop CBR flow vehicles over the network that start at different time instances and continue throughout the remaining time of the simulation. The transmission range is kept at 250 m. Simulation results are averaged over 20 simulation runs. Location-Aided Routing (LAR1) is used to compare it with our protocol; because we developed this protocol from source code of LAR1. These protocols are evaluated for packet delivery ratio, normalized routing load, number of generated errors and number of errors received at source according to vehicles density.

Packet delivery ratio: Figure 3 shows that our scheme has good packet delivery ratio and it clearly outperforms LAR1. This is because our scheme forwards data packets over roads by predicting both the route lifetime and the time of transmission of the data packet. Also, it chooses a stable route. But with the increase in network density, the packet delivery ratio of the two schemes decreases. This is because when network density increases, the transmission time of data packets increases; and also we do not yet use a method such as carry-and-forward to recuperate the lost data packets.

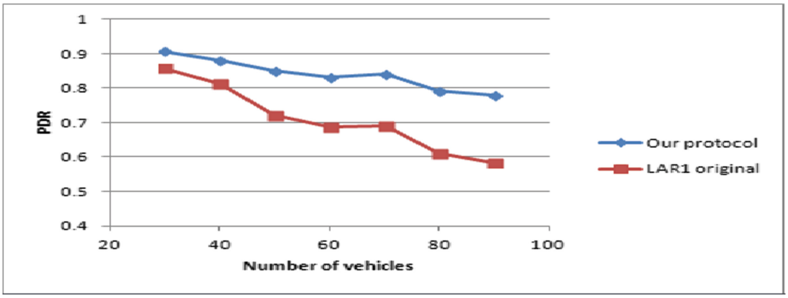

Fig. 3. PDR as a function of vehicle density

Normalized routing load: Figure 4 shows that Normalized Routing Load increases with increasing the density of network. Our scheme has a lowest normalized routing load compared to LAR1. This is explained by the decrease of route discovery process in reason of the select the stable route and the predicting the remaining time of route.

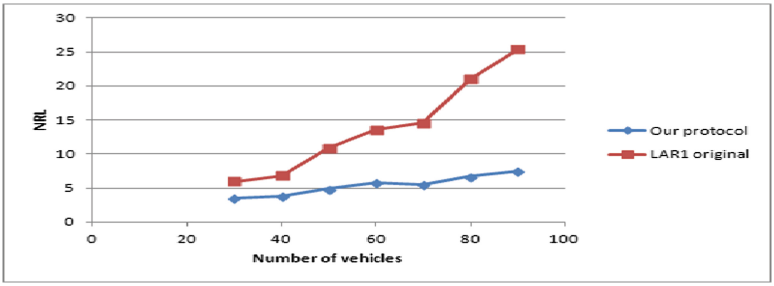

Fig. 4. NRL as a function of vehicle density

Number of error messages generated during transmission of data packets: Fig. 5 shows that the number of errors increases with increasing the density of the network. Our scheme has the lowest number of errors compared to LAR1. This is explained by predicting the route lifetime and the time of transmission of the data packet. Therefore, our protocol calculates the time left of route to the destination. So, it takes the decision before sending data packets.

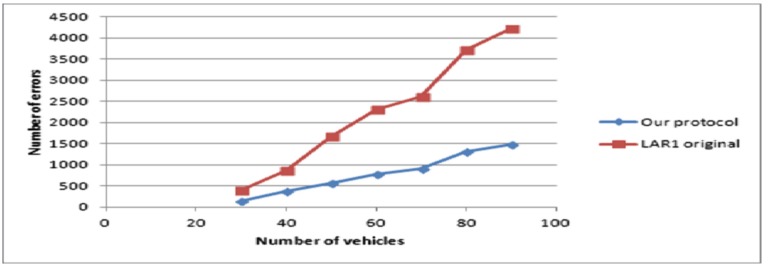

Fig. 5. Number of errors as a function of vehicle density

Number of error messages received at source: Fig. 6 shows the number of error messages received at source with varying network density. The percentage of error messages that arrived at source is always over 70% compared to that of LAR1. This is because of the stability of our protocol.

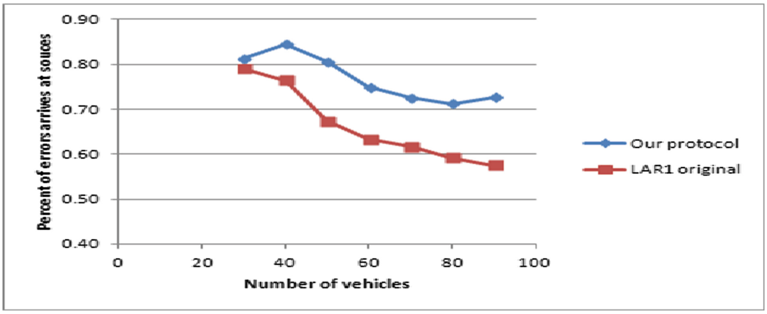

Fig. 6. Number of errors received at source as a function of vehicle density

5 Conclusion

Our protocol is designed to improve the communication in vehicular ad hoc networks in highway scenarios for non-safety applications. It strives to find a stable route, minimize contention phase and predict the time left of route to the destination before sending data packets to avoid the route disruption prior to its happening. Our protocol is based on four considerations that are stable route, minimization of contention phase, route lifetime prediction and transmission time prediction of the data packet. Our scheme increases the percentage of packets delivery, reduces the control overhead and decreases number of error messages generated during transmission of data packets. It is evaluated as function of vehicle density and it is compared with LAR scheme1. It is found that it outperforms LAR1 original in highway environment by using IDM_LC to generate realistic mobility files.

For future work, we will study the case of eliminating of error messages. Because, the source vehicle is able to take the decision about the transmission of data packet by calculating the time left of route to destination prior to send data packets.

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Proceedings of the 16th International Conference on
Hybrid Intelligent Systems (HIS 2016)
Abraham, A.; Haqiq, A.; Alimi, A.M.; Mezzour, G.; Rokbani,
N.; Muda, A.K. (Eds.)
2017, XIX, 601 p. 238 illus., Softcover
ISBN: 978-3-319-52940-0