AN INTELLIGENT MOVEMENT-BASED ROUTING FOR VANETs

Hamid Menouar[†], Massimiliano Lenardi[†], and Fethi Filali[‡]
[†]HITACHI Europe, “Le Thélème”, 1503 Route des Dolines, 06560 Sophia Antipolis, France
Phone: (+33)4 8987 4100, Fax: (+33)4 8987 4199
E-mail: {Hamid.Menouar, Massimiliano.Lenardi}@hitachi-eu.com
[‡]Institut Eurecom, 2229 route des Crêtes, BP-193, 06904 Sophia-Antipolis, France
Phone: (+33)4 9300 2916, Fax: (+33)4 9300 2627
E-mail: Fethi.Filali@eurecom.fr

ABSTRACT

Vehicular Ad hoc NETworks (VANETs) are a specific case of Mobile Ad hoc NETworks (MANETs), with high nodes mobility specification, and a large energy resource which could extend coverage and system lifetime. Frequent topology changes let VANETs have special research interests, like medium access control and routing optimization. In a previous work, we proposed a MOvement Prediction-based Routing (MOPR) for VANETs that improves the routing process by selecting the most stable route with respect to the movement of the vehicles. In this paper, we present further MOPR optimizations concerning the reduction of its overhead (bandwidth optimization) and its implementation and performance evaluation over AODV using the NS2 AODV-UU implementation.

KEYWORDS: Vehicle to vehicle communications, Routing protocol, Movement prediction, Information delivery.

INTRODUCTION

Vehicle-to-Vehicle Communications (V2VCs) are considered as a specific case of the traditional Mobile Ad hoc Network (MANET) communications, with the main difference that nodes are vehicles. This difference seems light, but the consequences are important. Having more resources (in terms of both storage and power) for V2VCs is an important advantage for the nodes, which can then have longer transmission ranges and virtually unlimited lifetimes [1]. Furthermore, in vehicular networks, positioning systems, such as GPS or Galileo, can be used continuously, without power constraints.

Another advantage in such networks is the non-random mobility of the vehicles; generally it is limited by roads which can be represented by digital maps. Also, the vehicle movements are limited by road rules which again may be digitally mapped.

In parallel to those advantages, V2VCs have some disadvantages related to the relatively high speed of vehicles which causes topology fast and frequent changes. An efficient support of access and routing protocols in vehicular environment is then facing several issues: available bandwidth estimation, medium access control, hidden and exposed nodes problem, high mobility, support of heterogeneous vehicles, node movement, fast speed, obstacles and fast handover. So, existing MANETs topology-based routing protocols are not suitable (as they are) for V2VCs [2, 3].

In [4] we proposed a MOvement Prediction-based Routing (MOPR) protocol for V2VC, that tries to predict the future vehicles' positions in order to avoid link ruptures so that frame loss rate is reduced while improving the network efficiency. In this paper, we present an improvement of MOPR by reducing the Receive Request (RREQ) packet size, and therefore reducing its bandwidth control overhead. In this work, MOPR is implemented on the AODV implementation of the Uppsala University (AODV-UU) [5] which is the NS2 implementation the most compliant with the AODV RFC.

The remainder of this paper is organized as follows: First, we give some motivations to use movement prediction to improve routing in V2VCs, then we overview the MOPR basic process with presenting the improvements, and before concluding the paper we present the MOPR AODV-UU implementation and some preliminary simulations results.

MOTIVATIONS BEHIND USING MOVEMENT PREDICTION

Several applications may be provided for V2VC. Indeed, vehicles can exchange real-time information, drivers can be automatically assisted, or passengers play distributed games, etc. In these cases we need a real-time transmission and sometimes we need to transmit data with a relatively large size over multi-hop paths. Hence, it is not suitable to use traditional routing protocols designed for MANETs because the specific characteristics of VANETs related to vehicles high speed.

Related to the data size to transmit, and related to the application for which the transmission will be used, sometimes it is better to select the most stable route among the available ones. For example, in case of relatively large data size to send or a real time transmission, we have to select the route that can guarantee as much as possible that link failures will be avoided during the whole transmission time.

Most of the reactive routing protocols, like AODV, select the shortest route, in terms of the number of hops, without knowing if they will be able to guarantee the connection during the whole transmission time. So, in V2VCs, using the shortest route is not every time the best choice. Because of the high movement of vehicles, the shortest route can be cut during the transmission, while another route, longer, but more stable, can exist.

The above motivations led us to use the movement prediction of vehicles in order to know which route will be the most stable during the transmission time.

MOPR OVERVIEW AND IMPROVEMENTS

Supposing that we have several potential multi-hop routes between a source vehicle and a destination vehicle, we propose to choose the route which is the most stable when considering the movement conditions of the intermediate vehicles with respect to the source and the destination vehicles. The intermediate vehicles can be other vehicles, stationary vehicles, or gateways along the roads.

By knowing the speeds and the directions of the nodes involved in the routes (including source and destination), MOPR can roughly predict their positions in the near future; eventually, by knowing the size of the data to send, it can know how long the transmission of each data frame will take.

Therefore, the optimal route selection for data transmission will provide the route composed by intermediate vehicles that are not likely to cause a rupture of the transmission during the transmission time because of their mobility. This approach should help as well in minimizing the risk of broken links and in reducing data loss and link-layer and transport retransmissions.

In [4], a first version of MOPR was presented. It was implemented on the classical AODV routing protocol using the Network Simulator NS2 [6]. In that version of MOPR each vehicle before forwarding the receive request (RREQ) packet, it adds in this packet its movement information (position, speed, and direction). When receiving the RREQ packet, the destination vehicle calculates if the corresponding route is more stable than the one already saved in its local routing table, eventually updates it and replies to the source vehicle again. This solution works well and decreases the transmission link failures, but it does not guarantee a good scalability in terms of networks size because of the data size of the RREQ packet which becomes more and more big in large networks.

In this paper we present a new version of MOPR, which is based on the same technique used in the old version. The main improvement is done by decreasing the RREQ packet size and by optimizing the most stable route calculation.

In this proposal, when receiving a new RREQ packet, an intermediate vehicle knows the position and the movement information of the neighbor from where the RREQ came. And by knowing its own position and movement information, it knows the current distance between it and that neighbor. Now, it has to estimate this distance after a duration time that corresponds to the transmission duration time, which is communicated over the RREQ packet.

In the following, we explain how to estimate the future distance between two vehicles i and j in the near future after a duration time Δt.

Let us assume two vehicles A and B moving along two directions from time t_0 to time t_1, with respectively two different static speeds $v1$ and $v2$ as illustrated in Figure 1. $D_0$and D_1 are the distances between the two vehicles at times t_0 and t_1 respectively. The lifetime of the link $[A - B]$ depends on the distance between A and B and their communication ranges.

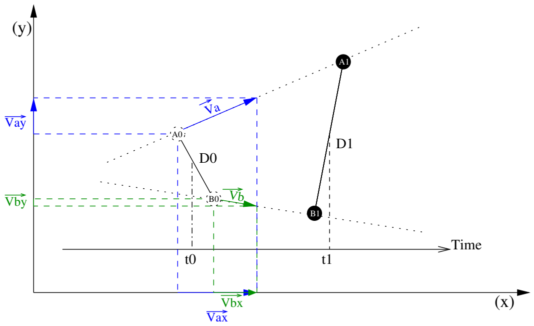

Figure 1: Schematic for Lifetime prediction.

$$\text{We have } \Delta t = t_1 - t_0$$

First of all, we have to calculate the future position (x, y) of both A and B at time t_1. Suppose that $Ax_1$and $Ay_1$are the positions of the vehicle A on the X and Y axes respectively, and $Bx_1$and $By_1$are the positions of the vehicle B on the X and Y axes respectively.

$$\left\{ \begin{array}{c} Bx_1 = Bx_0 + Vbx \cdot \Delta t \\ By_1 = By_0 + Vby \cdot \Delta t \\ Ax_1 = Ax_0 + Vax \cdot \Delta t \\ Ay_1 = Ay_0 + Vay \cdot \Delta t \end{array} \right\} \ldots . (1)$$

Now, after having the positions of both vehicle A and vehicle B at time t_1 on the (x, y) plane, it is easy to calculate the future distance D_1 as shown in follow.

$$D_1^2 = |Ax_1 - Bx_1|^2 + |Ay_1 - By_1|^2$$

$$\text{then, } D_1 = \sqrt{|Ax_1 - Bx_1|^2 + |Ay_1 - By_1|^2} \ldots . (2)$$

from (1) and (2) we have:

$$D_1 = \sqrt{|(Ax_0 - Bx_0) + (Vax - Vbx)\,\Delta t|^2 + |(Ay_0 - By_0) + (Vay - Vby)\,\Delta t|^2}$$

By knowing the estimation of the future distance to the node from where the the RREQ came, and by knowing the communication range, the intermediate node can determine whether the link between it and that previous vehicle is likely to cause a link failure or not.

So, if the intermediate vehicle sees that the distance is estimated to be bigger than the maximum communication range, it means that the corresponding transmission link is going to be cut. Then, in the RREQ packet, it increments by one a special counter "Fcnt" corresponding to the number of the transmission links that are going to be cut during the whole transmission time in the related routing route. Before forwarding the RREQ packet, an intermediate vehicle replaces in the RREQ packet the estimated future position of the previous vehicle by its own estimated future position. By this way, the RREQ packet size remains constant along the route until reaching the destination.

When receiving a RREQ packet, an intermediate node updates its routing table only if the corresponding new route is more stable than the one saved in its local routing table. And if this intermediate vehicle is the destination or it knows the stable route to the destination, it reacts by sending a reply packet to the source vehicle with the corresponding link failures number.

SIMULATIONS AND RESULTS

In this work, we implemented in NS2 the improved MOPR as an extension of AODV-UU, which is a well-known AODV implementation for Linux and the network simulators. We term our implemented algorithm AODVUU-MOPR. To prove the performances of our algorithm we compared the simulation results of the basic AODV-UU with that of AODVUU-MOPR.

As an example, when 40 nodes (vehicles) are simulated, Figure 2 shows the network topology. There are 20 vehicles on the horizontal road, and 10 vehicles on each vertical road, with initial position randomly chosen along the road.

The radio propagation rang was set to 250 m, and we used the classical 802.11 Medium Access Control (MAC) functionalities, i.e. Distributed Coordination Function (DCF), Carrier Sense Multiple Access with acknowledgments (CSMA/CA with ACK) and Request-To-Send Clear-To-Send (RTS/CTS), and fragmentation, even if we suppose the messages are enough small. Traffic type was CBR, and the four source/destination couples were selected randomly along the horizontal road in Figure 2. Each destination starts to transmit at time randomly chosen between 20s and 30s, and stops transmission at a time randomly chosen between 70s and 90s.

Some preliminary simulation results, which are obtained by 1000 simulation runs with 98% confidence interval, are presented. The metrics studied are the following:

- **packet delivery ratio:** defined as the number of correctly received packets at the destination over the number of packets sent by the source.
- **routing overhead:** defined as the number of bytes injected in the network by the routing protocol.

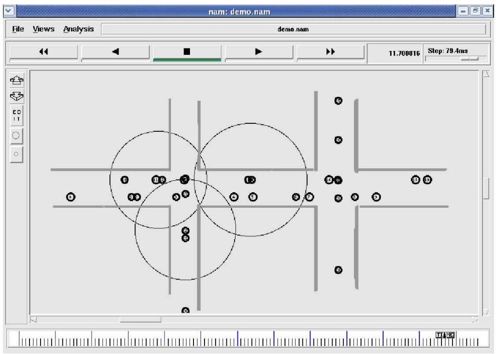

Figure 2: The simulated vehicular environment.

- **routing overhead ratio:** defined as correctly received packets (in bytes) at the destination over the routing overhead (in bytes).
- **end to end delay:** defined as the duration time that a packet takes to go from the source and arrive to the destination.

The four first figures in Figure 3 show performance versus the vehicle average speeds (randomly chosen within ranges around the X value). There are two curves in each Figure, one representing the standard AODV-UU performance, and the second represents the AODVUU-MOPR performance.

Figure 3-a shows AODVUU-MOPR generates only little more routing overhead than AODV-UU, where Figure 3-b shows that both of them guarantee almost the same routing overhead ratio. But in Figure 3-c and Figure 3-d, we can see clearly that AODVUU-MOPR improves AODV-UU in terms of delay and packet delivery ratio, which is mainly caused by reducing the link failures in case of MOPR-AODVUU.

The four second figures in Figure 4 show performance versus the maximum CBR throughput for each source/destination couples, which is incremented by 0.5 Mbps each time from 0.5 Mbps to 2.5 Mbps. There are two curves in each Figure, one representing the standard AODV-UU performance, and the second represents the AODVUU-MOPR performance.

In this part, the results can be seen in two parts, the first from 0.5 to 1.5 Mbps, and the second from 1.5 to 2.5 Mbps. In the first part, Figure 4-a and Figure 4-b show that AODV-UU, compared to MOPR-AODVUU, causes less routing overhead and less routing overhead ratio, when MOPR-AODVUU guaranties a small improvement in terms of packet delivery ratio and delay as shown in Figure 4-d and Figure 4-e respectively. In the second part, both protocols converge to almost same values in terms of routing overhead and routing overhead ratio, when MOPR-AODVUU gets more advantages in terms of delay and packet delivery ratio compared to AODV-UU.

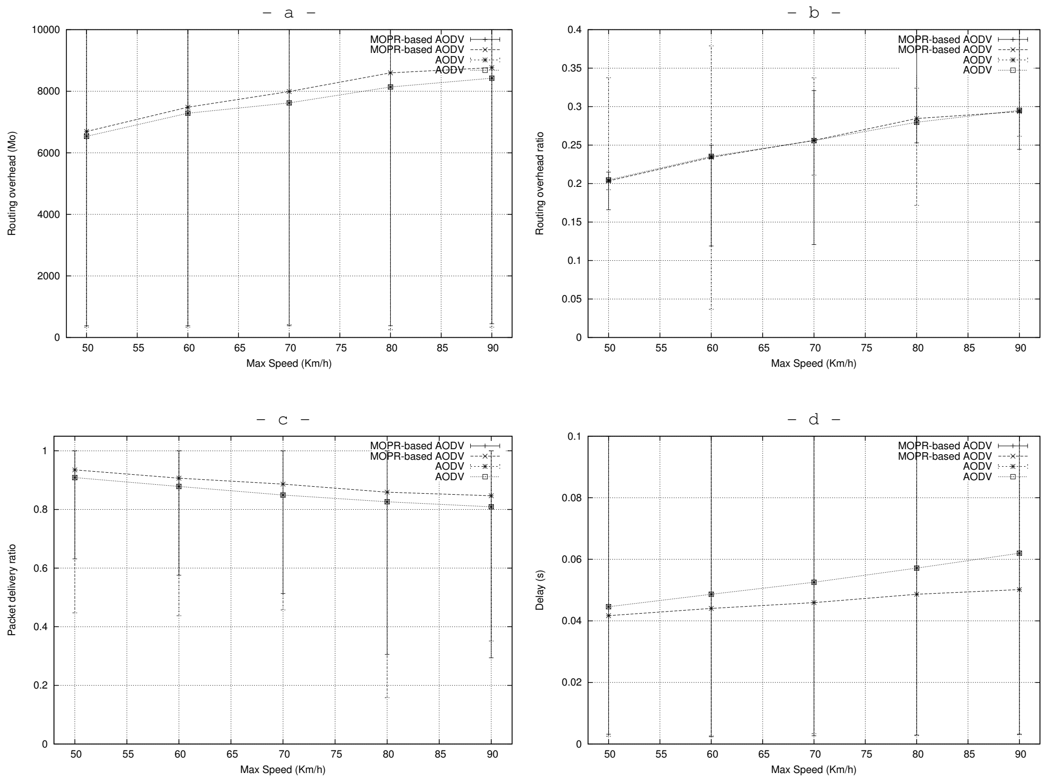

Figure 3: Performance versus the vehicle average speeds.

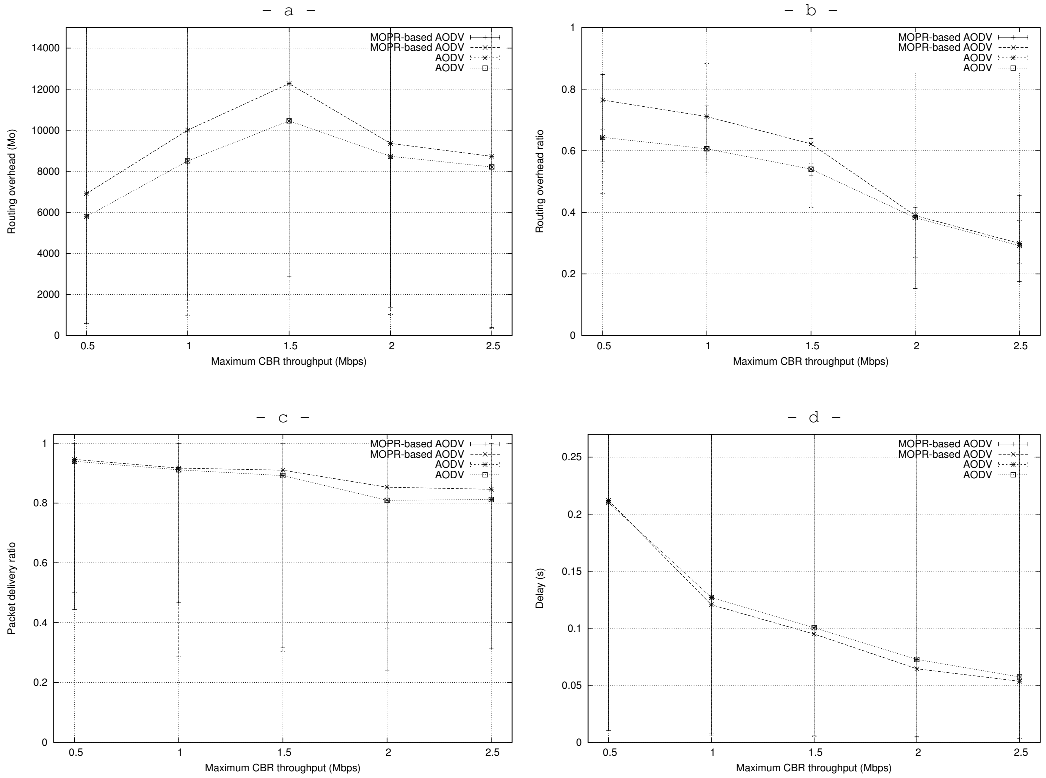

Figure 4: Performance versus the maximum CBR throughput.

All those simulation results show that, with increasing little bit the global data size of the whole control packets sent in the air, our algorithm improves the AODV-UU in term of transmission quality. By decreasing the transmission link failures during the transmissions, the number of the retransmissions, and the data loss rate, it directly improves the delay and the packet delivery ratio in the whole network. Those improvements are very important for vehicular communications established by real-time applications.

CONCLUSION

It is hard for traditional routing protocols to guarantee a well transmission quality in V2VC, because of the special characteristics of this kind of ad hoc networks. In [4] we presented a MOvement Prediction-based Routing (MOPR) algorithm. MOPR, by predicting the movement of the vehicles during a transmission, helps traditional routing protocols to select the better route to use. In this paper we presented some improvement of our MOPR algorithm by letting the data size of the whole control packets relatively stable. And in this work, our new proposal was implemented using NS2 on the AODV-UU, which is a well-know implementation of the classical AODV. We as well showed some simulation results that prove the performances of our algorithm over AODV-UU. They showed that the new MOPR version decreases the probability of transmission link failures without increasing the data size of the control packets in the networks.

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