Analysing Impact of Mobility Dynamics on Multicast Routing in Vehicular Networks

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***Abstract*—Enabling Internet to Vehicular multicast communication is fraught with challenges due to the heterogeneous nature of the two networks. While the conventional multicasting in the Internet relies on "structured" multicast routing, it is not clear how robust can be such routing structure in vehicular networks. We study the robustness of the multicast routing structure in vehicular networks for data flow from the Internet to a set of vehicles. In this paper, we investigate the impact of the urban traffic dynamics on the link stability of the multicast tree. Our study shows that in an intersection scenario, the link can be sufficiently stable without depending much on the relative direction of the vehicles, while on straight roads, the link stability is largely affected by the relative direction.**

I. INTRODUCTION

A number of ITS applications, including the vehicular fleet management and publish/subscribe geo-scoped services, requires multicast communications from the Internet to Vehicular networks. Enabling such application is challenging due to the hybrid communications path (the Internet and wireless media) and the highly mobile nature of the destination nodes, which are the members of the multicast group.

The conventional multicast routing in the Internet is based on protocols such as PIM (Protocol Independent Multicast) [1], which relies on a tree structure to deliver packets form the source to the destinations. Thank to the fixed topology of the Internet, the size of the multicast tree can be very large. On the other hand, due to the highly mobile nature of vehicular networks , it can be difficult to maintain a large tree in vehicular networks. Indeed, there is tendency to prefer structureless routing, e.g., opportunistic routing, for vehicular communications. However, it is not clear how such a structureless routing can be used for multicasting and how it can be combined with the structured multicast routing, which is used for the Internet, for Internet-to-Vehicular multicast communications.

To the best of our knowledge, very few studies are made on pure multicasting for Internet to vehicular communications for different road environments. The analysis made by [2] shows that multicasting is preferable to broadcasting when the number of nodes in the network or the size of the area increases. Most of the existing works on multicasting for vehicular networks including [3] assume that the multicast members are all the nodes that belong to a specific geographic area and tackle the problems of geographic broadcasting (geocast) among the vehicles. On the other hand, some other works focus on vehicular group clustering organization and management. Although promising solutions are proposed (e.g [4]), the proposals lack a deeper analysis of the impact of realistic road traffic on the communication between vehicles.

In this paper, we study multicasting for vehicular networks for data flow between Internet and vehicles. Since the tree-based multicast routing is the *de-facto* scheme in the Internet, we first investigate the stability and robustness of the tree structure in realistic road environments. This paper reports our preliminary analysis, which is carried out using the SUMO traffic simulator [5] targeting a realistic intersection road scenario. The simulations show the impact of the relative direction on straight road and the feasibility of stable link at the intersection.

This paper proceeds as follows. The related works are introduced in Section II. In Section III, we present our preliminary study concerning the impact of traffic dynamics on neighbor link stability. Finally we conclude the paper in Section IV.

II. RELATED WORK

A number of efforts made for multicasting in ad hoc networks. The authors of [6] showed the feasibility of maintaining a multicast delivery tree for vehicular ad hoc networks (VANET) in straight roads environments. The scheme identifies the set of vehicles, which are concerned by the message, and builds a delay-constrained minimum Steiner tree by using a cost function. Unlike our work, the intersection road scenarios, which create more complex traffic dynamics, are not considered in this study. [4] proposes a multicast mechanism to enable communication in architecture which integrates LTE and 802.11p VANET. In what they call "low-level multicasting" (group communication in a cluster), they build a two-hops sharing tree to disseminate the message from the Cluster Head to the members of the group. In their analysis, the authors claim that a use of multicast tree provides efficiency and low control overhead. However, the author didn't justify the chosen size of the tree and they did not analyse the effects of the vehicular traffic charachteristics on its stability.

In [7], the authors propose an approach to deliver multicast packets from the Internet to the vehicles which are located in a specific geographical area. In this approach, the packets are first forwarded to the access router, whose IP address is matched with the destination geographic area, and then the access router broadcasts the packets over one or more number of hops. [3] presents a broadcasting protocol named DV-CAST that addresses the problem of dealing with the extreme situations of dense and sparse vehicular traffic. The design of the protocol strongly relies on the one-hop neighborhood informations and shows a certain reliability in each road traffic situation. Although the approaches based on geobraodcast ensure robustness in some situations, it is not clear yet how efficient and scalable they are, especially in situations when the density is high or when the multicast group size is small as read in [2].

In [8], a study of the impact of the spatio-temporal traffic density variation in highway scenario is presented. The authors use in their study both empirical and analytical data to analyze and report the impact of different traffic situations on the communication performance. Although this work is similar to ours, it considers only simple dissemination mechanisms based on multi-hop geocast and single-hop broadcast.

III. Impact of Traffic Dynamics on Neighbor Link Stability

In our simulations, we consider an urban area with an intersection as illustrated in Figure 1. The size of the overall area is $4000m \times 4000m$. Each road has a single forward and a single backward lane. Vehicles are generated at the edge of each lane following the poisson process at the average generation frequency λ Hz. The velocity of the vehicles is limited to 50 Km/h. When the vehicles reach at the intersection, they select a random destinations and follow the route to their destination. The intersection is equipped with traffic lights and hence, the vehicles mobility are controlled following the road regulation. The total simulation time is 15 minutes. The aim of the simulations is to evaluate the number of K-hops neighbors of randomly chosen ego nodes (vehicles), the neighborhood lifetime, and the relative directions. We define a node as a neighbor of the ego node, if the distance between the node and the ego is less than R meters. The neighborhood lifetime is the period of time during which the nodes stay as neighbors. The relative direction is the angle difference between the moving directions of the neighbors. The distance R is set to 300 m, with the IEEE 802.11p technology, dedicated to vehicular communications, in mind.

Figure 2 illustrates the average value of the maximum neighborhood lifetime for 10 randomly chosen ego vehicles. For each simulation, we change the value of the density, λ. As shown is the figure, when the vehicular density on the road is low (λ=0.04 Hz), the maximum lifetime that we obtain is about 320 seconds, resulting in shorter neighborhood lifetimes with individual neighbors compared to those when density is high. Especially, when the density is high (i.e λ=0.2 Hz), the maximum neighborhood lifetime reaches 650 seconds. Nevertheless, the result shows that while the neighborhood lifetime linearly decrease with the decrease of the density, vehicles are able to share common links with their neighbors during relatively long period of time (i.e., neighborhood lifetime) for intersection scenario.

Figures 3 and 4 show the number of the neighbors and the relative direction measured (w.r.t ego node) when λ is

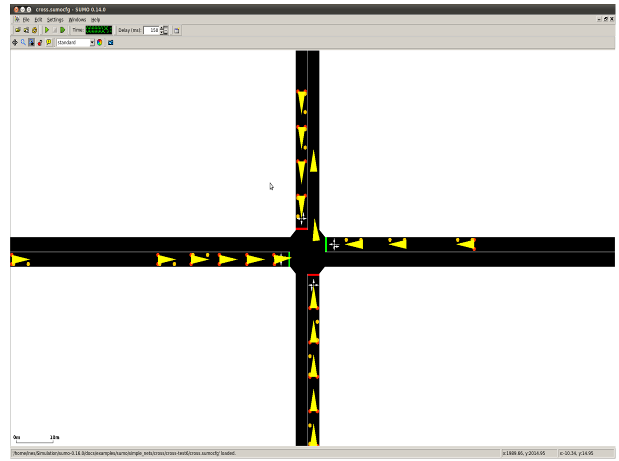

Fig. 1. Intersection scenario set up

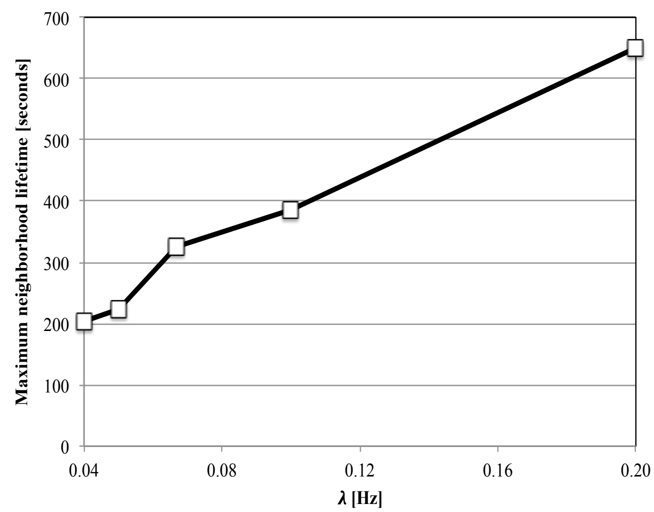

Fig. 2. Variation of the maximum neighborhood lifetime with the road density

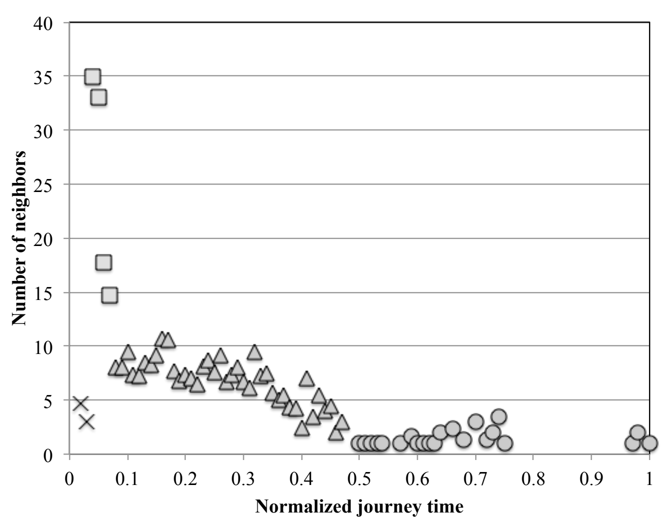

Fig. 3. Average number of neighbors.

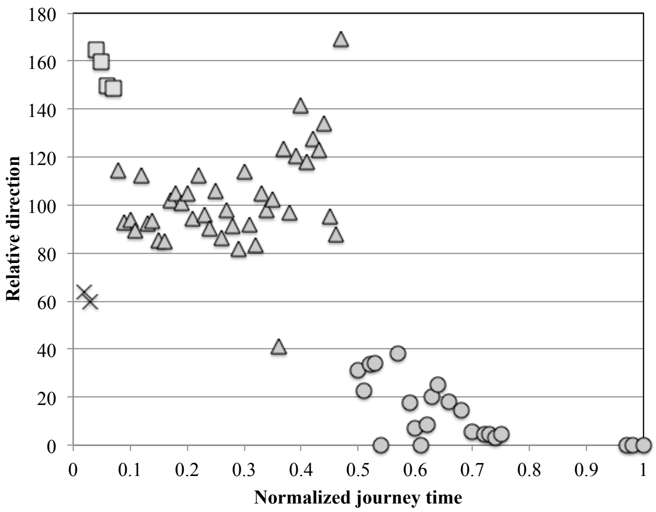

Fig. 4. Neighbors' relative direction w.r.t the ego vehicle.

0.1 Hz. The results are the average values for 10 ego vehicles. The horizontal axis is the normalized journey time with regard to the total journey time of the ego vehicle, whose total journey times are in the range of [300, 500] seconds. (Consequently 0.1, normalized journey time is approximately [30, 50] seconds.)

First of all, Figure 3 shows that a great number of neighbors, between 35 and 15 (expressed with rectangular markers), kept less than 0.07 of lifetime (more precisely between 4% and 7% of the total journey time). The relative direction of these neighbors are, as shown in Figure 4 are as high as close to 180 degrees (i.e., opposite direction with the ego vehicle). On the other hand, Figure 3 also shows that the lifetime of very few neighbors (1 to 3 neighbors) is longer than 50% of the total journey time and the corresponding relative direction is at most 40 degrees (expressed with the circle markers in the figures). Our investigation shows that such extremely short or long lifetime values reflect the situations where the ego vehicle is driving on the straight road. This implies that on the straight road, the relative direction provides a major impact on the link stability. While the ego node meets a larger number nodes, which are moving to the opposite direction, the neighborhood lifetime can be short and thus unreliable. On the other hand, while the number can be few, the neighbors, which are moving to the same direction as the ego node, can provide stable links, and the lifetime can be especially long. The relative direction stays 0 and the normalized lifetime is especially long, close to 1, if the the neighbors continue the journey to the same direction with the ego node even after the intersection. On the other hand, for the neighbors who start their journey on the same road segment as the ego node but take a different direction at the intersection, gives slightly shorter lifetime (between 0.5 to 0.8) and the relative direction is higher than 0. The lifetime in the range of [0.05, 0.08[(expressed with rectangular markers in the figures) corresponds to the neighbors who meet the ego node at the intersection. The relative direction of those nodes are relatively high, 80 to 160. It is interesting to observe that for those neighbors, the relative direction takes a high value for a long lifetime. Specifically, the neighbor with the relative direction [80, 120] had the neighborhood lifetime of [0.1, 0.3], whereas the neighbors with the relative direction 160 has neighborhood lifetime of 0.47. While further investigation is required, it can be explained from the fact that because velocity is very low at the intersection, nodes can build and maintain neighbors for sufficiently long period of time without depending much on the relative direction. At the intersection the velocity of individual vehicles is low, the link stability is not affected by the relative direction. Finally, an attention should be made to the case of lifetime neighborhood of less than 0.02 (expressed with "x" markers) that corresponds to the neighbors, who did not stop at the intersection and with whom the ego meets at the intersection. Because the neighborhood lifetime for such nodes is even shorter than those of the neighbors, who drive opposite direction at the straight road), such nodes should be distinguished from nodes, which stop at the intersection.

IV. Conclusion and future work

We study the traffic road impact on the stability of multicast routing for data flows from Internet to Vehicular networks. In this paper, we reported our preliminary study of the traffic dynamics impact on link stability for a realistic intersection road scenario. The study is carried out using the SUMO traffic simulator under different road traffic settings. Simulation results show that in an intersection scenario, the link can be sufficiently stable without depending much on the relative direction of vehicles. On the other hand, on straight roads, the link stability is largely affected by the relative direction. Specifically, for the target scenario, only 2 neighbors are kept for more than 80% of the total ego trip time, whereas 35 neighbors keep a link with the ego for 5%of the total travel time.

As a future work, we study the impact of vehicles' velocity and density on the neighborhood lifetime for K-hop neighbors under more complex urban scenarios. Based on our studies we plan to seek a multicast routing approach that fit to Internet to vehicular communications.

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