Analysing Impact of Mobility Dynamics on Multicast Routing in Vehicular Networks

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***Abstract*— Enabling the Internet to Vehicular multicast communication is fraught with challenges due to the heterogeneous nature of the two 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 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 distribution 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, 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. A number of efforts made for multicasting in ad hoc networks. The authors of [2] showed the feasibility of maintaining a multicast delivery tree for vehicular ad hoc networks (VANET) in a highway environment. 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. However, the intersection road scenario, which creates more complex traffic dynamics, is not considered in the study. Moreover, communications from Internet to the vehicular network was out of scope. In [3], the authors propose an approach to deliver multicast packets from the Internet to the vehicles that 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.

To the best of our knowledge, very few studies are made on pure multicasting for Internet to vehicular communications for different road environments. To this end, we study the 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 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.

II. Impact of Traffic Dynamics on Neighbour 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 × 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.

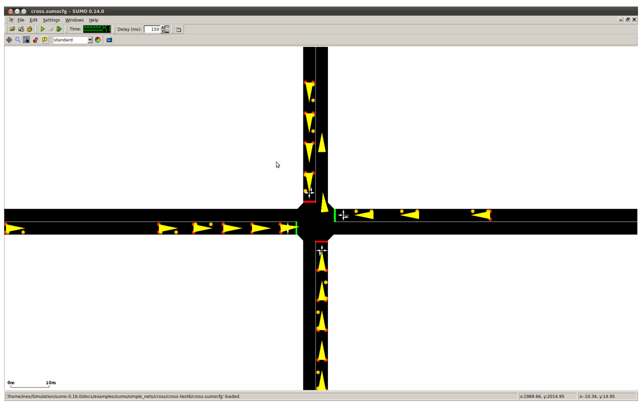

Fig. 1. Intersection scenario set up

The aim of the simulations is to evaluate the number of K-hops neighbours of randomly chosen ego nodes (vehicles), the neighbourhood lifetime, and the relative directions. We define a node as a neighbour of the ego node, if the distance between the node and the ego is less than R meters. The neighbourhood lifetime is the period of time during which the nodes stay as neighbours. The relative direction is the angle difference between the moving directions of the neighbours. The distance R is set to 300 m, with the IEEE 802.11p technology, which is dedicated to vehicular communications, in mind.

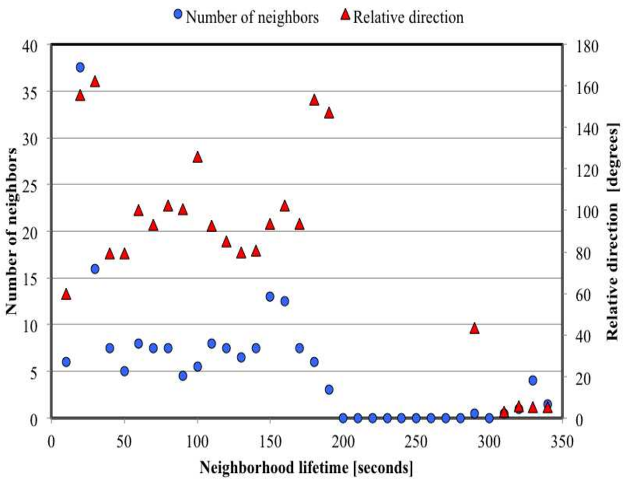

Fig. 2. Average number of 1 hop neighbours and relative neighbourhood direction

While we made extensive simulations for different road densities (i.e., λ), due to the space limitation, Figure 2 reports only the results for the case $\lambda = 0.1$ Hz. First of all, the figure shows that the majority of neighbours are kept less then 200 seconds (i.e., the neighbourhood lifetime is less than 200 seconds). The corresponding relative direction is larger than 60 degrees, indicating that those neighbours are not driving to the same direction as the ego vehicle. Specifically, it should be noted that a great number of neighbours, 38 and 17, are with only 20 and 30 seconds of neighbourhood lifetime. Moreover, the relative direction for these neighbours is almost 180 degrees (i.e., opposite direction with the ego vehicle). On the other hand, the figure also shows that very few neighbours (only 2) are with longer than 300 seconds of neighbourhood lifetime and the corresponding relative direction is approximately 0 degrees. Our further 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 neighbourhood lifetime can be very short and then unreliable. On the other hand, while the number can be few, the neighbours, which are moving to the same direction as the ego node, can provide stable links, and the lifetime can be especially long, if the neighbours continue the journey to the same direction with the ego node even after the intersection (such neighbours correspond to the lifetime longer than 300 seconds in Figure 2).

The lifetime in the range of 50 to 180 corresponds to the average number of neighbours of 5 to 13. For these cases, the neighbourhood contact is established at the intersection, as it can be explained by the relative direction of 70 to 130. In other words, for the target road density scenario, a neighbourhood link can be maintained for a sufficiently long period of time. Moreover, since the velocity of individual vehicles is low, the link stability does not affected by the relative direction.

Finally an attention has to be made to the case of 10 seconds of neighbourhood lifetime. This case corresponds to the neighbours, who did not stop at the intersection and with whom the ego meets at the intersection. Because the neighbourhood lifetime for such nodes is as short as those corresponding to 20, 30 seconds of lifetime (who drive opposite direction at the straight road) such nodes should be distinguished from nodes, which stop at the intersection.

III. Conclusions 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 neighbours are kept for more than 300 seconds, whereas the link duration with 38 neighbours is less than 30 seconds.

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

References

[1] H. Holbrook B. Fenner, M. Handley and I. Kouvelas, *Protocol independent* multicast - sparse mode (pim-sm), IETF, Internet draft, draft-ietf-pim-sm-v2-new-12.txt, March 2006.

[2] Carlos J. Bernardos, Roberto Baldessari and Maria Calderon, *Geosac - scalable address autoconfiguration for vanet using geographic networking concepts*, In PIMRC'08, 2008.

[3] Alvin Sebastien, Maolin Tang, Yanmming Feng, and Mark Looi, *A multicast Routing Scheme for Efficient Safety Message Dissemination in VANET*, WCNC 2010