Studying Vehicle Movements on Highways and their Impact on Ad-Hoc Connectivity

[Poster Abstract]

Holger Füßler* Marc Torrent-Moreno† Matthias Transier* Roland Krüger*
Hannes Hartenstein† Wolfgang Effelsberg*

1. INTRODUCTION

The mobility of the nodes in a Mobile Ad-Hoc Network (MANET) is a crucial factor in the performance studies of communication protocols for these kind of networks. For this reason, researchers usually use a randomized node movement model, such as the Random Way-Point Model [6], in the process of designing or analyzing the behavior of their protocols. Since movement is not very predictable in these scenarios, they serve as a "worst case assumption" of node mobility concerning communication protocol performance in the sense that a positive correlation between performance in an RWP scenario and an arbitrary scenario exists. Additionally, RWP is an analytically well-understood mobility scheme and the movements can be generated very easily with tools complementary to most of the common network simulators.

Vehicular Ad-Hoc Networks (VANETs) are one type of MANETs that is recently attracting the attention of both industry and academia. VANETs are characterized by the—usually—street-bound scenarios due to the special kind of their nodes, i.e., vehicles. Recent research [3] though, shows that protocol performance in VANETs is quite different from performance in RWP scenarios and specializing protocols in these scenarios can be both challenging but also beneficial.

In this work, we present a set of real scenarios of one of the common situations in vehicular environments, i.e., highways. Additionally, an analysis from a connectivity perspective has been performed intending to support the design and/or study of communication protocols tailored to this specific environments.

Starting from reality-audited highway movement data generated for the FleetNet project [5], we have created a set of node movement traces especially for the use with network simulators like ns-2 [7]. In addition, we provide a tool, called *HWGui*, for the visualization and computation of the set of statistics dealing (a) with the movements itself and (b) with the communication consequences assuming a Unit Disk Graph [2] radio connectivity model. A screen shot of `HWGui` can be found in Figure 1 showing a highway scenario with nodes moving from left to right. The yellow lines depicts the "being in each others range" probability of two cars.

*Holger Füßler, Roland Krüger, Matthias Transier, and Wolfgang Effelsberg are with 'Computer Science IV' at the University of Mannheim.
†Marc Torrent-Moreno and Hannes Hartenstein are with the Institut of Telematics at the University of Karlsruhe.

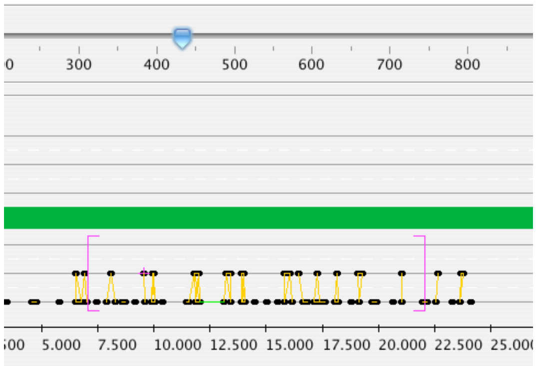


Figure 1: Partial screen shot of HWGui

For further information on the software and for downloading the movement traces and the software, please refer to [1, 4]. The next section will briefly outline statistical examples.

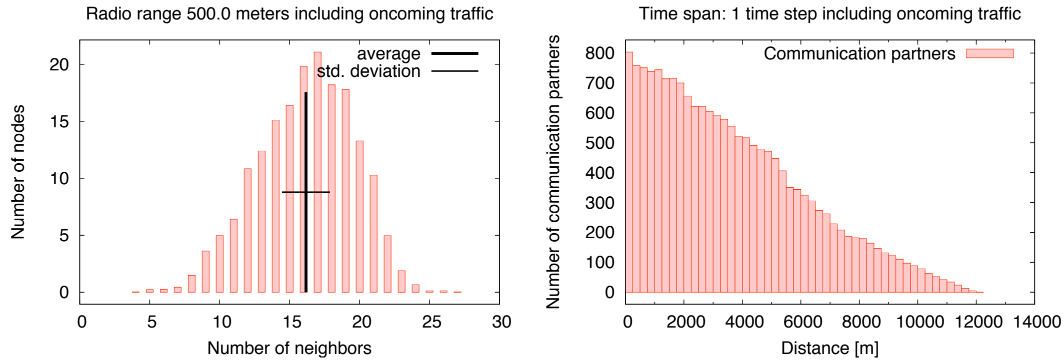
2. STATISTIC EXAMPLES

The available scenarios have different numbers of lanes and different node densities representing varying road traffic conditions. In the following, we will shortly outline some statistical values we have computed for one example scenario with two lanes per direction and a certain density setting (see [4]). Applying a unit disk graph model with an assumed radio range of 500m, Fig. 2(a) shows the distribution of nodes with n radio neighbors, e.g., about 20 nodes have 16 neighbors. This is an important property for the designers of routing/VANET application protocols.

Extending this single-hop value to the transitive closure of the "network", Fig. 2(b) shows the number of communication partners available at a certain distance, e.g., in the given scenario, approximately 360 communication partners are available at $6km$ distance.

While these parameter distribution are averaged over all nodes and the simulation time, it is also interesting to express the dynamics of the mobile network. Fig. 3 shows the number of topological changes occurring per time step (500ms) if nodes would have a radio range of 250m, i.e., the number of unit disk graph "links" appearing and disappearing between two neighboring position samples.

Another interesting question "answered" by the statistics set is the question of the critical transmission range, i.e., at which unit disk graph range is the network totally connected. Fig. 4 shows



(a) Neighbor histogram (b) Communication partner histogram

Figure 2: Connectivity statistics

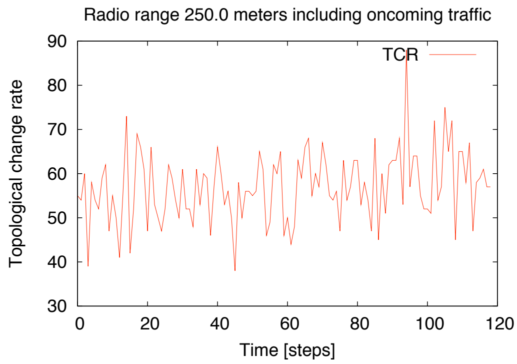


Figure 3: Topology change rate

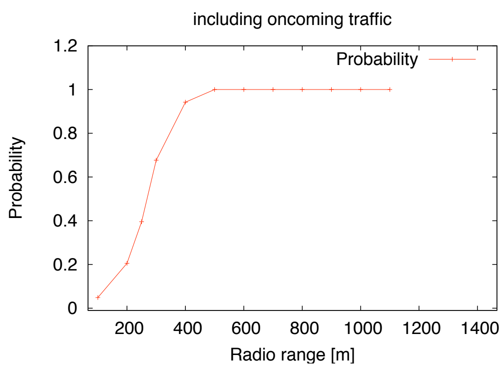


Figure 4: Probability of two nodes to be able to communicate w.r.t. radio range

the average probability of two arbitrary node pairs to be able to communicate with a given radio range. Thus, in the given scenario, the critical transmission range is approximately 470m.

[4] gives a complete description of the whole set of statistics. We strongly believe that the statistics assist a network developer in understanding his simulation results and understanding the upper boundaries the unit disk graph model implies on a MANET defined by the highway movements. Thus, complemented by the visualization tool, the presented work should be highly beneficial for research studying these kinds of networks.

Ackowledgements

Holger Füßler and Marc Torrent-Moreno acknowledge the support of the German Ministry for Education and Research (BMB+F) for the "Network-on-Wheels" project under contract no. 01AK064F.

3. REFERENCES

[1] HWGui and HighwayMovement Homepage. http://www.informatik.uni-mannheim.de/pi4/projects/HWGui.

[2] A. Faragó. Scalable Analysis and Design of Ad Hoc Networks Via Random Graph Theory. In *Proc. of ACM DIAL-M '02*, pages 43–50, Atlanta, Georgia, September 2002.

[3] H. Füßler, M. Mauve, H. Hartenstein, M. Käsemann, and D. Vollmer. A Comparison of Routing Strategies for Vehicular Ad Hoc Networks. Technical Report TR-02-003, Department of Computer Science, University of Mannheim, July 2002.

[4] H. Füßler, M. Torrent-Moreno, R. Krüger, M. Transier, H. Hartenstein, and W. Effelsberg. Studying Vehicle Movements on Highways and their Impact on Ad-Hoc Connectivity. Technical Report TR-2005-003, Department of Mathematics and Computer Science, University of Mannheim, 2005.

[5] H. Hartenstein, B. Bochow, A. Ebner, M. Lott, M. Radimirsch, and D. Vollmer. Position-aware ad hoc wireless networks for inter-vehicle communications: The FleetNet project. In *Proc. of ACM MobiHoc '01*, Long Beach, California, October 2001.

[6] D. B. Johnson and D. A. Maltz. Dynamic Source Routing in Ad Hoc Wireless Networks. In T. Imielinski and H. Korth, editors, *Mobile Computing*, volume 353, pages 153–181. Kluwer Academic Publishers, 1996.

[7] The ns-2 network simulator. http://www.isi.edu/nsnam/ns.