

# Modeling Mobility for Vehicular Ad Hoc Networks

(Extended Abstract)

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## ABSTRACT

Without realistic modeling of node mobility, simulation evaluation of performance of mobile ad hoc networks may not correlate well with performance in a real deployment. In this work, we present a new, realistic model of node motion based on the movement of vehicles on real street maps. Our model can be used with the *ns-2* network simulator. We compare our model with the Random Waypoint mobility model, the most widely used mobility model. Results show that, in many ways, the Random Waypoint mobility model is a good approximation for simulating the motion of vehicles on a road, but there are situations in which our new model is better suited.

**Categories and Subject Descriptors:** I.6.5 [Simulation and Modeling]: Model Development—*Modeling methodologies*

**General Terms:** Design

**Keywords:** Modeling, mobility, vehicular ad hoc networks, street mobility, *ns-2*, simulation, wireless networks

## 1. INTRODUCTION

One emerging, new type of ad hoc network is a *vehicular ad hoc network*, in which vehicles constitute the mobile nodes in the network. Simulation is an effective tool for the evaluation of protocols and architecture in such networks, but it is important to use a realistic mobility model so that the evaluation results correctly indicate the real-world performance of the system. However, almost all mobility models in use in current simulation tools such as *ns-2* [4] are not realistic; for example, the most commonly used mobility model, Random Waypoint [1], does not attempt to model any particular real mobility situation.

We have developed a realistic mobility model, compatible with *ns-2*, suitable for evaluating vehicular ad hoc networks. We make use of the publicly available TIGER (Topologically Integrated Geographic Encoding and Referencing) [3] database from the U.S. Census Bureau, giving detailed street maps for the entire United States of America, and model automobile traffic on these maps. We show that, surprisingly, in many cases the Random Waypoint mobility model is a good approximation of our new vehicular mobility model, but there are scenarios for which our model is better suited. Several other mobility models have been proposed, but to the best of our knowledge, this is the first work analyzing the characteristics of a realistic street mobility model that is of particular relevance to vehicular ad hoc networks.

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This work was supported in part by NSF under grants CCR-0209204, CNS-0325971, and CNS-0338856, and by a gift from Schlumberger. The views and conclusions contained here are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either express or implied, of NSF, Schlumberger, Rice University, or the U.S. Government or any of its agencies.

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VANET'04, October 1, 2004, Philadelphia, Pennsylvania, USA.  
ACM 1-58113-922-5/04/0010.

## 2. DESIGN AND EVALUATION

For each road segment in the TIGER road map, we convert the starting and ending coordinates to  $x$ - $y$  coordinates using a standard Mercator projection. We represent internally the map in a graph data structure in which the nodes in the graph represent the road intersections and the undirected edges in the graph represent each road segment. The edge weights are calculated as a function of the speed limit allowed on the road segment, the distance between the starting and the ending intersections of the road segment, and the number of cars on the road. The TIGER map database does not provide speed limit information, so we assume it based on the type of road. We do not currently model the edges as directed edges since the TIGER data does not identify one-way roads.

To introduce mobile nodes into the network, each node starts at a random point on some road in the network and moves towards another random point located on a random destination road. We use the standard Dijkstra's single source shortest path algorithm to calculate the route from source to destination, and the motion of the node is constrained along this path to the destination. Once a vehicle reaches its destination, it chooses another random destination, and repeats this process. For each movement of a vehicle on a road, we randomly pick a speed uniformly distributed within 5 miles/hour above and below the speed limit.

We have evaluated our new vehicular mobility model by analyzing its characteristics, comparing it to the Random Waypoint model, and by studying the performance of an example routing protocol, the Dynamic Source Routing protocol (DSR) [2], on both mobility models. We have studied two sample regions of Houston, Texas, but due to space limitations, we summarize here the results for only one, a square of side 1900 m. This region is connected such that no street is partitioned from the rest; it has a section of a freeway, a greater variety of street types, and speed limits that vary from 35 to 75 miles/hour. We generated scenarios, each simulating 900 s, with increasing number of mobile nodes (vehicles); in order to compare, we generated scenarios of the same dimensions and number of nodes in the Random Waypoint model with nodes moving with an average speed of about 35 miles/hour (15 m/s), uniformly distributed between 10 and 20 m/s. We used continuous mobility, since that is the most demanding operating condition. We used a nominal wireless transmission range of 500 m, since the more common 250 m simulated range led to a large number of unreachable node pairs.

Figure 1 shows the characteristics of these scenarios, evaluated at regular 10 s intervals. Each point in the graphs represents the average of 10 runs for that combination of parameters and scenarios. With just 50 nodes in the network, the connectivity fluctuates significantly (Figures 1(a) and 1(d)); with all numbers of nodes studied, the connectivity in the network is lower for the scenarios

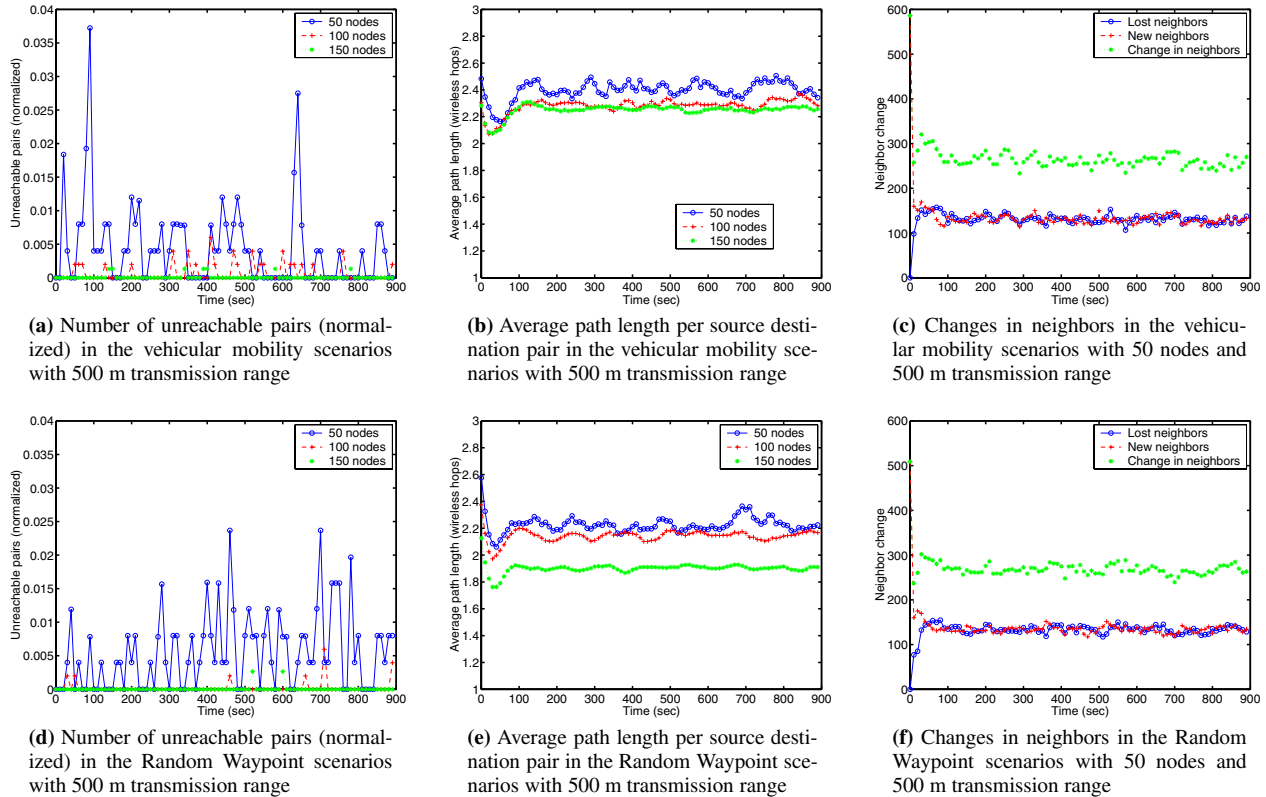


Figure 1: Network characteristics (500 m transmission range)

generated by our vehicular mobility model than with the Random Waypoint model. The average path lengths between pairs of nodes (Figures 1(b) and 1(e)) are longer for our vehicular model, since it is more restrictive in mobile nodes' locations and paths than is the Random Waypoint model. The number of neighbor changes in an interval is slightly less in scenarios generated using our vehicular mobility model (Figures 1(c) and 1(f)), since vehicles move in a more restricted manner in our model than in the Random Waypoint model; for example, two cars, one following the other, can be expected to stay at a similar relative distance for some time.

We simulated DSR [2] with both mobility models, in networks of 150 nodes with a wireless transmission range of 500 m; as shown in Figures 1(a) and 1(d), the network stays well connected with this combination of parameters. We evaluated *packet delivery ratio*, *packet delivery latency*, and *packet overhead*. The packet delivery ratio for DSR in the scenarios generated using our vehicular mobility model was slightly worse than that using the Random Waypoint model, at 90.5% and 91.6%, respectively. Packet delivery latency and packet overhead differed more, being about 25% higher for vehicular mobility; delivery latency was 18.2 ms vs. 14.2 ms, and average packet overhead was 141862.6 vs. 115795.6.

We believe that during the initial development of a protocol, the Random Waypoint model can be used; however, for more accurate results when the target application is a vehicular network, particularly when a site has been chosen for the deployment of the network, our vehicular mobility model should be used to more realistically model node mobility. We believe that our model will have substantial utility for the testing and development of newer applications, especially for vehicular ad hoc networks, since *such applications cannot be modeled using Random Waypoint motion*; Random

Waypoint cannot model patterns of cars along a road, for example, which is an important property of vehicular ad hoc networks.

### 3. CONCLUSION

We have presented a realistic mobility model for mobile ad hoc networks, especially vehicular ad hoc networks, based on *real* street map data and modeling vehicles traveling on these streets. This model can also be used with simulation tools for other kinds of wireless networks such as infrastructure based networks. In future work, we would like to identify residential and business areas in the geographical area for which we generate the mobility scenario. This would help us in getting more realistic movement patterns. Also, our work neglects the waiting time at an intersection and assumes that nodes do not have to wait at an intersection. Our tool for generating *ns-2* scenarios using our vehicular mobility model, based on the publicly available TIGER map data, is available for download at <http://www.monarch.cs.rice.edu/>.

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