ANALYSIS OF MOBILITY MODELS FRAMEWORK FOR VEHICULAR AD HOC NETWORKS

A.Manikandan[#1] and **Dr. C. Suresh Gnana Dhas**[#2]

#1 Research Scholar, Dept. of CSE, Paavai Engineering College, Namakkal [Dt], TamilNadu, India, 96009 82289 and s.a.manikandan@gmail.com
#2 Professor & Dean, Dept. of ECE, Park College of Engg. & Tech, Coimbatore [Dt], TamilNadu, India, 99529 93079 and suresh.me@gmail.com

ABSTRACT

Vehicular Ad-hoc Networks focusing attention from both research and industries. It is a generic mobility model providing an accurate, realistic vehicular mobility description at both macroscopic and microscopic levels. Today, mostly above this model only consider a limited macro-mobility, involving restricted vehicles movements, while little or no attention is paid to micro-mobility and its interaction with the macro-mobility counterpart. In this paper, we provide an overview and comparison of a large range of mobility models proposed for VANETs. We also initiate a capable of realistic vehicular mobility model and compare its weight on the performances of AODV and OLSR.

Keywords: MOBIL, Mobility Models, Performance Evaluation, Survey, VANETs.

Corresponding Author: Manikandan.A

INTRODUCTION

Vehicular Ad-hoc Networks signify a quick emerging and challenging class of Mobile Ad Hoc Networks (MANETs). VANETs are distributed self-organizing communication networks built up by moving vehicles and characterized by very high node mobility. Such particular features make standard networking protocols inefficient or unusable in VANETs, whence the growing effort in the development of communication protocols which are specific to vehicular networks. While it is critical to test and evaluate protocol implementations in a real tested environment, simulation is widely considered as a first step in the development of protocols and refinement of analytical models for VANETs. One of the critical aspects when simulating VANETs is the service of mobility models that reflect behavior of vehicular traffic. In this paper, we look into the degree of realism of the different mobility models available to the research area on VANETs. Realism is based on a framework related to realistic vehicular behavior and city configurations. According to it, we provide a wide view of the state-of-the-art mobility models adapted for VANETs. To the best of our knowledge, this is the first work that provides a detailed survey and comparison of mobility models for VANETs. We also introduce a promising vehicular mobility model compliant with the framework and illustrate how this model influences the performance of AODV and OLSR.

VEHICULAR MOBILITY MODELS OF FRAMEWORK

Vehicular mobility models are classified as either microscopic or macroscopic. When focusing on macroscopic, motion constraints such as roads, streets, crossroads, and traffic lights and the generation of vehicular traffic such as traffic density, traffic flows, and initial vehicle distributions are defined. The microscopic approach focuses on the movement of each individual vehicle and on the vehicle behavior with respect to others. This micro-macro approach is more a way to analyze a mobility model than a formal description. Another way to look at mobility models is to identify two functional blocks: Motion Constraints and Traffic Generator. Motion Constraints describe how each vehicle moves and it obtained from a topological map. Macroscopically, motion constraints are streets or buildings, but microscopically constraints are modeled by neighboring cars, by limited roads diversities either due to the type of cars or to drivers' habits. The Traffic Generator generates different kinds of cars and deals with their interactions.

Macroscopically, it models traffic densities or traffic flows, while microscopically, it deals with properties like inter-distances between cars, acceleration or braking. A realistic mobility model includes:

- **Accurate and Realistic topological maps:** It manages different densities of roads, contains multiple lanes, different categories of streets and associated velocities.
- **Smooth deceleration and acceleration:** Since vehicles do not abruptly break and move, deceleration and acceleration models should be considered.
- **Obstacles:** We require obstacles in the large sense of the term, including both mobility and wireless communication obstacles.
- **Attraction points:** As any driver knows, initial and final destinations are anything but random. And most of the time, drivers are all driving in similar final destinations, which creates bottlenecks. So macroscopically speaking, drivers move between a repulsion point towards an attraction point using a driver's preferred path.
- **Simulation time:** Traffic density is not uniformly spread around the day. An heterogeneous traffic density is always observed at some peak time of days, such as Rush hours or Special Events.
- **Non-random distribution of vehicles:** As it can be observed in real life, cars initial positions cannot be uniformly distributed in a simulation area, even between attraction points. Actually, depending of the Time configuration, the density of cars at particular *centers of interest*, such as homes, offices, shopping malls are preferred.
- **Intelligent Driving Patterns:** Drivers interact with their environments, not only with respect to static obstacles, but also to dynamic obstacles, such as neighboring cars and pedestrians. Accordingly, the mobility model should control vehicles mutual interactions such as overtaking, traffic jam, preferred paths, or preventive action when confronted to pedestrians.

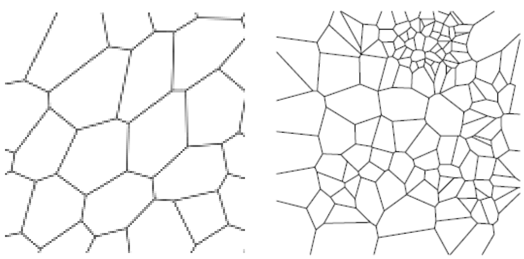
Currently, new open-source tools became available for the generation of vehicular mobility patterns. Most of them are capable of producing traces for network simulators. The IMPORTANT tool [1] and the BonnMotion tool [2] implement several random mobility models, in addition the Manhattan model. This tool includes the Car Following Model which is a basic car-to-car inter-distance control schema, the BonnMotion does not consider any micro-mobility. When related to the framework that the structure of both tools is very simple to represent realistic motions, as they only model basic motion constraints and hardly no micro-mobility. The GEMM tool [8] is an extension to BonnMotion's and improves its traffic generator by introducing the concepts of Attraction Points (AP), Activity and Role. Attraction points reflect a destination interest to multiple people. Activities are the process of moving to an attraction point. While the basic concept is interesting, its implementation in the tool is limited to a simple RWM between APs. It represents an initial attempt to improve the realism of mobility models. The MONARCH project [3] proposed a tool to extract road topologies from real road maps obtained from the TIGER database. The possibility of generating topologies from real maps is considered in the framework, however the complete lack of micro-mobility support makes it difficult to represent a complete mobility generator.

The Obstacle Mobility Model [9] takes a different approach in the objective to obtain a realistic urban network in presence of building constellations. Instead of extracting data from TIGER files, the simulator uses random building corners and voronoi tessellations in order to define movement paths between buildings. It also includes a radio propagation model based on the constellation of obstacles. According to this model, movements are restricted to paths defined by the Voronoi graph. The Mobility Model Generator for Vehicular Networks (MOVE) appears a quite complete tool, featuring real map extrapolation from the TIGER database as well as pseudo-random and manual topology generation.

A New Promising Approach

The basic criterion to understand a realistic driving pattern is to look at the driver's point of view. A driver's most important and straightforward task is obstacles avoidance, such as buildings, road furniture, other cars and pedestrians. Those obstacles may be easily classified between static and dynamic obstacles. Micro-Motion modeling is considered in mobility models for VANETs. CanuMobisim of extension called VanetMobiSim that it matches the objective to propose a model that would reflect, as close as possible, vehicular mobility. Generally described, an urban topology is a graph where vertices and edges represent, respectively, junction and road elements.

The distribution of obstacles should be fitted to match particular urban configurations. For instance, dense areas such as city centers have a larger number of obstacles, which in turn increases the number of Voronoi domains. By looking at topological maps, we can see that the density of obstacles is higher in presence of points of interests. To address these issues, the tool generates clusters of obstacles with different densities, which in turn creates clusters of Voronoi domains. In order to model the typical vehicular motion patterns, our objective is to create a relationship between the topological map and the traffic generator that could go beyond the simple constrained motions induced by graph-based mobility.



Uniform Topology **Cluster Topology**

Figure 1. Illustration of the random topology generation

	Input	MACRO-MOBILITY								
		Graph			Multilane	Initial position	Destination	Route	Velocity	Acceleration
		User defined	Random	Geo-graphical						
RiceM	TIGER	-	-	x	No	Random on graph	Random on graph	S-D Dijikstra	uniform	No
MOVE	TIGER	x	Grid. spider	-	No	random	random	RWalk, S-D Dijikstra	uniform	No
STRAW	TIGER	-	-	x	No	Random on graph	Random on graph	RWalk, S-D Dijikstra	smooth	uniform
GrooveSim	TIGER	-	-	x	No	random	random	RWalk, S-D Dijikstr	Uniform, road-dep	No

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Obstacle	No	-	Voronoi		No	random	random	S-D Dijikstra	uniform	No
Voronoi	No	-	Refined Voronoi	-	No	random on Channels	-	RWalk	uniform	No
GEMM	No				No	AP	AP	RWP	uniform	No
Canu-MobiSim	GDF. AWL	x	-	x	No	random on AP	random on AP	Random, S-D STOCH, Dijikstra	uniform	Uniform
City	No	grid	-	-	No	random	random	RWM	uniform	Uniform
Mobi-REAL	-	x	-	-	No	random	random	RWalk	smooth	No
SSM/ TSM	TIGER	grid	-	x	No	random	random	S-D Dijikstra	Uniform, road-dep	No
VanetMobi-Sim	TIGER. AWL	x	Clustered Voronoi	x	No	random on AP	random on AP	Random, S-D STOCH, Dijikstra	Uniform, road-dep	uniform

S-D: Source-Destination; **AP:** Attraction Point; **road-dep:** Road dependent;

Table 1. Macro-Mobility Features of the Major Vehicular Mobility Models

	MICRO-MOBILITY					Visualization Tool	Output
	Human Patterns	**Intersection**	**Overtaking**	**Obstacles**			
				Topology	**Radio**		
RiceM	No	No	No	No	No	No	NS2, glomoSim
MOVE	CFM	STOCH turns	No	graph	No	Yes	NS2. QualNet
STRAW	CFM	Traffic lights, signs	No	Yes	No	No	Swans
GrooveSim	No	No	No	graph		Yes	None
Obstacle	No	No	No	Building	Yes	Yes	NS2, glomoSim
Voronoi	No	No	No	Buildings	No	No	NS2
GEMM	No	No	No	No	No	No	NS2
Canu-	IDM	No	No	Graph	No	Yes	NS2,

MobiSim				building			glomoSim, qualNet, NET
City	IDM	STOCH turns	No	graph	No	Yes	
Mobi-REAL	CPE	No	No	Graph building	Yes	Yes	GTNets
SSM/ TSM	No	Random traffic lights, traffic signs	No	graph	No	No	NS2
VanetMobi-Sim	AIDM	traffic lights, traffic signs	MOBIL	Graph building	No	Yes	NS2, glomoSim, qualNet, NET

CFM: Car Following Model; **IDM:** Intelligent Driver Model **CPE:** Condition-Probability-Event;
AIDM: Advanced Intelligent Driver Model

Table 2. Micro-Mobility Features of the Major Vehicular Mobility Models

We offer the possibility to increase the number of lanes per road. Then, in order for the traffic generator to be able to act when reaching an intersection, the urban topology needs to contains traffic signs. According the model's configuration, we also add traffic lights at certain intersections. A driver approaching an intersection would slow down and then act according to the traffic signs or traffic lights he or she reads, and to the presence of other cars approaching the same intersection. To obtain a similar behavior we extend the existing Intelligent Driver Model implementation to derive the Advanced Intelligent Driver Model (AIDM) supporting intersection management. Finally, we add deceleration and acceleration models in proximity of road intersections, so that vehicles approaching a traffic light or a crossroad reduce their speed or stop.

We are describing the actions taken by drivers at intersections depending on the class of traffic signs, the state of traffic lights and other vehicles currently inside the intersection or waiting for their turns. Finally, it has been shown that the presence of multiple lanes and thus of vehicles moving at different speeds can noticeably affect the connectivity of a vehicular network. Accordingly a vehicle overtaking model included in order to allow vehicles to change lane and overtake each others. We chose the Minimizing Overall Braking decelerations Induced by Lane changes (MOBIL) model that it allows a vehicle to move to a different lane due to the terms of acceleration is high enough and it considering other vehicles disadvantage scaled.

Performance Analysis

The elements of the simulation are given in the following table, where we included 40% of traffic lights and 60% of stop signs for the intersection management. MOBIL is the extension of AIDM allowing cars to overtake.

ELEMENTS	PARTICULARS
Name of the Tool	NS2
Name of the Implementation	AODV-UV and NRLOLSR
Simulation time & speed	1000s and Uniform
No. of Nodes	As per the network simulation
Bit rate	Constant Bit Rate
Size of the packet	512 bytes

Table 3. Elements of the Simulation

Clusters	**Obstacles per 100m X 100m**
Downtown	2
Residential	0.5
Suburban	0.1

Table 4. Name of the Clusters

The difference between realistic and non-realistic mobility models is the variation of the car's mean speed as a function of the density and the acceleration rate. Most of the models set a fixed speed that a vehicle will maintain throughout its journey. A driver wish to reach a given speed, its interaction with the environment and other vehicles changes the bet. Accordingly, one factor to show the realism of a vehicular mobility model is the mean speed cars experience throughout the simulation. The following figure 2 of a steady-state RWM keeps a stable mean speed. VanetMobiSim shows a 75% decrease of this mean speed, which even further decreases as density is increased. It's called *clustering effects* at intersections. Another interesting feature, that have not been illustrated in the past, is the effect of overtaking on urban traffic. Certainly, VanetMobiSim using MOBIL obtains a 25% increase of the mean speed compared to VanetMobiSim using AIDM. As any driver knows, when vehicles are allowed to overtake a slower car, the clustering effect can be reduced.

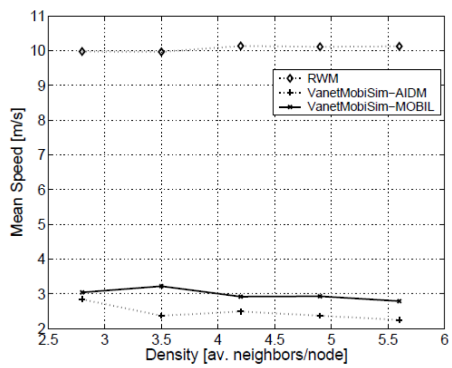

Figure 2. Increasing the density of vehicles on the mean speed

In Figure 4, we show the Packet Delivery Ratio (PDR) of AODV when tested with VanetMobiSim and by varying the density. By using realistic motion patterns, we actually increase the PDR compared to the regular RWM. One of the reason is due to the reduced mean speed that we illustrated before. However, there is also another border effect that explains this effect. Since nodes stop at intersections, the density increases at each intersection, which helps removing connectivity holes. This is clearly the only positive effect of traffic jams.

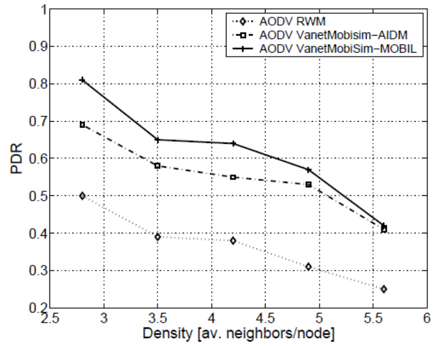

Figure 3. AODV Packet Delivery Ratio (PDR)

The following figure 4 also shows that the OLSR PDR is improved when tested with a realistic mobility model. However, unlike AODV, which could benefit from the overtaking model to improve the channel diversity and removes connectivity holes, OLSR is deal with severely by it. This might come from the fact that by overtaking another car, a vehicle needs to recompute its set of MPR nodes and also its routing table, which reduces its capacity to deliver CBR traffic. Finally, by comparing the PDR of OLSR and AODV, we can see first that under the RWM, both PDRs are almost identical. But, when we use MOBIL, our most realistic mobility model, we can notice that they vary differently, and that AODV eventually ends up outperforming OLSR. This further confirms our conviction that, without a realistic mobility model, we cannot conclude on the performances of routing protocols in vehicular ad hoc networks.

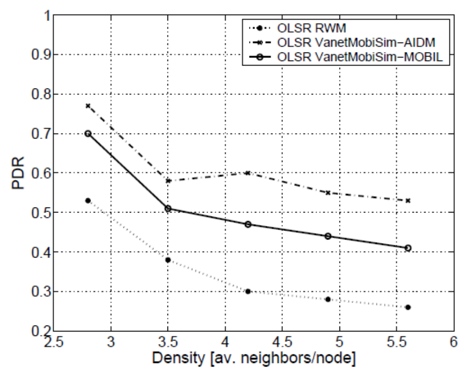

Figure 4. OLSR Packet Delivery Ratio (PDR)

CONCLUSION

Today's trend is to go toward an increased realism in the modeling of vehicular mobility. In this regard, we also presented promising model which includes complex motion patterns that cannot be found in similar tools freely available today. We additionally depicted how realistic motions modeled by VanetMobiSim that it allows to reproduce the basic phenomena encountered in real-life traffic. We further provided an example of those phenomena on the performance of AODV and OLSR. Further research is still required though in this domain. This improving realism for vehicular mobility models appears to be as motivating as it is crucial to perfect analysis and design of future generation ad hoc networks.

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