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Mobility Models for Vehicular Ad Hoc Networks: A Survey and Taxonomy

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Abstract

Vehicular Ad-hoc Networks (VANETs) have been recently attracting an increasing attention from both research and industry communities. One of the challenges posed by the study of VANETs is the definition of a generic mobility model providing an accurate, realistic vehicular mobility description at both macroscopic and microscopic levels. Today, most vehicular mobility models 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 vehicular ad hoc networks. We also introduce a promising realistic vehicular mobility model and compare its influence on the performances of AODV and OLSR.

Index Terms

Survey, Vehicle Ad Hoc Networks, Mobility Models, Performance Evaluation.

Contents

List of Figures

1 Introduction

Vehicular Ad-hoc Networks (VANETs) represent a rapidly emerging, particularly challenging class of Mobile Ad Hoc Networks (MANETs). VANETs are distributed, self-organizing communication networks built up by moving vehicles, and are thus characterized by a very high node mobility and limited degrees of freedom in the mobility patterns. Such particular features often 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 crucial to test and evaluate protocol implementations in a real testbed environment, simulation is widely considered as a first step in the development of protocols as well as in the validation and refinement of analytical models for VANETs.

One of the critical aspects when simulating VANETs is the employment of mobility models that reflect as closely as possible the real behavior of vehicular traffic. This notwithstanding, using simple random-pattern, graph-constrained mobility models is a common practice among researchers working on VANETs. There is no need to say that such models cannot describe vehicular mobility in a realistic way, since they ignore the peculiar aspects of vehicular traffic, such as cars acceleration and deceleration in presence of nearby vehicles, queuing at roads intersections, traffic bursts caused by traffic lights, and traffic congestion or traffic jams. All these situations greatly affect the network performance, since they act on network connectivity, and this makes the adoption of a realistic mobility model fundamental when studying VANETs.

In this paper, we investigate the degree of realism of the different mobility models freely available to the research community on vehicular ad hoc networks. Realism is based on a framework related to realistic vehicular behavior and urban configurations. According to it, we give a broad view of the state-of-the-art mobility models adapted for VANETs. To the best of our knowledge, this is the fist work that provides a detailed survey and comparison of mobility models for vehicular ad hoc networks. We also introduce a promising vehicular mobility model compliant with the framework, and illustrate how vehicular-specific mobility model influences the performance of two well-known ad-hoc routing protocol.

The rest of this paper is organized as follows. Section 2 describes the framework related to realistic vehicular motions. Then, in Section 3, we propose a detailed survey and a taxonomy of mobility models available to the vehicular networking community. Section 4 describes a new promising vehicular mobility model, while Section 5 provides a performance evaluation of AODV and OLSR on realistic environment. Finally, in Section 6, we draw some conclusions and give insights of future research directions in this field.

2 A Framework for Realistic Vehicular Mobility Models

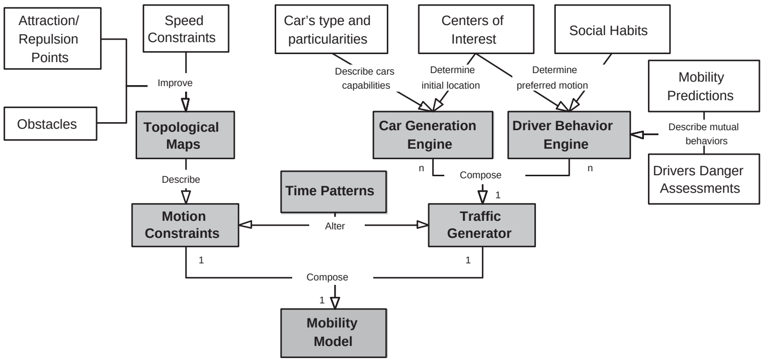


Figure 1: Proposed concept map of mobility model generation for inter-vehicle communications

In the literature, vehicular mobility models are usually classified as either **microscopic** or **macroscopic**. When focusing on a macroscopic point of view, motion constraints such as roads, streets, crossroads, and traffic lights are considered. Also, the generation of vehicular traffic such as traffic density, traffic flows, and initial vehicle distributions are defined. The microscopic approach, instead, focuses on the movement of *each* individual vehicle and on the vehicle behavior with respect to others.

Yet, 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 (its relative degree of freedom), and is usually obtained from a topological map. Macroscopically, motion constraints are streets or buildings, but microscopically, constraints are modeled by neighboring cars, pedestrians, or by limited roads diversities either due to the type of cars or to drivers' habits. The **Traffic Generator**, on the other hand, generates different kinds of cars, and deals with their interactions according to the environment under study. Macroscopically, it models traffic densities or traffic flows, while microscopically, it deals with properties like inter-distances between cars, acceleration or braking.

The framework states that a realistic mobility model should include:

- **Accurate and Realistic topological maps:** Such maps should manage 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 destination 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.

The approach can be graphically illustrated by a concept map for vehicular mobility models, as depicted in Figure 1.

3 A Taxonomy of existing VANETs Mobility Models

When mobility was first taken into account in simulation of wireless networks, several models to generate mobility patterns of nodes were proposed. The Random Waypoint model, the Random Walk model, the Reference Point Group (or Platoon) model, the Node Following mode, the Gauss-Markov model, just to cite the most known ones, all involved generation of random linear speed-constant movements within the topology boundaries. Further works added pause times, reflection on boundaries, acceleration and deceleration of nodes. Simplicity of use conferred success to the Random Waypoint model in particular, however, the intrinsic nature of such mobility models may produce unrealistic movement patterns when compared to some real world behavior.

As far as Vehicular Ad-hoc Networks (VANETs) are concerned, it soon became clear that using any of the aforementioned models would produce completely useless results. Consequently, the research community started to seek more realistic models. The simple Freeway model and Manhattan (or Grid) model were the initial steps, then more complex projects were started involving the generation of mobility patterns based on real road maps or monitoring of real vehicular movements in cities. However, in most of these models, only the macro-mobility of nodes was considered. Although car-to-car interactions are a fundamental factor to take into account when dealing with vehicular mobility, little or no attention was paid to micro-mobility.

Recently, new open-source tools became available for the generation of vehicular mobility patterns. Most of them are capable of producing traces for network simulators. In the rest of this section, we review some of these tools, in order to understand their strengths and weaknesses. We separated the analysis of each model into the comparision of the macro-mobility part (see Table 1) and the micro-mobility part (see Table 2).

The IMPORTANT tool [1], and the BonnMotion tool [2] implement several random mobility models, plus the Manhattan model. While the IMPORTANT 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, we can easily see that the structure of both tools is definitely too simple to represent realistic motions, as they only model basic motion constraints and hardly no micro-mobility.

The GEMM tool [12] 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 roles characterize the mobility tendencies intrinsic to different classes of people. While the basic concept is interesting, its implementation in the tool is limited to a simple RWM between APs. It however 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 [10] 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) was recently presented as an on-going work [4]. It seems a quite complete tool, featuring real map extrapolation from the TIGER database as well as pseudo-random and manual topology generation. No micro-mobility and complex traffic generation are considered yet, but the in-progress status of the project allows us to think that this might be corrected in the near future.

	Input	Macro-Mobility									
			Graph			Multi-lane	Initial Position	Destination	Trip	Velocity	Acceleration
		Random	User Defined	Random	Geographical						
Virtual Track [11]	no		x			no	random on track	random on track	RWP	uniform	no
IMPORTANT [1]	no	x		x		no	random	random	RWM, RWalk	smooth	uniform
Bonn-Motion [2]	no	x		x		no	random	random	RWM	uniform	no
RiceM [3]	TIGER				x	no	random on graph	random on graph	S-D Dijkstra	uniform	no
MOVE [4]	TIGER	x	x	grid, spider		no	random	random	RWalk, S-D Dijkstra	uniform	no
STRAW [5]	TIGER				x	no	random on graph	random on graph	RWalk, S-D Dijkstra	smooth	uniform
GrooveSim [6]	TIGER				x	no	random	random	RWalk, S-D Dijkstra	uniform, road-dep	no
Obstacle [10]	no			Voronoi		no	random	random	S-D Dijkstra	uniform	no
Voronoi [15]	no			Refined Voronoi		no	random on channels		RWalk	uniform	no
GEMM [12]	no	x				no	AP	AP	RWP	uniform	no
Canu-MobiSim [7]	GDF, AWL	x	x		x	no	random on AP	rand on AP	random, S-D STOCH, Dijkstra	uniform	uniform
City [13]	no		grid			no	random	random	RWM	smooth	uniform
Mobi-REAL [9]			x			no	random	random	RWalk	uniform	no
SSM/TSM [14]	TIGER		grid		x	no	random	random	S-D Dijkstra	uniform, road-dep	no
VanetMobiSim	TIGER, AWL	x	x	clustered Voronoi	x	yes	random on AP	random on AP	random, S-D STOCH, Dijkstra	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	Platform
	Human Patterns	Intersection	Overtaking	Obstacles				
				Topology	Radio			
Virtual Track [11]	no	no	no	no	no	no	ns-2	QualNet
IMPORTANT [1]	CFM	no	no	no	yes	no	ns-2	C++
BonnMotion [2]	no	no	no	no	no	yes	ns-2, glomoSim, QualNet	java
RiceM [3]	no	no	no	no	no	no	ns-2, glomoSim	C++
MOVE [4]	CFM	stoch turns	no	graph	no	yes	ns-2, QualNet	C++
STRAW [5]	CFM	traffic lights, signs	no	yes	no	no	Swans	Swans
GrooveSim [6]	no	no	no	graph		yes	none	C++ QT
Obstacle [10]	no	no	no	building	yes	yes	ns-2, glomoSim	C++
VoronoiM [15]	no	no	no	buildings	no	no	ns-2	C++
GEMM [12]	no	no	no	no	no	no	ns-2	java
CanuMobiSim [7]	IDM	no	no	graph, building	no	yes	ns-2, glomoSim, QualNet, NET	java
City [13]	IDM	stoch turns	no	graph	no	yes		
MobiREAL [9]	CPE	no	no	graph, building	yes	yes	GTNetS	C++
SSM/TSM [14]	no	random traffic lights, traffic signs	no	graph	no	no	ns-2	C++
VanetMobiSim	AIDM	traffic signs, traffic lights	MOBIL	graph, building	no	yes	ns-2, glomoSim, qualNet, NET	java

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

The Street Random Waypoint (STRAW) tool [5] is a mobility simulator based on the freely available Scalable Wireless Ad Hoc Network Simulator (SWANS). Under the point of view of vehicular mobility, it provides urban topologies extractions from the TIGER database, as well as micro-mobility support. STRAW is also one of the few mobility tools to implement a complex intersection management using traffic lights and traffic signs. Thanks to this, vehicles are showing a more realistic behavior when reaching intersection. The concept behind STRAW is very similar to the framework described in section 2, as it contains accurate mobility constraints as well as a realistic traffic generator engine. STRAW also includes several implementations of transport, routing and media access protocols, since they are not present in the original SWANS software. The main drawback of the tool is the very limited diffusion of the SWANS platform.

The GrooveSim tool [6] is a mobility and communication simulator, which again uses files from the TIGER database to generate realistic topologies. Being a self-contained software, GrooveSim neither models vehicles micro-mobility, nor produces traces usable by network simulators. The interesting feature of this model is the non uniform distribution of vehicles speeds. Indeed, motion constraints such as speed limitations, often force vehicles to give up in their effort to reach the velocity initially set by the model. Although that is might look as a straightforward pattern, this type of motion constraints is, at this time, considered only by a few simulators. GrooveSim includes four types of velocity models, where the most interesting is the road-based velocity when used in conjunction with a shortest trip path generation. The authors illustrated how vehicles were naturally choosing the roads with the highest speed limitations while on their journey. The main drawback of this tool is however its lack of a micro-mobility model as well as mobility traces for network simulators.

The CanuMobiSim tool [7] is a tool for the generation of movement traces in a variety of conditions. Extrapolation of real topologies from detailed Geographical Data Files (GDF) are possible, many different mobility models are implemented, a GUI is provided, and the tool can generate mobility traces for *ns-2* and *GloMoSim*. Unlike many other tools, the CanuMobiSim tool keeps micro-mobility in consideration, implementing several car-to-car interaction models such as the *Fluid Traffic Model*, which adjusts the speed given vehicles local density, or the *Intelligent Driver Model (IDM)*, which adapts the velocity depending on movements between neighboring vehicles. Also unlike other tools, CanuMobiSim includes a complex traffic generator that can either implements basic source-destination paths using Dijkstra-like shortest path algorithms, or similarly to the GEMM, it can model trips between *Attraction Points* depending on the class of users' specific motion patterns. This solution is actually the only fully implemented and available solution considering heterogeneous classes of user and destinations. In order to improve its modeling capability, CanuMobiSim has even been recently extended by the same authors and now includes radio propagation information for ns-2 and GloMoSim.

In recent months, a couple of research team proposed a new set of simulators that comes closer to the objective to accurately model vehicles' specific motions. The first one is the City Model [13]. It has been basically designed for routing protocols testing and no network simulator traces are provided. Unlike GrooveSim, this model includes the IDM. However, this simulator falls short from realistically representing vehicular motions mostly due to the unique grid-based mobility constraints it includes.

The second is the SSM/TSM model [14]. It represents actually two different mobility models, a *Stop Sign Model* and a *Traffic Sign Model*. The motion constraints part is dealt using a TIGER parser, while the traffic generator includes the *Car Following Model*. As GrooveSim, both SSM and TSM include a road-dependent velocity distribution. However, this model goes farer than GrooveSim, since it contains a basic traffic generator which makes its mobility traces more realistic than GrooveSim's. And similarly to STRAW, SSM/TSM has been specifically designed to model vehicles' motions at intersections. The authors managed to show how a basic intersection management such as a simple stop sign was able to bring out a clustering effect at those intersection. In urban environment, this effect is better known under the name *Traffic Jam*, and is hardly represented in most of the actual simulators.

The Voronoi Model [15] is an illustration of how voronoi graphs proposed by previous simulators could be refined and improved to generate smoother roads. Unlike other mobility models including voronoi tessellations, this *Voronoi Model* does not model roads as graph edges, but as voronoi channels. A voronoi channel is a spatial area obtained after multiple application of a Voronoi Tessellation algorithm. It provides the global moving direction, while keeping some degree of liberty in the local direction patterns. Most of this model contributions are on the improvement of the motion constraints component as a promising random topology generator, while the traffic generator engine is a simple implementation of a Random Walk within each voronoi channel.

Finally, a new solution named *MobiREAL* has been recently presented [9]. Although that it seems more focused on the modeling of pedestrian mobility, its strict compliance with the framework and its novel approach of cognitive modeling makes it very promising for a future extension to vehicular mobility. The most interesting features is that MobiREAL enables to change a node or a class of nodes' mobility behavior depending on a given application context. At this time, only CanuMobiSim, VanetMobisim and MobiREAL are able to include this feature. This particular application context is modeled by a *Condition Probability Event (CPE)*, a probabilistic rule-based mobility model describing the behavior of mobile nodes, which is often used in cognitive modeling of human behavior. As most of recent mobility models, MobiREAL is able to include geographical informations. Moreover, it is also able to use this information to generate obstacles and more specifically it is able to model radio's interference and attenuations on the simulation field. With CanuMobiSim's extension and the Obstacle model, they are the only models that are able to both generate motion traces and signal attenuation information. MobiREAL's major drawback at this time is the limited diffusion of

Georgia Tech Network Simulator (GTNets) and the manual configuration of all necessary parameters, which requires a full recompilation of the simulator at each reconfiguration.

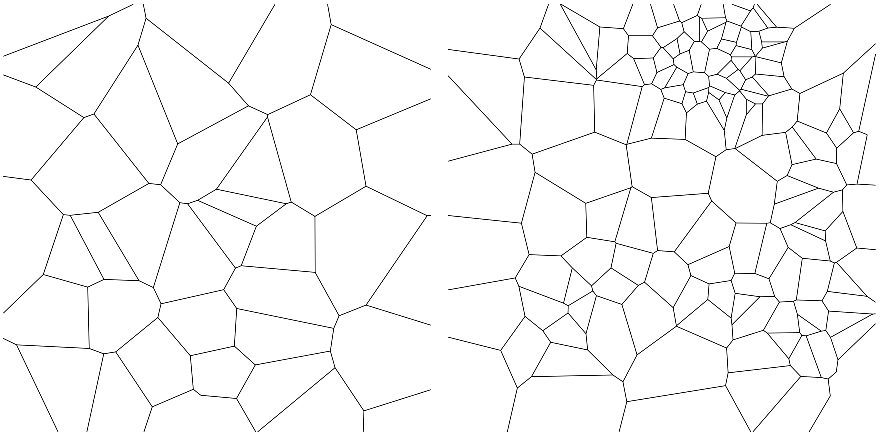
4 A New Promising Approach

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. Whereas dealing with static obstacles may be easily trained, particularly by regular usage, or the use of GIS systems, reacting to dynamic obstacles is usually what attracts most of a driver's attention. And most of its driving dynamic will depend on its reaction to those dynamic obstacles. This is what is usually called **Micro-Motion modeling**, and this feature is rarely considered in mobility models for VANETs. Yet, this is exactly what makes vehicular motions so specific and what usually contributes to the degradation of the performances of routing protocols.

As it can be seen from Table 1 and Table 2 and with respect to Section 2, none of the actual and most up-to-date available mobility models meet all requirements to be considered as realistic toward vehicular-specific motions. Accordingly, we lately proposed a promising extension to CanuMobisim, called **VanetMobiSim**, which is compliant with the framework we presented in the previous section. It also matches the objective to propose a model that would reflect, as close as possible, vehicular mobility.

Roughly described, an urban topology is a graph where vertices and edges represent, respectively, junction and road elements. As proposed by [8], a good solution to randomly generate graphs on a particular simulation area is Voronoi tessellations. We therefore begin by distributing points over the simulation area, representing obstacles (e.g., buildings). Then, we draw the Voronoi domains, where the Voronoi edges represent roads and intersections running around obstacles. Accordingly, we obtain a planar graph representing a set of urban roads, intersections and obstacles.

Although being an interesting feature, these graphs lack realism too. Indeed, 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. Figure 2(a) presents a random topological map with uniformly spread obstacles, while Figure 2(b) depicts a topological map considering three different types of clusters with different obstacle densities.



(a) Uniform Topology (b) Cluster Topology

Figure 2: Illustration of the random topology generation

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. Accordingly, we first 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 can also add traffic lights at certain intersections.

Then, 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 extends the existing Intelligent Driver Model implementation to derive the **Advanced Intelligent Driver Model (AIDM)** supporting intersection management. To this end, 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 also include a set of rules 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 has been 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 as the lane changing model, due to its implicit compatibility with the AIDM. This model allows a vehicle to move to a different lane if its advantage in terms of acceleration is high enough, considering also other vehicles disadvantage scaled by a *politeness* factor.

5 Performance Analysis

The objective of this section is first to compare the RWM with VanetMobiSim, then to provide a performance evaluation of AODV and OLSR with a realistic mobility model. The parameters of the simulation are given in Table 3, where we included 30% of traffic lights and 70% of stop signs for the intersection management. As we wanted to illustrate the effect of overtaking on traffic, MOBIL is the extension of AIDM allowing cars to overtake.

Network Simulator	ns-2
OLSR Implementation	NRLOLSR
AODV Implementation	AODV-UU
Simulation time	1000s
Simulation Area	1000m x 1000m grid
Number of Nodes	40, 50, 60, 70, 80
Tx Range	150m
Speed	Uniform
Initial Speed	$velo^{min}$=5m/s,$velo^{max}$=25m/s
Density	$\#nodes \cdot \frac{\pi \cdot range^2}{X_{dim} \cdot Y_{dim}}$
Packet Size	512 bytes
Traffic	CBR 4 pckt/s

(a) Simulation

Clusters	#obstacles per $100m \times 100m$
Downtown	2
Residential	0.5
Suburban	0.1

(b) Spatial model

Table 3: Simulation parameters

One straight 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. Indeed, most of the models set a fixed speed that a vehicle will maintain throughout its journey. Of course, this feature is far from reality. Indeed, although a driver may wish to reach a given speed, its interaction with the environment and other vehicles often changes the bet. Accordingly, one factor to show the realism of a vehicular mobility model is the mean speed cars experience throughout the simulation.

Figure 3 is a perfect illustration of this feature. As it would be expected from a steady-state RWM, the RWM keeps a stable mean speed. VanetMobiSim, on the other hands, shows a 75% decrease of this mean speed, which even further decreases as density is increased. This is mostly due to the so called *clustering effects* at intersections. Another interesting feature, that have not been illustrated in the past, is the effect of overtaking on urban traffic. Indeed, 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.

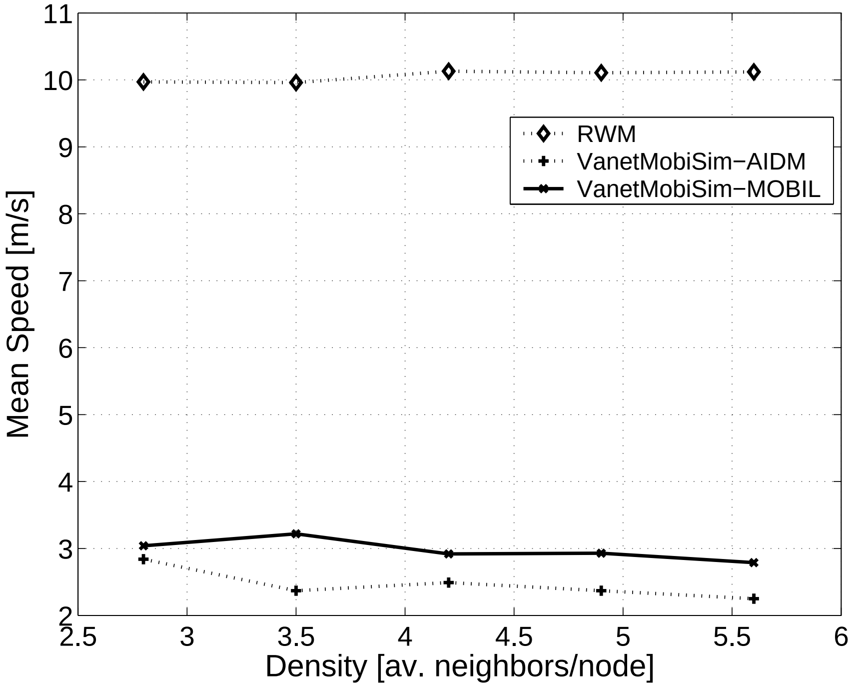


Figure 3: The effect of increasing the density of vehicles on the mean speed

In most of the papers written on AODV or OLSR, simulations and comparisons have almost always been done using the Random Waypoint model. But could we assess that those results hold if performed using a more realistic mobility model? Well, the answer is unsurprisingly no, as it has been shown by the various teams that implemented the models described in Section 3.

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 explain this effect. Since nodes stop at intersections, the density increases at each intersection, which helps removing connectivity holes. This is obviously the only positive effect of traffic jams.

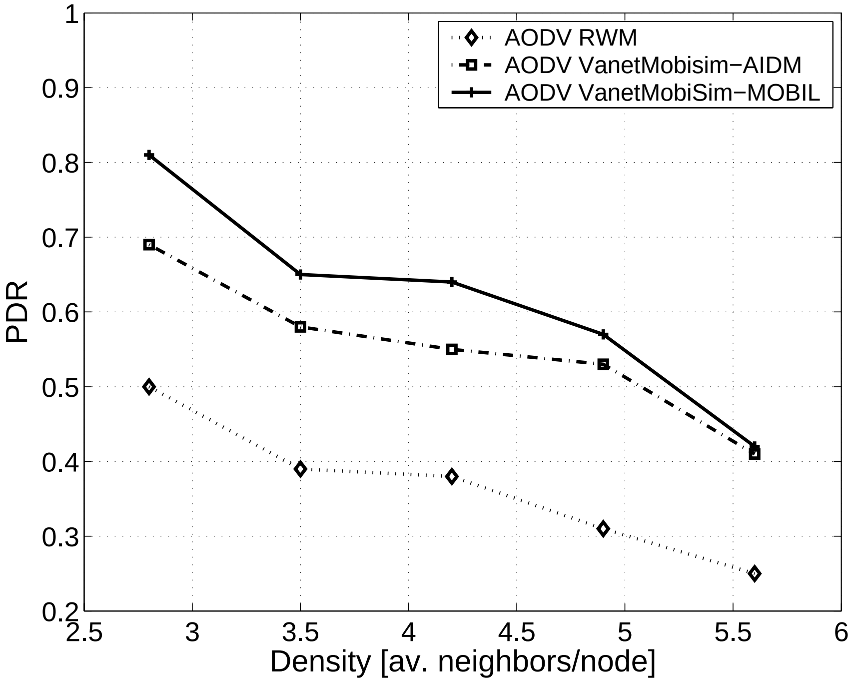


Figure 4: AODV Packet Delivery Ratio (PDR)

Figure 5 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 penalized 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.

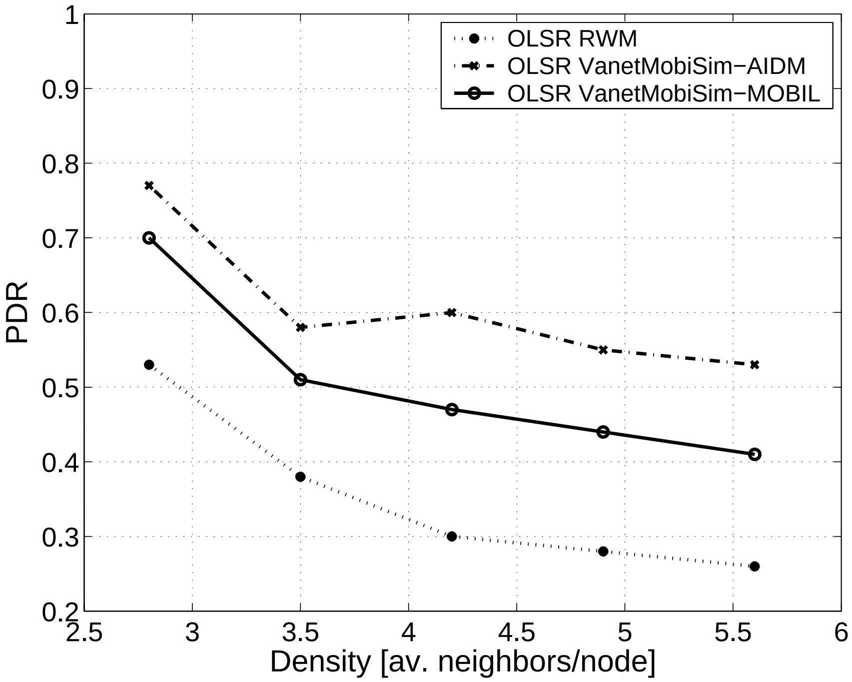


Figure 5: OLSR Packet Delivery Ratio (PDR)

6 Conclusion

A taxonomy of described mobility models for vehicular networks has been given in Table 1 and Table 2. We also provided a large overview of actual mobility models available to the research community in Vehicular Ad Hoc Networks. We illustrated that todays trend is to go toward an increased realism in the modeling of vehicular mobility. For that matter, 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 allows to reproduce basic phenomena encountered in real-life traffic, especially the effect of intersections or the effect of overtaking on vehicles mean speed. We further provided an example of those phenomena on the performance of AODV and OLSR.

Further research is still required though in this domain. Indeed, this review did not include discussion on radio interferences usually caused by both static and dynamic obstacles. This article also did not cover driver's stimulus when confronted to stress, irritation, fatigue, notably on the reaction time and the aggressiveness towards other drivers. Improving realism for vehicular mobility models appears to be as motivating as it is crucial to accurate analysis and design of next generation networks.

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