On Meaningful Parameters for Routing in VANETs Urban Environments under Realistic Mobility Patterns

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***Abstract*— A Vehicular Ad Hoc Network (VANET) is an instance of MANETs that establishes wireless connections between cars. In VANETs, routing protocols and other techniques must be adapted to vehicular-specific capabilities and requirements. As many previous works have shown, routing performance is greatly dependent to the availability and stability of wireless links, which makes it a crucial parameter that should not be neglected in order to obtain accurate performance measurements in VANETs. Although routing protocols have already been analyzed and compared in the past, simulations and comparisons have almost always been done considering random motions with non-urban specific parameters. But what would be the effects of urban motions on the simulation parameters, and what would be their consequences on routing performance?**

In this paper, we illustrate how realistic motion patterns affect the velocity and how new parameters become necessary to evaluate the performance of routing protocols in VANETs. To express our point, we evaluate the performance of AODV with realistic urban scenarios. We show how new urban specific parameters have significant impacts on routing, and de-facto replace some non-urban specific parameters. For example, the average velocity appears to be irrelevant in urban scenarios and should be replaced by road segment lengths.

***Index Terms*— Simulation Parameters, Urban Environment, Realistic Vehicular Mobility Models, AODV, Performance, VANET.**

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I. 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. Hence, ad hoc routing protocols must adapt continuously to these unreliable conditions, whence the growing effort in the development of communication protocols which are specific to vehicular networks.

One of the critical aspects when evaluating routing protocols for VANETs is the employment of mobility models that reflect as closely as possible the real behavior of vehicular traffic. Simple random 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 or traffic bursts caused by traffic lights. All these situations greatly affect the network performance, since they act on network connectivity, which makes vehicular specific performance evaluations fundamental when studying routing protocols for VANETs. Initial works [1], [2] on performance evaluation were based only on random motions, such as random walk models, and lacked any interaction between cars, generally referred as *micro-mobility*. Following the recent interest in realistic mobility models for VANETs, new studies appeared on performance evaluations of VANETs in urban traffic or highway traffic conditions [3], [4]. As these new models generates urban specific spatial and temporal dependencies, the real mobility parameters differ from the initial and controlled ones. Performance comparison may become unfair and arguable.

Another critical aspect is to use the appropriate parameters in order to evaluate routing protocols. A crucial parameter influencing the performance of Vanets is referred by the generic term *mobility*. In simple models, mobility is equal to velocity. However, on the eve of realistic mobility models, it becomes hard to understand the real parameters controlling this *mobility*. However, no study has been done illustrating how realistic motion patterns influence the mobility and other configuration parameters.

In this paper, our objective is to illustrate how realistic urban motions reduce the effect of some standard evaluation metric, and how they generate new urban-specific performance parameters never described in the past. In order to model realistic vehicular motion patterns, we make use of the *VanetMobiSim* tool we previously developed (see [5]). This model is able to closely reflect spatial and temporal correlations between cars, or between cars and urban obstacles. Notably, the tool illustrates clustering effects obtained at intersection, also commonly called *traffic jam*, or drastic speed decays. Accordingly, it becomes possible to evaluate more realistically ad hoc routing performances for vehicular networks. We configure VanetMobiSim to model urban environment, then evaluate the performance of AODV in terms of *(i) Packet Delivery Ratio (PDR) (ii) Delay (iii) Hop Count*. We test AODV in three different conditions *(i) velocity (ii) road segment length (iii) cluster effect*. We first show how the average velocity has a minor impact on performance as it cannot reflect the real velocity in urban traffic. A more significant parameter is the road segment length, as this is the parameter controlling the real velocity. We also exhibit how the clustering effect obtained at intersection has a major effect on the effective average velocity during the simulation.

The rest of the paper is organized as follows: In Section II, we shortly provide some related work in the performance evaluation metrics field, while in Section III, we briefly depict the AODV protocol. Section IV presents the Vehicular Mobility Model (VMM) we used in this paper to model urban motion patterns, while Section V illustrates the effects of VMM mobility patterns on standard performance parameters. Finally, in Section VI, we discuss the scenario characteristics and the simulation results, and in Section VII, we draw some conclusion remarks and highlight future works.

II. Related Work

Several studies non-specific to VANETs have been published comparing the performance of routing protocols using different mobility models or performance metrics. One of the first comprehensive studies was done by the Monarch project [1]. This study compared AODV, DSDV, DSR and TORA and introduced some standard metrics that were then used in further studies of wireless routing protocols. As they used random mobility models, the mobility parameter they used was simply the *pause time*. A paper by Das et al. [2] compared a larger number of protocols, yet only with traffic parameters.

Another study [6] compared the same protocols as the work by Broch et al. [1], yet for specific scenarios as the authors understood that random mobility would not correctly model realistic network behaviors.The authors introduced a generic *mobility* multi-parameter describing the relative motion of the network, as a single parameter was not sufficient to describe complex mobility scenarios.

Although that the proactive OLSR protocol has been developed in 2002, very few studies compared it with other ad hoc network protocols. Clausen *et al.* [7] evaluated AODV, DSR and OLSR with parameters such as *velocity* or *density*, and *traffic type* and *rate*.

Following the developments started with scenarios-based testing, it also became obvious that, as scenarios were able to alter protocol performances, so would realistic node-to-node or node-to-environment correlations. This approach became recently more exciting as VANETs attracted more attention, and a new wave of vehicles-specific models appeared. The most comprehensive studies have been performed by the Fleetnet project [8]. In a first study [3], authors compared AODV, DSR, FSR and TORA on highway scenarios, while [4] compared the same protocols in city traffic scenarios. In both studies, the authors understood that the average velocity was irrelevant to evaluate routing protocols and they only increased the *number of cars* (which actually increases the gap between the real speed and the average speed). However, they also fell short of pinpointing another important parameter which was the *lengths of the road segments*. Another study [9] compared a position-based routing protocol (LORA) with the two non-position-based protocols AODV and DSR. However, the parameters they used were *hop count* and *traffic rate*. Similar tests and results has been reached by members of the NoW project [10], by using *transmission range* as parameter.

III. Ad-hoc On-demand Distance Vector (AODV)

For our performance comparison study, we picked up one ad hoc routing protocols that reached the IETF RFC level, the on-demand AODV protocol (RFC[3561] [11]). We shortly address this protocol in the rest of this section. For a more detailed description, the reader is referred to the RFC.

In AODV, when a source node has data traffic to send to a destination node, it first initiates a route discovery process. In this process, the source node broadcasts a Route Request (RREQ) packet. Neighbor nodes which do not know an active route for the requested destination node forward the packet to their neighbors until an active route is found or the maximum number of hops is reached.

When an intermediate node knows an active route to the requested destination node, it sends a Route Reply (RREP) packet back to source node in unicast mode. Eventually, the source node receives the RREP packet and opens the route.

IV. Vehicular Mobility Model

As depicted in [12], a mobility model clearly affects the simulation results. Thus, since simple models like the Random Waypoint mobility model do not consider vehicles' specific motion patterns, they cannot be applied to simulation of vehicular networks. Accordingly, we developed *VanetMobiSim* ([5]), a new realistic mobility simulator. VanetMobiSim implements a novel mobility model called *Vehicular Mobility Model (VMM)*, that is compliant with the principles of the general framework for mobility models generation described in [13], and capable of modeling detailed vehicular movements in different traffic conditions.

Following the general classification proposed by [14], *VMM* contains a **micro-mobility** and a **macro-mobility** component:

A. Macro-Mobility

The macro-model is represented by a graph where vertices and edges represent, respectively, junction and road elements. As proposed by [15], a good solution to randomly generate graphs on a particular simulation area is Voronoi tessellations based on distributed points over the simulation area which represent obstacles (e.g., buildings). Accordingly, we obtain a planar graph representing a set of urban roads, intersections and obstacles. Then, in order to increase the realism, as dense areas such as city centers have a larger number of obstacles which in turn increase the number of Voronoi domains, the model generates clusters of obstacles with different densities, eventually creating clusters of Voronoi domains.

In order to model the typical vehicular motion patterns, the objective is also 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, the macro-model first offers the possibility to separate single flows roads, as well as to increase the number of lanes per road. Then, as the traffic generator needs to act when reaching an intersection, the urban topology is also enhanced by traffic signs. According the model's configuration, traffic lights or stop signs may be added, depending on the type of intersection.

B. Micro-Mobility

When considering *micro-mobility*, one should look at the driver's point of view. When a driver approaches an intersection, it should slow down 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, the existing Intelligent Driver Model [16] is extended to derive the **Intelligent Driver Model with Intersection Management (IDM_IM)**, and the **Intelligent Driver Model with Lane Changing (IDM_LC)**. To this end, deceleration and acceleration models inspired by the Akcelik's acceleration/deceleration model [17] are added in proximity of road intersections, so that vehicles approaching a traffic light or a crossroad reduce their speed or stop. Included are also 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. The lane changing and overtaking are controlled by rules similar to MOBIL [18].

V. Influence of VMM on Vehicular Motion Patterns

VMM requires many configuration parameters, which all have effects on the modeling of vehicular motions. In this section, we illustrate the average *road segment length*, the average *acceleration, resp. deceleration rate*, and the *clustering effect*, which are three major novel motion parameters VMM defines, and compare their influence with the RWM.

With these parameters, VMM generates motion patterns that cannot be modeled by pure random motions.

Yet, these parameters deeply influence the spatial distribution and velocity of cars in the network. Indeed, any single one or any combination of them is able to generate a significant difference between the initial average velocity and the real velocity, or between the average and the local density. This problem may be formulated as the difference between initial distribution of the statistics of mobility parameters and the steady state distribution. However, as the problem of analytically computing the steady state distributions of realistic mobility models is much more complex than that of random models, the only way to illustrate this effect is through simulations. The corollary is that any simulation must be undertaken after a sufficient large "warming" time in order to reduce the effect of the transient state.

A. Parameters Definition

Before going further, we would like to define the particular parameters we used in this paper.

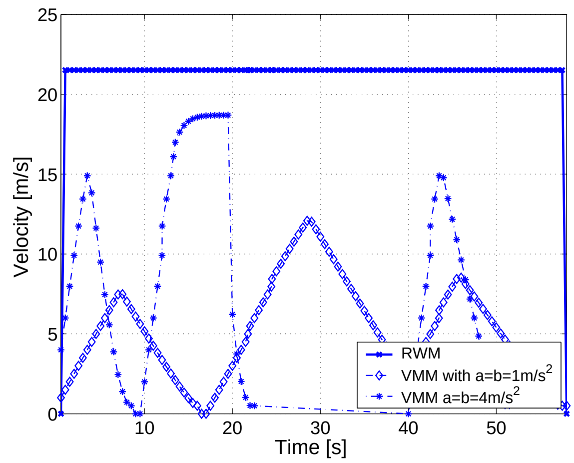
We first provide *Speed* related definitions

- *Average Speed*– The average speed controls the distribution of the random variable that determines the speed between each destination point.
- *Desired Speed*– The desired speed is the speed sampled at each destination point. It is therefore the speed a driver aims at reaching using a smooth acceleration. However, according to traffic regulation, there is no guarantee that this speed may ever be reached.
- *Real Speed*– The real speed is the temporal speed obtained at each time instant. It is subject to traffic, traffic signs and drivers habits.
- *Speed Decay*– The speed decay is the gap between the desired speed and the real speed.

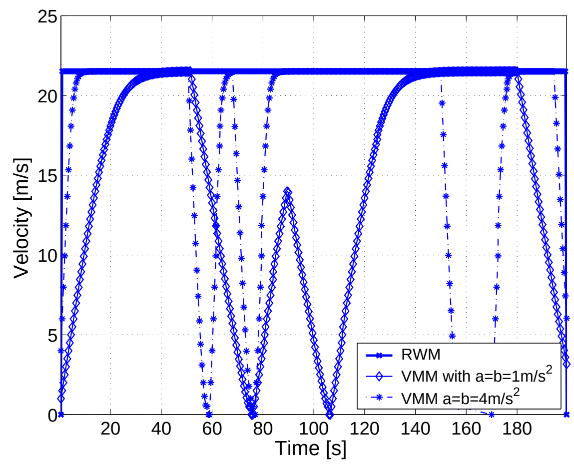
Then, the *Clustering Effect* is a particular parameter specific to realistic mobility models which should not be mistaken with the *density* or the *number of nodes*. Indeed, the cluster effect is a parameter taken from the urban traffic modeling and controls the aggregation at the intersections. We indeed want to spot out effects solely dependent to the urban traffic distribution and not dependent to effects on the MAC layer or on routing protocols from an increased number of neighbors. Accordingly, the cluster effect is controlled by increasing the number of vehicles in the urban area, while reducing the transmission range in order keep the average network density constant[1] (in terms of average number of neighbors per vehicles). Thanks to it, we are able to see the effect of the spatial and temporal dependencies on routing protocols, and not only the effect of the density which has already studied in the past.

[1]It is possible to obtain a significant performance difference if we have a large cluster effect at a low density or a low cluster effect at a high density.

Finally, a *Road Segment* is defined as the piece of road connecting two intersections. The length of a road segment is therefore the distance between two intersections. Its major effect on realistic mobility models is its control of the gap between the desired speed and the real speed. It is also able to control the cluster effect.



(a) Road segment length=150m



(b) Road segment length=250m

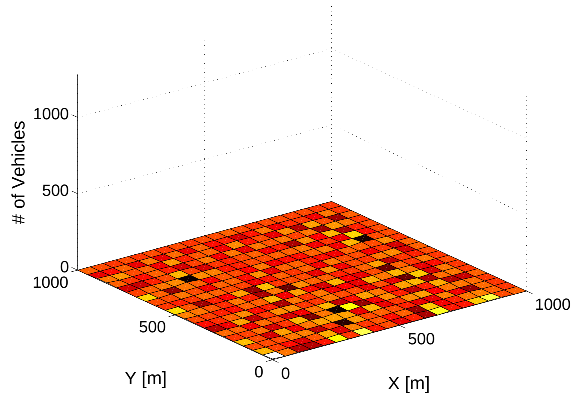
Fig. 1. Illustration of vehicles real velocity on a single trip

B. Illustration

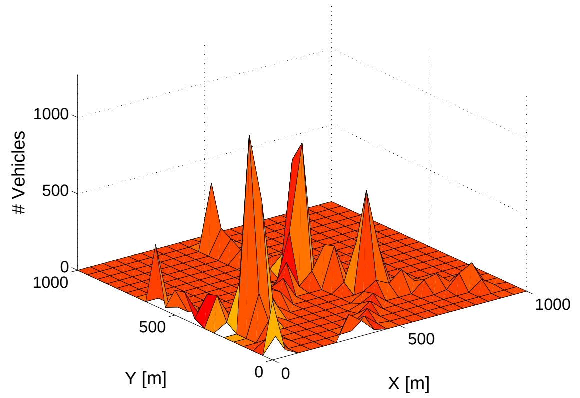
In Fig. 1, we illustrate the effects of the average road segment length and the acceleration, resp. deceleration rate on vehicles real velocities. In both figures, the desired velocity is the one reached at any time by RWM, and we modeled the velocity of a single vehicle during on single trip. Unlike the RWM which ignores the VMM's parameters, the velocity modeled by VMM fluctuates significantly as it is influenced by the acceleration rate and the road segment length. By considering the acceleration rate $1m/s^2$ and comparing Fig. 1(a) and 1(b), vehicles never reach the desired speed in the former figure, as cars modeled by VMM respect traffic regulations and must decelerate and stop at each intersection contained in the trip. However, the effect may be limited by increasing the distance between two successive intersections as it can be seen in the latter figure. The second parameter is the acceleration, resp. deceleration rate. Considering Fig. 1(a), for a fixed distance between two intersections, a car with a strong acceleration rate is quickly going to reach the desired speed and will run faster on the selected road segment than a car with a smaller acceleration rate. As the real velocity is an important parameter for routing protocols in mobile ad hoc networks, we expect these new parameters to be more fundamental than simply average, or desired velocities.

RWM's objective is to keep vehicles position uniformly distributed in the network, an effect that may be sought for SANETs for instance. However, for VANETs, this is seldom the case as vehicles follow predefined paths and aggregate at intersections. This leads to a non-uniform distribution of vehicles in the network, which we call the *clustering effect*. As we see on Fig 2(b), the number of vehicles observed in the network is higher on predefined roads and even higher on intersections, while the number of vehicles is, as expected, uniformly distributed in Fig 2(a). As the distribution of vehicles in the network have an impact on connectivity and data dissemination, we also expect the clustering effect to have a significant influence on performance of mobile ad hoc network in vehicular urban areas.

As an illustration of a possible effect on performance, we show in Fig. 3 the average speed decay from a desired velocity that vehicles experience with VMM. However, this desired velocity is subject to speed limitations that cannot be exceeded, or to any obstacle that either reduces or even stops the car. Accordingly, there is no guarantee that this velocity can even be reached during the simulation. As we can see on Fig. 3(a), there is a stable drastic decay as a function of the desired velocity, whereas the decay is not stable in Fig. 3(b), since it is influenced by the road segment length or acceleration, resp. deceleration rates.



(a) RWM



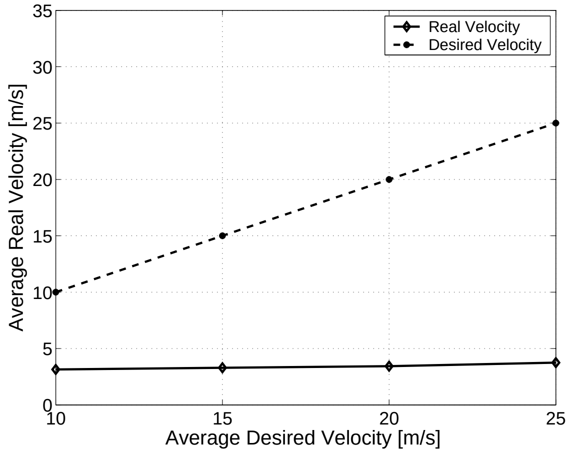
(b) VMM

Fig. 2. Spatial distribution of vehicles in the urban environment (Cluster Effect)

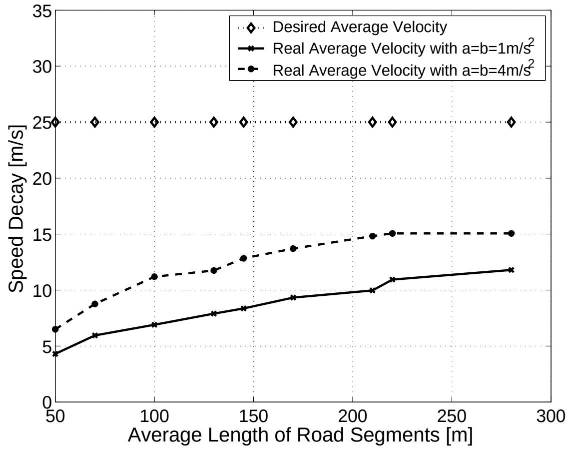
The major conclusion is that network mobility as defined in previous works cannot be used as an evaluation metric for vehicular ad hoc networks. We should rather define new metrics as acceleration/deceleration factors, cluster effect or distance between two intersections.

VI. Performance Evaluation

In order to illustrate the influence of the new parameters described in the previous section on routing protocols, we used the open source network simulator ns-2 in its version 2.27 as it is widely used for research in mobile ad hoc networks. We first provide a description of the scenarios characteristics and then describe results we obtained.



(a) Desired velocity



(b) Average length of roads segments

Fig. 3. Illustration of Speed Decay, where a, resp. b are the acceleration, resp. deceleration rates

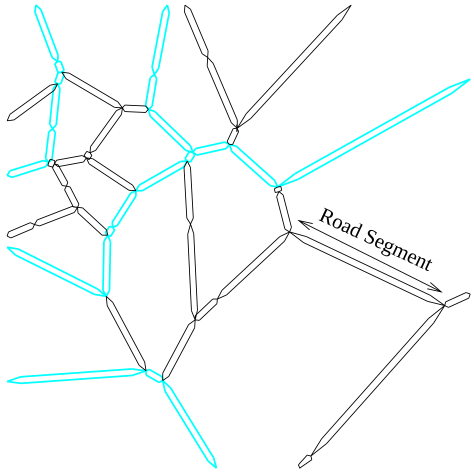


Fig. 4. Illustration of an urban graph used for the simulations

A. Scenario Characteristics

In this paper, we consider squared urban areas of 1000x1000m constituted of three different cluster categories: downtown, residential and suburban. The different obstacle densities for these three categories are summarized in Table II(b). Fig. 4 displays an example of an urban graph used in this paper. The simulation parameters are given in Table I. We test each protocol with a spatial model composed of 30% of traffic lights and 70% of stop signs.

Vehicles are randomly positioned on intersections. Then, each vehicle samples a desired speed and a target destination. After that, it computes the shortest path to reach it, taking into account single flow roads. Eventually, the vehicle moves and accelerates to reach a desired velocity according to streets regulations. When a car moves near other vehicles, it decelerates to avoid the impact. When it is approaching an intersection, it first acquires the state of the traffic sign. If it is a stop sign or if the light is red, it decelerates and stops. If it is a green traffic light, it slightly reduces its speed and proceeds to the intersection. At target destination, the car decelerates, stops, and then samples a new destination. The different parameters for the micro-model are given in Table II(a).

Network Simulator	ns-2 2.27
Mobility Models	RWM [19], VMM [5]
AODV Implementation	AODV-UU
$Hello^{aodv}$ Interval	3s
Simulation time	1000s
Simulation Area	1000m x 1000m grid
Number of Nodes	10 $\longrightarrow$ 80
Tx Range	100m
Speed	Uniform
Density	$\#nodes \cdot \frac{\pi \cdot range^2}{X_{dim} \cdot Y_{dim}}$
Data Type	CBR
Data Packet Size	512 bytes
MAC Protocol	IEEE 802.11 DCF
MAC Rate	2 Mbits/s
Confidence Interval	95%

TABLE I
SIMULATION PARAMETERS

We finally decompose our performance analysis in three different scenarios, where parameters are fixed according to Table III. In the first scenario, we want to see the influence the average velocity. Then, in the second scenario, we analyze the effect of different lengths of road segments. In the last scenario, we are interested

Param	Description	Value
a	Maximum Acceleration	$0.9m/s^2$
b	Maximum Deceleration	$0.5m/s^2$
l	Vehicle Length	5m
s_{com}	Minimum Congestion Distance	2m
t	Safe headway time	1.5s
b_{sav}	Maximum "safe" deceleration	$4m/s^2$
p	Politeness	0.5
a^{th}	Lane Change Threshold	$0.2m/s^2$
T^{light}	Traffic Light Transition	30s

(a) Micro-model

Clusters	#obstacles per $100m \times 100m$	#cluster per $1000m \times 1000m$	ratio
Downtown	50	4	10%
Residential	12.5	4	40%
Suburban	2.5	4	50%

(b) Macro-model

TABLE II

VEHICULAR MOBILITY MODEL PARAMETERS

in the cluster effect at intersections. Each point is the average of 10 samples, while the error bars represent a 95% confidence interval. We also point out that in all three scenarios, we maintain the same average density, as we want to exhibit results not related to an increased density. Finally, for each scenario, we simulate AODV for the RWM [19] and the VMM. Accordingly, we will be able to see the effect of realistic urban motions on the parameters and on the performances.

Scenarios	Data Rate [Mbits/s]	Network Mobility [m/s]	Nodes Density	Road Length [m]	Nbr. of Nodes	Tx Range [m]
Velocity	0.8	v^{min}=0, v^{max}=20 to v^{min}=15, v^{max}=35	11.78	50	40	100
Road Segment Length	0.8	v^{min}=15, v^{max}=35	11.78	50 to 280	40	100 to 500
Clustering Effect	0.8	v^{min}=15, v^{max}=35	11.78	150	20 to 60	424 to 244

TABLE III

SIMULATION SCENARIOS

B. Simulation Results

We measured several significant metrics for MANETs routing that are mostly influenced my mobility:

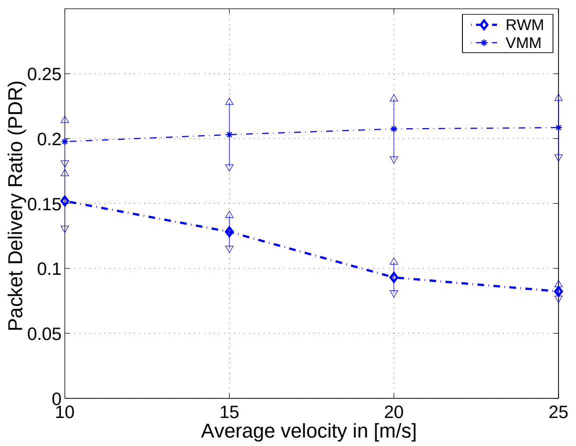
- *Packet Delivery Ratio (PDR)*– It is the ratio between the number of packets delivered to the receiver and the number of packets sent by the source.
- *Delay*– It measures the average end-to-end transmission delay by taking into account only the packets correctly received.
- *Hop Count*– It represents the number of hops that a packet has taken before it has been correctly delivered.

In Fig. 5(a), we see that for VMM[2], the average velocity does not have any effect on the PDR, which is a strange results as the velocity is a common metric in performance evaluation, and previous results have shown that AODV was sensitive to it. On the other hand, the performances with RWM are influenced by the velocity and that also significantly differ from those with VMM. Indeed, we see in Fig. 5(b) that an increasing velocity worsens the delay for the RWM, but does not significantly impact the VMM. Similarly, Fig. 5(c) illustrates how a higher velocity reduces the number of hops for VMM, but does not conclusively affect RWM.

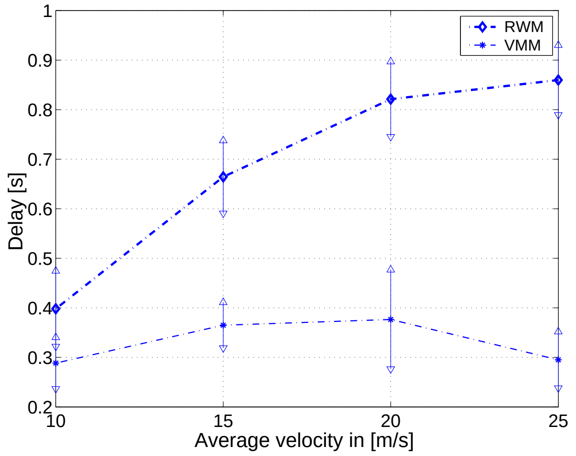
Actually, the explanation for this behavior comes from the micro-model and its interaction with the spatial environment. Indeed, when modeling smooth transitions and realistic interactions with urban traffic regulations, a fixed initial velocity does not make any sense. Instead, we define an *average desired velocity* a driver aims at reaching with a smooth acceleration. However, this desired velocity is subject to speed limitations that cannot be exceeded, or subject to any obstacle that either reduces or even stops the car. Accordingly, there is no guarantee that this velocity can even be reached during the simulation. And, as is can be seen in Fig. 3(a), the real speed is stable with respect to the average velocity, and significantly lower than the desired velocity, which explains the relative stability of AODV with VMM.

We illustrate, on the next set of simulations, the effect of the average length of road segments on the performance of AODV. By increasing the length of road segments from 50m to 300m, we actually model urban traffic distribution observed from small roads in highly urban areas, to highways in major commuting corridors. By fixing the average desired velocity and increasing the road length, we increase the time spent by vehicles on

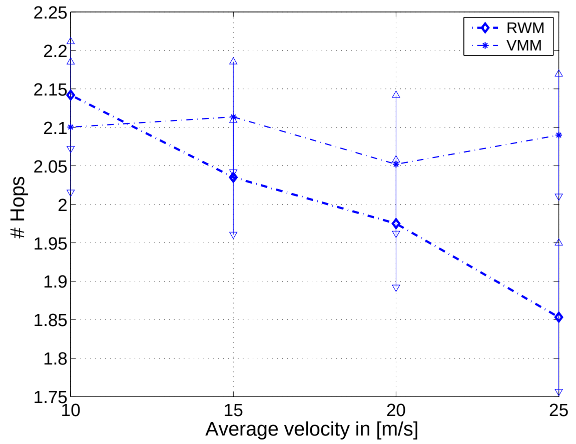
[2] In the rest of the paper, we will refer only to the mobility model for actually mentioning AODV using the mobility model



(a) Packet Delivery Ratio (PDR)



(b) End-to-end delay



(c) Number of hops

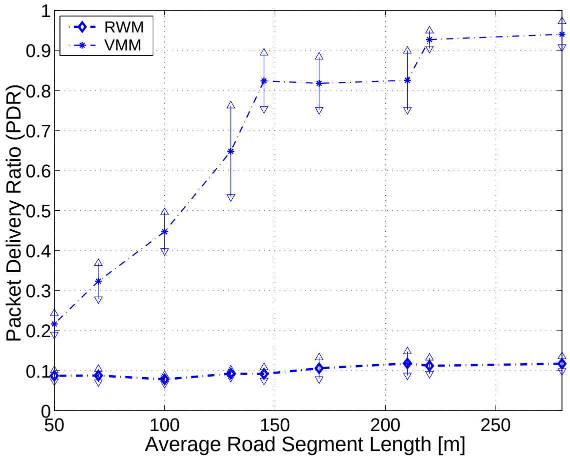
Fig. 5. Performance evaluation of AODV as a function of the average desired speed

the road elements, which in turn reduces the clustering effect and also increases the chance to reach the desired speed. In order to see the sole effect of the length of road segments and not network disconnections, we maintain a fixed node density and we increase the transmission range accordingly.

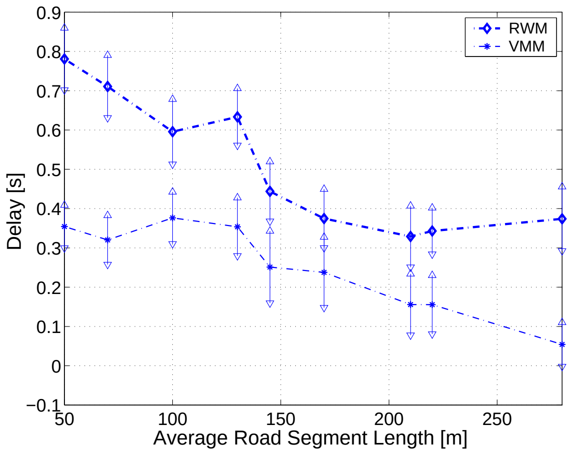
We illustrate in Fig. 6(a) how a longer road segment impacts AODV's PDR. As we could expect, RWM is not influenced by longer road segments. However, AODV's PDR with VMM is significantly improved. And by looking at Fig. 6(b) and Fig. 6(b), we see that the length of road segments also influences the delay and the number of hops of AODV. Not only can we see that the average segment length has an effect on the performance of AODV, but also that the difference between VMM and RWM is not negligible. As VMM models more realistic motion patterns than RWM, we expect the performances in Fig. 6 for VMM to be closer to the reality. Consequently, the length of road segments in urban scenarios should not be neglected.

We further carry on the analysis of urban traffic distribution and its effects on AODV. On the next set of figures, we increase the number of vehicles in the urban area, while reducing the transmission range in order keep the average network density constant (in terms of average number of neighbors per vehicles). We indeed want to spot out results solely dependent on the urban traffic distribution and not on effects on the MAC layer or on routing protocols from an increased number of neighbors. The average road length in this set of figures is set to 150m. By increasing the number of vehicles and keeping fixed average road length, we actually increase the interaction of each car with its environment, which in turn limits its ability to reach a desired speed.

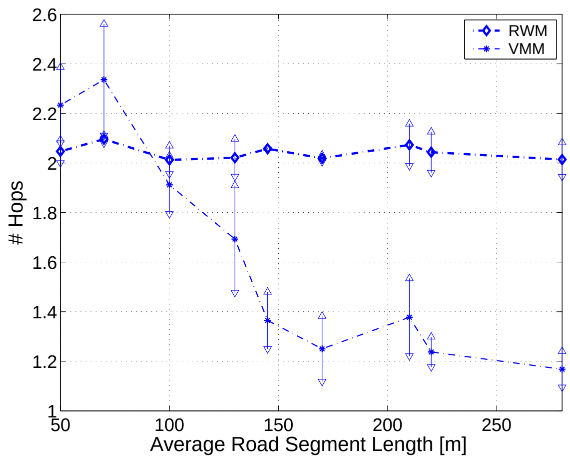
In Fig. 7(a), we depict the effect of traffic clusters at intersections, a parameter that does not influence RWM. As it has an impact on the spatial distribution of the vehicles, the PDR is reduced. This observation is corroborated by looking at Fig. 7(b), where we see the increasing end-to-end delay, and at Fig. 7(c), where the hop count is reduced as the network is only able to deliver data to vehicles in nearby clusters. Again, besides the influence of the parameters on the performances, we see a major performance gap between VMM and RWM. We therefore illustrate how this new parameter is also able to control the performance of AODV for realistic mobility patterns in a way that is not possible by standards parameters.



(a) Packet Delivery Ratio (PDR)

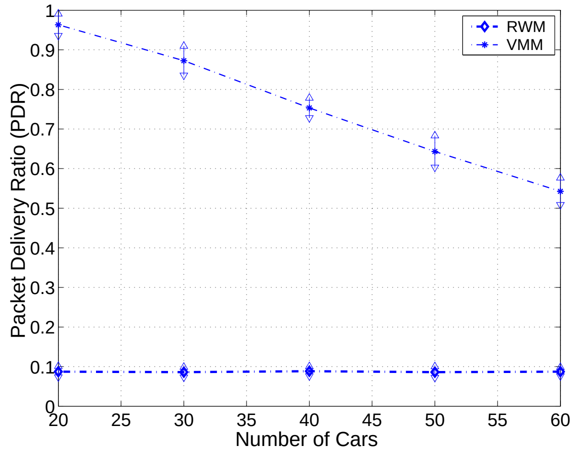


(b) End-to-end delay

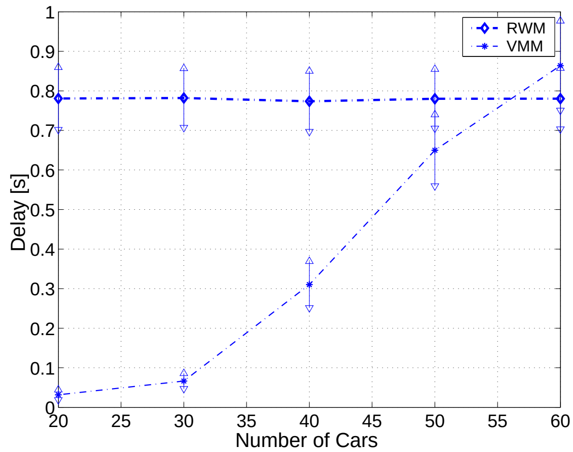


(c) Number of hops

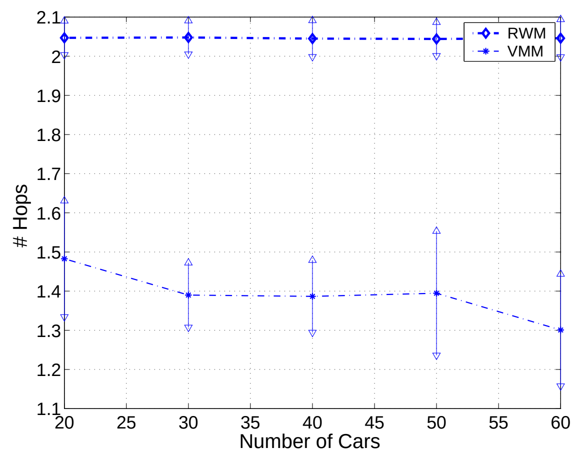
Fig. 6. Performance evaluation of AODV as a function of the average length of the roads segments



(a) Packet Delivery Ratio (PDR)



(b) End-to-end delay



(c) Number of hops

Fig. 7. Performance evaluation of AODV as a function of the number of vehicles (cluster effect)

VII. Conclusion

We illustrated in this paper how vehicular ad hoc networks in urban environment experience particular motion patterns which cannot be properly described by standard parameters. Indeed, the traffic regulations and the vehicles characteristics handled by the *Vehicular Mobility Model (VMM)* are creating a clustering effect at intersection. This effect has remarkable properties on the spatial and temporal distribution of vehicles. The first one is that neither initial nor maximum velocity have a total influence on the real velocity in urban environments. Indeed, due to the interactions with the spatial environment and other neighboring cars, vehicles experience a non negligible speed decay. Then, a second property is the non-uniform distribution of urban traffic which locally increases the density of vehicles.

As neither the average velocity, nor the average density are able to control the spatial and temporal dependences generated by realistic urban vehicular motion patterns, we defined new meaningful parameters such as the *average length of road segments*, *the acceleration* or *the cluster effect*. By representing the true parameters of the topology or the mobility patterns, we illustrated how they have a significantly larger impact on the performance of AODV.

Another observation is that not only these new parameters were able to remarkably describe urban motions, but also that these urban motions were actually improving the performances of AODV, as they were significantly increased compared to those with the Random Waypoint. These parameters become therefore an important key to more realistic performance evaluations of vehicular ad hoc networks in urban environments.

VanetMobiSim is planned to include realistic signal propagation models. As obstacles limit the speed, radio obtacles limit the connectivity. In future work, we plan to study the effect of realistic radio propagation models, including obstacles, on the performance of routing protocols.

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