Int. J. Advanced Networking and Applications
Volume: 01 Issue: 01 Pages: 252-257 (2010)

Packet Transmission Analysis in Vehicular Ad Hoc Networks using Revival Mobility Model

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ABSTRACT

Vehicular Ad-hoc Networks (VANETs) have been recently attracting an increasing attention from both research and industry communities. VANETs are currently deployed on a large scale, research in this area is mostly simulation based. Mobility models or the movement patterns of nodes communicating wirelessly, play a vital role in determining the protocol performance in VANET. We still have a limited understanding of the required level of mobility details for modeling and simulating VANETs. Thus, it is essential to study and analyze various mobility models and their effect on VANET protocols. In this paper, we examined different mobility models proposed in the recent research literature. We proposed Revival Mobility Model (RMM) and evaluate its effect on packet delivery in VANETs by ns-2 simulations.

Keywords: **Vehicular Ad Hoc Networks, Mobility Modeling, Revival Mobility Model, Packet Delivery Ratio**

Date of Submission: December 4, 2009 Accepted: January 17, 2010

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 very high node mobility and limited degrees of freedom in the mobility patterns. Difficulties in the conducting large-scale and extensive field trials of logistic, economic and technological nature make simulation the mean of choice in the validation of networking protocols for vehicular networks. It is a common practice in the preliminary stages of real-world technologies development. However, quite surprisingly, most of the simulative approaches to the analysis of inter-vehicle communication tend to pay small attention to vehicular mobility, thus neglecting the most characterizing aspect of vehicular networks. As a matter of fact, networking a vehicular environment is made especially challenging by peculiar features of nodes mobility, such as the high speed of cars, the strict constraints on nodes movement patterns, the periodicity of dense and sparse network areas, the clustering of users at intersections or in traffic jams. These phenomena can only be captured with a limited level of realism in the simulated cars movement, and their impacts on the network performance cannot be ignored. But need to be studied to guarantee the network simulation outcome to be reliable. Earlier mobility models proposed for ad hoc networks have been largely studied and surveyed in literature [1, 2]. The objective of this paper is thus to understand what degree of interest the networking research community could have toward different mobility models, each of which providing an increasing level of detail in the vehicular movement description. To this extent, we recall in Section 2 some common classification of mobility models employed in the vehicular networking literature, and we define vehicular mobility modeling in networking in Section 3. In Section 4, some of the existing VANET mobility models are discussed. In Section 5, a new mobility model is proposed and the effect of the adoption of different mobility models on inter-vehicle communications metrics is studied. Finally, we wrap up our simulation result and analysis in Section 6.

2. VEHICULAR MOBILITY MODELING

Modeling Mobility is one of the important aspects in Vehicular Network. Various approaches can be adopted in modeling the movement of vehicles [5, 6]. Mobility models can be commonly classified into the following categories:

2.1 Macroscopic models*:* Vehicular traffic is regarded as a continuous flow, and gross quantities of interest, such as the density or the mean velocity of cars, are modeled, often using formulations borrowed from fluid dynamics theory.

2.2 Mesoscopic models: Individual mobile entities are modeled at an aggregate level, exploiting gas kinetic and queuing theory results or macroscopic-scale metrics, such as velocity/density relationships, to determine the motion of vehicles.

2.3 Microscopic models: Each vehicle's movement is represented in great detail, its dynamics being treated independently from those of other cars, except for those near enough to have a direct impact on the driver's behavior. Microscopic models are able to reproduce fine-grained real-world situations, such as front-to-rear car interaction, lane changing, flows merging at ramps, and intersections. Although macroscopic and mesoscopic descriptions are employed to capture the dynamics of large-scale vehicular systems, such as those occurring over road topologies covering whole regions or countries, microscopic models, due to their high computational cost, are usually applied to reproduction of traffic in smaller areas, such as single highways or urban areas. However, the traditional branching of models into macroscopic, mesoscopic, and microscopic becomes less meaningful when considering vehicular mobility models employed in network simulation. Thus, a different, better fitting classification could be constructed by differentiating on the nature of the diverse analytical representation of car motion encountered in the vehicular networking literature. We propose the following categorization

2.4 Stochastic models: Vehicle movement is regarded at a microscopic level which is constrained on a graph representing the road topology, mobile entities follow casual paths over the graph, traveling at randomly chosen speed. Stochastic models are the most trivial way to mimic car mobility, and were introduced by pioneering works in the field of vehicular networking.

2.5 Traffic stream models: Vehicular mobility is observed from a high level and treated as a continuous phenomenon. Traffic stream models determine cars' speeds, leveraging fundamental hydrodynamic physics relationships between the velocity, density, and outflow of a fluid, and thus fall into the macroscopic or mesoscopic categories defined before.

2.6 Car-following models: The behavior of each driver is computed on the basis of the state (position, speed, and acceleration) of the surrounding vehicles.

2.7 Flows-interaction models*:* Built upon an instance of one of the previous categories, flows interaction characterizes the mutual dynamics that merging vehicular flows induce reciprocally, e.g., at highway ramps or urban intersections.

3. VEHICULAR MOBILITY MODELING IN NETWORKING

The formal definitions of models in the following employ the notation depicted in Fig.1.

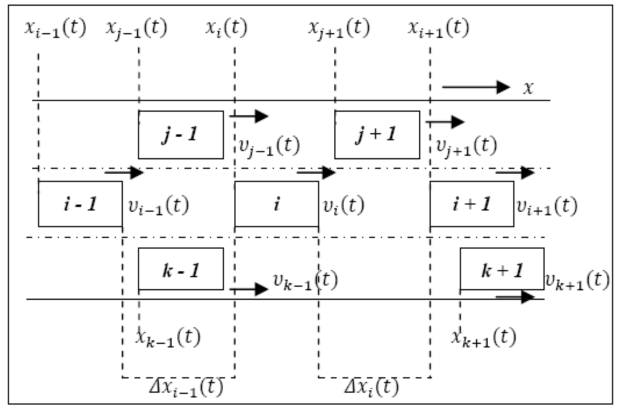

Fig.1: Notation for the models' formal definition

There, the index i refers to the vehicle under investigation, while $i+1$ identifies the front (+) and back (-) vehicles on the current lane. Furthermore, for a generic vehicle i at time t, $x_i(t)$ and $v_i(t)$ represent its position and speed, meaning that its instantaneous acceleration can be expressed as $dv_i(t)/dt$. The front bumper to back bumper distance between i and $i+1$ is identified as $\Delta x_i(t)$, while the relative speed $v_{i+1}(t) - vi(t)$ is denoted by $\Delta v_i(t)$. Note that, according to its definition, in the following a positive $\Delta v_i(t)$ will always mean that the distance of car i from its leading vehicle $i+1$ is growing. The back and front cars on the *left* lane with respect to the one vehicle i is traveling on are denoted by $j-1$ and $j+1$, respectively. The back and front cars on the *right* lane with respect to the one vehicle i is traveling on are denoted by $k-1$ and $k+1$, respectively.

4. EXISTING VANET MOBILITY MODELS

In this section we present the models that were proposed for simulating VANETs. Basically, these models simulate movements in routes. As we will see, the considered parameters differ from one model to another. For instance, some models use route intersections, and others just assume continuous movement at these points. Some assume routes to be single lane, some others support multi-lanes routes.

4.1 Freeway Mobility Model (FMM)

Freeway is a generated-map -based model, defined in [3].The simulation area, represented by a generated map, includes many freeways, each side of which is composed of many lanes as shown in the Fig.2. No urban routes, thus no intersections are considered in this model. At the beginning of the simulation, the nodes are randomly placed in the lanes, and move using history-based speeds. A security distance should be maintained between two subsequent vehicles in a lane. If the distance between two vehicles is less than this required minimal distance, the second one decelerates and let the forward vehicle moves away. The change of lanes is not allowed in this model. The vehicle moves in the lane it is placed in until reaching the simulation area limit, then it is placed again randomly in another position and repeats the process. This scenario is definitely unrealistic.

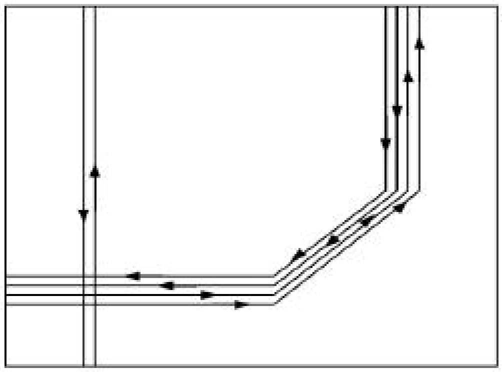

Fig. 2: Freeway Mobility Model

4.2 Manhattan Mobility Model (MMM)

This is also a generated-map-based model, introduced in [3] to simulate an urban environment. Before starting a simulation, a map containing vertical and horizontal roads is generated as shown in the Fig 3. Each of these latter includes two lanes, allowing the motion in the two directions (north/south for the vertical roads and east/west for the horizontal ones). At the beginning of a simulation, vehicles are randomly put on the roads. They then move continuously according to history-based speeds (following the same formula like the freeway model). When reaching a crossroads, the vehicle randomly chooses a direction to follow. That is, continuing straightforward, turning left, or turning right. The probability of each decision is set by the authors respectively to 0.5, 0.25, 0.25.The security distance is also used in this model, and nodes follow the same strategy as in the freeway model to keep this distance. But contrary to the previous model, a vehicle can change a lane at a crossroads. Nonetheless, there is no control mechanism at these points (crossroads), where nodes continue their movements without stopping, which is unrealistic.

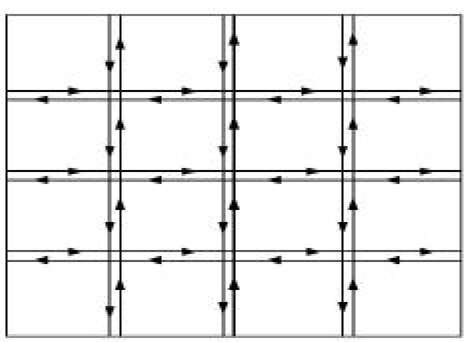

Fig. 3: Manhattan Mobility Model

4.3 City Section Mobility Model (CSM)

CSM [4] can be viewed as a hybrid model between Random Way Point (RWP) and Manhattan, as it introduces the principle of RWP, especially the pause time and random selection destination, within a generated-map-based area as shown in the Fig.4.

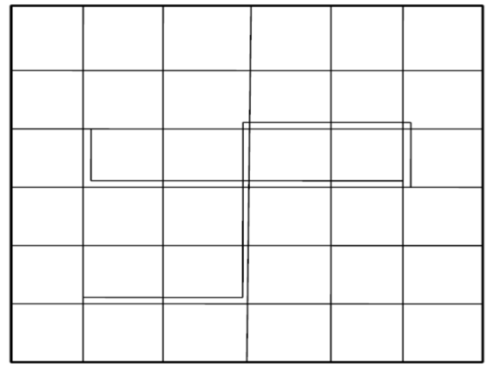

Fig. 4: City Section Mobility Model

At each step of the vehicle's movement a random point is selected from the generated road map, toward which it moves following the shortest path. After reaching that destination, it remains there for a pause-time, and then repeats the process. The speeds of nodes are constrained by the security distance, along with the maximum speed limit of the road.

5. PROPOSED VANET MOBILITY MODEL

5.1 Revival Mobility Model (RMM)

We use Revival Mobility model (RMM) to simulate the movement pattern of moving vehicles on streets or roads defined by maps from the GPS equipped in the vehicles. In Revival Mobility model (RMM), the road comprises of two or more lanes. Vehicles or nodes are randomly distributed with linear node density. Each vehicle can move in different speed. This mobility model allows the movement of vehicles in two directions. i.e. north/south for the vertical roads and east/west for the horizontal roads.

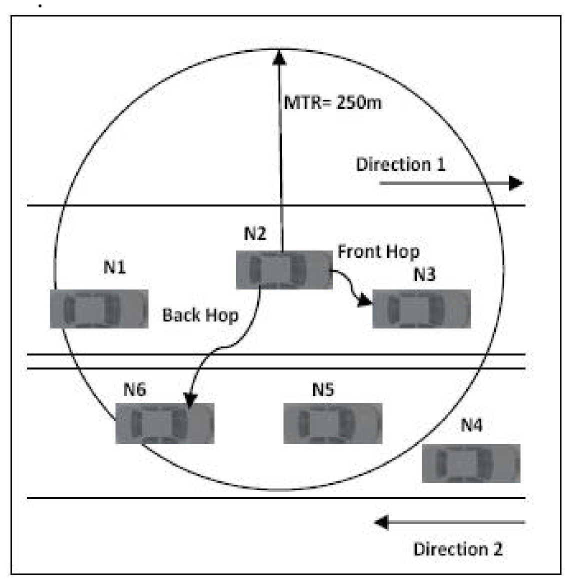

Fig. 5: Revival Mobility Model

In cross roads, vehicles choose desired direction based on the location of destination node. A security distance should be maintained between two subsequent vehicles in a lane. Overtaking mechanism is possible, one vehicle can able to overtake the preceding vehicle. Packet transmission can be done by vehicles moving in both directions, which means front hopping and back hopping of data packet is possible as shown in the Fig. 5. Packet transmission can be done in longitudinal and transverse mode. In this mobility, deterministic and instantaneous transmission mechanism is possible in which a message is available for receiving within a certain radius *r=250m* from the sender with certainty, but unavailable further away. Vehicles can unicast, multicast and broadcast packets to the neighbor vehicle which is present within its transmission range. The features of different VANET mobility models are mentioned in Table 1.

Table 1: VANET Mobility Model features

FEATURES	FMM	MMM	CSM	RMM
Real maps	no	no	no	no
Number of lanes	many	one	one	many
Direction-Vehicle movement	one	two	one	two
Intersections	no	yes	yes	yes
Changing lanes at intersections	no	yes	yes	yes
Traffic Control	no	no	no	no
Overtaking	no	no	no	yes
Security Distance	yes	yes	yes	yes
Pause-time	no	no	yes	yes

6. SIMULATION RESULTS AND ANALYSIS

The simulation model was based on the ns-2.27 [7] and VANET. The IEEE 802.11 Distributed Coordination Function (DCF) is used as the Medium Access Control Protocol.?The packet size was fixed to 512 Bytes. The Traffic sources are UDP. Initially the nodes were placed at certain specific locations, and then the nodes move with varying speeds towards new locations. In the simulation study, the Directional Greedy Routing Protocol (DGRP) was used as the routing protocol. The simulation parameters are mentioned in Table 2.

Table 2: Simulation Parameters

Parameter	Value
Simulator	ns - 2.27
Simulation Area	1000m x 1000m
Number of Vehicles	0 - 100
Mobility of vehicles	0 –50 (meter/sec)
Number of packet Senders	30
Transmission Range	250m
Constant Bit Rate (CBR)	2 (Packets/Second)
Packet Size	512 Bytes
Routing Protocol	DGRP
MAC Protocol	802.11 DCF
Vehicle mobility models	FMM,MMM,RMM
Performance Metrics	Packet Delivery Ratio

6.1 Performance Metrics to evaluate simulation:

Packet delivery ratio (PDR)

The ratio of the packets that successfully reach destination. In this part, we compare the performance of FMM (Freeway Mobility Model), MMM (Manhattan Mobility Model) and Revival Mobility Model (RMM) in terms of packet delivery ratio. We will show how packet delivery is affected by the features of different mobility models.

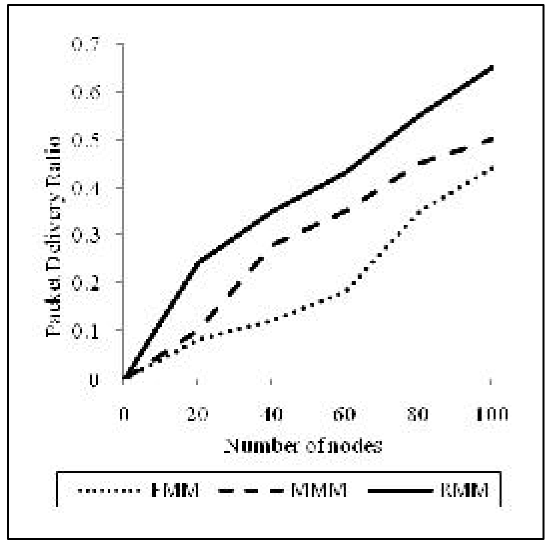

Fig. 6: PDR vs. Number of nodes

Fig. 6 shows the packet delivery ratio (PDR) as a function of CBR rate and compares the performance under different vehicle traffic densities. In all mobility models, the packet delivery ratio is very low when the number of nodes in the network is less. The packet delivery in FMM and MMM is comparatively less with RMM because of its restricted features. In RMM, data transmission can be done in longitudinal as well as transverse mode, which gives maximum possibility to meet neighbor vehicle to forward the packet. So, RMM provides better packet delivery compared to other mobility models. The RMM gives an improved packet delivery ratio of about 9% compared to the MMM.

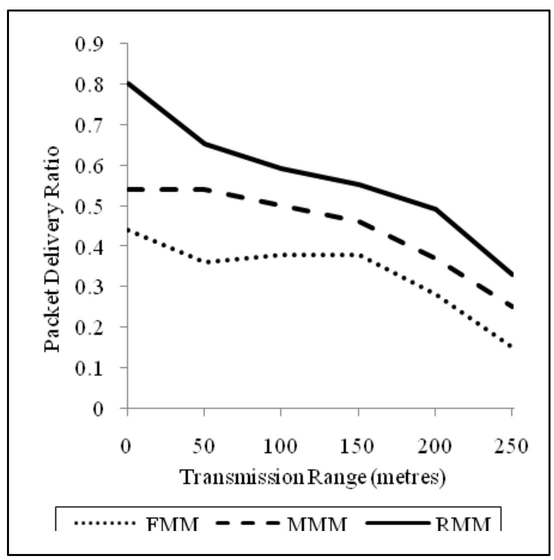

Fig. 7: PDR vs. Transmission Range

Fig. 7 shows the packet delivery ratio as a function of CBR rate and compares the performance under different transmission range of a vehicle. When the transmission range is between 50m to 150m, packet delivery ratio is good for all mobility models. Beyond 150m range, signals strength becomes weak and also due to high speed of vehicles, possibility of packet drop increases, which leads to decrease in packet delivery. In this case, the RMM gives an improved packet delivery ratio of about 12.5% compared to the MMM.

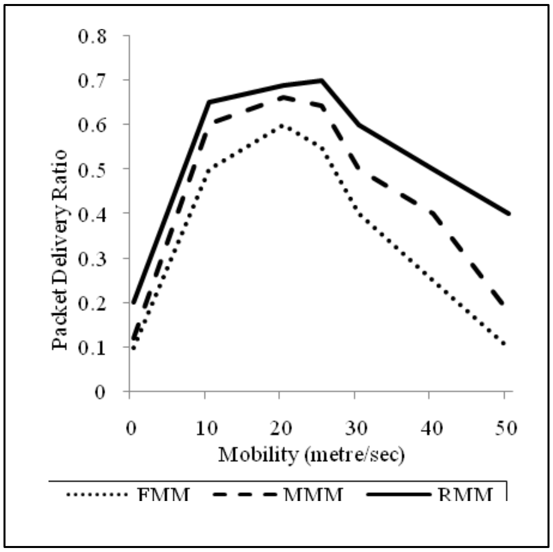

Fig. 8: PDR vs. Mobility

Fig. 8 shows the packet delivery ratio as a function of CBR rate and compares the performance under different speed of a vehicle. In FMM and MMM the speed of the vehicles is constant. At high speed, possibilities of error rate in data transmission increases. In RMM the speed of vehicles vary based on traffic densities and intersections. This provides better packet delivery in RMM compared to other mobility models. The RMM gives an improved packet delivery ratio of about 10.67% compared to the MMM.

7. CONCLUSION

This paper presents an overview of the categories of vehicular mobility models and performance metrics used to determine the effectiveness in VANET. In this paper, we have proposed and discussed a new vehicular mobility model, Revival Mobility model that can capture the movement pattern of vehicles at varying levels in detail. We dealt with mobility models such as FMM, MMM, CSM and RMM, which are based on unrealistic maps that can be used to simulate vehicular Adhoc networks (VANETs). In our perspectives, we investigated the impact of FMM.MMM and RMM on the packet delivery ratio in VANETs. Our results indicate that the feature of RMM using DGRP is comparatively better than other mobility models in terms of packet delivery ratio. Our work provides a sound starting point for further understanding and development of mobility models for VANETs.

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