Challenges on Mobility Models Suitable to Vanet

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Abstract: Vehicular Ad Hoc Networks (VANETs) are the extension of multi hop Mobile Ad Hoc Networks (MANETs) formed by fast moving vehicles on the roads as computing and communicating nodes to provide safety services in the Dedicated Short Range Communication (DSRC) system developed upon the family of IEEE 802.11 standards. Establishment of direct wireless communication between fast moving vehicles on the road ensures the exchange of data between them even in the absence of any previously deployed communication infrastructure like road side access points and base stations. It is a widely accepted fact that simulating the network behavior is the feasible and cost effective way to do research on the network, rather implementing such a real world system. The topological changes due to movement of nodes in the network are reflected by the mobility models and it is a challenge of providing a dynamic vehicular mobility model to exhibit the realistic behavior of nodes accurately. Researchers show interest in developing communication protocols to support this technology and the network performance in view of routing protocols, connectivity, packet delivery, delays, congestion etc. is being inspired by the mobility pattern of nodes. It is a challenge that the traditional MANET mobility models cannot be applied to VANETs as such. Existing mobility models are not considering the strengths of the VANET such as constrained mobility, absence of power constraints or the ability of nodes to know their geographical position. This paper studies the existing mobility models for VANETs and reason out the challenges in incorporating MANET mobility models into VANET.

Key Words: MANET, VANET, mobility models, simulation.

1. Introduction

MANET is the network formed by people carrying any portable device equipped with communication capability. Devices such as laptops, cell phones and PDAs carried by a person are considered to communicate with each other while the person is on move. The mobility pattern is influenced by the walking speed of the person carrying the device. One of the most promising and challenging application areas of MANET is VANETs, in which the network is formed with fast moving vehicles on the road connected in wireless mode. Vehicles within a range of approximately 100 to 300 meters shall be connected with each other to form a network. The network is being influenced by the characteristics of the road and the other vehicles moving on the road. Any vehicle move out of the signal range, the drop out will be managed with the other vehicles join in with the network.

Safety and control messages are disseminated between vehicles on the road by establishing a communication network among them by equipping the vehicles with on board electronic devices capable to communicate with a nearby vehicle equipped with a communication and computation device. VANET establishes distributed and self-organizing dedicated short range wireless communication among moving vehicles on the road supports Intelligent Transport System (ITS) to accomplish its goals of reducing road accidents, distribution of traffic load to reduce congestion in road, driver assistance and infotainment. It broadly supports safety applications and comfort applications, and assists drivers for safe and comfort journey.

ITS requires the VANET to establish the following three possible ways of communication architectures.

- Vehicle-to-Vehicle (V2V): Direct multi hop wireless communication between the moving vehicles on the road, without the support of any communication infrastructure.
- Vehicle-to-Infrastructure (V2I) : Communication between vehicles and roadside units to establish communication between vehicle and other networks such as cellular networks, WiMax ,WiFi and with road side access point. This kind of communication suffers with lack of dense enough road side infrastructure [1]
- Hybrid architecture: Combination of V2V and V2I to ensure a long distance connection especially in the highway scenario.

It has been widely accepted by the recent researchers that, though VANET is the extension of MANET, the network solutions proposed for MANET will not be applicable for VANET scenario. It is the need of the day to develop realistic mobility models to mimic the realistic behavior of vehicular environment. The characteristics of network architecture, dynamic change of topology with frequent network partitions, an uneven network density and a high demand for scalability of network due to large number of vehicles makes VANET distinct from MANET. High mobility of vehicles and the sparse networking scenarios due to less traffic intensity makes inefficient the 'store-and-forward' communication strategy used in MANET [1].

In recent years, leading car manufacturers are progressing towards the deployment of VANET technology by embedding their cars with intelligent on-board wireless devices capable of computation and communication, sensors and navigation devices to establish a driver support system. Industry, academia and standardization agencies are working together to come out with prototypes and suitable standards specific to vehicular communication. Academia and industry researchers are contributing towards optimizing the routing protocols, connectivity mechanisms, security standards, etc. to improve the performance of the network. Performance of the network behavior is being evaluated using simulators, as the implementation of such a real system is economically not feasible.

Authors of [1] listed few of the following research avenues exclusively specific to VANET scenarios, which is a clear indication that the existing MANET based solutions are inefficient and insufficient to handle realistic VANET related issues. (1) Knowing fundamental performance limits for data aggregation , asymptotic throughput capacity, the optimal broadcasting structure, and the multicast capacity for hybrid VANETs with directional antennas, (2) Dynamic Spectrum Access (DSA) for inter-vehicle communications, (3) Simulation, validation and experimental results, (4) Highly Heterogeneous VANET systems, (5) Application-aware VANET networking, (6) Information-centric networking for VANETs, (7) Software Defined VANETs and (8) Security and privacy.

To the interest of this paper, we have done further survey on the challenges and research avenues specific to mobility models in the simulation of VANET scenario. Fast moving vehicles on the road changes its position rapidly and keeps the network topology more dynamic. The movement pattern of vehicles constitutes the mobility model which mimics the traffic scenario on the road and it plays a vital role in the evaluation of the performance of the network. Number of lanes, traffic signals, speed regulations, diversion, obstacles, direction of movement, traffic jam in road junctions and behavior of the driver are few of the parameters effect the mobility scenario of the network. The mobility model is expected to consider all these motion constraints and dynamically adaptable to them, makes the mobility model more realistic and dynamic. Rest of the paper is organized as follows. Section II describes the classifications and impact of mobility models on the network performance, Section III discusses about few of the realistic mobility models, Section IV describes about the VANET simulation environment, Section V describes about the specific characteristics to be considered while developing VANET mobility models and the paper is concluded in Section VI.

2. Impact of Mobility Models

In general mobility models are classified in to following categories.

1) *Random Mobility Models:* In this model, the nodes are expected to move freely without any restriction. Attributes like speed, direction and destination were chosen randomly and a pause is included between changing the value of attributes. Random Waypoint (RWP) [3][5] is the traditional mobility model assumes the nodes can move around in an open field obstruction in any direction. The velocity is determined from a given range [Vmin- Vmax].Every node selects a random destination and then moves to that destination in a chosen velocity v, after reaching the destination, pauses for a pre-determined time and then moves again to another random destination with new velocity and direction. This traditional RWP model is well suited for MANETs in which people can walk in any direction without any obstruction. This model is being widely used in all the network simulators. In contrast with RWP, the urban scenario of VANET is characterized by the high speed of the vehicles, road layouts, junctions with traffic signals, buildings and other obstacles. RWP model is not applicable in VANETs because it does not represent the actual behavior of vehicles [15]. Random Direction (RD) model [15], the nodes randomly and uniformly selects the direction between [0,2π] and velocity between [minspeed, maxspeed] and maintain the same value till reaches the boundary. RD model also not suitable for VANETs, since it mimics only the behavior of pedestrian walking in straight walk segments. Random Walk mobility model [27] is similar to RWP and while moving from current position to new position, nodes randomly chooses the new speed of range [minspeed, maxspeed] and direction [0,2π] from the predefined ranges. However this modes does not mimics the real life scenario, because there may exist a dependency among current and earlier velocity.
2) *Temporal Mobility Models:* In this category of mobility, the movement is regulated by the laws of physical motion and the current mobility is dependent on previous movement history. Gauss Markov Mobility Model [28] falls into this category, in which ***the*** node's velocity is to be correlated with time. In the beginning the nodes were assigned with a speed and direction, at a time interval t, the mobility takes place by incorporating the new speed and direction. Smooth Random Mobility Model [29] presents an approach in which the speed of the node changes in an incremental and smooth manner avoids the sudden increase and decrease of speed and sudden and sharp change of direction.
3) *Spatial Mobility Models:* The location of the node plays a vital role in the mobility pattern in such a way that there exists a probabilistic dependency between the current location of the node at a time instant and the location at next time. Probabilistic Random Walk (PRW) [30] in which a probability matrix is used to determine the node position ***at*** the next time instant by providing three different states for position x and y each. Reference Point Group Mobility Model (RPGM) [31] is the model in which the nodes move together in a group or platoon in accordance with the group leader. The group leader's movement at time t can be represented as a motion vector Vt group and it can be chosen either by random or based on predefined paths. Column Mobility Model (CMM) [31] is the model which the nodes are moving a certain fixed direction in columns but not in random fashion.

4) *Geographical Mobility Models:* These mobility models are restricted with geographical environment in which the mobility is constrained with bounded campus, guided pathways, blockage by building of any other obstacles. Pathway Mobility Model [33] works based on a graph created either by random or by careful definition of a real city map. The graph is denoted by G, building of the city forms the vertices V and nodes are randomly placed on the edges E, forms the streets and freeway between the buildings. Node moves towards the destination through the shortest path, pauses in the destination and then move towards next destination. Manhattan Grid model [9] is the variant of pathway mobility model in which in mobile nodes move along a grid of possible ways. Nodes are randomly put on the roads, then they move continuously according to history based speeds. While reaching the intersection, the vehicle randomly chooses a direction to travel, either turns left, right or goes straight. Freeway mobility model [13] [34] is the other variant of Pathway mobility model, in which nodes are randomly placed in lanes, and move with a speed in history. A safe distance will be maintained between two subsequent vehicles in a lane and lane change is not allowed in this model. If the distance between two vehicles is less than the required minimal distance the second one slows down its speed and let the forward vehicle moves away. Vehicles moves in a lane reaches the boundary of simulation and then placed randomly in another position and start moves which is unrealistic. Obstacle mobility model [35] is the model in which obstacles are inserted in the path of the moving node and the node has to change its direction of movement.

In MANET, earlier researchers focused on the cellular networks and its movement scenario as mobility patterns in macroscopic level. Mobility patterns of cellular networks were used to analyze the issues in cellular system such as hand over, location management, traffic load, blocking probability etc. These mobility models provides a basic foundation and influence the performance of routing protocols in such a way that different results will be obtained for different mobility scenarios though the same protocol is being tested [25]. Thus, when evaluating MANET protocols, it is necessary to choose the proper underlying mobility model. For example, the nodes in Random Waypoint model behave quite differently as compared to nodes moving in groups. It is not appropriate to evaluate the applications where nodes tends to move together using Random Waypoint model [26]. Therefore, there is a real need for developing a deeper understanding of mobility models and their impact on protocol performance.

While comparing with MANET, simulation for VANET requires large scale road traffic scenarios and special and specific characteristics of vehicular environment. Implementing, testing and evaluating the complex VANET scenario in reality is expensive and time consuming, leads to inaccurate results. Traffic simulation tools can be used as an alternate choice for conducting cheap and repeatable evaluations prior to real implementation and accurate results shall be obtained comparing to real test bed environment. It has been confirmed that the accuracy of the simulation depends on the mobility models which determines the pattern in which the nodes (vehicles) are located in the topology at any point of time, which in turn affects the performance of the network connectivity and it is expected that the simulator must be equipped with mobility models to exhibit the realistic behavior of the real traffic scenario [2] [4].

According to [15], mobility pattern specific to VANET is influenced by the factors like construction of roads or streets (number of lanes, intersections), block size (group of vehicles at intersections), traffic control mechanism (stop signal), interdependent vehicular motion (inference of surrounding vehicle) and average speed (connectivity depends upon the speed).

Mobility plays a vital role in increasing the transmission capacity of the network [16], improving the networks' coverage [17], enhancing the security in ad hoc networks [18].

3. Realistic Mobility Models

Survey on most of the presently available mobility models was done and they are classified according to the approach followed to construct that model.

1) Models Based on Simulation Traces: Further classified in to Real world traces and artificial traces. Real world traces are extracted from realistic traces such as GPS traces, whereas in artificial traces, the roads and traffic are proposed and modeled by software using mathematical models. During the simulation, corresponding trace file will be generated for further analysis on traffic and movement. Real world mobility traces [11] were obtained from vehicles and it was post –processed and then the node mobility was controlled by reading these trace files. The META model (Metropolitan Taxis mobility model) [19] developed by collecting the real world traces of GPS data by running 4000 taxis in a urban area for three months. The collected GPS data was analyzed for further extraction of information and parameters required in the simulation to prepare the traces. Turn probability, road section speed and travel pattern are the parameters used during the experiment. Parameters of real traffic situations on the roads such as attraction points, speed variations, traffic lights, node movement, and the topology of the simulation area were considered by the authors of [15]. Rather than obtaining real traces of mobility, artificially modeling the mobility traces came in to existence in 2004 by [12].
2) Models Based on Real World Maps: This approach uses the real world maps obtained from databases. Authors of [2] contributed towards Stop Sign Model (SSM), Probabilistic Traffic Sign Model (PTSM) and Traffic Light Model (TLM) to capture the realistic behavior of vehicular mobility on urban streets. They brought out clustering effect at the intersections which influenced the performance of the network protocol. Simulations were performed based on real street maps obtained from the TIGER database (Topologically Integrated Geographic Encoding and Referencing)[20], which provided them with additional information on speed limit and number of lanes. This work [2] is assumed to be pioneer in developing dynamic mobility models suitable to VANET. Geographic Information System (GIS) based Mobility model [21] uses the street maps extracted from GIS including speed limit information and other useful data. The simulation results proved the evolution of realistic mobility model to overcome the limitations of RW model.
3) Integration of existing models : Existing models are integrated together by extracting the good features of the existing model. Integrated Mobility Model (IMM) [22] proposed by Alam Muhammad et. Al by integrating Manhattan, Freeway, stop sign and traffic sign mobility models. The characteristics of Manhattan Model in which the intersections are formed with vertical and horizontal streets with two lanes in urban area. At intersections points, the nodes will take a direction according to the turning probability. Vehicles of each lane maintain a velocity, and velocity dependency between vehicles of the same lane will also be maintained. High spatial and temporal dependency is maintained in Manhattan Model. In freeways scenario, multiple lanes present in both directions. Lane restriction will be followed for the vehicles and a safe distance will be maintained between vehicles and the velocity of the following node cannot exceed that for the preceding one. IMM combined both these characteristics in such a way that street are represented with freeway model and nodes' behavior follows the Manhattan model. To enhance the realism, the stop signs, traffic lights, stop time, wait time, safe inter-vehicle distance and acceleration/deceleration are embedded in this model. While looking at the simulation results, it has been observed that realism of traffic environment is maintained but the network performance is not appreciable.

4. Vanet Simulation

In general, the vehicular traffic simulators are classified into the following categories [14]:

1) Microscopic Simulators: Movement of individual vehicle and its behavior with nearby vehicles should be determined by the simulators that can provide simulated values for a wide range of parameters.
2) Macroscopic simulators: This model does not consider vehicles alone. Flow of large number of vehicle will be viewed at global perspective by considering the road topology, road characteristics and condition, traffic density and distribution, traffic lights, traffic flow to compute road capacity and the distribution of the traffic in the road network.
3) Mesoscopic simulators: The interaction between the vehicles is ignored in this model, but it gives elaborate details about single entities.

During the simulation of vehicular communications, individuality of every vehicle is to be considered. Interaction between vehicles is the very important factor to measure the performance of network connectivity. Due to these factors, all the different solutions for VANET simulation have until now adopted a microscopic model [23].

According to the authors of [6], following are the important parameters to be considered for the simulation of vehicular environment. (1) Realistic and accurate topological maps exhibits the intersections, lane, streets, speed limits etc.(2) Points of attraction/repulsion points which specifies the source and destination (3) Characteristics of Vehicles such as heavy vehicles, light vehicles, emergency vehicles etc. (4) Smooth deceleration and acceleration (5) Driving pattern of driver like normal driving, overtaking, lane changing, any abnormalities in driving pattern (6) Managing Intersection and Obstacles such as traffic lights, stop signs, obstacles etc.

Authors of [5] claims that the network simulators NS2 or OMNet++ are not sufficiently equipped for adequately simulating the mobility of moving cars. Authors also claim that, among the three traffic models, macroscopic, mesoscopic and microscopic models, only microscopic simulation has been considered as an adequate mobility model for vehicular networks. Simulators like GlomoSim, QualNet, OPNET, NS2 progressed towards using the real world traces[11], artificial mobility traces [12]. Due to the distinct nature of VANET, the network simulator alone is not sufficient to measure the performance of the network, since the network simulators were modeled to handle only the MANET environment.

However, it is very much essential to have a strong bidirectional interaction between the road traffic simulator and the network simulator with a very low latency and with high accuracy to measure the performance of the network behavior under any vehicular scenario. To give a solution to this issue, bidirectionally coupled simulators [7][8] were developed in which the traffic simulator and network simulator are coupled together as two inter-dependent processes running concurrently. The characteristics of vehicles like speed, direction, acceleration and the road characteristics like number of lanes, intersections were simulated in the traffic simulator and the impact of the mobility pattern on the network is evaluated by network simulators. General example for this integration is the Veins environment [8] coupling SUMO (traffic simulator) with OMNeT++ or NS2 (Network Simulators)

5. Vanet Characteristics

The following distinct features and characteristics of VANET while comparing with MANET, depicts the need of developing a specific solution exclusively suitable to VANET [24].

1) Topology: Comparing with MANET, the nodes (vehicles) of VANET moves very fast which makes the topology highly dynamic in nature. Moreover the road environment also plays a vital role in change of topology. In urban environment, vehicles are expected to travel in a relatively low speed comparing with vehicles flying in highways with relatively high speed. This is the challenging aspect in VANET to develop a communication solution for different environments. As a result of very fast

movement of nodes, change of their direction of travel at any time and frequent join and disjoint of nodes at any time keeps the topology more dynamic always.

2) Connectivity: Due to the highly dynamic nature of vehicular topology, the network suffers with frequent disconnections. While the vehicles leave the network due to change of direction or any other reason, the transmission get disconnected due to link failure.
3) Positioning: Vehicles in the networks are identified based on their geographical position which makes VANET distinct from other networks.
4) Mobility pattern: The movement of vehicles is always influenced by the conditions of the road, city roads and high ways, obstacles on the road, traffic signals at intersections, speed restrictions and driving behavior of driver.
5) Propagation Model: Commonly known propagation model for ad hoc networks are discussed in [36]. It is a challenge to fit a common model among the propagation models for vehicular networks, due to the different environment in which the network operates. The model suitable for highway may not be suitable for rural and city environments. Widely freeway model is suggested for highway, but the signal propagation suffers with reflection. Variable vehicle density, buildings, trees and other objects affects the signal propagation leads to shadowing, multipath and fading effects. Fields, hills, climbs, dense forests etc. are the factors cause signal reflection and attenuation of signal propagation. Interference of signals from other vehicles and access points also to be considered while developing propagation model for VANET.
6) Spatial-Temporal Constraints: Topological, geometric or geographic constraints and change of velocity according to time are to be considered for VANET scenario. Authors of [37] contributed towards these issues.
7) Heterogeneity of Vehicles: Normally vehicles running on the road are expected to maintain different speed, rather a fixed speed. Different types of vehicles (Car, bus, lorry) will exhibit different lane discipline and movement patterns.

6. Conclusion

Research on VANET always focuses on the reliable solution for improving the performance of network behavior. As the mobility models play an vital role on the optimization of network parameters, wide research is in progress towards the development of realistic mobility models for VANET to mimic the actual behavior of road traffic. In this paper we have presented an study about the features and limitations of MANET of mobility models and the avenues of optimizations to progress towards VANET mobility models. It is being concluded that a wider opportunity is open for researchers in developing realistic and adaptable mobility model for VANET scenario and this paper will help the new researchers to develop new realistic mobility models

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