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Impact of Vehicle Mobility on Performance of Vehicular Ad Hoc Network IEEE 1609.4

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Abstract
Vehicular Ad hoc Network (VANET) is a new communications system for moving vehicles at high speed, which are equipped with wireless communication devices, together with additional wireless roadside units, enabling communications among nearby vehicles (vehicle-to-vehicle communication) as well as between vehicles and nearby fixed equipment (vehicle-to-infrastructure communication). Inter-vehicular communications aim to improve road traffic safety and provide multimedia services. VANET has become an important communication infrastructure for the Intelligent Transportation System (ITS). In this work we have studied the impact of vehicle mobility on the quality of service in VANET based on IEEE 1609.4. The performance of this network is evaluated through exhaustive simulations using the VanetMobiSim and Network Simulator-NS2 under different parameters like delay, packet delivery ratio, packet loss and throughput. The simulation results are obtained when vehicles are moving according to a freeway mobility model is significantly different from results based on Manhattan model. When the Manhattan model is used, there is an increase in the average end-to-end delay and packet loss.
Keywords: Vehicular Ad Hoc Network, Multi-Channel, Mobility Model, Network Simulator

I. INTRODUCTION

The specific nature of vehicular ad hoc network makes this network different from other kind of networks. Some of its characteristics can be mentioned as follow: high mobility, short communication periods, limited bandwidth and the network has unpredictable characteristics such as its dynamic topology and signal strengths fluctuate with environment and time. Due to these unique features, providing an efficient data dissemination model is one of the most challenging areas in VANET. In addition to end to end delays problem, packet loss in vehicle communication are also major concerns for delay sensitive applications such data dissemination for safety applications.

Vehicle mobility is one important issue in vehicular network because it directly effects on the network topology and the availability of transmission range between vehicles, so it is necessary to implement a realistic vehicular movement in the simulation [1]. In other words, all of the important parameters should be implemented accurately in the VANET simulation, so that results from the simulation correctly reflect the real vehicular networks.

Several recent papers have studied and evaluated the impact of vehicle mobility on VANET. Alam, M et al. [2] and [3] evaluated the performance vehicle mobility in various routing protocols including DSR, AODV and OLSR. Authors in [4] analyzed the impact of vehicles as obstacles on vehicle-to-vehicle (V2V) communication. In [5], the author propose random way-point model evaluate its effect in VANETs by NS-2 simulations.

The main novelty of this research is to implement the key parameters of IEEE 1609.4 standard in NS-2 simulator [6], and prepare the realistic vehicular mobility model by VanetMobiSim [7]. We carried out performance evaluation of VANET in several realistic scenarios to analyze four aspects: end-to-end delay, packet delivery ratio, packet loss and throughput, with different values to parameters such as the number of nodes and the mobility model.

The rest of this paper is organized as follows. Section 2 presents literature review of VANET, Multi-channel operation IEEE 1609.4 and mobility model on VANET. Next, in the following section, we explain the simulation scenario and perform analysis of the simulation results according to the given aspects. Finally, concluding remarks and future research directions are provided in last section.

II. TECHNICAL BACKGROUND

A. Vehicular Ad Hoc Network

A vehicular network is a type of ad hoc network, formed by moving vehicles on a road, which are equipped with wireless communication devices. Vehicular networking can comprise vehicle-to-vehicle (V2V) communication, vehicle-to-infrastructure (V2I) communication.

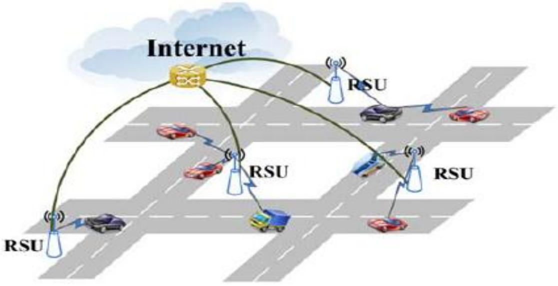

Fig. 1. Vehicular Ad-hoc Networking [8]

The main applications of VANET are classified into two categories: safety and non-safety applications [9]. The safety application mainly aimed at increasing road safety. The safety applications can be categorized into three groups according to their safety natures: assisting, warning and informing [10]. Intersection assistant, cooperative collision avoidance and lane-changing assistant are the type of assisting application. Examples of warning safety are obstacle, emergency or road condition warnings. Informative safety may include speed limit, direction or mobility prediction of neighboring vehicles.

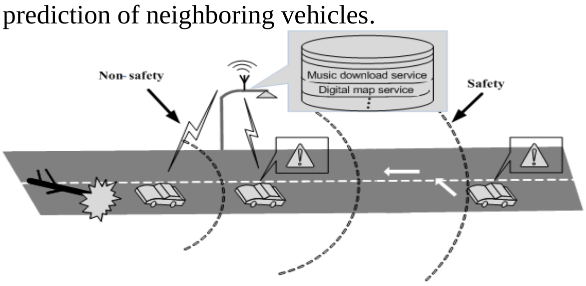

Fig. 2 Safety and non-safety related applications on VANET

Periodic and event driven messages are the main safety messages which are communicated among vehicles for safety applications. To prevent hazardous condition, vehicle broadcast messages periodically which contain position, direction and speed information. An occurrence of a potential hazard may cause an event driven messages to be generated. For example, wrong driving maneuvers or reckless high speed driving of neighbor car.

Beside to enhance safety, VANET also designed to improve traffic efficiency and comfort on roads, for example monitor real-time traffic conditions on roads and highways so can avoid congestion and find best way or route to destination.

B. Multi-Channel Operation of IEEE 1609.4

Multi-channel operation IEEE 1609.4 [11] is a standard of the IEEE 1609 protocol family, which manages channel coordination and supports MAC service data unit delivery. This standard describes seven different channels with different features and usages. To this aim, the FCC has allocated 75 MHz of Dedicated Short Range Communication (DSRC) spectrum for vehicular usage at 5.9 GHz. The bandwidth of each channel is 10 MHz. There are six service channels (SCH) and one control channel (CCH). The control channel is used for system control and safety data transmission. On the other hand, service channels are assigned for exchange of non-safety related data. In addition, these channels use different frequencies and transmit powers.

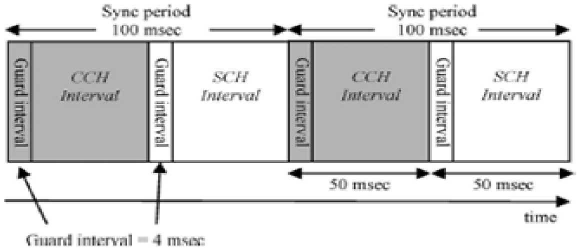

Fig. 3. Allocation CCH interval and SCH interval [11]

WAVE device exchanges the safety messages in the control channel and the non-safety communications are limited to service channels. For the purpose of supporting the coexistence of safety and non-safety applications, WAVE device may periodically and synchronously switch the control channel and one of the service channels, according to rules defined by the IEEE 1609.4 standard. Multi-channel operation helps both types of communication simultaneously so that the problem of contention between applications can be avoided. Based on this standard, vehicles must monitor CCH and SCH at a regular interval by synchronous switching scheme between CCH Interval and SCH Interval with 50 ms of each as shown in Figure 3. At the beginning of each scheduled channel interval, there shall be a guard interval.

Channel access options include continuous access at single-channel, and alternating control channel and service channel as illustrated in Figure 4. In single-channel mode, there is no channel switching occurs, and all vehicles are always tuned on a single-channel to transmit safety and non-safety related messages simultaneously. On the contrary, multi-channel operations, in which the vehicles periodically switch between CCH and SCH intervals to transmit safety related messages on CCH interval and transmit data of non-safety applications on service channels.

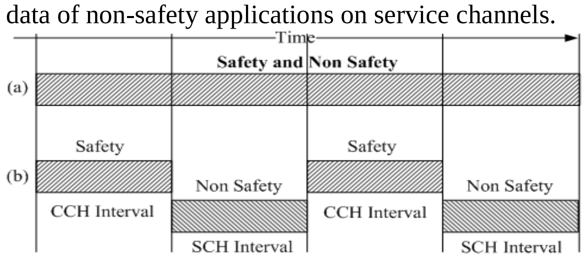

Fig. 4. Single-channel and multi-channel operation

C. Mobility Model

Vehicles mobility directly affects the network topology, the availability of transmission range, link change rate and link availability. In vehicular ad hoc network, data traffic is more susceptible to vehicle mobility due to higher route change and route failure probability. Various models for mobility at city section are:

1) Freeway Mobility Model

The Freeway Mobility Model [12] is a simple model that is model emulates the motion behavior of vehicles on a freeway. It can be used in tracking a vehicle or exchanging traffic status on a freeway. Each vehicle movement is not allowed to change its lane and restricted to its lane on the freeway. The velocity of vehicle is temporally dependent on its previous velocity. The Figure 5 shows example of freeway mobility model.

2) Manhattan Model

In the Manhattan model [12] to simulate an urban environment with the movement pattern of vehicles on road defined by map. The map is composed of a number of vertical and horizontal roads. Each road includes two lanes for each direction (north/south direction for vertical roads, east/west for horizontal roads). The vehicles are allowed to move along the grid of horizontal and vertical road on the map. At an intersection of a horizontal and a vertical road, the vehicle can straight forward, turning left or turning right. As shown in the Figure 6.

III. SCENARIO AND SIMULATION

A. Simulation Scenario

The simulation is divided into two scenarios: freeway mobility and Manhattan model. In both scenarios, we present a communication model between vehicles-to-vehicle and vehicle-to-RSU. These scenarios are implemented and modeled using network simulator NS-2 [13] version 2.34 and VanetMobiSim traffic simulator [7].

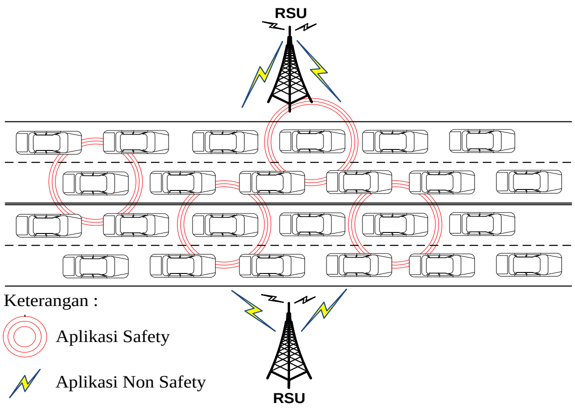

Fig. 5 Freeway mobility model

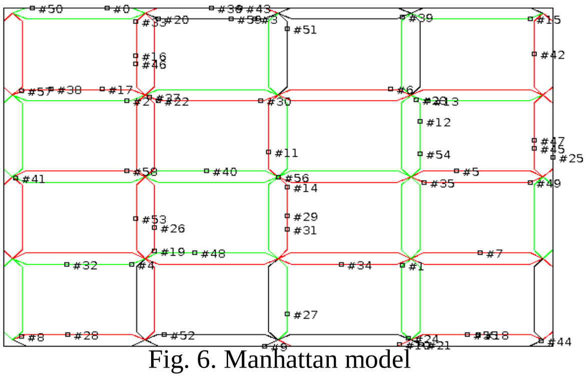

Fig. 6. Manhattan model

Based on the NS-2 simulator [13] version 2.34, we observed the performance of vehicle mobility for safety and non-safety application on VANET with periodic switching channel SCH and CCH. Different vehicular safety and non-safety communication scenarios are simulated in this work in order to observe the performance of IEEE 1609.4 on VANET. Each scenario is constructed with the payload size of 400 bytes, the bit rate 3 Mbps and varying number of vehicles (4-100 vehicles). We observed the impact of the number of vehicles to the average delay, packet delivery ratio, packet loss and throughput. The simulation scenarios are shown in Figure 5 and 6.

The simulation parameters are listed in Table 1.

Table 1. The Simulation Parameter

Parameter	Value
Simulation time	2 s
Range transmission	250 m
Number of vehicles	4 -100
Channel data rate (R)	3 Mb/s
Number of channels	7
SCH interval	50 ms
CCH interval	50 ms
Guard interval	4 ms
Packet size	400 bytes

B. Performance Evaluation

Based on the scenario implemented in the simulation, we analyzed four important metrics in order to evaluate the performance of vehicle mobility on VANET.

1) Average Delay

The average delay refers to the time required by a data packet to be generated, transmitted across the network, and received by the destination.

2) Packet Delivery Ratio

Packet delivery ratio is the ratio of the number of received packets to the total number of sent packets.

Packet delivery ratio= (Σ Received packets / Σ Sent packets) x 100 % (1)

3) Packet Loss

This metric is the difference between the number of packets sent and the number of packets received.

Packet lost= Number of packet send – Number of packet received (2)

4) Throughput

Throughput is the rate of successful packet delivery through a network connection per unit of time.

Throughput= (Σ Total successful packet received / Σ Unit of time) x 100 % (3)

C. Simulation Result and Analysis

The objective of these scenarios presented in this section is to evaluate the performance metrics of multi-channel with freeway mobility and Manhattan model.

1) Average Delay

The delay is one of the parameters that determine the performance of a system. Significant differences in their respective QoS parameters can be seen in the end-to-end delay. Delay on the network is influenced by the density of traffic due to the increasing number of vehicles, causing the transmission queues. Figure 8 shows the performance comparison of the average delay safety and non-safety applications of freeway mobility and Manhattan model.

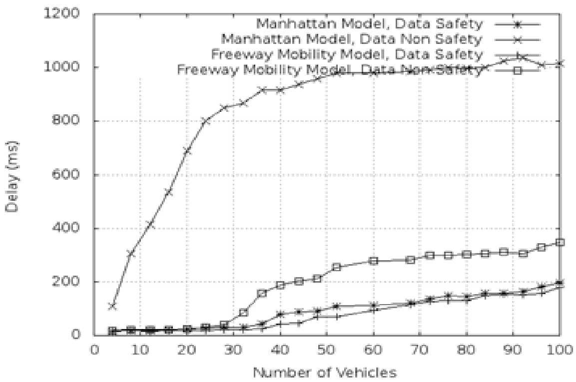

Fig. 7. Variation of delay with number of simulated vehicles

From Figure 7, we found that at a small number of vehicles, these two data safety plots look similar. Since the number of vehicles is increase more than 30 vehicles, average delay of freeway mobility is lower than Manhattan model.

In the non-safety application with the multi-channel scheme, the high delay as a consequence of the untransmitted non-safety related messages there is queue during all the CCH interval before performing a new transmission attempt on the service channel. According to Figure 7, the average delay of Manhattan model is greater than freeway mobility model. This is impact of the various distances between vehicles to RSU, which affect reception signal strength and propagation delay.

2) Packet Delivery Ratio

Figure 8 demonstrates the packet delivery ratio in freeway mobility and Manhattan model for safety and non-safety applications. As the density of the vehicles increase, the packet delivery ratio will also decrease. The increase of data traffic exceeds the channel capacity, will cause a decrease in quality of packet delivery ratio. The decrease is due to many contentions and collisions. A lot of collision causing the probability of message reception will reduce. According to Figure 8, we can see that freeway mobility model provides the higher packet delivery ratio than Manhattan model.

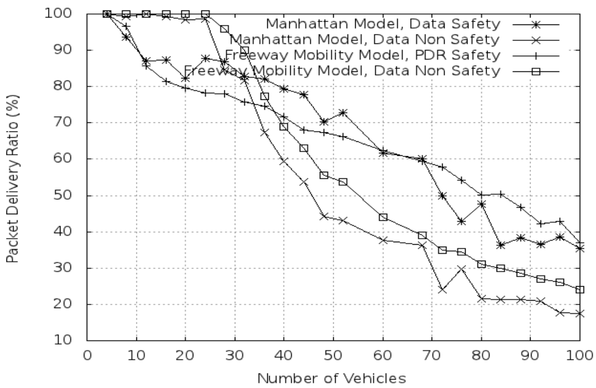

Fig. 8. Variation of packet delivery ratio with number of simulated vehicles

3) Packet Loss

Packet loss shows the number of lost data packets during the data transmission in the network. Packet loss is caused by several factors, including received signal strength, number of packets in the queue, messages scheduling on the channel and packet collision. Packet loss parameter is closely related to the packet delivery ratio. Overall, increasing the number of vehicles in the network will also increase the packet loss. The comparison of loss in freeway mobility and Manhattan model for safety and non-safety applications is depicted in Figure 9.

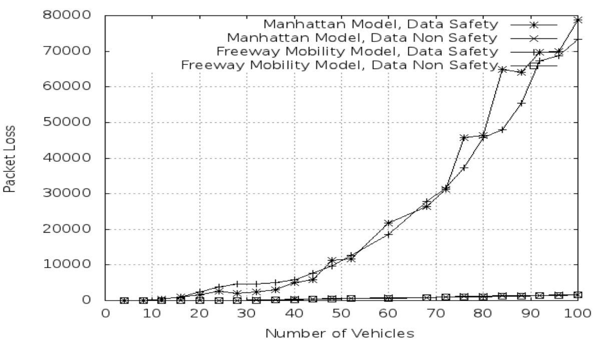

Fig. 9. Variation of packet loss with number of simulated vehicles

Based on the analysis of the simulation result, we get the packet loss of data safety for freeway mobility is lower than of Manhattan model, but in the non-safety application, freeway mobility and Manhattan model nearly similar packet loss.

4) Throughput

The throughput indicates the amount of data which could have been transmitted on the network at one time. As the number of vehicles increased, the aggregate throughput will be increase. Figure 10 demonstrates the throughput of the freeway mobility and Manhattan model. As shown in this figure, that finds high performance throughput on the freeway mobility model.

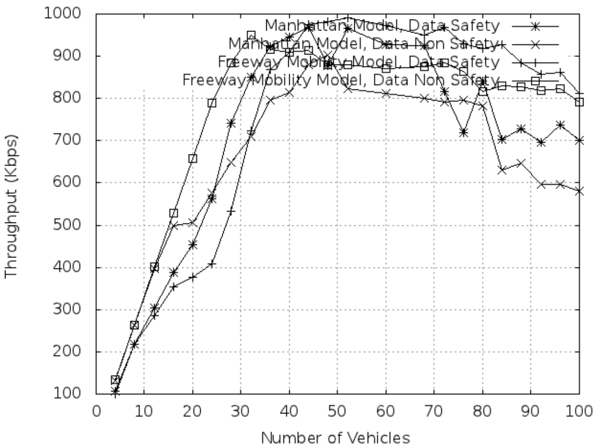

Fig. 10. Variation of throughput with number of simulated vehicles

IV. CONCLUSION

In this work, we analyzed impact of vehicle mobility on performance of safety and non-safety related applications based on multi-channel operations in vehicular communication. The levels of vehicles mobility will affect the reception of signal strength, transmission and propagation delay in the network. It may cause performance also drops off significantly. Simulation results confirm that Manhattan model with high mobility rate can significantly increases the average delay and packet loss.

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