CHAPTER 1
INTRODUCTION

1.1. Background

Currently, traffic congestion is a big problem in big cities, an increasing number of traffic accidents and the waste of energy of fossil fuels leading to increased air pollution. As one solution that can be offered is the development of intelligent transportation technologies that integrate information and communication technology with transportation infrastructure, vehicles, and users.

Vehicle ad-hoc networks (VANETs) technology can be used as a means of communication between vehicles. With the development of intelligent transportation system applications, the number of accidents and waste of energy from fossil fuels is expected to diminish.

Some applications of intelligent transportation that can be developed on VANET such as a collision warning system, determining the safe distance between the cars, driver assistance, cooperative cruise control, dissemination of information about the condition of the highway, internet access, location maps, automatic parking, autonomous car, and others.

VANETs utilizing short-range wireless communication within vehicles moving on the highway. In addition to communicating with a neighboring vehicle, the vehicle also communicates with the radio device mounted on the side of the road, such as traffic lights, Wi-Fi access point, eNodeB, and others. Communication among vehicles called V2V communication, while communication between vehicles with the roadside unit called V2I communications. A typical illustration VANET is shown in Figure. 1, where there V2V and V2I link.

Because VANET has slightly different characteristics than the MANET, like highly dynamic topology changes as the vehicle are moving at high speed make characteristics of VANET different than MANET. Mobility model in MANET is not necessarily appropriate when used at VANET. Previous research shows that the model of mobility affecting network performance, so the average packet delivery ratio, throughput, and delay that occurs depends on this factor.

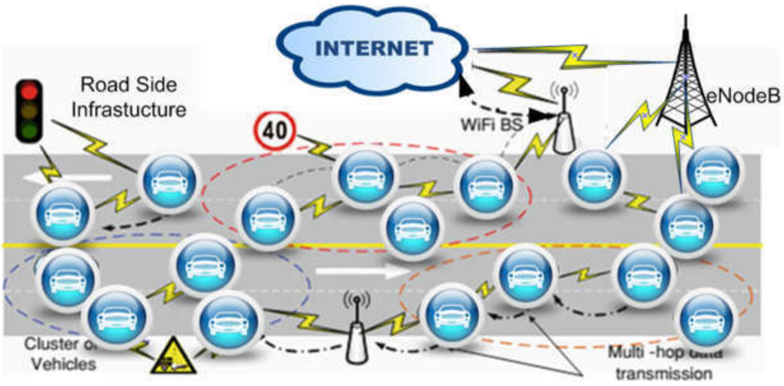


Figure. 1 Typical VANET communications [17]

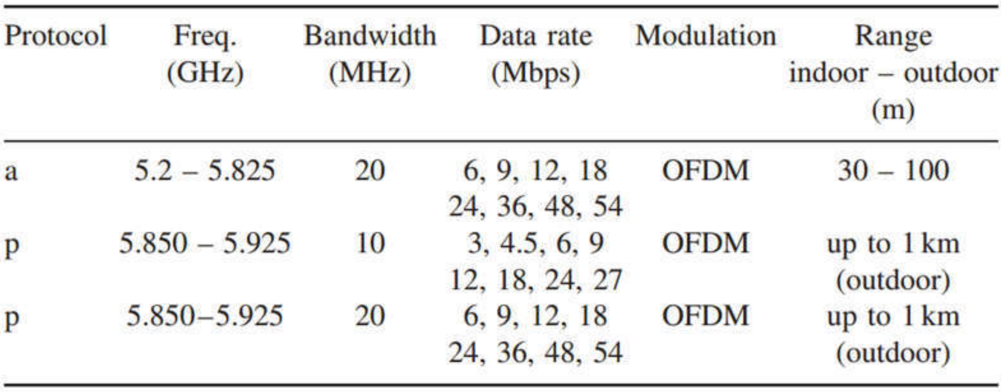
Although various wireless technologies can be used to realize VANET, the standard protocol used on VANET is 802.11p that developed from Wi-Fi protocol 802.11 standard and has been adopted as a standard for the advancement of radio used for V2I and V2V communication.

MAC layer IEEE 802.11p is specifically designed to be used on the network where the topology changes very dynamic, so it can cope radio propagation in the PHY layer. At the MAC layer, the procedures for the setup and operation of a wireless link between two mobile nodes (MN) has been greatly simplified compared with IEEE 802.11a/b/g. In particular, the concept of Basic Service Set (BSS), which is considered too complicated to setup a wireless link, no longer used in the IEEE 802.11p, MN can establish a wireless link "on-the-fly", without having to set up an Independent BSS or join a pre-existing BSS. So the delay that occurs when the LAN access the channel declined compared with the Wi-Fi. This is very important in VANET because some links appear/disappear in just a few seconds [29].

PHY Layer IEEE 802.11p is a modified layered of 802.11a PHY, which operates at a certain frequency. Especially the 75 MHz spectrum between 5850 and 5925 GHz has been allocated for the protocol IEEE 802.11p in the USA, while in Europe only allocated 30 MHz of the spectrum between 5875 and 5905 GHz frequency is also allocated for the same purpose. The main difference between the PHY layer IEEE 802.11p and 802.11a is the channel width is reduced from 20 to 10 MHz. This is done to address the problem of multi-path delay spread and Doppler effects, caused by high mobility and road environments. However, IEEE 802.11p allow the use of 20 MHz channels to transmit on two adjacent 10 MHz channels.

Another difference between the two specifications above are in the range of transmission, in which IEEE 802.11p has a longer range correspond to greater transmission power, permitted up to 44.8 dBm (approximately 30 W) in the United States, compared with 802.11a only allowed 20 dBm (100 mW).

Table 1 Main features of the IEEE 802.11a and 802.11p PHY layer [29].



Protocol	Freq. (GHz)	Bandwidth (MHz)	Data rate (Mbps)	Modulation	Range indoor – outdoor (m)
a	5.2 – 5.825	20	6, 9, 12, 18 24, 36, 48, 54	OFDM	30 – 100
p	5.850 – 5.925	10	3, 4.5, 6, 9 12, 18, 24, 27	OFDM	up to 1 km (outdoor)
p	5.850–5.925	20	6, 9, 12, 18 24, 36, 48, 54	OFDM	up to 1 km (outdoor)

Another important difference is the multi-channel operation, where there are no specific rules on Wi-Fi are set for the channel assignment so that the device will find a Wi-Fi if other devices within transmission range should scan all available channels, that's why the discovery process is relatively slow. In VANET establishment of a wireless link between the vehicles should be fast and reliable.

There are two actions have been done to enhance the reliability and responsiveness of the vehicular wireless link: first, a set of channels has been exclusively reserved for vehicular networks to reduce interference from other types of networks; second, use of the available channels has been at least partially regulated, require specific requirements on the different channels in the IEEE 802.11p frequency band [29]. Channel arrangements have been made to diminish interference from other networks types and the utilization of available channels requires certain preconditions on the typical channels in the frequency band IEEE 802.11p, this is done to increase the reliability and responsiveness of the vehicle wireless link.

A channel has been established as a control channel to establish a wireless link between the adjacent vehicles to quickly to exchange necessary information status. Unlike Wi-Fi, IEEE 802.11p devices need to periodically adjust the radio to find a new vehicle and exchange the information status, other available channels so-called service channels are used for other types of communication services.

MN movement patterns are distinguished by a model of mobility. Mobility model describes the movement pattern of a mobile node, including the change of location, velocity, and acceleration as well as the direction of MN at any time. One mobility model that is often used in research is the Random Waypoint. Two primary issue in Random Waypoint model is changing sharp direction and unexpected stop, while Gauss-Markov model has proposed as an answer for defeat this issue, in which the present state will be influenced by the previous state. The various random levels in this model are determined by a parameter called α. The parameter

α ($0 \le \alpha \le 1$) determines the level of randomness of MN mobility in a time frame. The smaller the value of α (close to 0), the degree of randomness will increase, whereas if α is equal to 1 then the Gauss-Markov model of mobility will resemble the model of the Random Waypoint. At the beginning, MN will be given a mean speed and direction to determine the movements mean further. At a specified time interval, MN will calculate the next move by the speed and direction before [40].

Because opportunities for VANET technology development that can be used for various applications for an intelligent transportation system, we try to evaluate network performance metrics, in particular, PDR, throughput and delay on a network that combines VANET with LTE while MN movement follows Gauss-Markov mobility model. Hybrid LTE-VANET network is expected to improve network performance metrics with using the advantages of both types of these networks. As a reference in this paper also performed simulations to measure PDR, throughput, and delay on the pure VANET network with the same parameters as in the hybrid network LTE-VANET. The analysis was also conducted to measure the correlation between variables that are used during the simulation by using Spearman correlation and Pearson.

1.2. Gap of The Real Condition and The Future

The results of previous studies have demonstrated that the mobility of a MANET and WSN node affect network performance. Mobility can also result in reduced performance due to changes in the wireless link and topology are dynamic. The novelty of this research is to try to measure network performance on a hybrid network LTE-VANET which the movement of MN follows the model of Gauss-Markov Mobility and analyses the correlation between several variables.

A lot of research comparing the performance of various models of mobility, such as Random Way Point vs Random Walk and Random Way Point vs Gauss-Markov on Mobile Ad Hoc Network (MANET)[6][40].

Muhammad Amir Nisar *et al.* [26] review and categorized the mobility models in MANETs and VANETs. Then analyze the performance of different types of existing mobility models of MANETs and VANETs through a case study, analyze the performance of mobility models with varying mean speed of nodes and also varied the routing protocol. The results of the analysis from the case study show the suitability of some key mobility models of MANETs and VANETs in various scenarios.

One of previous research comparing the IEEE 802.11p and LTE on VANET. Delay, reliability, scalability, and mobility were evaluated under different network configurations.

The results showed that LTE provides better network capacity and support the mobility of IEEE 802.11p. The paper concludes that LTE is more appropriate for many applications and use cases[25]. LTE performing better capability than any other mobile communications standard, this capability can be use in VANET applications, where topology changes rapidly and the very rigorous delay specification, made some performance requirements on the communications scheme very difficult to achieve.

Because research on Gauss-Markov model of the hybrid network LTE-VANET has not been done, this research attempts to complete the study of the Gauss-Markov if applied to a hybrid LTE-VANET network, analyzing whether incorporating LTE technology with IEEE 802.11p protocol would be more beneficial if applied in real conditions.

This research seeks to analyze network performance, PDR, throughput and delay on hybrid LTE-VANET network with Gauss-Markov model of mobility. To the analysis of simulation results on Gauss-Markov model, this research will be compared with the model of the Random Waypoint mobility.

1.3. Problem Defenition

In general, the 802.11 standard performance depends on network parameters, such as the number of nodes, types of traffic data, and carrier sensing range. At VANETs, protocol performance is also affected by other factors such as the node position, speed, direction, duration of communications, and a number of communication neighbors. All these factors are very dynamic in VANET and difficult to predict, especially when MN move extremely [4].

There are many models of mobility that may occur in VANET, MN mobility models will lead to changes in the network topology, highly dynamic topology changes will affect network performance. So it is important to analyze the effect of mobility models used in VANET network design and its influence on the network protocol.

A routing protocol is an algorithm used to determine the path that can be used to transmit data. The routing protocol must be able to reduce the computational load on the host or mobile node, and also in terms of reducing the overhead that occurs when sending packets on the network. At VANET routing protocols can be classified into two, namely the topology-based and position-based. AODV routing protocol included in the category of topology-based and are reactive. Evaluation of network performance on pure VANET and LTE-VANET topology that uses AODV routing protocol is expected to help to understand the influence of Gauss-Markov mobility model to the performance of the network. The simulation results in this thesis are expected to contribute to the development of VANET technology.

For analysis the results of the simulation, this paper will compare the Gauss-Markov mobility with Random Waypoint mobility model on pure VANET network. On random Waypoint mobility models, the position of each MN randomly selected in a specified area and then move to a new position with a linear pattern and random speed consistently [6]. This movement will be stopped in a time period called pause time before continuing the next movement. Pause time determined by the model initialization and the speed uniformly distributed between [0, Maxspeed].

MN moves with the direction of linear movement except when approaching the boundary area, MN will be reversed with a sharp turn. Random Waypoint Mobility constantly will cause changes in topology. Pause time and maximum speed affect the mobility behavior of MN. If the lower maximum speed and pause time high, then the topology is relatively stable, whereas if a high maximum speed and pause time smaller than the topology will change very dynamically.

Two issues on the model of the Random Waypoint mobility is a sharp turn and sudden stop. Sharp turn occurs when there is a change of direction in the range [90^0, 180^0]. A sudden stop occurs when there is a change in speed is not related to the previous speed. Both of these problems can be solved by using the influence of speed and direction before to determine the speed and direction the next. Gauss-Markov model of mobility can resolve these two issues thus the movement of the MN is more realistic.

MN movement on Gauss-Markov mobility model is not influenced by others MN on the network. Each MN given initial conditions mean speed, S, and the mean direction, d. For any period of the time constant, an MN calculates the speed and direction based on an earlier time period in accordance with the degree of randomness.

Based on reference [25], the author compares the two protocols that can be used in vehicular networking applications, namely LTE and 802.11p. The number of nodes used is 25, 50, 75, 100, 125 and 150. The simulation was performed using the parameters beacons in different frequencies. From the simulation results it appears that the same frequency beacons increasing the number of nodes affect the metric performance i.e PDR, throughput and delay, however, LTE provides better performance compared to 802.11p. LTE network can reach up to 100% PDR.

LTE performing better capability than any other mobile communications standard, this capability can be use in VANET applications, where topology changes rapidly and the very rigorous delay specification, made some performance requirements on the communications scheme very difficult to achieve. However, LTE has a limited scope and user access patterns of uneven thus affecting the quality of the connection. Preferably LTE and VANET can collaborate to support heterogeneous networks .

This research attempts to evaluate network performance metrics on heterogeneous or hybrid network architecture that combines network-based infrastructure (LTE) networks and ad-hoc network (VANET). Hybrid LTE-VANET network is expected to improve network performance metrics with using the advantages of both types of these networks.

The performance are evaluated in this thesis is as follows :

1. Packet Delivery Ratio (PDR): PDR is a proportion of the number of packets received at the destination MN and the number of packets being sent by the MN source. The greater value of packet delivery ratio means the better performance of the protocol.
2. Throughput: Throughput is the size of the packet or successfully delivered to the recipient via a communications link compared to the unit of time, the measure used is bits per second (bps).
3. Average End-to-end delay: the average time it takes a packet to be sent from source to destination. Expressed as: (Σ latency Individual data packet)/(Σ the total amount of transmitted data packets). The lower value of end to end delay means the better performance of the protocol.

1.4. Problem Limitations

Limitation of problem in this research is:

1. Standard protocol used IEEE 802.11p and LTE
2. NS3 software used to simulate Gauss-Markov and Random Waypoint mobility model
3. MN moves without hindrance assuming there are no obstacles
4. The performance observed are PDR, throughput, and delay
5. Only one certain mobile node IP Address allocated as packet destination on pure VANET topology and a remote host on LTE-VANET topology
6. Correlation between a number of MNs and network performance with mobility models were calculated using Spearman and Pearson correlation coefficients.
7. In this simulation, each host delivered a 512 Kbps UDP packet to one destination simultaneously.

1.5. Research Objectives

The objectives of this research are:

1. To analyze impact of randomness in Gauss-Markov mobility model according to PDR, Throughput, and Delay results on hybrid LTE-VANET network

2. To measure correlation among PDR, throughput, and delay with α, between PDR with throughput and delay, and between throughput and delay using Spearman and Pearson Correlation coefficient.
3. Trying to collaborate VANET networks with LTE and comparing network performance of pure VANET with the hybrid LTE-VANET network.

The analyzed parameters are :

1. rxBytes (number of received Byte)
2. rxPackets (number of received packets)
3. TimeLastRxPacket (end time of the flow from the point of view the receiver)
4. TimeFirstTxPacket (start time of the flow from the point of view the transmitter)
5. delaySum (sum of delay value)
6. txPackets (total number of transmitted packets for the flow)

There are three types of variables in the research:

1. Dependent variable: throughput, end to end delay, PDR and Correlation coefficient
2. Independent variables: network topology, source and destination nodes, packet size and transmission data rate
3. Control variables: number of nodes, speed, index of randomness (in Gauss-Markov mobility model), and mobility model

1.6. Hypotheses

The hypotheses in this research are :

1. At VANETs, protocol performance is also affected by other factors such as the node position, speed, direction, duration of communications, and a number of communication neighbors.
2. MN mobility models will lead to changes in the network topology, highly dynamic topology changes will affect network performance.
3. Various levels of randomness in Gauss-Markov mobility Model, affect packet delivery ratio, throughput, and delay.
4. When the speed of MNs is as high as a fast automobile, the performance result using Random Waypoint mobility model is significantly different from Gauss-Markov mobility model. Therefore, Gauss-Markov mobility model should be used instead[6].
5. The bigger the value of α will make the Gauss-Markov mobility model tends to approach the Random Waypoint mobility model.
6. Hybrid LTE-VANET network will produce better network performance than pure VANET

1.7. Scope of Work

The work contains two part activities below.

1. Obtaining the suitable Vehicular ad-hoc network for simulation
    a. Simulation run on Network Simulator 3 (*ns-3*)
    b. Communication between nodes to transfer data using multi-point to point, all mobile nodes send packet data to one certain mobile node
    c. Conduct separate simulations for each type of mobility nodes. All nodes using the same mobility nodes at certain time
    d. Parameters to observed : number of received Byte, end time of the flow from the point of view the receiver, start time of the flow from the point of view the transmitter, mean delay, number of received packets
    e. There is no obstacle in the network
    f. Simulations scenario performed with different numbers of mobile nodes, different indexes of randomness on Gauss-Markov mobility model.
2. Utilizing *ns-3* and Microsoft Excel to gather and analyze data. The analysis will be conducted based on:
    a. Collected data as simulation result
    b. Processed data, such as data and graphs of the relationship between PDR, throughput and delay with a quantity of MN, and between PDR, throughput and delay with the index of randomness, between PDR with throughput, PDR with delay, and also throughput with delay for Gauss-Markov mobility models using Spearman and Pearson correlation coefficient.

1.8. Writing Organization

This thesis consist of five chapters, chapter 1 describes the background of the research, VANET and LTE technology, the gap of the real condition and the future, problem definition and limitations, objective of this research, hypotheses, and scope of work. Chapter 2 contains literature review study related to Gauss-Markov mobility model, VANET, LTE, and Spearman Rank Correlation and Pearson Correlation Coefficient. Chapter 3 presents the Gauss-Markov mobility model and scenario simulation on LTE network-VANET, procedure and flow chart. Chapter 4 discusses the simulation process and data outcome analysis. Chapter 5 contain the final conclusions and recommendations of this research.