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Performance Evaluation of Gauss-Markov Mobility Model in Hybrid LTE-VANET Networks

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Abstract

Vehicular Ad-hoc Network (VANET) is developed based on mobile ad-hoc networks (MANET). VANET has different characteristics than MANET. On VANET, a mobile node (MN) moves faster, topology changes dynamically. The previous research shows that the model of mobility affects to the network performance. In this paper, a Gauss-Markov mobility model is used to illustrate the motion of the MN. This paper enriches the evaluation of the performance of Gauss-Markov mobility model on LTE-VANET hybrid network, by evaluating various network performance metrics, i.e. packet delivery ratio (PDR), throughput, and delay. This research simulates the Gauss-Markov mobility model with various numbers of nodes and randomness index (α), using Network Simulator-3 (NS-3). The result shows that strong correlation among PDR, throughput, and delay with the addition number of MNs. Based on the simulation result, the hybrid LTE-VANET have smaller 40% average delay than the existing VANET. This simulation also concludes that different value of alpha on Gauss-Markov mobility model does not influence PDR, throughput, and delay.

Keywords: *Vehicular ad-hoc network (VANET), Gauss-Markov mobility, LTE-VANET hybrid network, randomness index*

1. Introduction

1.1. Vehicular Ad-hoc Networks

Vehicular ad-hoc networks technology defined as communication between vehicles, and with the development of intelligent transport systems applications. 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 between vehicles called V2V communication, while communication between vehicles with the roadside unit called V2I communications.

VANET has slightly different characteristics than the MANET, thus mobility model in a MANET is not necessarily appropriate when used to VANET. The previous research shows that the model of mobility affecting network performance. The standard protocol used on VANET is 802.11p which is developed from Wi-Fi protocol 802.11 standard. The channel arrangements are made to mitigate 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 arrangement completed to improve the reliability and responsiveness of the vehicle wireless link.

Table 1 describes the different characteristic between IEEE802.11p standard and Wi-Fi 802.11a standard. A control channel establish as wireless links within the adjacent vehicles to quickly 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. A mobility model describes the movement pattern of an Mobile Nodes (MN), including the change of location, velocity, and acceleration as well as the direction of MN at any time. In this research, we use the Random Waypoint mobility model. Two primary issue in Random Waypoint model are changing sharp direction and unexpected stop. The Gauss-Markov model has proposed as an answer for 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 α. The

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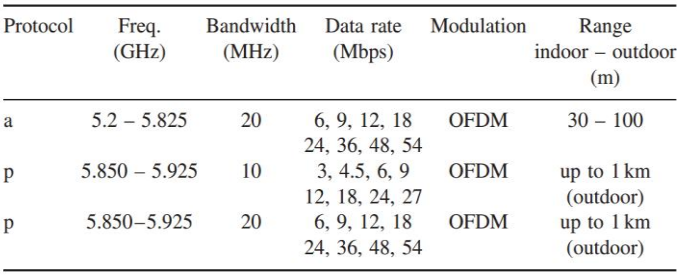
parameter α (0 ≤ α ≤ 1) determines the level of randomness of MN mobility in a time frame. The smaller the value of α (close to 0), the bigger the degree of randomness, whereas if α is equal to 1 then the Gauss-Markov model of mobility will resemble the model of the Random Waypoint. At the beginning, MN have given a mean speed and direction to determine the movements mean further. At a specified time interval, MN calculates the next move by the previous speed and direction.

Table 1. The primary characteristic of the IEEE 802.11a and 802.11p PHY layer [1]



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)

1.2. Long Term Eution (LTE)

In 2005 the 3rd Generation Partnership Project (3GPP) started to design a next generation wireless network which is only based on packet-switched. The research was conducted in two programs. The first program was LTE, which concentrates on the study of the architecture of the radio network and air interface. The second was Service Architecture Eution (SAE) program which focused on developing a new core network infrastructure. Next, LTE and SAE consolidated into a single program namely Eved Packet System (EPS). Nevertheless, the ‘LTE’ was predominant in research and many documents still use LTE than EPS.

Figure 1 describes the network elements of Eve packet System. In the access network, eNodeB is responsible for ensuring that the QoS required for the carrier over the radio interface as needed. Any bearer has an Allocation and Retention Priority (ARP) and a Class Identifier Related (QCI). Any QCI has a tolerable packet loss rate and budget priority packet delay which determines how the packet is handled in the eNodeB. In Table 2 Explain the requirement standard for QoS Class Identifier (QCI) for EPS.

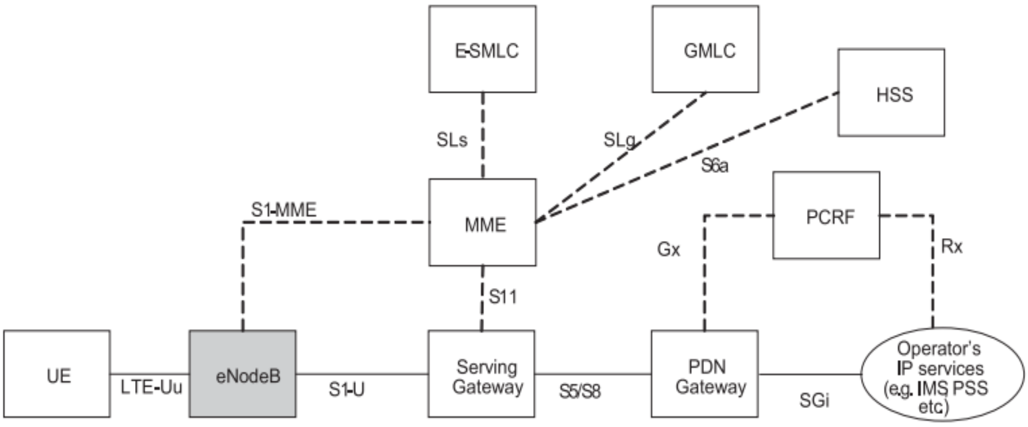
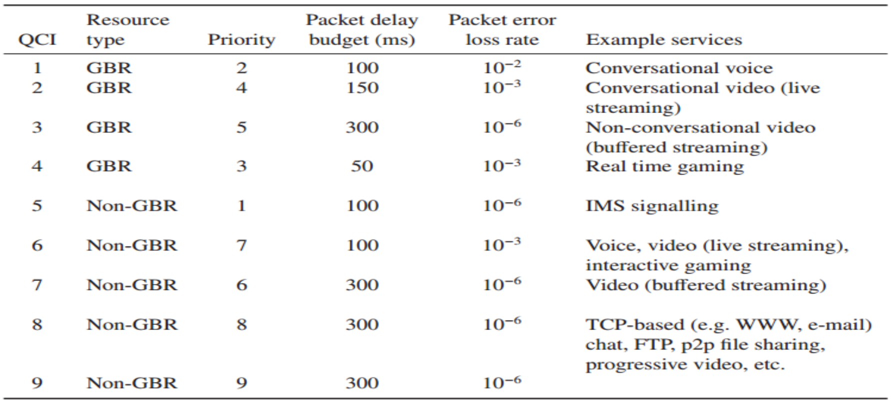


Figure 1. The EPS network elements [2]

Table 2. Standardized QoS Class Identifier (QCI) for LTE [2]



QCI	Resource type	Priority	Packet delay budget (ms)	Packet error loss rate	Example services
1	GBR	2	100	10^{-2}	Conversational voice
2	GBR	4	150	10^{-3}	Conversational video (live streaming)
3	GBR	5	300	10^{-6}	Non-conversational video (buffered streaming)
4	GBR	3	50	10^{-3}	Real time gaming
5	Non-GBR	1	100	10^{-6}	IMS signalling
6	Non-GBR	7	100	10^{-3}	Voice, video (live streaming), interactive gaming
7	Non-GBR	6	300	10^{-6}	Video (buffered streaming)
8	Non-GBR	8	300	10^{-6}	TCP-based (e.g. WWW, e-mail) chat, FTP, p2p file sharing, progressive video, etc.
9	Non-GBR	9	300	10^{-6}	

LTE performs better capability than any other mobile communications standard. This capability is useful 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. This paper evaluates network performance (QoS) metrics, in particular, PDR, throughput, and delay on a network that combines VANET with LTE. Hybrid LTE-VANET network is expected to improve network performance metrics also by making use of the advantages of both types of these networks. The network architecture is shown in Figure 2. As a reference in this paper also performed simulations to measure PDR, throughput, and delay on the existing VANET network like Figure 3, with the same parameters as in the hybrid network LTE-VANET.

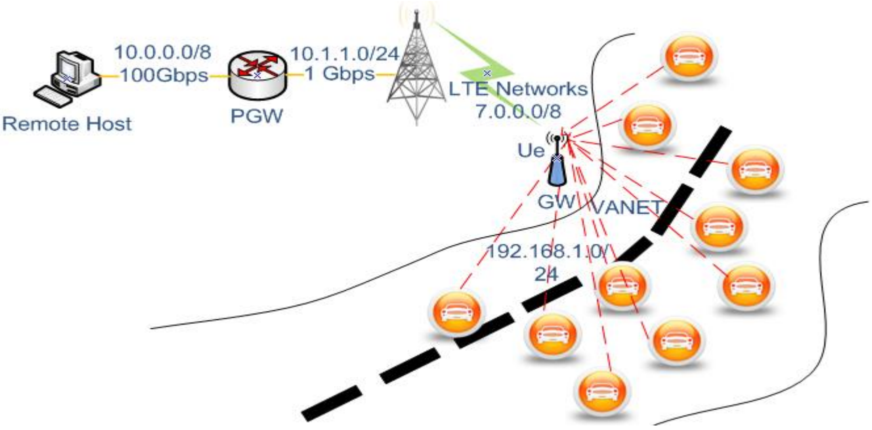


Figure 2. LTE-VANET Architecture

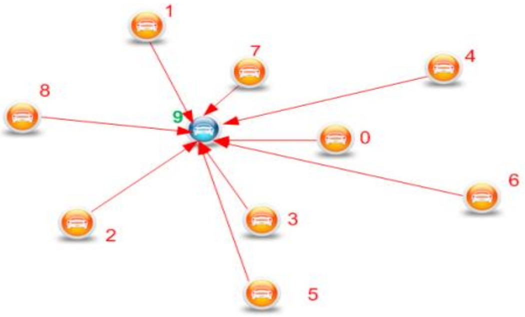


Figure 3. Existing VANET network

The contribution of this paper is to enrich the evaluation of performance metrics on LTE-VANET networks with Gauss-Markov mobility model and the number of nodes that vary from several to heavy and with a different value of α. This research results are expected to support the implementation of VANET technology in the real world. The remains of this paper are arranged as follows: Section II describes the work of earlier researchers. In Part III presents the Gauss-Markov mobility model and scenario simulation on LTE network-VANET, section IV discusses the process simulation and data analysis of simulation results and Section V we present the conclusions of the analysis and recommendations for future research.

2. Related Work

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 [3]. Zuhairi [4] analyze three very different models of mobility in terms of node movement behavior and proposed new estimation procedure called probability of route connectivity to measure the success rate of route setup. Ray [5] investigated the influence of mobility model selection on the performance of reactive and proactive routing protocol. PDR, throughput, and delay evaluated with a different number of nodes densities. Rani [6] and Jiang [7] compare three routing protocols performance, namely AODV, DSDV and DSR with different parameters. Ahmad [8] analyzed the PDR, throughput and routing overhead at Random Walk and Random Waypoint mobility model with reactive routing protocols DSR and AODV and one Proactive routing protocols DSDV. Analysis showed the Random Walk and Random Way Point mobility model with DSR, AODV, and DSDV routing protocol produces the same performance for the same inputs but nevertheless the paused time increased thereby increasing the difference in performance. They showed that their movement, direction, angle direction, speed is the same under both models of mobility.

Meghanathan [9] evaluating the Gauss-Markov mobility model and its effect on network connectivity, hop count and the lifetime of routes. The Random Waypoint mobility model is utilized as a comparator in the evaluation of simulation result. Comprehensive simulations have been done for the distinctive number of the node, and different level of randomness parameter α ($0 \le \alpha \le 1$). On networks with a little number of nodes, network connectivity on Gauss-Markov models is basically lower than the Random Waypoint. In networks with a medium and large number of nodes, network connectivity on both models practically equivalent. For the Gauss-Markov mobility model, the average hop count per minimum hop path is impressively larger than under the Random Waypoint. The level of randomness in the Gauss-Markov model seem not fundamentally affect the average hop count. On Gauss-Markov mobility model the minimum hop path has shorter route lifetime than the Random Waypoint. There is always a trade-off between the delay and the network capacity at various mobility models. From the literature that has been studied, the characteristic of this trade-off is completely impacted by the selection of the mobility model. Sharma [10] investigate delay and capacity trade-offs in MANET. System capacity is shared among a number of nodes, consequently, since the network size grows bigger each node gets smaller throughput, thereby indicate that static ad-hoc networks are not scalable. It is important to systematically consider how much delay can be allowed because of a node mobility simultaneous as a result of an increase of the network capacity. The idea of critical delay enables us to observe at several kinds of node mobility analyzed in the report from a general aspect and to distinguish and compare them.

Muhtadi [11] evaluated the impact of load-balanced mobility model on VANET network performance. Simulations performed using ns-2 and mobility model generated using a simulator VANETMobiSim. It was concluded that the performance of the network with load balancing schemes mobility model tended to decline relative to the network without load balancing. Devarajan [12] try to enhance the performance metrics in terms of delay, jitter, and PDR of the VANET by integrating it with LTE network utilizing QualNet v6.1. They conclude that the integration improves network performance. Mir [13] compares IEEE 802.11p and LTE on VANET. Delay, reliability, scalability, and mobility evaluated under different networking configuration. The result shows that LTE gives better network capacity and mobility support than IEEE 802.11p. This paper concludes that the LTE is more proper for many applications and use cases. Shelly [14] to modify the greedy perimeter stateless routing protocol (GPSR) by exploiting information about the link reliability to select one-hop forwarding vehicles. Routing scheme modifications proposed, the vehicle closer to the objectives and meet the criteria of the reliability of the link will be selected as the forwarding of the vehicle. From the simulation results show that the proposed protocol provides better PDR results.

Isernia [15] comparing the performance of two MANET routing protocols namely DSR and AODV using Random waypoint mobility. Some measured performance is PDR, throughput, and average delay. From the simulation results, it appears that the model of mobility affects the performance metric. From the related work that is made in the reference, it was concluded that the mobility model which used in the ad-hoc network and the number of MNs are inved in the network affect network performance metrics, particularly PDR, throughput, delay, and jitter. In the Gauss-Markov mobility model values of α do not have a significant impact on the performance metric. Expected by combining network type VANET with other networks will improve the performance.

3. Simulation Gauss-Markov Mobility Model on Vehicular Ad-Hoc Network

3.1 Gauss-Markov Mobility Model

Initially, the Gauss-Markov mobility model designed for simulation in the PCS [14], however, this mobility model was utilized to simulate the ad-hoc network. Initially, any node is given a mean speed, Ŝ, and mean direction value, đ, then for each fixed time interval t, a node recalculate the speed and direction again based on values of the previous time interval.

Index of Randomness (α), is a measure of randomness of MNs movement for a period of time. The measure of randomness diminishes whilst α increase from 0 to 1. Meanwhile, if α is approaching 0, the measure of randomness is high, which may cause sharp direction changing. If α is approaching 1, the velocity and direction and during of the past time interval are given more significance (the model is temporary dependent) and the node favor to move with a speed and direction closer to something it has been using before. This simulation uses Index of Randomness between 0 ≤ α ≤ 1. In the Gauss-Markov mobility model, initially, any node defines a random mean direction, S, selected from the range [0 ... 360˚]. While a node moves closer to the edge of the simulation, the average direction of nodes need to flip 180˚, hence, the node keeps on the inside of the region. Figure 4 compares the pattern of movement of nodes on Gauss-Markov mobility model with α =0.5 and α =1 and node movement if the mobility model is Random waypoint.

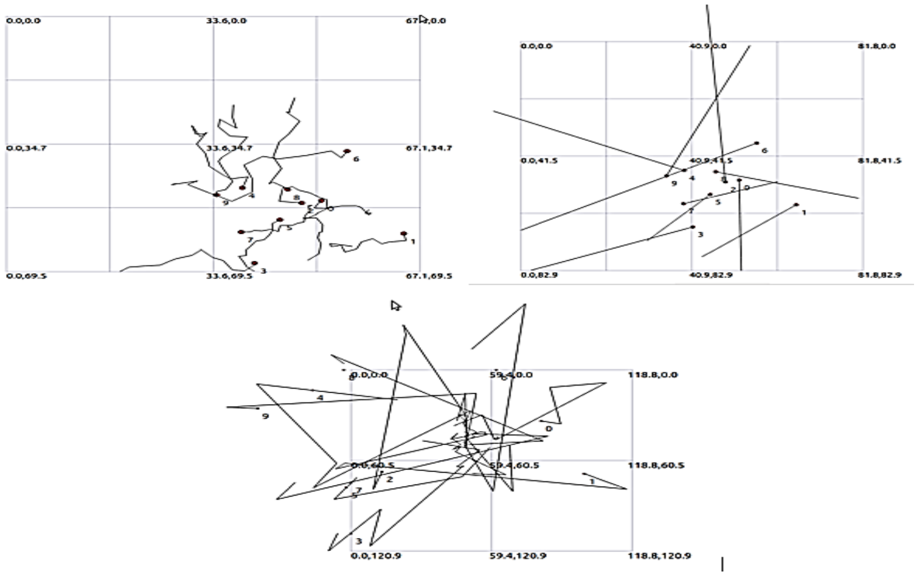


Figure 4. Gauss-Markov mobility model with α=0.5, α=1 and Random Waypoint mobility model with MN=10

3.2 Simulation Procedure

Simulation scenario used in this paper constructs VANET topology with MNs which located in clusters connected by a roadside unit (VANET static node) utilizing the LTE. MNs movement follows the patterns of Gauss-Markov. Once network is established, model is used for simulation, afterward set parameters that will be applied in this simulation. Table 3 and 4 shows the parameters used in the simulation process.

Figure 5 show that this paper has 3 parameter scenarios. For each scenarios, will have variation in number nodes. So, for parameter randomness there are 88 simulations, and for parameter packetsize and datarate will have each 32 simulation. Every result from each parameter will be calculated with 95% of confidence level.

Table 3 Simulation parameter for hybrid LTE-VANET

Parameter	Values
Simulation time	50 second
Number of MNs	5, 10, 20, 30, 40, 50, 60 and 70
Simulation Area	300 x 300 m^2
Subnet IP Address	192.168.1.0/24 for VANET, 1.0.0.0/8 for the remote host, 7.0.0.0/8 for LTE network and 10.1.1.0/24 for peer-to-peer network.
Routing Protocol	AODV for VANET and Static routing
Index of Randomness (α)	0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0
Packet Size	128, 256, 512, and 1024 byte
Data Rate	128, 256, 512, and 1024 Kbps
Transport Protocol	UDP
Velocity	vmin = 3 m/s and vmax =30 m/s

Table 4 Simulation parameter and values for existing VANET

Parameter	Values
Simulation time	50 second
Number of MNs	5, 10, 20, 30, 40, 50, 60 and 70
Simulation Field Area	300 x 300 m^2
Subnet IP Address	10.1.1.0/24 for VANET network.
Routing Protocol	AODV for VANET
Index of Randomness (α)	0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0
Packet Size	128, 256, 512, and 1024 byte
Data Rate	128, 256, 512, and 1024 Kbps
Transport Protocol	UDP
Velocity	vmin = 3 m/s and vmax =30 m/s
Paused Time	0.5 s

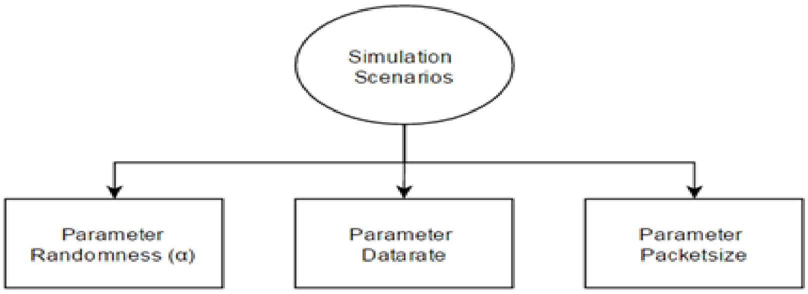


Figure 5. Simulation scenarios divided into 3 parameter

3.3 Simulation Scenarios

Simulations were conducted out using the ns-3 simulator. Observations were made for simulation output as follows:

a. rxBytes (total amount of received bytes for the flow)
b. rxPackets (total amount of received packets for the flow)
c. txPackets (total amount of transmitted packets for the flow)
d. TimeLastRxPacket (end time while the last packet in the flow was received)
e. TimeFirstTxPacket (start time of the flow from the point of view the transmitter)
f. Mean delay (Contains the total of all end-to-end delays for all received packets of the flow divide by number of the flow)

Based on these data, it could be calculated the PDR, throughput, and delay using formulas (3)-(6) [15]:

$$\text{Packet Delivery Ratio } = \frac{\text{rxPackets}}{\text{txPackets}} \tag{3}$$

$$\text{Throughput } = \frac{rxBytes*8}{timeLastRxPacket-timeFirstTxPacket} \tag{4}$$

$$\text{Mean Delay } = \frac{delaySum}{rxPackets} \tag{5}$$

Confidence interval calculated using formula:

$$\frac{Upper}{\text{Lower}}bound = x \pm 1.96 * \frac{\sigma}{\sqrt{n}} \tag{6}$$

3.4 Spearman Correlation Coefficient Analysis

Spearman Correlation Coefficient is used to discover the strength of the linear correlation between two variables. The result is always a value between +1 and −1, where +1 is a perfect positive correlation meanwhile 0 indicates there is no correlation exist, and −1 is a perfect negative correlation. It is commonly employed in the sciences as a basis of the degree of linear dependence between two variables. The positive correlation occurs when a variable value goes up or down then the other variables are also experiencing the same thing, while a negative correlation occurs when the value of variable decreases, the other variable vice versa. When the value of a variable does not change when the value of the other variable is changed, it is called uncorrelated or zero correlation. Based on the results of the simulation of various scenarios are implemented, will be seen the correlation between the parameters below:

a. Speed and throughput, Speed and delay and Speed and Packet Delivery ratio for both mobility model
b. Consistency of Coefficient Correlation for both mobility model

3.5 Flow Chart

The result obtained from ns-3 simulator output will be utilized to earn the Packet Delivery Ratio, Throughput, and Delay and analyzed utilize Spearman Correlation Coefficient. Microsoft Excel formula used to calculate Spearman Correlation Coefficient. The overall scheme activities for hybrid LTE-VANET could be found in the Figure 6. For existing VANET overall scheme activities could be found in the in the Figure 7.

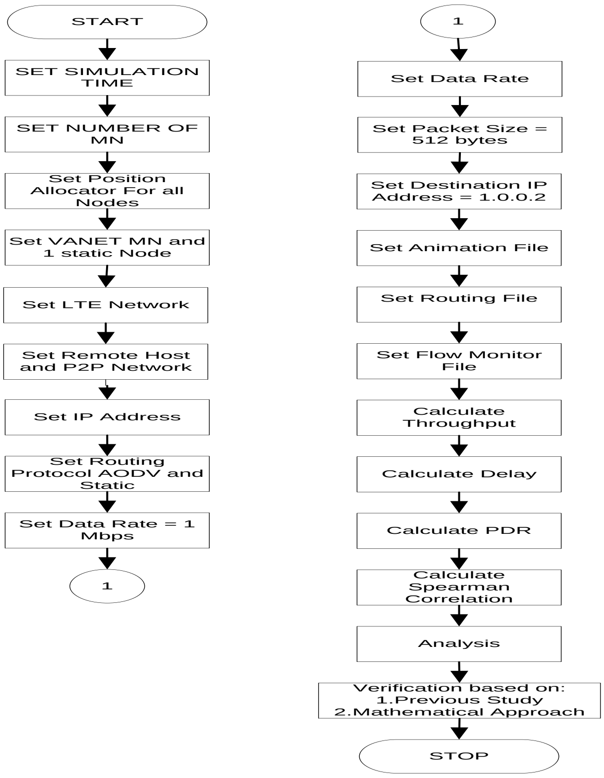


Figure 6. Flowchart of simulation LTE-VANET hybrid network

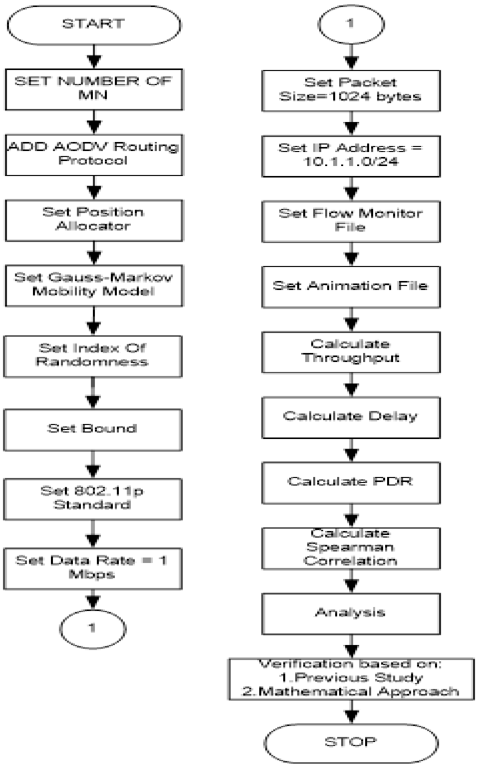


Figure 7. Flowchart of simulation scenario on existing VANET

4. Simulation Process and Analysis

There are two main stages in the research scenario, the simulation, and calculation process. The simulation process intends to get information about packet delivery ratio, throughput, and delay on each traffic flow by capturing traffic utilizing flow monitor function of ns-3. The Calculation process is done by calculating the average of PDR, throughput, and delay and calculates the Spearman correlation coefficient of data generated by simulation process.

4.1 Simulation Result for PDR

Simulation in Gauss-Markov mobility model carried out with 8 type's number of MNs (5, 10, 20, 30, 40, 50, 60, and 70). Based on the simulation results that shown in Figure 8 appear that if the number of nodes increases, the PDR will decline. Figure 9 and Figure 10 are the same, when the number of nodes increase, the PDR also decline, although there are variation for parameter data rate and packet size. Increasing the number of nodes from 5 to 10 resulted in PDR average decreased by about 52%, as well as further from 10 to 20 PDR decreased by about 46%, and so on.

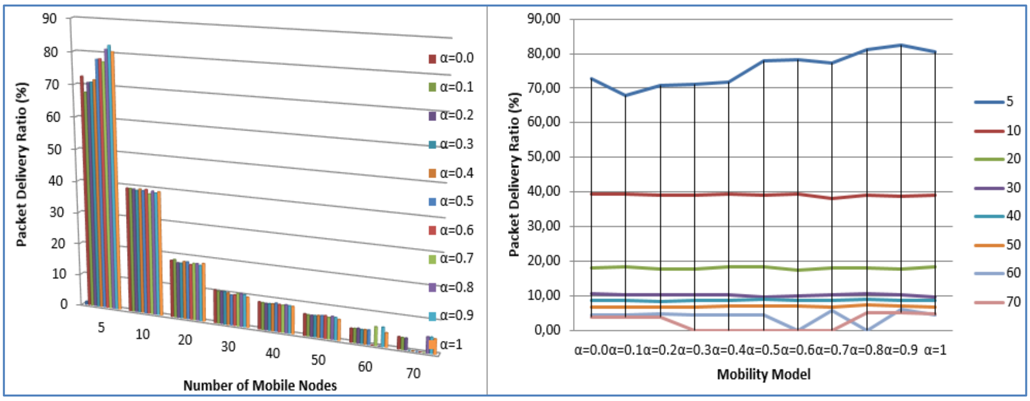


Figure 8 Packet Delivery Ratio with 12.10 ± 2.65 *(%) Confidence Interval* (parameter randomness (α))

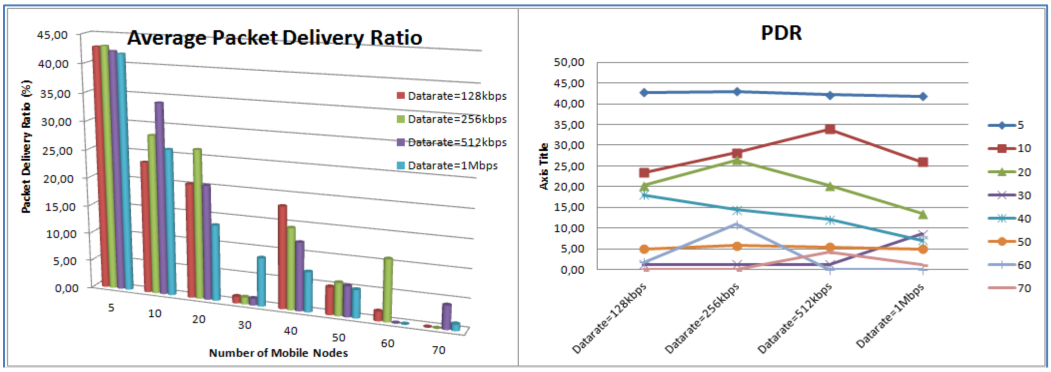


Figure 9, Packet Delivery Ratio with 14.52 ± 4.97 *(%) Confidence Interval* (parameter datarate)

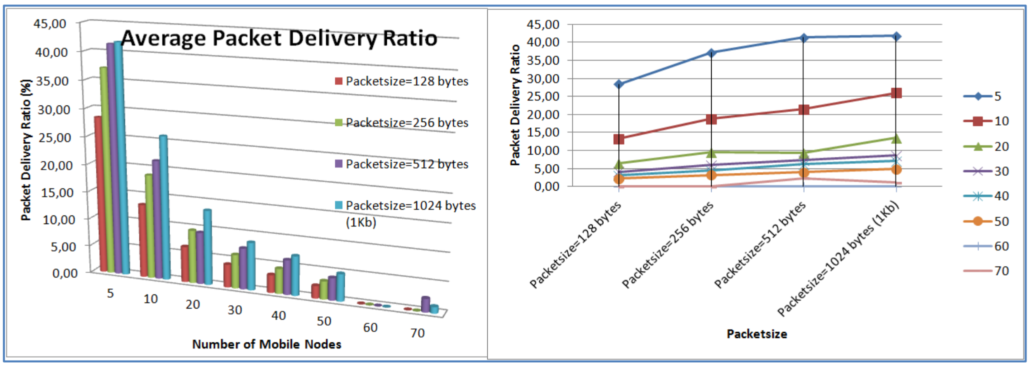


Figure 10 Packet Delivery Ratio with 10.39 ± 4.24 *(%) Confidence Interval* (parameter packetsize)

4.2 Simulation Result for Throughput

Two Scenarios are performed to compare AODV and OLSR on IEEE 802.11ah Standard. From the simulation results are shown in Figure 11, 12 and 13 show that if the number of nodes increases, the throughput will decrease. Figure 11 show, increasing the number of nodes from 5 to 10 resulted in an average throughput dropped to about 49%, as well as further from 10 to 20 PDR dropped to about 50%, and so on. Figure 12 and Figure 13 show that when the number node increase, the throughput also decline as well, although it has different variation with Figure 11 because of the difference in packet size and data rate.

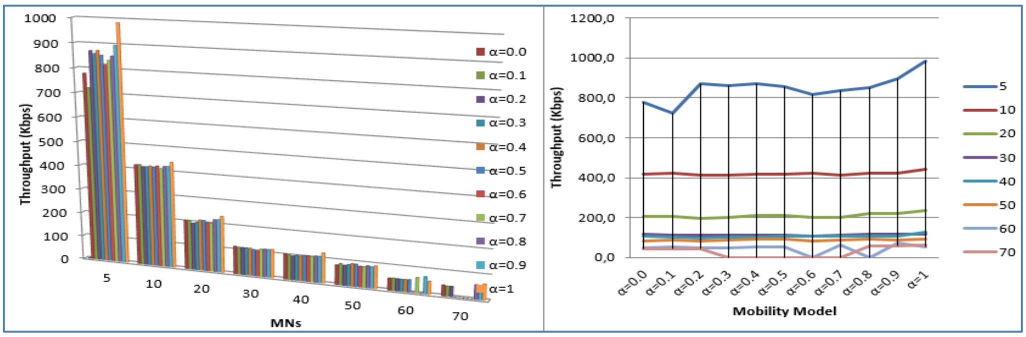


Figure 11. Throughput with 236.3 ± 47.95 *(kbps) Confidence Interval* (parameter randomness (α))

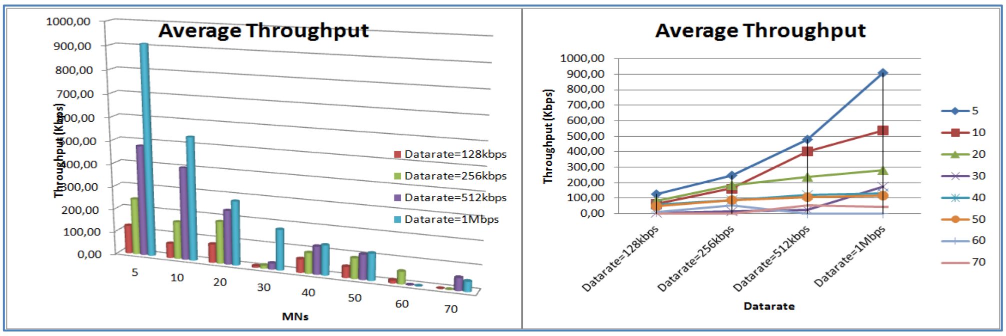


Figure 12. Throughput with 152.775 ± 67.365 *(kbps) Confidence Interval* (parameter datarate)

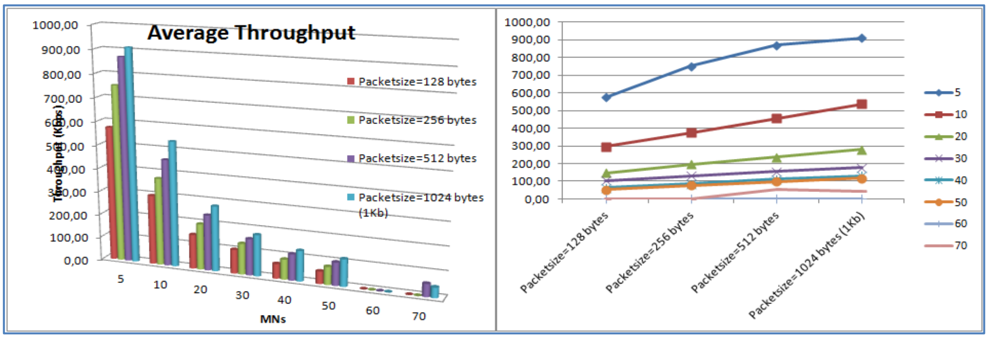


Figure 13 with 219.663 ± 88.413 *(kbps) Confidence Interval* (parameter packetsize)

4.3 Simulation Result for Delay

Figure 14 show that if the number of nodes increases, the delay will increase. Figure 15 show Increasing the number of nodes from 5 to 10 resulted in an average delay increased to about 2.5 times, as well as further from 10 to 20 PDR increased to about 2.4 times, and so on. Figure 16 show that delay increase when the data rate increase to 256kbps. For parameter packet size, in Figure 16, delay decline when the packet size increase for MN 5 and 10, but it increase inline with the number nodes incline.

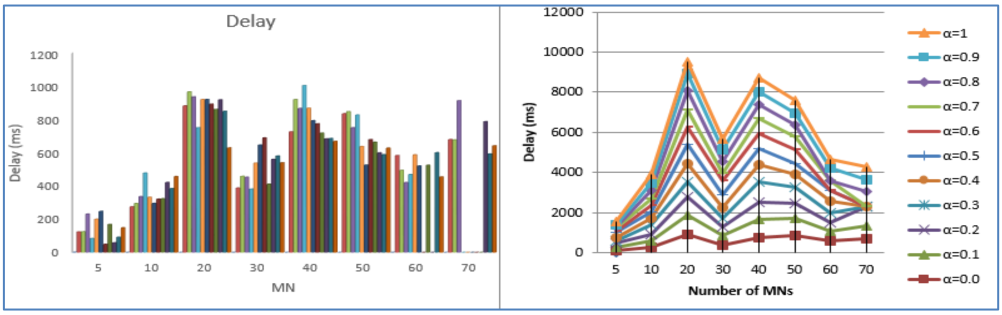


Figure 14. Delay with 369.01 ± 41.98 *(ms) Confidence Interval* (parameter randomness (α))

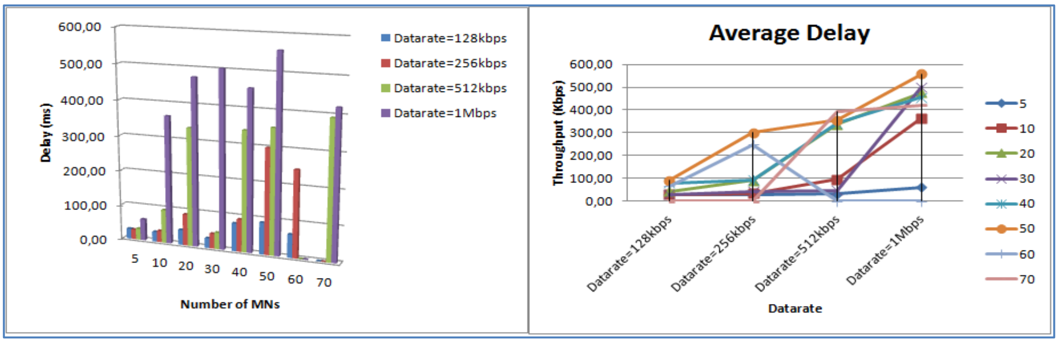


Figure 15. Delay with 201.213 ± 67.66 *(ms) Confidence Interval* (parameter datarate)

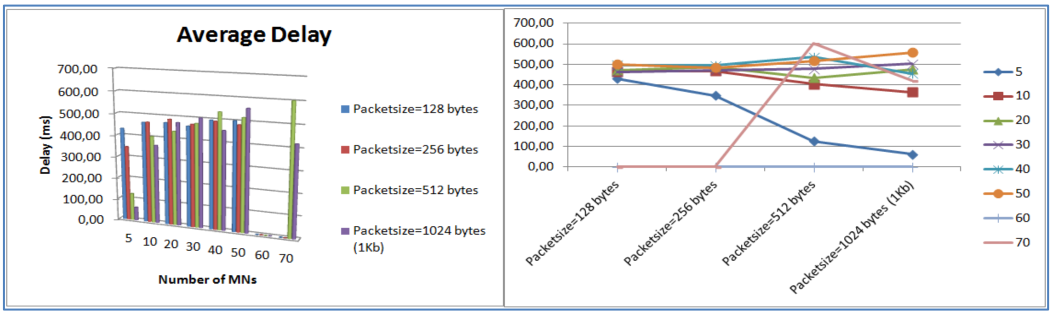


Figure 16. Delay with 442.65 ± 78.515 *(ms) Confidence Interval* (parameter packet size)

4.3 Spearman Correlation Coefficient Analysis

The association between the two variables can be explained by the correlation. The strength of the correlation is not considered statistical test; in fact, they describe the level of statistics that show the strength of correlations in two or more variables [15].

Based on data on Figure 17 it appears that the value of the Spearman correlation coefficient at each α almost always close to -1, it indicates a strong negative correlation between the decreases in the value of PDR with a number of additional nodes. From Figure 18 it appears that the value of the Spearman correlation coefficient at each α almost always close to -1, it indicates a strong negative correlation between the decreases in the value of throughput with a number of additional nodes.

From the data in Figure 19 shows that the value of the Spearman correlation coefficient at each α showed a positive correlation between the decline in the value of throughput by increasing the number of nodes. From the data simulation results, it appears that changes in the value of α do not have a significant effect on the value of the PDR and throughput,, but it make a variation in result for delay. From Figure 20 it appears that PDR and throughput positively correlated one with another. From Figure 21 and Figure 22, it appears that PDR and Throughput have a correlation with delay when throughput and PDR increase delays will decrease.

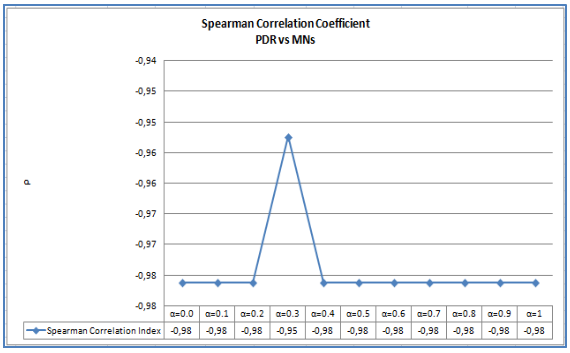


Figure 17. Spearman Correlation Coefficient PDR and Number of MNs (parameter randomness (α))

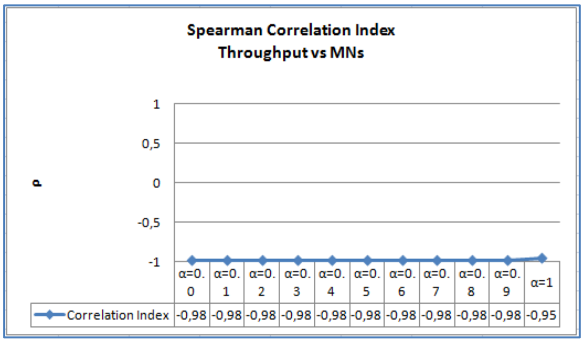


Figure 18. Spearman Correlation Coefficien between Throughput and MNs (parameter randomness (α))

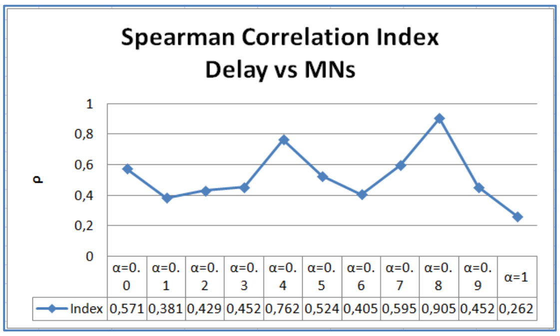


Figure 19. Spearman Correlation Coefficient between delay and MNs (parameter randomness (α))

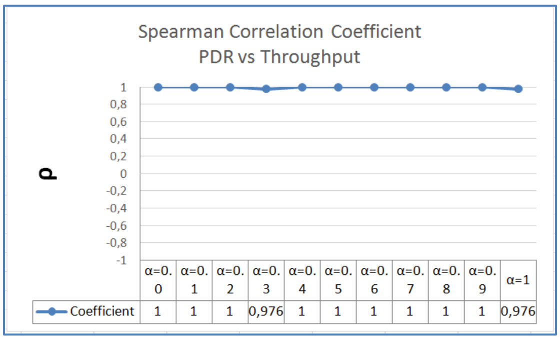


Figure 20. Spearman Coefficient correlation between PDR and throughput (parameter randomness (α))

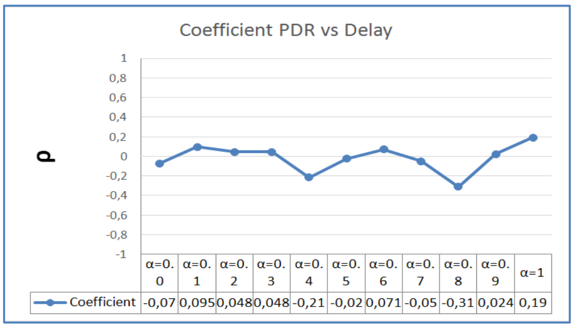


Figure 21. Coefficient correlation between PDR and delay (parameter randomness (α))

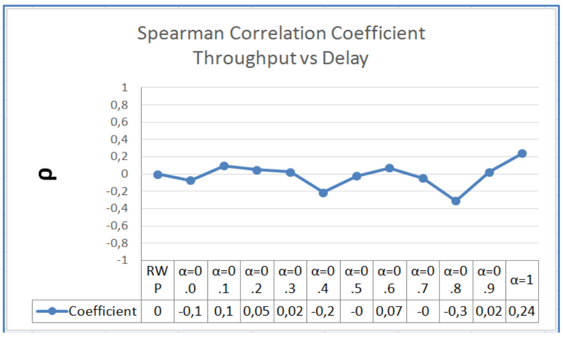


Figure 22. Spearman Correlation Coefficient between Throughput and Delay (parameter randomness (α))

Figure 23 and Figure 24 show a same behaviour with previous Figure in parameter mobility. PDR vs Throughput and Delay vs MN always have a positive correlation. Throughput vs MN and PDR vs MN always have a negative correlation. The vatiation in Throughput vs Delay and PDR vs Delay almost the same for parameter packetsize and datarate.

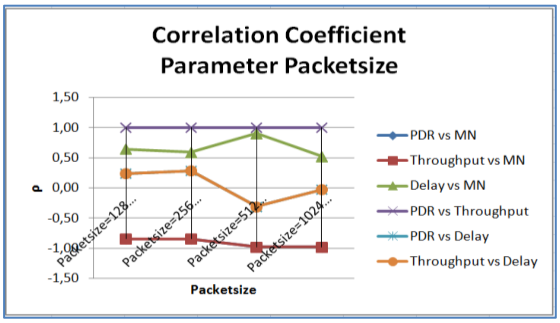


Figure 23. Spearman Correlation Coefficient between Throughput and Delay (parameter packetsize)

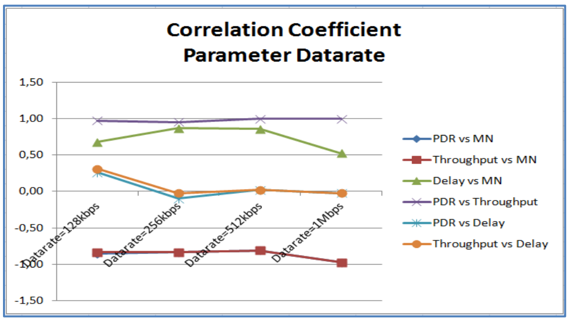


Figure 24 Spearman Correlation Coefficient between Throughput and Delay (parameter datarate)

4.5 The Simulation Results on Existing VANET Network

The simulation results on existing VANET network shows that PDR, throughput, delay and the correlation the resulting is not significantly different compared with the results of the simulation LTE- VANET.

From Figure 25, 26 and 27 we can see that the pattern of PDR, throughput and delay have the same trend as LTE-VANET pattern. Figure 28 describes the Spearman coorelation between PDR, throughput and delay with MN and between PDR with thrpughput, PDR with delay and throughput with delay.

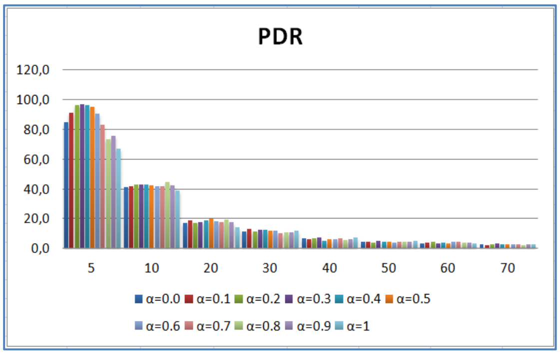


Figure 25 PDR with 21.9 ± 5.77 *(%) Confidence Interval,* on existing VANET network (parameter randomness (α))

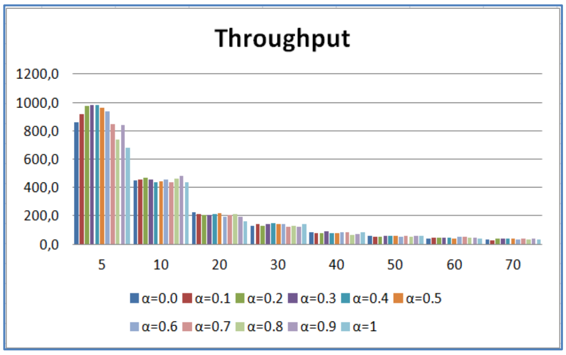


Figure 26 Throughput with 236.4 ± 58.55 *(kbps) Confidence Interval*, on existing VANET network (parameter randomness (α))

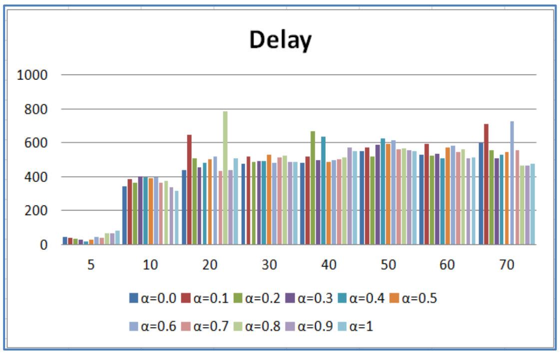


Figure 27 Delay with 455.33 ± 36.88 *(ms) Confidence Interval* ,on existing VANET network (parameter randomness (α))

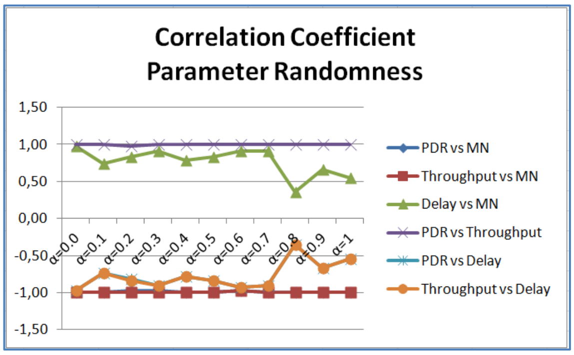


Figure 28 Spearman Correlation Coefficient on existing VANET (parameter randomness (α))

4.6 Simulation Result Comparison from LTE-VANET and Existing VANET

From the simulation results obtained in LTE-VANET and existing VANET, it can be concluded that the network performance on the network VANET in one cluster with Hybrid network performance LTE-VANET does not differ significantly even tend to be similar. Figure 29, Figure 30 and Figure 31 comparing the simulation result in relating with PDR, throughput and delay between existing VANET and LTE-VANET for parameter randomness comparison. Parameter datarate and packetsize is also have a similar graphic with parameter randomness.

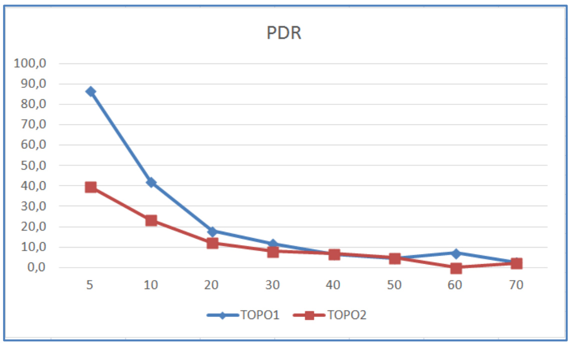


Figure 29. PDR result in comparison from LTE-VANET and Existing VANET (parameter randomness (α))

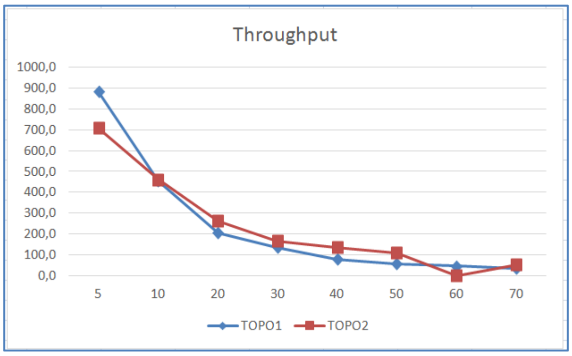


Figure 30. Throughput result comparison from the first and the second simulation scenario (parameter randomness (α))

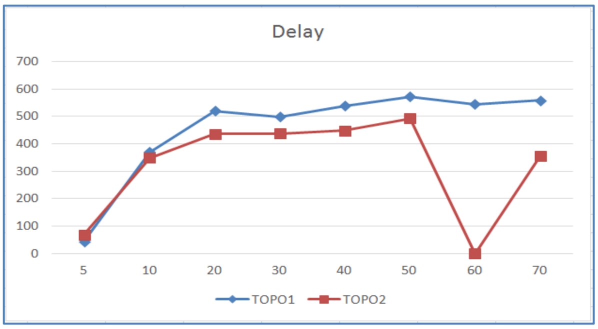


Figure 31. Delay result in comparison from the first and the second simulation scenario (parameter randomness (α))

5. Discussion

Based on reference [11], 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 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. So LTE is better used for vehicular networking applications compared to 802.11p. 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 heteregenous networks. In this paper, we propose a heterogeneous or hybrid network architecture that combines network-based infrastructure (LTE) networks and ad-hoc (VANET). Although the resulting performance especially PDR and throughput are relatively similar, but the heterogeneous network can work to provide the advantages of each type of network and address the deficient conditions of each and gives better delay compare to existing VANET. For a number of nodes 5 delays generated between the LTE-VANET and existing VANET relatively the same, but for a number of nodes 10, 20, 30, 40, 50, 60 and 70 the average delay resulting on LTE-VANET smaller by about 40% compared with existing VANET network.

In this simulation, each host delivered a 512 Kbps UDP packet simultaneously. So that the static VANET node will receive a packet of the node number is multiplied by 512 Kbps. In theory, a VANET node has a bandwidth capacity of half of the 802.11a standards, i.e 27 Mbps. When the number of nodes reached 60, the total packet that can be accepted by node static VANET is more than 27 Mbps, so a lot of missing data. In theory, a device access point Wi-Fi (802.11a) can handle 30 clients, but in practice, the average client can only handle 20 only. Sharma *et al* explain that because of the capacity of the system is divided into n node, throughput per node is inversely related to the number of nodes, with Θ scale $(1/\sqrt{n})$. Thus, when the number of nodes gets smaller, the throughput will be increased [8]. In line with previous research on the above, this simulation results in the same thing, where the greater number of MNs inved in the network will generate smaller throughput per MN.

6. Conclusion

We conclude that the greater number of MN then PDR and throughput getting smaller and Delay is getting bigger, this is due to the occurrence of the network congestion. Based on the calculation of Spearman correlation coefficient between PDR, Throughput, Delay, number of MN and index of randomness we conclude as follows : there is a strong negative correlation between the PDR and Throughput with a number of MNs, there is a strong positive correlation between delay and number of MNs, it appears that on Gauss-Markov mobility model, the different value of alpha has no impact on PDR, Throughput, and end-to-end delay, it appears that packet delivery ratio has a strong positive correlation with throughput, and it appears that PDR and throughput have negation correlation with delay.

For further research, the researchers can make change the simulation scenario for different topology, traffic flow, different packet size and also different routing protocol and since the Gauss-Markov mobility model MN moves randomly, try to combine Gauss-Markov model with geographic restriction mobility model.

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