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# Investigation Performance Analysis and Evaluation of VANET Routing Protocol on Urban Scenario Simulation: A Case Study of Melaka

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**ABSTRACT**

Vehicles on the road create a VANET network using IEEE 802.11P for wireless data exchange. However, VANET is challenging since the characteristics of VANET such as high mobility and frequent topology making it harder to design an effective routing protocol. The needs of an efficient performance routing protocol are crucial since it is to ensure a better network Quality of Service (QoS). In this paper, the evaluation of the IEEE 802.11P performance is simulated in real-world scenario using the Melaka City roadmap. In an urban setting, the impact of vehicle density on the performance of VANET routing protocols including OLSR, AODV, and DSDV are examined. Reviewing the effectiveness of the current VANET routing protocols is the goal of this research since it is crucial to know which routing has high performance under specific circumstances. Quantitative measurements including Packet Delivery Ratio (PDR), Packet Loss Ratio (PLR), and end-to-end delay are evaluated using the Network Simulator NS-3 and SUMO. Findings from the investigation show that while proactive routing protocols like OLSR and DSDV perform better in terms of end-to-end delay, AODV performs exceptionally well in terms of PDR and PLR.

## 1. Introduction

VANET stands for Vehicular Ad Hoc Network. In the recent years, the rapid development of wireless technology can be observed. A typical vehicle is equipped with wireless communication device known as the On-Board Unit (OBU) was reported both by Ahmad *et al.,* and Hussain *et al.,* [1,2]. This device enables vehicles to communicate with each other on the road and share information on the traffics. The purpose of communicating among vehicles is to increase the convenience of the road users as depicted both by El Omda *et al.,* and Jamil *et al.,* [3,4]. VANET supports two types of applications which are safety and non-safety. The safety applications transmit information such as

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traffic congestion or traffic accidents while non safety is for entertainment purpose such as web browsing or video streaming was presented by Shamsul *et al.,* [5]. VANET is a sub-class of Mobile Ad Hoc Network (MANET) in agreement with Kumar *et al.,* [6].

VANET has its own special characteristics which are frequent topological changes and high mobility according to both by Saini *et al.,* and Boucetta *et al.,* [7,8]. As a result, the VANET is seeing an increase in demand for the development of a more effective and intelligent routing protocols as stated by Gawas *et al.,* [9]. In VANET, the vehicles can communicate with other vehicles which is known as Vehicle-to-Vehicle (V2V) interaction. The vehicles also can communicate with a Road Side Unit (RSU) which is known as Vehicle-to-Infrastructure (V2I). The RSU are frequently found next to roadways based on Chaeriah *et al.,* [10]. The VANET type of communications is shown in Figure 1.

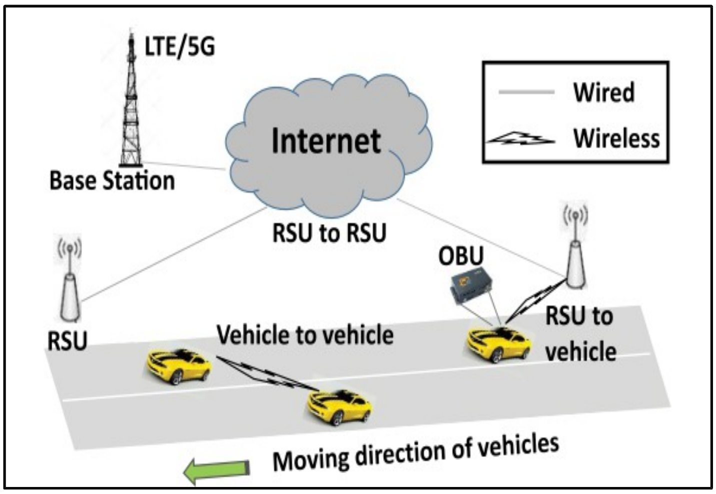


**Fig. 1.** VANET communications illustrated by Choi *et al.,* [11]

In order to increase vehicle safety, routing is described as the act of choosing the optimum routes between the sender (the source node) and receiver (the designated node) through a collection of VANET nodes. VANET routing protocols can be classified into topology-based and position-based which is further explained in the next section. Regarding a VANET's routing protocols, there are various challenges. Scalability, quality of service, security and privacy, energy efficiency, transmission bandwidth limitations, and broadcasting issues are the most prevalent in view of both by Ahamed *et al.,* and Yogarayan *et al.,* [12,13]. Due to its complexity and a variety of factors, designing routing protocols for VANETs is a difficult undertaking with reference to Hayat *et al.,* [14].

VANET environments are dynamic and subject to change due to factors like traffic patterns, communication technologies, and vehicular densities. Existing studies may not adequately address the evolving nature of VANETs, leading to a research gap in understanding how routing protocols adapt to changing conditions. By investigating how routing protocol performance varies under different conditions, this study is essential to know which routing have good performance in certain condition The rest of this paper is organized as follows: Section 2 will discuss related works. Section 3 will explain in details about VANET routing protocols. Section 4 will present anything related to the simulation. Section 5 will discuss and analyses results from the simulation and finally Section 6 concludes the whole discussion and analysis that have been done.

## 2. Background Studies

Previous research had been carried out to test the performance of various VANET routing protocols. As indicated by Aji *et al.,* [15] the authors have done a performance analysis on the routing protocols with different propagation loss model using the map of Jakarta to simulate. Refer to Amina *et al.,* [16] have done performance analysis on routing protocols such as AODV, DSDV, OLSR, GPSR and GPCR where they evaluated the performance metrics such as overhead, packet delivery ratio, average throughput and average end to end delay in the city of Morocco. The work in Shaban *et al.,* [17] evaluate AODV, OLSR and DSDV routing protocols in low-density and high- density environment and the results show that for low-density cars, AODV seems to be a good routing protocol, whereas OLSR outperforms the competition in high-density situations. Meanwhile the authors of Rajhi *et al.,* [18] got analysed and determined how well the topology-based routing protocols (AODV, DSDV, OLSR, and DSR) function at various node densities based on end-to-end delay, packet delivery, MAC PHY overhead, transmission power, etc. Lastly, the work performed by Liu *et al.,* [19] compared the performance of AODV, DSDV, GPSR and DSR with varying nodes based on packet delivery rate and routing overhead. Figure 2 shows the flowchart of the respective process design as revealed by Liu *et al.,* [19]. The difference can be seen from the selection of simulation scenario and the performance metrics. This works includes the use of real-world map imported from OpenStreetMap. An additional performance metrics is also analysed in this work which is the end-to-end delay. Performance metric such as end-to-end delay is important since VANET needs a timely delivery to ensure excellent Quality-of-Service (QoS).

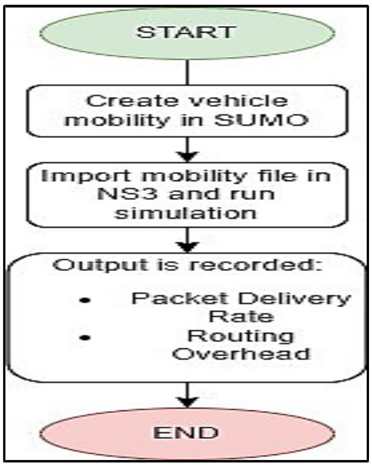


**Fig. 2.** Process Design as shown by Liu *et al.,* [19]

## *2.1 VANET Routing Protocol*

Routing protocol is a mechanism on how nodes in a network communicate with each other and establish route to transmit data. Due to VANET special characteristics and being categorized as ad hoc network that does not rely on a specialized infrastructure such as the router, VANET routing protocols can be classified into topology-based and position-based. Figure 3 shows the taxonomy of routing protocols that are being evaluated in this paper.

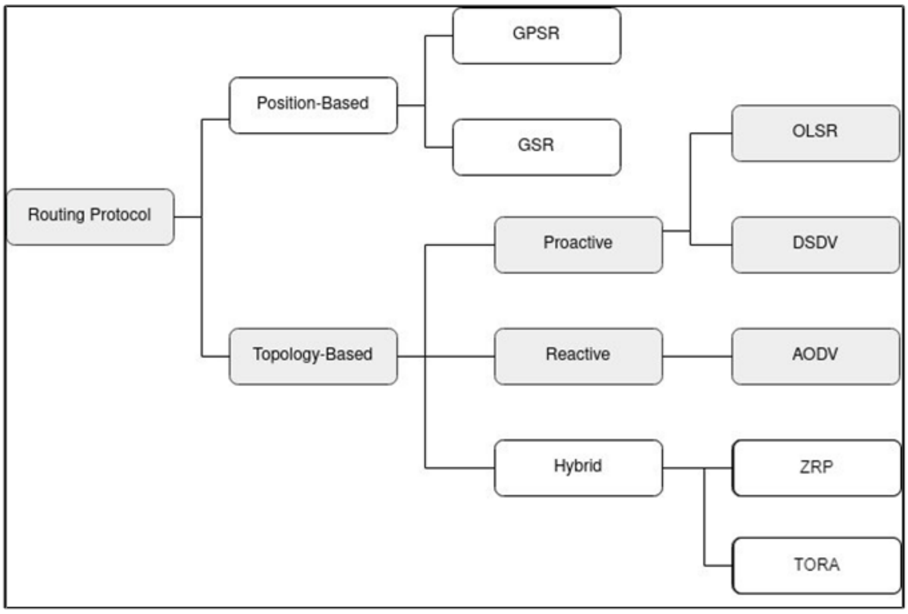


**Fig. 3.** Taxonomy of routing protocols

*2.1.1 Topology-based routing protocol*

This category of routing protocols transmits data packets from source to destination using the network's link information as exemplified by Bengag *et al.,* [20]. In topology-based routing protocols, there are three classifications of these routing protocols which are proactive, reactive and hybrid.

*2.1.1.1 Proactive routing protocols*

In the proactive routing protocol, all of the network's destinations and routes are organised as rows and columns in the routing tables, which are clearly specified inside the network for periodic inspection. The routing information is initially processed before transmission of the packets, and it is shared when transmission of the packets is happening. That is, the set of routes from source to sink are already predetermined in the work as evidenced by khan *et al.,* [21]. The example of proactive routing protocol that will be analysed in this paper are OLSR and DSDV.

*2.1.1.2 Reactive routing protocols*

Reactive protocols only construct routes when are needed, and only maintain the routes that are in use. In this scenario, an additional delay is needed at the start of each session to search for the route to the target. It was created in a way that minimises the overhead that proactive routing methods incur. This overhead is minimised by sustaining only those routes that are currently in use. The example of reactive routing protocol that will be analysed in this paper is AODV.

*2.1.1.3 Hybrid routing protocols*

Hybrid routing protocol is a combination of both proactive and reactive routing protocols that can improve routing effectiveness. They seek to shorten the initial path discovery delay in reactive routing protocols as well as the overhead associated with keeping data about the entire network. Example of hybrid routing protocols are ZRP and TORA. However, the performance of hybrid routing protocols is not further analysed in this works.

### *2.1.2 Position-based routing protocol*

A location service, such as a Global Positioning System (GPS) that provides the physical position information of vehicles on the road is necessary for location-based routing protocols When data is being forwarded, it uses position-related information to choose the next best relay neighbour. Instead of using IP addresses to route packets, it primarily makes use of the geographic coordinates of moving vehicles. Location-based routing decisions are therefore dependent on local information rather than topology-wide information, which is especially successful in situations when the topology is highly dynamic. Example for position- based routing protocols are GSR and GPSR. For further clarification, the performance of the position-based routing protocols is not further analysed in this works.

## 3. Simulation Approach

In this section, details about the simulation is explained. The simulation is carried out in the Ubuntu 20.04.4 LTS operating system. The software used for the simulation purpose is SUMO and NS-3.29. The process of the whole simulation can be seen in the flowchart depicted in Figure 4.

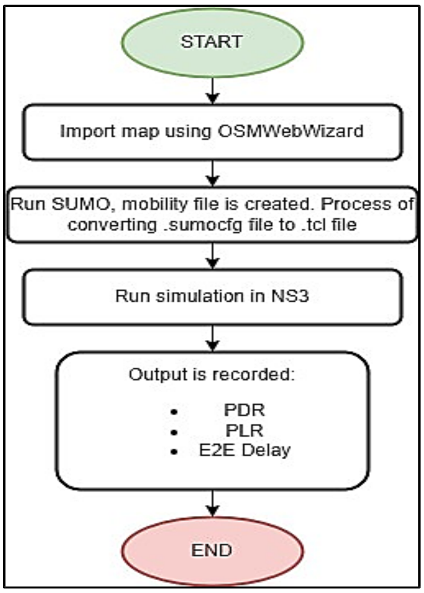


**Fig. 4.** Stage of research flowchart

### *3.1 Simulation Software*

An open source, highly portable, microscopic, and continuous traffic simulation tool called "Simulation of Urban Mobility" (SUMO) is made to manage massive networks as shown in SUMO documentation of German Aerospace Centre [22]. The evaluation uses a real- world map exported from OpenStreetMap. The SUMO Python tools' osmWebwizard application is a helpful resource for basic scenario preparation. With the help of this application, it may create a simulation situation via online with just a few mouse clicks as reported by Lopez *et al.,* [23].

The Melaka City is chosen to represent the urban city scenario as shown in Figure 5. After the desired map is downloaded from the OpenStreetMap, the data from the map is imported to SUMO and SUMO will generate the mobility file. Next, the. sumocfg file generated by SUMO needs to be converted to trace the .xml file and then it is converted to .tcl file. The .tcl file is then imported into the NS-3 script. The script is then compiled and built using the NS-3 software. From the simulation, output such as the performance metrics is recorded for analysis purpose. The NS-3 according to what it is described in the official website is a discrete-event network simulator primarily intended for academic and research purposes. Free open-source software under the GNU GPLv2 license, the NS-3 is accessible to the general public for usage, development, and research purposes as outlined in the nsmam documentation [24].

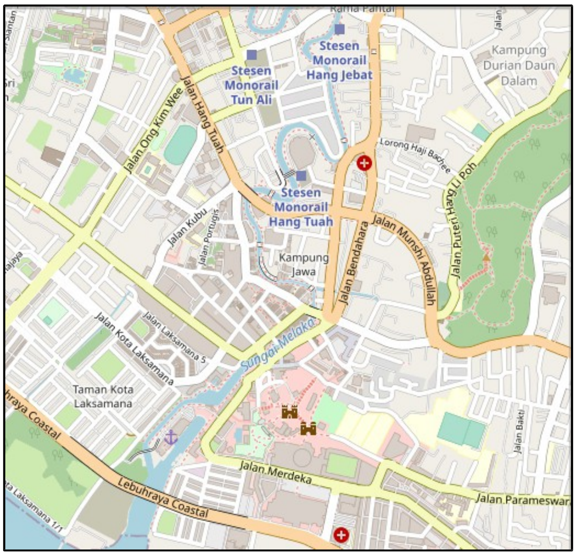


**Fig. 5.** The Melaka City Map in OpenStreetMap

*3.2 Simulation Framework*

The map of the Melaka City is chosen to represent the urban scenario. The size of the map is 3.86km by 2.9km. The various nodes from 50, 100, 150, 200, 250, and 300 are chosen to represent the sparse and dense scenario. All the vehicles are assumed to have IEEE 802.11p transceivers, enabling them to function as mobile network nodes. The maximum speed is set to 17 meter per second (m/s) which is the default speed limit set in a city environment in Malaysia. Table 1 illustrates the simulation parameters set for the framework.

**Table 1**
Simulation Parameter

| Parameter | Setting |
|---|---|
| Area | 3.86 km x 2.9 km |
| Number of nodes | 50, 100, 150, 200, 250, 300 |
| Propagation Model | Two-Ray Ground |
| MAC | IEEE 802.11P |
| Simulation times | 300s |
| Maximum Speed | 17 m/s |

*3.3 Performance Metrics*

The results of the simulation will be analysed using the following metrics:

i. Packet Delivery Ratio: The Packet Delivery Ratio (PDR) is the ratio of total packets delivered to total packets sent from source nodes to destination nodes. The goal is for the greatest number of data packets possible to arrive at the intended location. The network's performance rises in tandem with the value of PDR.

ii. Packet Loss Ratio: The Packet Loss Ratio (PLR) is the opposite of PDR. PLR calculates the proportion of packets lost due to fading and/or collisions as revealed by Liu *et al.,* [25].
iii. End-to-End Delay: End-to-end Delay shows how long it took to send the data from the destination and how many packets were successfully delivered.

## 4. Results and Analysis

This section presents the analysis of IEEE 802.11P performance of routing protocols with vehicles density. The analysis is done with the following performance metrics:

### *4.1 Packet Delivery Ratio (PDR)*

For PDR analysis, the greater the value of PDR, the more reliable the path that the protocol chooses. This is because more successful packet is delivered. From Figure 6, the OLSRs PDR performance drops when the number of nodes increases while AODV and DSDV show better PDR. For AODV, the PDR increases from 30% to 86%. For DSDV, the PDR shows improvement from 18% to 28% as the number of nodes increased. In the low-density scenario, OLSR performs better than the rest of the routing protocols but when the number of nodes is increasing, OLSR performance degrades from 85% to 55% when there are 250 nodes. When the simulation starts from the nodes being low value, the value of PDR is also low and will increase when the number of nodes is added into the simulation. Hence, there are currently enough intermediate nodes available for routing, hence the routing establishment is more successful, and the end-to-end connection is improved. When the density of nodes is observed as dense, the AODV outperforms the other routing protocols. Even though the DSDV shows improvement, but it still very lows value in PDR. However, as the number of nodes increase, data packet losses and connection are congested, slowing down the delivery of packets and thus the PDR value decreases.

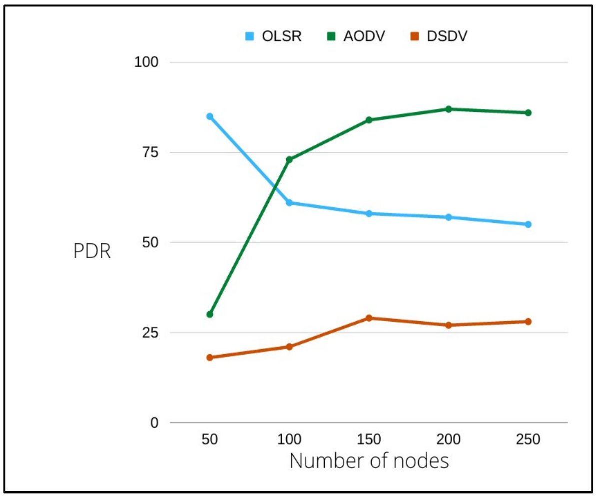


**Fig. 6.** Packet Delivery Ratio (PDR) performance

### *4.2 Packet Loss Ratio (PLR)*

Packet Loss Ratio (PLR) is the total opposite of PDR. PLR measures how many packets is lost and dropped during a transmission. The higher the value of PLR, the quality of the network is considered bad. As depicted in Figure 7, the OLSRs PLR value is increasing when the number of nodes is high. It went from 14% to 44%. For AODV and DSDV, the PLR shows downward trend however the DSDV has the highest PLR values among other routing protocols. The AODV recorded the percentage of PLR went down from 69% to 13% while for DSDV the PLR start at 81% and decreased to 71%. In a sparse traffic scenario, the OLSR shows good performance where the value of PLR is low. However, on dense traffic scenario, the AODV outperform OLSR and shows better routing performance.

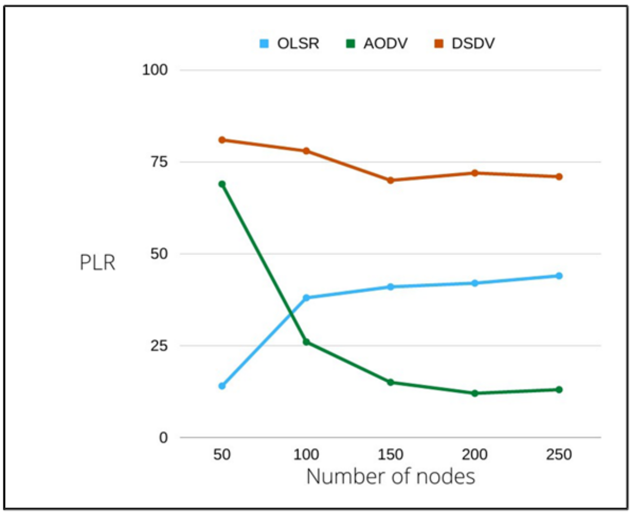

**Fig. 7.** Packet Loss Ratio (PLR) performance

### *4.3 End-To-End Delay*

For end-to-end delay when referring to Figure 8, the AODV recorded the largest value which shows that AODV has the highest delay among other routing protocols. Whereas, the OLSR has the lowest delay and DSDV is in between. When the number of nodes is 250, the delay recorded for OLSR is 367 seconds, 735.2 seconds for DSDV while AODV shows a whopping value of 16782.6 seconds. OLSR and DSDV are classified as proactive routing protocols and maintained routing tables which have the updated routes and faster route establishment. Proactive routing protocols can be seen here to perform better than AODV. The AODV however is classified as reactive routing protocols where the route is established on demand and showing great delay. The process of path discovery in AODV with the establishment of Route Request (RREQ) and Route Reply (RREP) contribute to high value of delay. To conclude, due to the time required for route computing, the delay grows as the number of nodes increases.

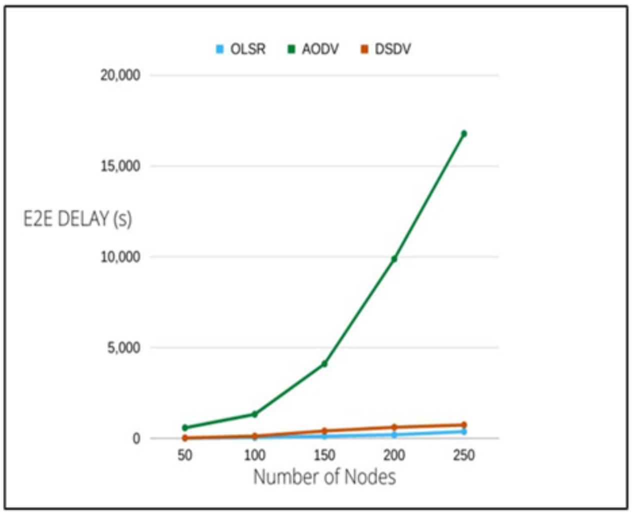


**Fig. 8.** End-To-End Delay performance

To conclude this section, three different performance metrics are chosen to analyses three routing protocols (AODV, OLSR and DSDV, respectively). The routing protocols presented in this paper are further classified into proactive and reactive routing protocols. The proactive routing protocols are OLSR and DSDV. Proactive routing protocols shows low level of PDR and high level of PLR. However, proactive routing protocols provide an excellent performance in terms of end-to-end delay. The AODV represents as the reactive routing protocols in the simulation. From the results, reactive routing protocols shows high level of PDR, low level of PLR and have a high end-to-end delay value.

## 5. Conclusions

This paper analyses the performance of VANET routing protocols (OLSR, AODV, DSDV) with vehicle density simulated using the SUMO and NS-3 in an urban scenario. The performance is measured based on desired performance metrics which are the Packet Delivery Ratio (PDR), Packet Loss Ratio (PLR) and end-to-end delay. From the analysis results, performance of the AODV is outstanding in terms of 56% improvement in PDR and PLR. For end-to-end delay, proactive routing protocol such as the OLSR and DSDV shows better performance compared to AODV. The AODV shows the largest increment in end-to-end delay with 16.2 s while 0.36 s and 0.72 s increments of end-to-end delay for the OLSR and DSDV respectively. As a future works, researchers can consider to analyse the routing protocol performance with other aspects such as varying the routing protocol, setting up with different speed, propagation loss model and road scenario, accordingly.

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