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The Implication of Different Transmission Protocols for Vehicular Networks using NS-2

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ABSTRACT

A vehicular network, categorized as an ad-hoc network, operates without fixed base station infrastructure or centralized management. In this setup, each network entity can serve as a router or a host, facilitating communication via multiple links. Unlike a mobile ad-hoc network, a vehicular network allows nodes to freely join or leave the network. For data transmission, various network layers are involved in delivering packets, with TCP and UDP protocols commonly employed. However, prior research has highlighted the limitations of Vehicular Ad-Hoc Networks (VANETs), particularly due to the surge in vehicular numbers on roads. This situation can trigger issues such as network congestion, leading to increased packet delivery delays and potential packet drops, ultimately compromising network performance. Moreover, when vehicles travel at high speeds on highways, quick message transmission is crucial, often without waiting for acknowledgments from both the transmitter and receiver. To address these challenges, some of the benefits of the User Datagram Protocol (UDP) can be integrated into vehicular network technologies. Consequently, this study aims to assess the data transfer performance between Transmission Control Protocol (TCP) and UDP, focusing on metrics like packet delivery ratio, packet loss, and packet drop, while varying vehicle density. The research location was Persiaran Permai, Seksyen 7, Shah Alam, Malaysia, and simulation was conducted using tools such as JOSM, MOVE, and NS-2. The findings reveal noteworthy differences: TCP exhibits a superior average packet delivery ratio (99.44% vs. 83.56%) and lower packet loss (0.56% vs. 16.45%) compared to UDP. Conversely, UDP demonstrates better performance in terms of average packet drop (0 compared to 6.75) when compared to TCP.

1. Introduction

A collection of wireless mobile nodes forms ad hoc networks that function without centralized management or fixed base station infrastructure [1]. Within this framework, each network entity can

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function as either a host or a router, engaging in communication through various wireless links. The communication protocol involves the transmission of packets traversing multiple nodes to reach their intended destinations, a concept known as multi-hop wireless communication. Mobile Ad-Hoc Network (MANET), a subset of ad-hoc networks, offers the notable advantage of swift deployment without requiring administrative intervention. Equipped with networking capabilities, MANET consists of nodes that can communicate autonomously without a central network. A specialized variant of MANET is the Vehicular Ad-hoc Network (VANET), a technology that has garnered significant attention due to its dynamic topology changes. Developing an efficient routing protocol among vehicles in VANET proves challenging due to frequent disconnections arising from two distinct communication modes: vehicle-to-vehicle (V2V) and vehicle-to-roadside infrastructure (V2I). This technology primarily aims to enhance driver safety, as depicted in Figure 1 [2]. For instance, in the event of an accident-causing traffic congestion, VANETs can disseminate safety messages to nearby vehicles, notifying them of the incident and proposing alternative routes for more distant vehicles.

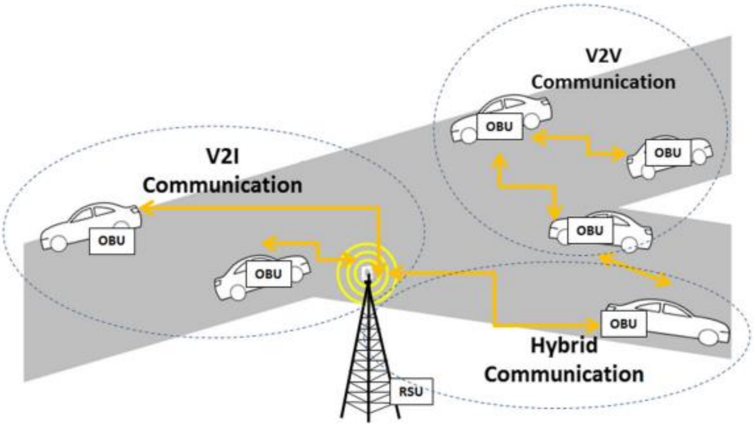

Fig. 1. The concept of VANET that has been implemented on the road

Designing VANET applications poses significant challenges, including the intricacies of high dynamic topology, mobility modelling, battery management, frequent network disruptions, and storage constraints, thereby accentuating the distinctive characteristics of VANET compared to MANET. High dynamic topology refers to the fact that every connection is bounded by its range and limit, leading to a continuously shifting network structure driven by the movement and velocity of vehicles on the road. An investigation by [3] demonstrated the disconnections between two vehicles moving at different speeds, even when kept in pairing. This suggests that mobility patterns in VANET are inherently dynamic, influenced by factors such as road layouts, vehicle velocities, and traffic conditions.

Central to VANET discourse lies the On-Board Unit (OBU), a core component with crucial significance. In accordance with [4], the OBU encompasses several components, notably the data collection unit. This unit is responsible for acquiring data on distances between two test vehicles within a 250-meter range, along with the respective speeds of these vehicles—data sourced from a driving simulator. The OBU should also feature a vehicle state judgment and display unit, offering diverse modes like security, alert, and prompt modes, contingent on the assessment of vehicle distances and speeds. The architectural configuration of the OBU is depicted in Figure 2. It is worth noting that the connection between OBUs and other servers in an intranet environment employs the User Datagram Protocol (UDP) for transmitting simulator data to the server. Subsequently, data transmission from the server to the client, utilizing the TCP/IP protocol, is stored in SQL. Transmission

Control Protocol (TCP) and UDP operate on the same OSI layer between different hosts' application processes, serving as mechanisms for logical communication [5]. These protocols facilitate the transmission of data packets across the network. TCP, a connection-oriented protocol, establishes and maintains connections through a three-way handshake and a four-way handshake for connection termination, ensuring data exchange between sending and receiving parties. In contrast, UDP operates as a connectionless protocol, dispensing with handshakes for data transfer and connection establishment.

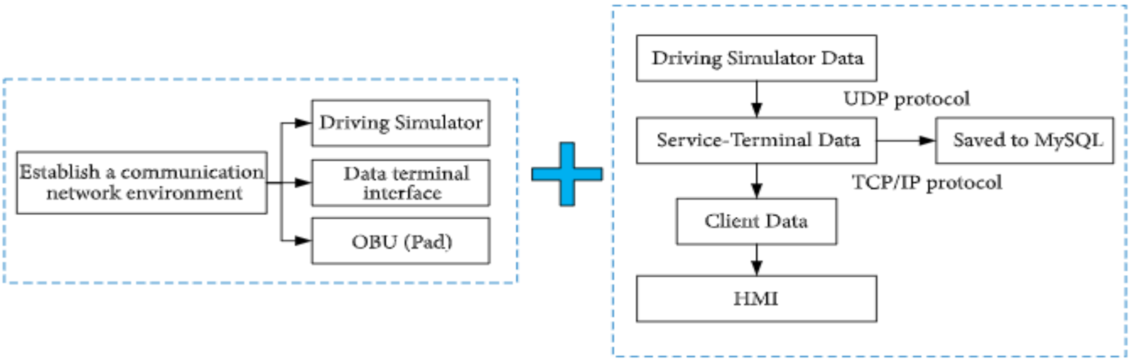

Fig. 2. The architecture of the OBU system

2. Related Study

Several reports and technical papers have explored the compatibility of TCP and UDP in VANET, examining their distinct mechanisms for data transport within the network. In a study by [6], these transport protocols were compared to evaluate their Quality of Service (QoS) performance. The findings revealed that while UDP excels in swift video and data transmission, TCP outperforms UDP in terms of data quality. TCP emerges as a suitable protocol for VANET communication, albeit the selection of the right TCP variant is emphasized as crucial [7]. Notably, TCP encompasses variants like TCP NewReno and TCP Vegas, each with its own merits and demerits. While TCP Vegas offers better bandwidth utilization, TCP NewReno surpasses in aspects such as goodput, swift recovery, and capacity to operate at a larger window size. While TCP Vegas garners praise for its proficiency in various facets, including average packet drops, average delay, and managing a small number of nodes [8]. The authors recommend a cross-layer design approach to adapt and recalibrate sending rates in response to wireless node congestion notifications.

Another investigation points to TCP's susceptibility to the number of hops between source and destination, asserting that throughput vehicles should minimize hops to maximize TCP performance, achieved by increasing transmission power [9]. VANET's transmission rate isn't uniform and varies based on data packet size, which profoundly affects performance when transmitting data to neighbouring nodes. Research exploring the relationship between transmission performance and different packet sizes underscores the impact of packet size disparities in the VANET environment [10]. Next, a previous study [11] have highlighted the limitations of VANET due to the rising number of vehicles on roads, leading to issues such as network congestion that heightens packet delivery delays. Consequently, this can result in packet drops and a reduction in VANET's overall performance. Addressing this challenge requires exploring various strategies to enhance packet delivery rates. The primary goal of this proposal is to compare the performance of data transport within VANET. Notably, many prior investigations [11,12] have primarily concentrated on the TCP data protocol, neglecting research on the UDP protocol, even though both protocols operate within the transport layer.

Consequently, our study seeks to delve deeply into both protocols within VANET to provide valuable insights for evaluating the performance of this technology.

The study discussed in reference [13] compares the performance of TCP traffic in VANET using both IEEE 802.11 protocol and IEEE 802.11e protocol. The methodology employed in this research involves simulating the performance through Network Simulator (NS-2) with specific parameters for two scenarios. These scenarios revolve around two distinct cars: one moving at 108 km/h and the other already involved in an accident on the road, simulating a near collision. The key difference between these scenarios lies in the utilization of the IEEE 802.11e protocol in one and an alternative communication protocol in the other. The findings indicate that in the first scenario, TCP exhibits greater priority than UDP. This is evident in the higher throughput and reliability of TCP, which proves beneficial for vehicles during congestion when swift delivery of accident-related information is crucial. However, the second scenario involves TCP sharing bandwidth with UDP during a critical period, potentially leading to a reduction in the alerting rate. IEEE 802.11e extends the IEEE 802.11 MAC protocol to support Quality of Service (QoS). Simulation outcomes suggest that the performance of TCP traffic in VANETs improves significantly when utilizing the 802.11e protocol, particularly in emergency scenarios like accidents.

The subsequent research introduces an innovative cross-layer-based TCP algorithm designed to select the most dependable links for forwarding, thus ensuring precise TCP congestion control across a range of TCP states [14]. This project was implemented through simulations using NS-2, with a simulation time of 1000 seconds and a 100-second clear time. The simulated field encompassed an area of 100m x 100m, while the number of nodes (NDS) ranged from approximately 20 to 100. Wireless transmission ranged from 175m to 250m. The IEEE 802.11p protocol was employed for the layer 2 MAC protocol. Experimentation encompassed speeds ranging from 20 to 90 km/h, with the experiment replicated 25 times. The outcomes indicate that, across various node counts, CL-TCP exhibited the highest packet delivery ratio, surpassing conventional TCP which displayed a comparatively lower packet delivery ratio. Furthermore, in terms of average packet delivery delay under varying loss rates, delays increased as loss rates escalated. CL-TCP demonstrated a slightly elevated packet delivery delay compared to other conditions.

The significance of this study is rooted in the evolving landscape of vehicles over the past decade, driven by technological advancements like automatic transmission, internal combustion engines, and enhanced safety features. These safety measures, including seat belts, airbags, collapsible steering columns, and more, have played a pivotal role in reducing accidents and fatalities. In this context, VANET technology emerges as a critical player in vehicle safety. VANET seeks to establish seamless communication between vehicles and infrastructure, with the goal of preventing accidents and enhancing driver comfort. Despite its potential, VANET awareness remains relatively low, necessitating a deeper exploration of its objectives and potential advantages. This study focuses on transmission protocols within VANET networks, specifically TCP/IP and UDP. While TCP's 3-way handshake mechanism makes it a popular choice, UDP also holds promise for future VANET developments. Thus, this study is designed to achieve two main objectives: firstly, to create a real-time traffic scenario simulation within a vehicular network using NS2 while incorporating diverse transmission protocols; secondly, to comprehensively assess the performance of data transfer in the transportation layer by comparing TCP and UDP in terms of metrics such as packet delivery ratio, packet loss, and instances of packet dropping. By implementing and analysing real-time transportation protocols, this study aims to provide insights into the superiority of TCP/IP over UDP, while also showcasing the potential benefits that UDP could offer for forthcoming VANET applications.

3. Methodology

This study will utilize the Ubuntu operating system as an open software platform to execute network-related applications. Additionally, several supportive software tools will be employed, including the Java Open Street Map (JOSM) Editor, the Simulator of Urban Mobility (SUMO), and the Mobility Model Generator for VANET (MOVE). The SUMO tool will facilitate the analysis of traffic management systems and road traffic, while MOVE will concentrate on generating realistic traffic patterns for VANET simulations. The geographical scope of the study encompasses Persiaran Permai, Seksyen 7, Shah Alam. Specifically, the study will zero in on a junction point equipped with a traffic light infrastructure, enabling the analysis of interactions between Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications.

The flowchart presented in Figure 3 describes the procedural framework of this study. Prior to initiating simulations, the installation and configuration of the Ubuntu Linux software package on devices is a prerequisite. A virtual PC platform, such as VirtualBox, enables the deployment of multiple operating systems on a single computer. The subsequent step involves utilizing JOSM to replicate the process after Ubuntu installation. Once the specific target area is determined, JOSM is employed to download the location's map data. This data is then converted from the downloaded (.osm) format to (.xml), facilitating its use in SUMO for simulating vehicular movement on the road. Through the command-line interface within the terminal, files like (.net.xml) and (.rou.xml) are generated. In SUMO, routes are established, considering both vehicle movement and quantity. Files such as (sumoTrace.xml) and (sumo.cfg) are prepared to execute the final simulation. The SUMO file, encompassing real-time vehicular movement, is utilized to replicate this movement in a simulated environment. In the concluding step, all datas are extracted from NS-2.

In Figure 4, the study's location is depicted, featuring four junctions with each lane demarcated by green and red strip lines symbolizing real-time traffic lights at Persiaran Permai, Seksyen 7, Shah Alam.

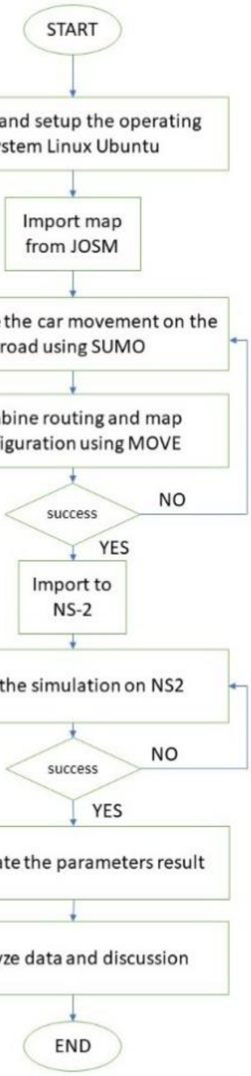

Fig. 3. Flowchart of the project

```
Loading route-files from '/home/amrul/Documents/fyp2/300_vehicle/shah_alam_300.rou.xml' ... done (127ms).
Loading done.
Simulation started with time: 0.00
```

```
'/home/amrul/Documents/fyp2/300_vehicle/shah_alam_300.sumo.cfg' loaded.   56   x:1348.26, y:452.34   lat:3.067108, lon:101.492170
```

Fig. 4. The simulation movement of the vehicles on the road at Persiaran Permai

Figure 5, on the other hand, illustrates the simulation conducted using the NS-2 simulator, portraying the interactions between vehicles or nodes through circular wave patterns. It is worth noting that before initiating this simulation, the delay parameters must be appropriately configured to ensure accurate readings during the simulation of interactions between vehicles or nodes. The simulation conducted in this study entails a comparison of performance outcomes for distinct transportation protocols within the context of Persiaran Permai, Seksyen 7, Shah Alam, employing the NS-2 simulator. The simulations were repeated eight times, each involving four distinct vehicle quantities: 100, 150, 200, and 250. These simulations encompassed two distinct types of transport protocols namely TCP and UDP. Ad-hoc On-demand Distance Vector (AODV) has been employed as the routing protocol due to its resilience against diverse network behaviors, encompassing node mobility, packet losses, and link failures.

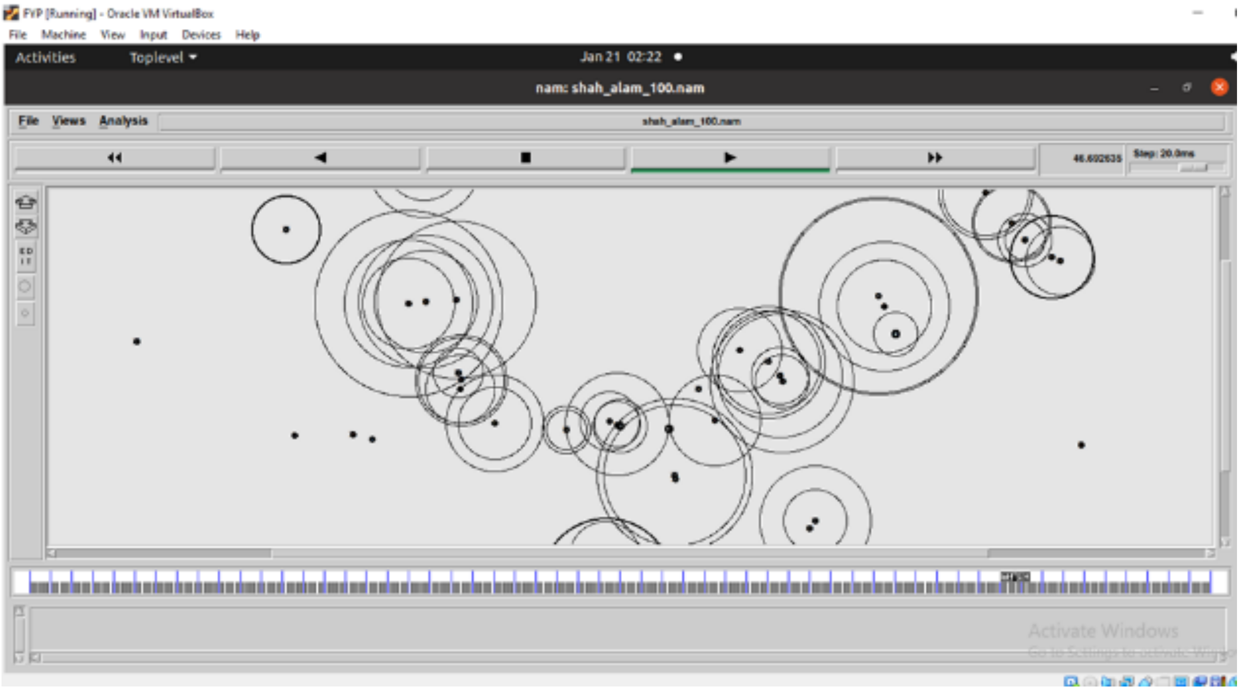

Fig. 5. The circle waves disperse from the nodes in the NS-2 simulator

The simulation utilizes an OmniAntenna, ensuring uniform radio power emission in all directions. Various parameters essential for the simulation are detailed in Table 1.

Table 1
The Parameters

Parameter	Value
Channel	Channel/WirelessChannel
Radio propagation	Two-ray Ground
Network interface type	Phy/WirelessPhyExt
MAC type	IEEE 802.11p
Interface queue type	Queue/DropTail/PriliQue
Antenna model	Omni antenna
Routing protocol	AODV
Stop time	1000s
Number of nodes	100,150,200,250

3. Results

The evaluation of data transmission performance between TCP and UDP will be conducted based on specific parameters, including packet delivery ratio, packet loss, and packet drop. Specifically, the packet delivery ratio will be determined by calculating the ratio of the total number of generated packets to the number of received packets for each node in both TCP and UDP protocols.

3.1 Packet Delivery Ratio

Figure 6 and Figure 7 illustrate that the TCP data consistently exhibit higher values than the UDP data, both in terms of generated and received packets. In Figure 6, the generated packets for UDP remain relatively constant across nodes, ranging from 1000 to 1500 generated packets, whereas TCP demonstrates a range of approximately 2000 to 2500 generated packets. Notably, the TCP-generated packets experience a decline as the number of vehicles or nodes increases.

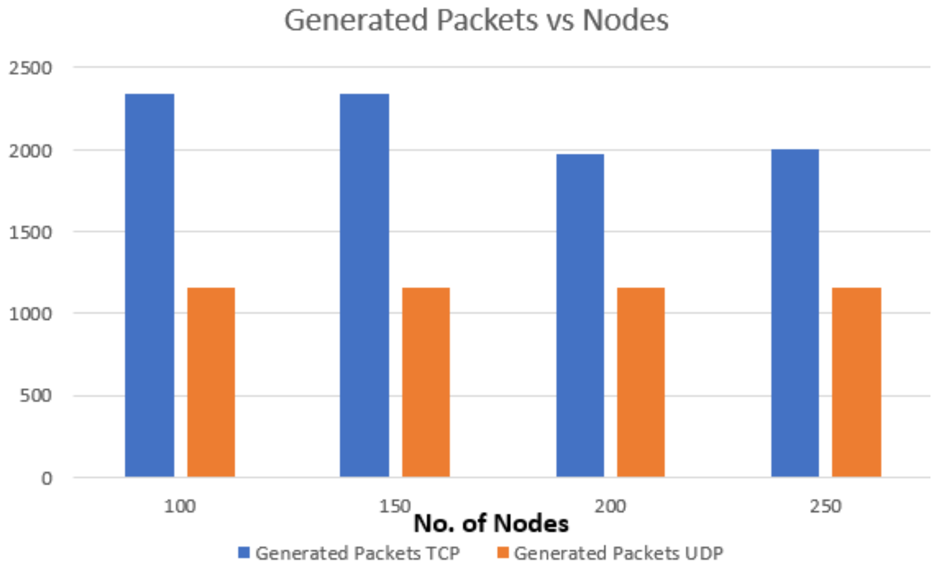

Fig. 6. The generated packets of TCP and UDP

Similarly, the pattern observed in received packets, as shown in Figure 7, follows a similar trend for both TCP and UDP. The only minor distinction lies in the UDP data, where a decrease in received packets occurs between nodes 200 and 250. The observed trend in the figures, where TCP data consistently exhibit higher values than UDP, aligns with the expected behaviour of these protocols. TCP's reliability mechanisms ensure that more packets are successfully delivered and received, resulting in higher generated and received packet counts. However, this reliability comes at the cost of additional overhead due to acknowledgments and retransmissions, which can lead to decreased efficiency when network congestion occurs.

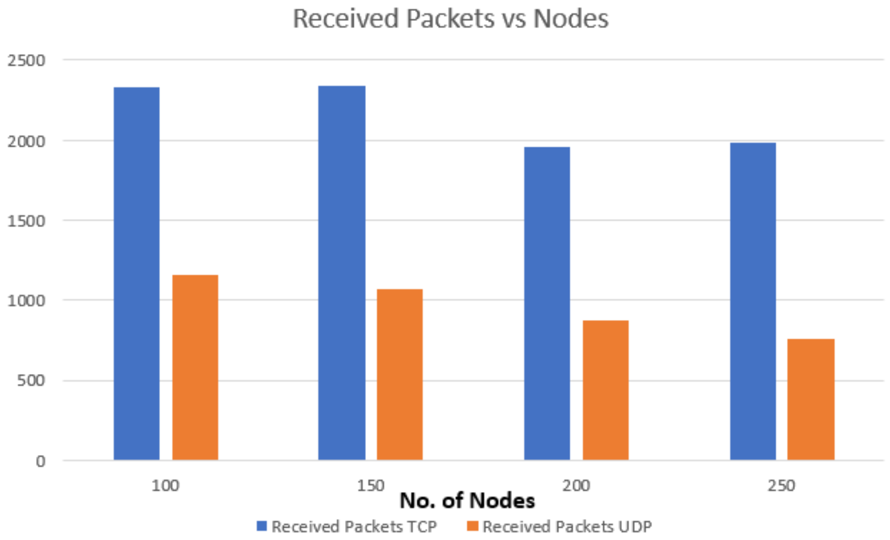

Fig. 7. The received packets of TCP and UDP

The constant nature of generated packets for UDP within a specific range suggests that the protocol is transmitting packets consistently, regardless of network conditions. UDP's lack of reliability mechanisms means that it does not guarantee successful delivery, which could explain why the generated packet count remains stable. The drop in TCP-generated packets as the number of vehicles or nodes increases can be linked to the congestion control mechanisms of TCP. As more nodes compete for limited network resources, TCP's congestion control algorithms may reduce the transmission rate, leading to fewer generated packets. The slight drop in received UDP packets around nodes 200 to 250 highlights UDP's lack of reliability. Without mechanisms to ensure successful delivery, some packets may be lost, resulting in the observed dip in the received packet count. In conclusion, the critical analysis of the presented results showcases the trade-offs between TCP and UDP in terms of reliability and efficiency. The higher counts of generated and received packets for TCP align with its reliability mechanisms, while the stable nature of UDP-generated packets reflects its connectionless nature. The drop in TCP-generated packets underlines its congestion control mechanisms, and the dip in received UDP packets highlights the lack of reliability in UDP. These results emphasize the importance of selecting the appropriate protocol based on the specific requirements of the network scenario.

While Figure 8 illustrates the comparative packet delivery performance of TCP and UDP across different node counts. Initially, at 100 nodes, the distinction between TCP and UDP is marginal. However, this discrepancy becomes more apparent as the node count increases. TCP consistently maintains a delivery rate around 99%, while UDP experiences a significant drop to 92.74% at 150 nodes. Subsequently, as the node count reaches 200, UDP's delivery rate further declines to 75.8%, with TCP's rate decreasing modestly. The contrast continues at 250 nodes, where UDP achieves a 65.77% delivery rate compared to TCP's robust 99.35%. This divergence can be attributed to the fundamental differences between TCP and UDP. TCP's end-to-end communication model, encompassing mechanisms like retransmissions, timeouts, and message acknowledgments, ensures the reliability of packet delivery. It meticulously tracks and retransmits lost packets, ensuring successful transmission. On the other hand, UDP's connectionless nature lacks these reliability mechanisms, rendering it incapable of guaranteeing successful data delivery. This leads to UDP's lower packet delivery ratio compared to TCP. This analysis underscores the trade-offs between TCP and UDP. While TCP's reliability mechanisms contribute to its higher packet delivery ratio, they also introduce overhead, potentially affecting efficiency, especially in congested networks. In contrast, UDP's lightweight approach allows for faster transmission but at the expense of reliability. The choice between TCP and UDP should be made based on the specific requirements of the network scenario, where reliability and efficiency considerations play a crucial role.

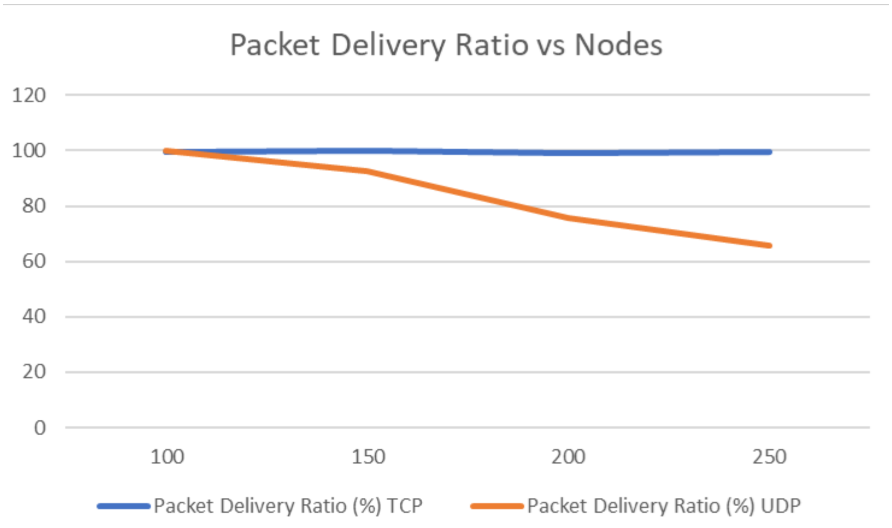

Fig. 8. Packet delivery percentage between TCP and UDP

3.2 Packet Loss

Figure 9 illustrates the examination of packet loss percentages for both TCP and UDP within the context of VANET. The insights gleaned from this analysis shed light on how these protocols handle packet loss under varying conditions. Notably, TCP exhibits a consistent pattern of packet loss across different node counts, indicating a relatively stable behaviour. On the contrary, UDP showcases an upward trajectory in packet loss as the number of vehicles or nodes increases. Initially, at 100 nodes, both TCP and UDP maintain low packet loss percentages, hovering around 0%. However, as the node count rises, a distinct divergence emerges between the two protocols, offering intriguing implications. With UDP, the packet loss percentage climbs notably to 7.29% with the expansion of the node count. This signifies a growing challenge in ensuring reliable packet delivery as the network experiences higher congestion levels. In contrast, TCP manages to keep its packet loss percentage consistently below 1%, even as the node count escalates.

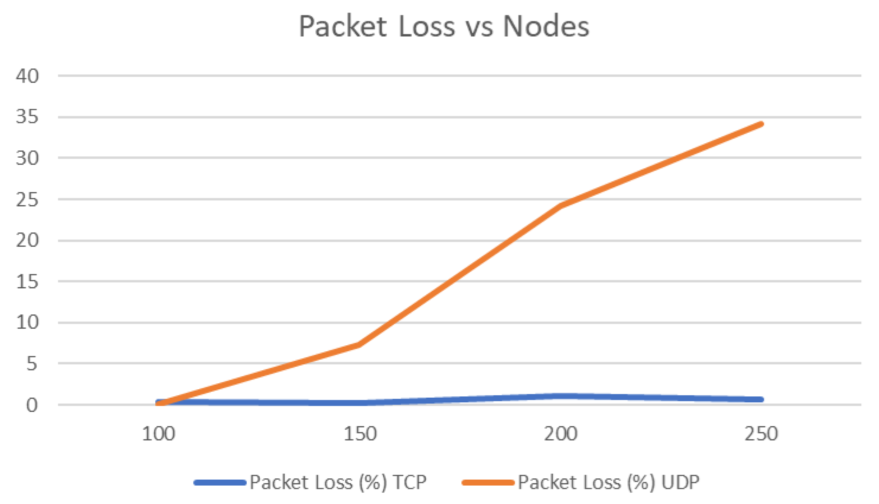

Fig. 9. Packet loss percentage between TCP and UDP

When integrating UDP streams with TCP synchronization, specific intricacies arise due to the dynamics of synchronization processes. Notably, the full utilization of node buffers during TCP connections' synchronization leads to a situation where a substantial influx of packets converges on bottleneck nodes simultaneously. This convergence of packets, particularly from TCP connections, contributes to the compromise of UDP packet loss performance. Consequently, TCP's ability to effectively distribute available bandwidth among its connections using flow control mechanisms inadvertently impacts UDP's performance. In essence, these findings underscore the nuanced interplay between TCP synchronization and UDP packet loss. While TCP connections adeptly manage resource sharing, this collaborative utilization can inadvertently hinder UDP's efficiency.

3.3 Packet Dropped

Figure 10 illustrates a clear distinction in how UDP and TCP handle dropped packets within the VANET context, shedding light on their distinct behaviors in various scenarios. Notably, UDP consistently maintains a total of 0 dropped packets as the number of nodes increases. This is due to UDP's connectionless nature, which avoids retransmitting undelivered packets. This approach ensures uninterrupted communication even during high traffic periods, although it comes at the cost of potential dropped packets. Conversely, TCP's response to dropped packets is more complex. With an increasing number of nodes, TCP records varying instances of dropped packets: 8, 7, 5, and 7 for node counts ranging from 100 to 250. TCP's congestion control mechanisms attempt to manage network traffic by detecting congestion and retransmitting packets. However, TCP's inability to distinguish between slow and congested links introduces intricacies. In congested scenarios, TCP's retransmissions can inadvertently lead to more dropped packets, affecting its overall efficiency. In essence, Figure 10 underscores the balance between UDP and TCP in handling packet drops within VANET. UDP prioritizes continuous communication even in the face of potential packet losses, while TCP's adaptability to congestion introduces complexities that can contribute to dropped packets.

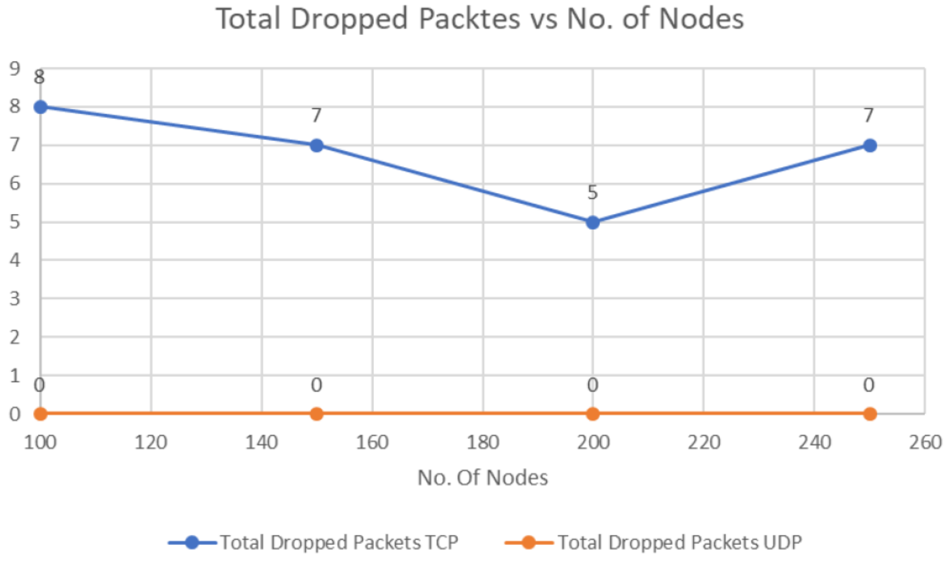

Fig. 10. Packet dropped between TCP and UDP

4. Conclusion and Future Works

The comparative analysis of TCP and UDP protocols was conducted through a comprehensive simulation framework involving NS-2, SUMO, MOVE, and JOSM. Our efforts involved customizing the programming to extract UDP simulation data via NS-2. By collecting metrics such as average packet delivery, packet loss, and packet drop, we were able to discern the distinct performance attributes of these transmission protocols. The results demonstrate a clear distinction in performance between TCP and UDP. TCP exhibited superior performance in terms of average packet delivery ratio and packet loss, recording 99.44% and 0.56% respectively, compared to UDP's values of 83.56% and 16.45%. On the other hand, UDP outperformed TCP in terms of average packet drops, registering a value of 0 compared to TCP's 6.75. These findings provide valuable insights into the trade-offs between TCP and UDP in VANET communication, highlighting their respective strengths and limitations.

Looking ahead, there are several opportunities for further exploration and potential enhancements in the context of VANET communication using TCP and UDP protocols. Firstly, given that TCP demonstrated superior packet delivery ratio and lower packet loss compared to UDP, further investigation could delve into optimizing TCP's performance in scenarios involving high network congestion or dynamically changing topologies. This might involve refining TCP's congestion control mechanisms or exploring adaptive approaches that adjust its behaviour based on VANET-specific conditions. Secondly, while UDP showcased advantages in terms of lower packet drops, its reliability limitations should be addressed. Future work could involve designing mechanisms to enhance UDP's reliability without compromising its connectionless nature. This might entail exploring hybrid protocols that leverage the strengths of both TCP and UDP, potentially mitigating packet losses and ensuring timely and efficient data delivery in diverse VANET scenarios. Moreover, the study could extend its scope to examine the impact of various network parameters, such as vehicle density, traffic patterns, and communication range, on the performance of TCP and UDP. This could offer insights into how these protocols behave under different conditions and aid in tailoring their usage for specific VANET scenarios. By addressing the identified strengths and weaknesses of these protocols, researchers can pave the way for more efficient and reliable vehicular communication systems that align with the evolving demands of modern transportation networks.

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