Aviation Electronics, Information Technology, Telecommunications, Electricals, and Controls (AVITEC)
Vol. 7, No. 1, February 2025, pp. 65~72, p-ISSN 2685-2381, e-ISSN 2715-2626
http://dx.doi.org/10.28989/avitec.v7i1.2867

Optimizing Connectivity and Network Management with SDN Technology on VANET Using the SSF Method

Hane Yorda Dinata*, Galura Muhammad Suranegara
Department of Telecommunication Systems, Purwakarta Regional Campus, Universitas Pendidikan Indonesia

Article Info

Article history:
Submitted February 6, 2025
Accepted February 19, 2025
Published February 20, 2025

ABSTRACT

Vehicular Ad-Hoc Networks (VANET) represent a crucial innovation in transportation technology, enabling vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. However, VANET faces challenges such as signal fluctuations, data security issues, and high mobility, which affect network reliability. This study aims to optimize connectivity and network management in VANET using the Strongest-Signal-First (SSF) method supported by Software-Defined Networking (SDN). The research was conducted through simulations using Mininet-WiFi. The system was designed with two vehicles and four access points to evaluate the performance of the SSF method, focusing on quality of service (QoS) parameters such as data transfer, jitter, packet loss, and bandwidth. Data were collected over a 30-second simulation under varying bandwidth conditions. The results demonstrate that the SSF method effectively maintains communication reliability, achieving a maximum packet loss of only 0.05% and an average data transfer rate of 285 – 324 kB. However, the effects of fading and network dynamics caused fluctuations in minimum transfer rates (102 – 114 kB) and jitter (0.1 – 1.0 ms), particularly at lower bandwidths. The SSF method has proven to enhance communication stability in VANET. Nevertheless, challenges such as fading and high mobility require additional mechanisms to further improve network performance in dynamic environments.

Keywords:
Vehicular Ad-Hoc Networks (VANET);
Strongest-Signal-First (SSF);
Software-Defined;
Networking (SDN).

Corresponding Author:
Hane Yorda Dinata,
Program Studi Sistem Telekomunikasi, Universitas Pendidikan Indonesia
Jl. Veteran No.8, Nagri Kaler, Kec. Purwakarta, Kabupaten Purwakarta, Jawa Barat 41115
Email: *haneyorda21@upi.edu

1. INTRODUCTION

In the rapidly advancing digital era, vehicle technology has seen significant development, particularly in Vehicle-to-Vehicle (V2V) communication. This system is an integral part of Vehicular Ad-hoc Networks (VANETs), enabling real-time information exchange between vehicles to enhance road safety and traffic efficiency. Previous research has shown that VANETs can reduce traffic congestion by up to 30% through optimized traffic flow based on inter-vehicle communication [1]. Additionally, other studies suggest that this technology holds great potential for reducing carbon emissions by enabling more efficient route management [2]. However, adopting this technology comes with various challenges, both global and internal. Despite its many advantages, VANETs face significant global challenges, including high traffic accident rates, congestion, and air pollution, which are becoming increasingly urgent issues. According to WHO data, approximately 1.3 million people lose their lives each year due to road accidents, and VANET technology can play a crucial role in reducing these numbers. By facilitating inter-vehicle communication, VANET can provide early warnings about potential hazards, allowing drivers to take quicker and more appropriate actions. Furthermore, VANETs can optimize traffic flow, reducing congestion and greenhouse gas emissions [3]. By minimizing vehicle idle time or complete stops, the system enhances fuel efficiency, directly contributing to lower air pollution levels. This is particularly relevant for urban areas struggling with poor air quality due to heavy traffic [4]. However, internal challenges must also be addressed. Data security is a major concern, as the information exchanged between vehicles must be protected against potential misuse. Without robust security protocols, private data and sensitive information could be exposed [5]. Additionally, not all vehicles are equipped with the necessary technology to participate in a VANET. In this context, the Strongest-Signal-First (SSF) method could serve as a solution in VANETs, as it prioritizes communication links with the strongest signal for data transmission. This approach is often regarded as an effective strategy for enhancing reliability and efficiency in dynamic and dense vehicular environments

[6]. In VANET communication, SSF provides the necessary framework for V2V and Vehicle-to-Infrastructure (V2I) interactions. It supports various applications, ranging from critical safety systems to infotainment services, by ensuring low-latency data transmission and high reliability [7]. Software-Defined Networking (SDN) has also emerged as a promising solution for providing a scalable and flexible architecture for VANETs. SDN enables centralized control by separating control and data planes, allowing efficient network resource management [8].

Furthermore, SDN can help alleviate network congestion by dynamically adjusting network traffic based on real-time demands [9]. The rapid changes in network topology and high vehicle speeds pose additional challenges. Relying solely on signal strength for connectivity may lead to unstable connections in high-mobility environments. To address this, position-based routing schemes have been proposed, which consider geographic vehicle locations to make routing decisions. This approach helps mitigate signal fluctuation issues by predicting future vehicle positions and selecting more stable next-hop nodes [10]. VANET is a key component of Intelligent Transportation Systems (ITS), enabling vehicles to exchange information wirelessly. This communication enhances both road safety and traffic efficiency by allowing vehicles to share data on speed, location, and road conditions. The integration of advanced technologies such as 5G networks and Massive MIMO is essential for enhancing V2V communication capabilities, facilitating real-time interactions, and supporting the development of autonomous driving systems [11]. The high speed and low latency offered by these technologies allow vehicles to respond faster to potential road hazards, including emergency braking and sudden lane changes [12]. In such situations, vehicles can communicate with each other and with Roadside Units (RSUs) to facilitate data offloading. Specifically, this highlights how a source vehicle, which is out of RSU range, can relay data through peer vehicles connected to an RSU.

SSF in VANETs offers several advantages that enhance network performance. This protocol prioritizes routing based on signal strength, which is crucial in dynamic and rapidly changing VANET environments. By focusing on the strongest signal, SSF can improve reliability and data transmission efficiency, ensuring stable connectivity and real-time communication between vehicles. Through complex traffic pattern analysis, this technology can also reduce collision risks by identifying potentially intersecting vehicle paths [12]. The following sections will detail the specific benefits and network performance improvements associated with SSF routing protocols [13]. By selecting routes with the strongest signal, SSF ensures more stable connections, reducing the likelihood of packet loss and enhancing overall data reliability [14]. Furthermore, previous research has suggested that the Least-Loaded-First (LLF) method may serve as a more efficient alternative in SDN-based Wi-Fi networks, as it considers network load distribution to minimize jitter and packet loss during handovers. While LLF has demonstrated better performance than SSF in static Wi-Fi network scenarios, its application in vehicular environments still requires further investigation. Therefore, a hybrid approach combining SSF and LLF in vehicular networks could provide an effective solution for enhancing network efficiency in high-mobility conditions [15].

2. RESEARCH METHODS

This study employs an experimental approach using simulation methods to evaluate the performance of VANET based on the SSF method. SSF was chosen for its ability to select the communication path with the strongest signal, thereby enhancing the reliability and efficiency of the VANET network. The simulation was conducted using Mininet-WiFi in a controlled virtual environment to observe various performance parameters.

Figure 1 illustrates the research workflow, which consists of three main stages: simulation design, simulation execution, and data analysis. In the first stage, the network topology was designed by determining the number of vehicle nodes and Road-Side Units (RSU) as access points (APs). Each vehicle node was configured with a unique IP address to ensure stable communication. Once the topology was established, experimental parameters were set, including environmental scenarios with static and dynamic conditions, as well as bandwidth variations ranging from 1 Mbps to 1000 Mbps. After the design phase was completed, the implementation phase involved preparing the required hardware and software. The system was installed using Ubuntu 20.04 with Mininet and Mininet-WiFi as the primary emulators. Next, a simulation script was developed based on the SSF method, encompassing VANET network configuration, addition of vehicle nodes, IP address allocation, and RSU configuration to ensure optimal vehicle-to-vehicle communication. The simulation was then executed via the Mininet-WiFi Command Line Interface (CLI) to test network connectivity under various conditions. The final phase involved analyzing the simulation results. Once the simulation was completed, data were collected and analyzed based on Quality of Service (QoS) parameters, including data transfer rate, jitter, packet loss, and bandwidth. To ensure accuracy, measurements were conducted using Iperf, which allows for more detailed network performance analysis. As a validation measure, this study adopts a QoS-based evaluation approach, comparing the obtained results with network performance benchmarks from previous studies. For instance, research by Larasati et al. demonstrated that SSF outperforms other methods such as Least-Loaded-First (LLF) in selecting stable communication paths. However, their study had limitations in measuring jitter in high-mobility environments. Therefore, this study strengthens the findings by conducting simulations under various scenarios and considering fading effects in dynamic conditions to obtain more accurate results.

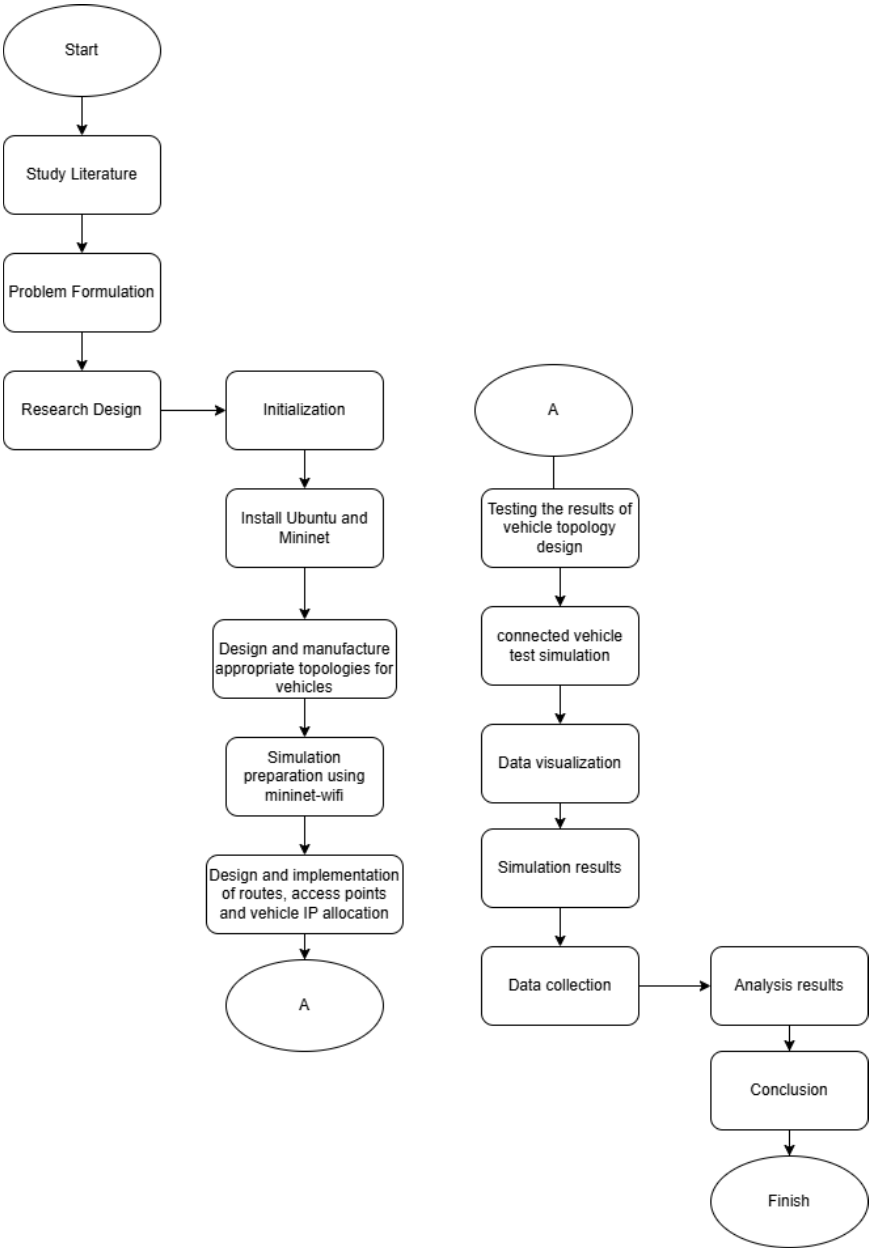

Figure 1. Overview of the entire Research Flow

Additionally, the SSF method was compared with the Mininet-WiFi baseline, which employs a standard connection selection algorithm. This comparison highlights SSF's performance improvements, particularly in achieving lower packet loss and more stable jitter than the default method. The simulation results were also compared with wireless network quality standards used in previous studies. Through this validation, even though a direct comparison with LLF was not conducted in this simulation, an evaluation based on performance benchmarks and Iperf measurements provides confidence that SSF enhances network stability in VANET and can be considered an optimal solution for connectivity optimization. With this approach, this study aims to assess the effectiveness of the SSF method in improving communication stability in VANET, particularly in addressing challenges related to fading and high-mobility environments.

2.1 Research Implementation

The Vehicular Ad-Hoc Network (VANET) is implemented using a combination of Software-Defined Networking (SDN) technology and the SSF method. The network configuration is set up by integrating SDN technology with the SSF method to enhance network performance. Mininet-WiFi is utilized to simulate SDN-based communication within a network topology consisting of two vehicle nodes and four Road-Side Units (RSUs) serving as access points (APs). The simulation is conducted in a virtual machine environment using a computer with the following hardware specifications: Intel i7 11700F processor, 32 GB RAM, NVIDIA RTX 4060 GPU, and a 512 GB NVMe SSD. The operating system used is Ubuntu 20.04, with Mininet-WiFi installed as the primary emulator.

In this network topology, each vehicle node is assigned a unique IP address, while the RSUs are strategically placed to support signal-based communication and manage vehicle connectivity. The simulation runs with bandwidth variations ranging from 1 Mbps to 1000 Mbps, where the SSF method ensures that communication occurs through the strongest available signal path. Throughout the simulation process, data from the implementation is collected and analyzed based on key network performance parameters to evaluate the effectiveness of the approach.

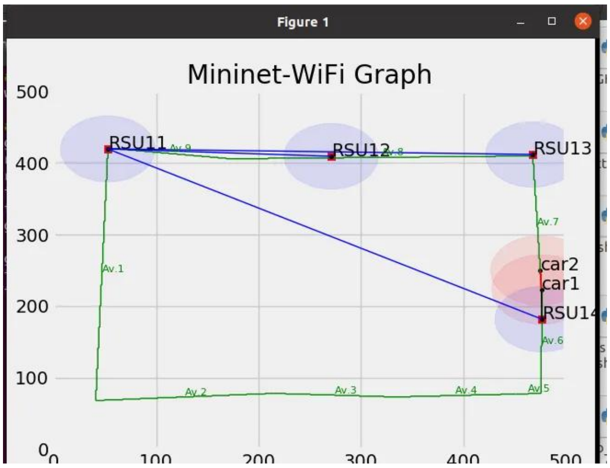

Figure 1. Experimental simulation results

Figure 2 visualizes the Mininet-WiFi network simulation results, depicting a network topology consisting of Road-Side Units (RSUs) and vehicles. Four RSUs, identified as RSU11, RSU12, RSU13, and RSU14, represent the network infrastructure, which can be strategically positioned at key locations such as road intersections or high-traffic areas. The circles around each RSU indicate their signal range or effective coverage area. Two vehicles, car1 and car2 (where "car" stands for "automobile"), are modeled as moving entities within the network. Connectivity between RSUs and vehicles is visualized using colored lines, with green lines representing inter-RSU connections and blue lines indicating connections between RSUs and vehicles. Additionally, Av.1 to Av.7 denote relative location markers or avenues, indicating the positions of network components.

The X and Y axes on the graph represent relative coordinates or distances between network components, allowing for the interpretation of relative positioning and spacing between RSUs and vehicles. Overall, this visualization provides a clear graphical representation of RSU-vehicle interactions within the simulated wireless network scenario, serving as a foundation for network performance analysis, identification of potential connectivity challenges, and the development of optimization solutions to enhance network reliability.

2.2 Quality Of Service (QoS)

2.2.1 Data Transfer

Data transfer is a multifaceted process that involves moving data from one location to another, which can occur within a single device or across multiple devices and networks. This process is crucial for various applications, ranging from simple clipboard operations on a desktop computer to complex data transmissions across global networks [15]. The efficiency and effectiveness of data transfer depend on the technology and methods used, which can vary significantly based on the context of the transferred data [16].

2.2.2 Jitter

Jitter is the variation in the time between arriving packets, caused by network congestion, timing deviations, or route changes [17]. In Quality of Service (QoS), jitter refers to the fluctuation in packet delay during network transmission. It is an essential metric that impacts quality; therefore, maintaining consistent timing is crucial [18].

2.2.3 Bandwidth

Bandwidth is the data transfer rate that a network link or path can support, which is critical in ensuring network service performance and reliability [19]. Bandwidth refers to the amount of data that can be transmitted over a network within a given time period, playing a vital role in traffic management, delays, and packet loss [20].

2.2.4 Packet Loss

Packet loss refers to the failure of data packets to reach their intended destination across a network, which can significantly impact the performance and quality of various applications and data transfers [21].

3. RESULTS AND DISCUSSION

The QoS testing in the VANET simulation using the SSF method was conducted by collecting implementation data based on a vehicle trajectory scenario over 30 seconds. The collected data includes maximum, minimum, and average values for parameters such as data transfer, jitter, packet loss, and bandwidth, which are presented in Table 1.

Table 1. Measurement results VANET SSF

Metric	Target Bandwidth	Strongest-Signal-First	Result
Transfer (kB)	1 Mbps	Maximum	491
		Minimum	103
		Average	285
	10 Mbps	Maximum	499
		Minimum	114
		Average	324
	100 Mbps	Maximum	500
		Minimum	107
		Average	306
	1000 Mbps	Maximum	497
		Minimum	102
		Average	288
Jiter (ms)	1 Mbps	Maximum	1.0
		Minimum	0.1
		Average	0.5
	10 Mbps	Maximum	1.0
		Minimum	0.1
		Average	0.6
	100 Mbps	Maximum	1.0
		Minimum	0.0
		Average	0.5
	1000 Mbps	Maximum	1.0
		Minimum	0.1
		Average	0.5
Packet Loss	1 Mbps	Maximum	0.05
		Minimum	0.00
		Average	0.02
	10 Mbps	Maximum	0.05
		Minimum	0.00
		Average	0.02
	100 Mbps	Maximum	0.05
		Minimum	0.00
		Average	0.02
	1000 Mbps	Maximum	0.05
		Minimum	0.00
		Average	0.03

Figure 1 illustrates the total amount of data successfully transferred across various bandwidth scenarios. The X-axis represents bandwidth variations in Mbps, while the Y-axis indicates the amount of data transferred in kilobytes (kB). The graph shows that an increase in bandwidth generally results in a higher volume of transferred data, although some fluctuations are observed due to fading effects and network interference.

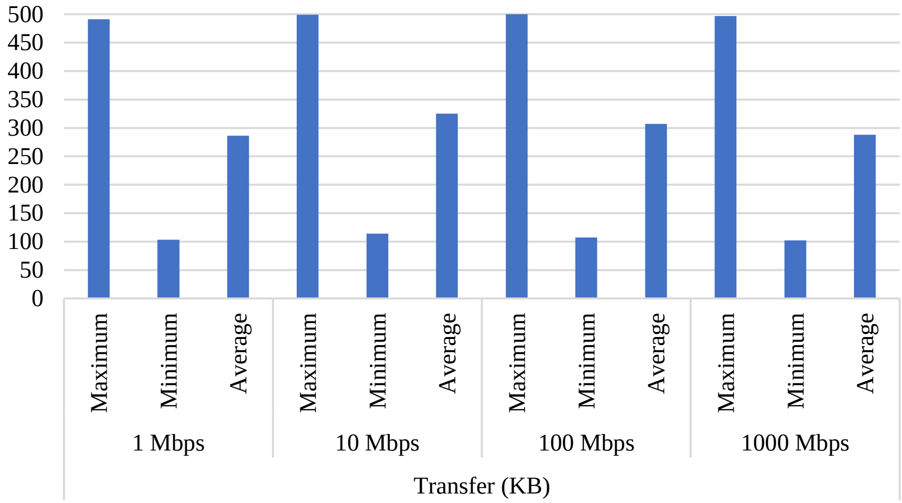

Figure 1. The measurement result of the transfer rate for SSF.

Figure 2 illustrates jitter variations across different test scenarios. The X-axis represents the bandwidth used (Mbps), while the Y-axis indicates jitter in milliseconds (ms). The results show that jitter remains relatively low but experiences a slight increase at higher bandwidths, primarily due to greater traffic density.

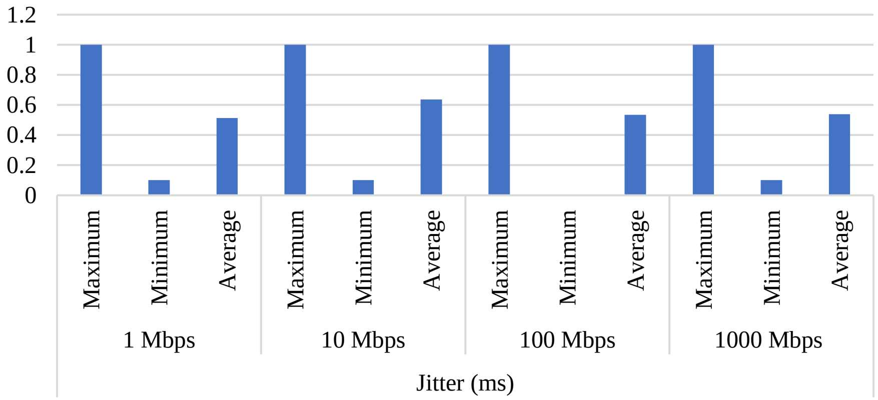

Figure 2. The measurement result of Jitter for SSF.

Figure 3 illustrates the percentage of packet loss in each bandwidth scenario. The X-axis represents bandwidth variations, while the Y-axis shows the packet loss percentage (%). The results indicate that the SSF method maintains a very low packet loss rate, with a maximum value of only 0.05%.

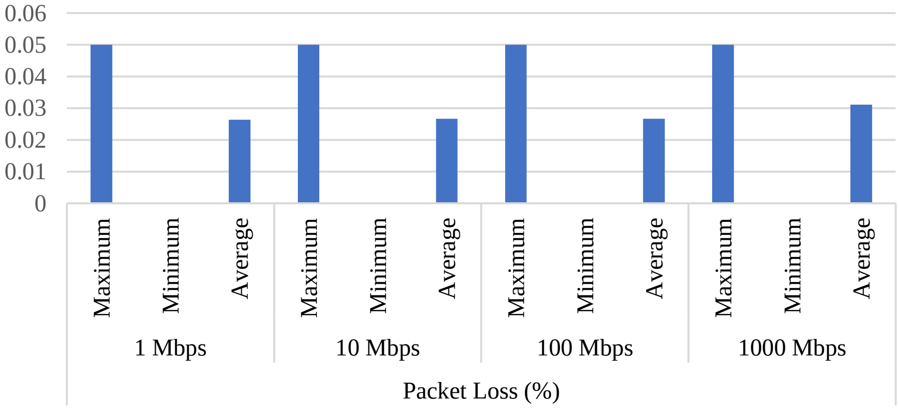

Figure 3. The measurement result of packet loss for SSF

The Quality of Service (QoS) measurements for the vehicular network using the SSF method were evaluated based on parameters such as data transfer, jitter, packet loss, and bandwidth. To determine whether the obtained results are optimal, a comparison was made with service quality standards used in previous studies. According to Keinan Shofiandieni Haryo Putri et al., V2V communication in a 5G network should have a delay of less than 1 ms and a reliability of approximately 99% to ensure stable connectivity in high-mobility environments. However, their study was conducted in the context of 5G networks, whereas this study utilizes Mininet-WiFi to simulate vehicular communication. Therefore, the obtained results are compared with these standards as a reference. The experimental results show that the SSF method achieves a maximum packet loss of 0.05% and jitter between 0.1 ms and 1.0 ms, which remains within the acceptable limits for real-time communication in vehicles. While previous studies established a reliability standard of up to 99% in 5G networks, the findings of this study demonstrate that SSF maintains stable communication even in a Wi-Fi environment within the tested vehicular scenarios. A stable vehicular network should ideally maintain a packet loss below 0.1%, jitter below 1 ms, and consistent data transfer to ensure reliable inter-vehicle communication. The test results indicate that the SSF method achieves a maximum packet loss of 0.05% and an average of 0.02%, remaining within the acceptable range for real-time vehicular communication. Additionally, jitter values ranging between 0.1 ms and 1.0 ms confirm that SSF is capable of maintaining latency stability in V2V communication. For further validation, this study compares SSF with the default Mininet-WiFi baseline, which uses a standard connection selection mechanism. The simulation results show that SSF achieves lower packet loss and more stable jitter than the default method, particularly in low-bandwidth scenarios. This demonstrates that choosing the strongest signal through SSF enhances communication reliability compared to conventional methods.

Furthermore, this study also compares SSF with the Least-Loaded-First (LLF) method, based on research by Harashta Tatimma Larasati et al., which suggests that LLF considers network load when selecting communication paths. Their findings indicate that LLF performs better than SSF in static Wi-Fi networks, achieving higher data transfer rates, lower jitter, and reduced packet loss. However, the key difference between their study and this research is the testing environment. The previous study was conducted in a stationary Wi-Fi network, while this study focuses on vehicular networks, which involve high mobility and network interference. The results of this study confirm that SSF can still maintain stable connectivity in vehicular networks, with performance metrics aligning with vehicular communication standards. While previous studies indicate that LLF performs better in static Wi-Fi networks, the findings suggest that SSF remains effective in vehicular networks by ensuring connectivity without requiring complex load-balancing mechanisms.

Thus, the differences in testing environments indicate that an optimal method for Wi-Fi networks may not necessarily be optimal for vehicular networks. For further validation, future research could explore the use of LLF in vehicular scenarios to determine whether load balancing can improve performance in high-mobility environments.

4. CONCLUSION

After conducting a series of experiments and analyses, it can be concluded that the implementation of the Strongest-Signal-First (SSF) method in Vehicular Ad-Hoc Networks (VANETs) demonstrates good performance in maintaining wireless communication quality. This is evidenced by the low packet loss rate, with a maximum value of 0.05% and an average of 0.02% across various bandwidths, indicating the effectiveness of SSF in selecting the strongest signal. However, network performance is still influenced by small-scale fading, which causes fluctuations in data transfer rates and jitter. The minimum data transfer rate ranges between 102–114 kB, while the average rate varies between 285 and 324 kB, particularly at lower bandwidths, indicating a decline in quality due to high mobility and network dynamics. Additionally, jitter variations between 0.1 ms and 1.0 ms reveal the presence of unstable delays, especially under low-bandwidth conditions. Compared to the Mininet-WiFi default baseline, SSF demonstrates an improvement in network stability, with lower packet loss and more stable jitter. However, previous research indicates that the Least-Loaded-First (LLF) method performs better in static Wi-Fi networks, achieving higher data transfer rates and lower jitter. This suggests that the testing environment significantly influences the effectiveness of the applied method. Therefore, while SSF proves effective in minimizing packet loss and maintaining network reliability in vehicular environments, it still has limitations in adaptively managing network load. Thus, challenges such as fading, interference, and node mobility must be addressed through additional mechanisms to enhance VANET performance. Future research could explore the combination of SSF with other methods, such as LLF, to improve load balancing efficiency, as well as consider AI-based algorithms to optimize connection selection in high-mobility conditions.

REFERENCE

[1] G. Kaur and D. Kakkar, “Hybrid optimization enabled trust-based secure routing with deep learning-based attack detection in VANET,” *Ad Hoc Networks*, vol. 136, no. C, p. 102961, Nov 2022. https://doi.org/10.1016/j.adhoc.2022.102961

[2] Y. Lu et al., “STRICTs: A Blockchain-enabled Smart Emission Cap Restrictive and Carbon Permit Trading System,” *Applied Energy*, vol. 313, p. 118787, 2022. https://doi.org/10.1016/j.apenergy.2022.118787

[3] J. Wheeder, S. Ponnusamy, R. A. H. Khan, P. R. Ponnusamy, and M. Muqeem, "Blockchain-based Framework for Security and Privacy Solutions in VANET,” *International Journal of Innovative Science*

and Research Technology (*IJISRT*), vol. 9, no. 5, pp. 2630-2637, 2024. https://doi.org/10.38124/ijisrt/IJISRT24MAY2184

[4] D. Vashist, M. Maitra, G. Saxena, and A. Mittal, "Analysis of a start-stop system for an energy-efficient micro-hybrid two-wheeler," in Smart Electric and Hybrid Vehicles, CRC Press, 2024.

[5] Y. Ji, T. Liu, Z. Li, and J. Chang, "Key-Escrow-Free and Vehicle-Revocable Data Sharing Protocol for Vehicular Ad Hoc Network," Sep 23, 2023, Social Science Research Network, Rochester, NY: 4581214. https://doi.org/10.2139/ssrn.4581214

[6] A. Jafarian, U. Erez, and S. Vishwanath, "Should one always connect to the base station with the strongest signal?," in 2009 Conference Record of the Forty-Third Asilomar Conference on Signals, Systems and Computers, pp. 1828–1832, Nov 2009. https://doi.org/10.1109/ACSSC.2009.5470214

[7] J. A. Guerrero-Ibáñez, C. Flores-Cortés, and S. Zeadally, "Vehicular Ad-hoc Networks (VANETs): Architecture, Protocols and Applications," in Next-Generation Wireless Technologies, Springer, pp. 49–70, 2013. https://doi.org/10.1007/978-1-4471-5164-7_5

[8] M. Arif, G. Wang, T. Wang, and T. Peng, "SDN-Based Secure VANETs Communication with Fog Computing," in Security, Privacy, and Anonymity in Computation, Communication, and Storage, Springer International Publishing, pp. 46–59, 2018. https://doi.org/10.1007/978-3-030-05345-1_4

[9] T. Badageri, B. Hamdaoui, and R. Langar, "Load-Balanced Multipath Routing Through Software-Defined Networking," in 2024 International Wireless Communications and Mobile Computing (IWCMC), pp. 1068–1073, May 2024. https://doi.org/10.1109/IWCMC61514.2024.10592316

[10] G. Abbas, S. Ullah, M. Waqas, ZH. Abbas, M. Bilal, "A position-based reliable emergency message routing scheme for road safety in VANETs," *Computer Networks*, vol. 213, August 2022. https://doi.org/10.1016/j.comnet.2022.109097

[11] R. Ali, D. N. Hakro, M. R. Tanweer, and A. A. Kamboh, "Simulation based Vehicle to Vehicle and base station communication," *in 2019 International Conference on Information Science and Communication Technology* (*ICISCT*), pp. 1–6, Mar 2019. https://doi.org/10.1109/CISCT.2019.8777411

[12] K. S. Haryo Putri and U. Kurniawan Usman, "Analysis of Vehicle to Vehicle Communication Parameter on 5G Network," *in 2019 Symposium on Future Telecommunication Technologies* (*SOFTT*), Kuala Lumpur, Malaysia: IEEE, pp. 1–6, Nov. 2019. https://doi.org/10.1109/SOFTT48120.2019.9068620

[13] B. Saoud, T. Zireg, and I. Bouaoud, "Routing Protocols in VANET, Study and Evaluation," *in 2023 2nd International Conference on Electronics, Energy and Measurement* (*IC2EM*), pp. 1–5, Nov. 2023. https://doi.org/10.1109/IC2EM59347.2023.10419846

[14] D. R. de Assis, J. Alves Junior, and E. C. G. Wille, "Strategies to increase connectivity and performance of VANETs: Analysis of route lifetime and routing protocol proposal," *Transactions on Emerging Telecommunications Technologies*, vol. 34, no. 1, p. e4665, 2023. https://doi.org/10.1002/ett.4665

[15] H. T. Larasati, F. H. Ilma, B. Nuhamara, A. Mustafa, R. Hakimi, and E. Mulyana, "Performance evaluation of handover association mechanisms in SDN-based wireless network," *in 2017 3rd International Conference on Wireless and Telematics* (*ICWT*), Palembang: IEEE, pp. 103–108, July 2017. https://doi.org/10.1109/ICWT.2017.8284148

[16] F. P. A. Zaquinaula et al., "Data Transmission Technologies and Networks: A Review," *Journal of Namibian Studies: History Politics Culture*, vol. 33, pp. 3190–3201, May 2023. https://doi.org/10.59670/jns.v33i.955

[17] J. Woodruff and J. Alexander, "Data transfer: A longitudinal analysis of clipboard and drag-and-drop use in desktop applications," *International Journal of Human-Computer Studies*, vol. 132, pp. 112–120, Dec 2019. https://doi.org/10.1016/j.ijhcs.2019.08.005

[18] S. Thangam, M. Gurupriya, A. S. Revanth, D. Arun Joel, C. M. Shankar, and I. S. Koushik, "VoIP QoS Refinement through Call Sequencing using Adaptive Jitter Buffer Algorithm," *in 2024 15th International Conference on Computing Communication and Networking Technologies* (*ICCCNT*), pp. 1–7, June 2024. https://doi.org/10.1109/ICCCNT61001.2024.10725456

[19] V. Kartashevskiy and M. Buranova, "Analysis of Packet Jitter in Multiservice Network," *in 2018 International Scientific-Practical Conference Problems of Infocommunications. Science and Technology* (*PIC S&T*), pp. 797–802, Oct. 2018. https://doi.org/10.1109/INFOCOMMST.2018.8632085

[20] D. S. Pradana, M. Orisa, and F. X. Ariwibisono, "Implementation of Dynamic Quality of Service (QoS) Hotspot Login Management Bandwidth Using Hierarchical Token Bucket (HTB) Method," *JATI* (*Jurnal Mahasiswa Teknik Informatika*), vol. 8, no. 2, 2024. https://doi.org/10.36040/jati.v8i2.9088

[21] D. Lártiga, N. Boettcher, Y. Prieto, and J. E. Pezoa, "QoSApp: Dynamic bandwidth management for QoS applications using OpenFlow," *in 2016 IEEE 37th Sarnoff Symposium*, pp. 1–2, Sept 2016. https://doi.org/10.1109/SARNOF.2016.7846733

[22] H. Wu, Y. Liu, S. Ni, G. Cheng, and X. Hu, "LossDetection: Real-Time Packet Loss Monitoring System for Sampled Traffic Data," *IEEE Transactions on Network and Service Management*, vol. 20, no. 1, pp. 30–45, 2023. https://doi.org/10.1109/TNSM.2022.3203389