
Performance Analysis and Quality of Service for Video Streaming in Vehicular Adhoc Networks

Hussein Ali Al-Gubouri

Directorate of Nineveh Education, Vocational Education, Nineveh,
Iraqi Ministry of Education, Iraq
hussein.mohammed@uoninevah.edu.iq

Ayat Abbas Fadhil

Department of Artificial Intelligence, College of Science, University of Alkafeel,
Najaf, Iraq
aayat.alkhazali@alkafeel.edu.iq

Hajir A. Alzubaydi

ITRDC, University of Kufa, Iraq
hajara.alzubaydi@uokufa.edu.iq

Abstract

Although safety applications have been the main driving force behind the development of Vehicular Ad-hoc Networks (VANETs), non-safety applications can also greatly benefit vehicular networks. Video streaming services, among non-security applications, can offer appealing features to many users and draw a large number of users. However, the adoption of video services in vehicular networks is challenging due to the high mobility characteristics of VANETs and packet loss during communication blackouts. This research is unique in the field of software-defined networks that examined a video streaming service's effectiveness to investigate how well a video on demand service would work for users in vehicles on a highway. The packet loss caused by network reconfiguration during handoffs and its impact on the quality of the video transmitted have both been examined. With the help of SDN technology, we were able to maintain uninterrupted video streaming between vehicles in a vehicular ad hoc network.

Keywords: SDN, VANET, QoS, Adhoc, SUMO, RSU, NETWOTK.

1-Introduction

The rapid development of intelligent transportation systems has significantly changed the way vehicles interact with their surrounding environment. Modern vehicles are no longer isolated units; instead, they have become active components within complex communication systems that aim to improve road safety, traffic efficiency, and user experience. With the continuous growth in the number of vehicles on the road, traditional transportation solutions are no longer sufficient to meet current demands, particularly in highly dynamic and densely populated urban areas.

In this context, wireless communication technologies have emerged as a key enabler for enhancing information exchange among vehicles and between vehicles and infrastructure. These technologies allow real-time sharing of critical data related to traffic conditions, road hazards, and navigation assistance. Beyond safety-related applications, they also support a wide range of value-added services designed to improve passenger comfort, such as multimedia content delivery and Internet connectivity during travel. As a result, vehicular communication networks have attracted considerable attention from both academic researchers and industry practitioners.

However, the unique characteristics of vehicular environments introduce several technical challenges that distinguish them from conventional wireless networks. High vehicle mobility, rapidly changing network topology, and frequent link disruptions make it difficult to ensure stable and reliable communication. These challenges become more pronounced when supporting delay-sensitive applications, such as real-time video streaming, which require high data rates, low latency, and consistent Quality of Service. Consequently, designing efficient communication mechanisms capable of operating under such dynamic conditions remains a critical research problem.

Addressing these challenges requires a comprehensive understanding of vehicular network behavior, communication constraints, and service requirements. Various approaches have been proposed to improve data delivery performance and resource

utilization; however, achieving an optimal balance between reliability, efficiency, and scalability is still an open issue. Therefore, further investigation is necessary to develop solutions that can effectively support advanced applications while maintaining acceptable service quality in realistic vehicular scenarios.

A unique variation of MANET that enables wireless communication between vehicles on the roadside is the vehicular ad hoc network. This wireless communication network is autonomous and self-organizing, with nodes acting as clients or servers to share and exchange information. Three types of network architecture exist for VANETs: pure ad hoc, WLAN/ cellular and hybrid. New technology has drawn a lot of attention from the government, academic community, and business community. [1]. Around the world there are many research which are related with video streaming adhoc networks like DRIVE, COMCAR, CarTALK 2000, FleetNet , and Network on Wheels (NoW) and CarNet [2-7].

Figure (1) displays a form of VANET. There are some applications of VANET for example Security distance warning, Vehicle collision warning, Cooperative driving, Cooperative cruise control, Dissemination of road information, Internet access, Driver assistance, Automatic parking, Driverless vehicles and Map location [1].

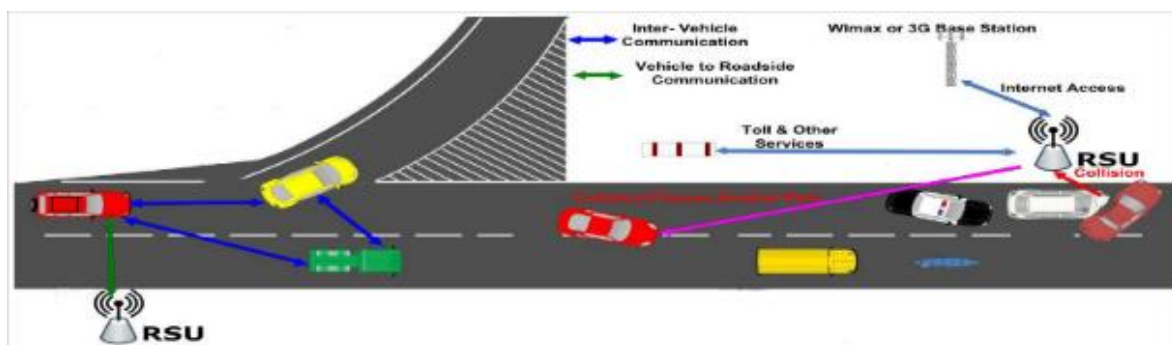


Fig (1): Several applications of VANET.

Over the past few years, Vehicular Ad Hoc Networks (VANETs) have attracted increasing research interest and are considered an essential component in the future development of wireless communication services [8], [9]. This technology opens new

opportunities for improving advanced solutions that support reliable vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, as illustrated in Fig (2) [10]. In order to achieve fast and efficient data exchange, vehicles are equipped with wireless communication systems operating over short- or medium-range distances [11]. At present, VANETs commonly rely on Dedicated Short Range Communication (DSRC), which is based on the IEEE 802.11p standard, and has been widely adopted to enhance road safety and traffic efficiency [12].

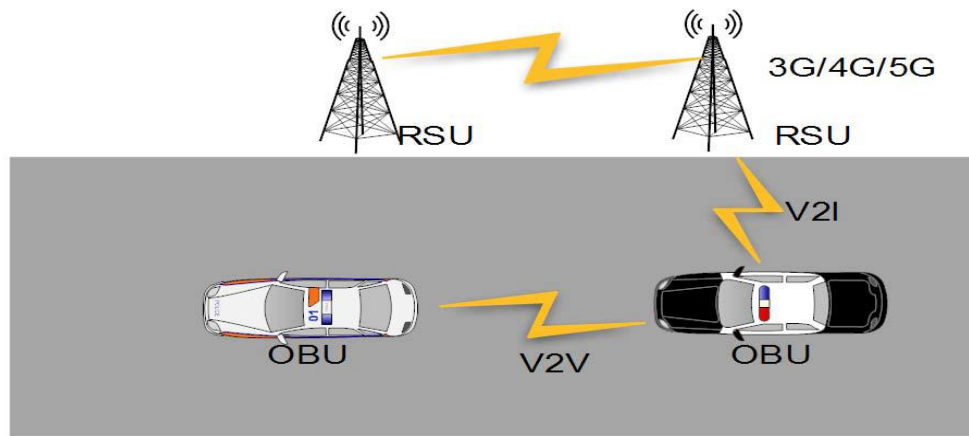


Fig (2): General VANETs architecture

Vehicular Ad Hoc Networks (VANETs) are characterized by their self-organizing nature and autonomous operation, enabling vehicles to exchange and disseminate information without centralized control [8]. By integrating wireless communication technologies, vehicles can directly interact with one another to support safety-related functions such as emergency alerts and warnings for stationary vehicles [12]. Beyond safety applications, VANETs also facilitate a range of infotainment services aimed at improving passenger comfort, including audio delivery, video streaming in both real-time and non-real-time modes, as well as Internet access through roadside units (RSUs) [12], [13]. Among these services, video streaming has emerged as a key application that significantly contributes to the advancement and practical adoption of vehicular networks [13]. Nevertheless, such applications impose strict resource requirements in order to ensure an acceptable level of Quality of Service (QoS). In particular, video

streaming demands high data rates along with reliable communication links. Meeting these requirements necessitates efficient interaction between vehicles and RSUs, which are typically connected to heterogeneous communication technologies. Despite the considerable advantages offered by VANETs, guaranteeing enhanced QoS for video streaming applications remains a major challenge. In the context of real-time video streaming, achieving a clearly defined and acceptable level of service quality places strict and often uncompromising demands on the underlying network infrastructure [14]. Ensuring Quality of Service (QoS) in VANETs is particularly challenging due to the dynamic nature of several network parameters, including bandwidth availability, transmission delay, throughput, and latency. This challenge mainly arises from the rapidly changing network topology caused by the high mobility and varying speed of vehicles [9], [11]. Such frequent topological changes can result in unstable or broken communication links between vehicles and roadside units (RSUs) [9], which in turn leads to increased packet delays, higher levels of data congestion, and continuous fluctuations in the number of active vehicles within the network over time. Consequently, in order to further advance VANET technologies, enhance road safety, and improve passenger comfort, the design of efficient routing protocols (RPs) is essential for reliable communication between RSUs and onboard units (OBUs) [15], [16].

Recent advancements in Intelligent Transportation Systems (ITS) and wireless communication technologies have significantly increased research interest in Vehicular Ad Hoc Networks (VANETs). While early research primarily focused on safety-related applications, recent developments have expanded VANET usage to include non-safety services such as multimedia applications and video streaming. Among these services, video streaming is one of the most demanding applications due to its strict Quality of Service (QoS) requirements, including high data rates, low latency, minimal packet loss, and continuous connectivity [17], [18].

Supporting high-quality video streaming in VANET environments remains challenging due to inherent network characteristics such as high vehicle mobility, frequent topology

changes, and intermittent connectivity. These factors often lead to communication disruptions and increased packet loss during handoff events between Roadside Units (RSUs), significantly degrading video quality. Recent studies indicate that traditional routing and mobility management mechanisms fail to maintain acceptable QoS levels under such dynamic conditions [19], [20].

To address these limitations, Software-Defined Networking (SDN) has emerged as a promising paradigm for enhancing video streaming performance in vehicular networks. By decoupling the control plane from the data plane, SDN enables centralized control, global network visibility, and adaptive resource management. Recent research demonstrates that SDN-based VANET architectures can effectively reduce packet loss, minimize handoff latency, and improve overall QoS for multimedia streaming applications [21], [22].

In line with recent studies, the results presented in this work demonstrate that integrating SDN into VANET architectures significantly enhances video streaming performance. Simulation outcomes show noticeable improvements in QoS metrics, particularly in reducing packet loss and maintaining stream continuity during handoff operations, even under high vehicle mobility scenarios. These findings confirm the effectiveness of SDN-enabled solutions for supporting reliable video streaming services in future vehicular networks [22], [23].

The contributions of my paper are summarized as follows:

- Performance evaluation of video streaming over VANETs under high mobility conditions.
- Design of an SDN-enabled VANET architecture to mitigate packet loss during handoff events.
- Comprehensive QoS analysis demonstrating improved stream reliability.
- Validation of SDN feasibility for future vehicular multimedia services.

2- Related Works

Recent studies have explored a wide range of approaches aimed at supporting multimedia services, particularly video streaming, in vehicular ad hoc networks. These works mainly focus on routing strategies, cross-layer optimization techniques, and adaptive communication mechanisms to cope with the dynamic characteristics of vehicular environments. Several solutions attempt to enhance data delivery performance by exploiting vehicle density, mobility patterns, and roadside unit assistance, while others emphasize reducing delay and packet loss through intelligent forwarding and resource allocation schemes.

Despite these efforts, the effectiveness of the proposed approaches is often constrained by the highly dynamic topology of VANETs and the frequent disconnections between vehicles and infrastructure components. Variations in bandwidth availability, link stability, and vehicle speed continue to pose significant challenges to maintaining consistent Quality of Service (QoS), especially for real-time video streaming applications. Consequently, existing studies highlight that further improvements are still required to ensure reliable, scalable, and QoS-aware communication in realistic vehicular scenarios.

Video streaming in Vehicular Ad hoc Networks (VANETs) presents significant challenges in achieving high Quality of Service (QoS) and reliable delivery due to the dynamic topology, frequent link breakages, and stringent delay and bandwidth requirements inherent in vehicular environments [24]. These challenges affect key performance like delay, end to end, packet loss, jitter, and ultimately the user's perceived Quality of Experience (QoE) for real time video applications.

Adaptive cross layer mechanisms have been introduced to improve video streaming performance in VANETs by mapping video frame priorities to appropriate MAC layer queues, taking into account frame importance and current network conditions. These mechanisms aim to minimize delay and maximize received video quality by reducing congestion and packet loss impacts on time sensitive streams [25]. Complementing

these approaches, geographic and QoE aware routing techniques consider both network and application layer metrics, such as delay, packet delivery ratio, and user perception scores, to select optimal relay vehicles for streaming data and improve user satisfaction compared with distance based routing protocols [26].

Comprehensive surveys have highlighted the intrinsic relationship between QoS and QoE in vehicular video streaming. These studies systematically evaluate various models and techniques for measuring QoS and QoE trade offs, as well as their influence on the design of efficient video streaming systems in VANETs [27]. Hybrid routing strategies that combine V2V and vehicle to infrastructure (V2I) communications have also been explored to enhance video dissemination, leveraging intelligent scheduling and distribution nodes to reduce packet loss, balance load, and improve throughput [28].

Swarm intelligence and other bio inspired multipath routing protocols demonstrate adaptability in selecting multiple optimal paths, balancing throughput and delay under varying vehicle densities, which contributes to sustained video quality in mobile environments [24]. In parallel, hybrid routing that integrates geographic and multipath strategies has been proposed to minimize frame loss and maintain continuity of video streams even under high mobility conditions [26].

Moreover, research has investigated enhancements to traditional routing protocols to improve stability and QoS for video streaming, such as utilizing predicted link lifetime as a route stability metric to reduce link failures and enhance performance in high speed scenarios [29]. Finally, comparative and survey studies emphasize the complexity of multimedia video streaming over VANETs, identifying various QoS/QoE mechanisms, routing protocols, and system level trade offs necessary to achieve efficient and reliable real time video delivery [30], while recent work also pushes toward cross layer and machine learning based prediction models to further refine QoE estimation and adapt streaming strategies accordingly [31][32][33].

3- Methodology

In order to evaluate the performance and Quality of Service (QoS) for video streaming over Vehicular Ad hoc Networks (VANETs), simulation experiments were conducted using Mininet-WiFi, which is widely adopted for performance analysis and modeling of vehicular network scenarios and applications. The simulations were executed on an Ubuntu 20.04 64-bit laptop equipped with an Intel Core i5 10th Generation processor and 8 GB of RAM, providing sufficient computational resources for realistic vehicular network emulation.

In the simulation environment, vehicles were modeled as mobile nodes with wireless application-based protocols, allowing dynamic behavior that reflects realistic vehicular movements and network connectivity. One key advantage of using Mininet-WiFi is its ability to generate diverse traffic types, enabling the study of video streaming performance under various network loads and traffic conditions.

The main network and simulation parameters used in the experiments, including node density, mobility patterns, transmission ranges, and traffic generation settings, are summarized in Table 1. These parameters were carefully selected to provide a realistic and reproducible environment for assessing the impact of network dynamics on video streaming QoS in VANETs.

Simulation of Urban Mobility (SUMO) is an open-source, microscopic, and multi-modal traffic simulation platform that enables detailed modeling of vehicular movement within urban road networks. SUMO simulates the motion of individual vehicles, each with its own route and unique trajectory, allowing researchers to study traffic behavior at a fine-grained level.

Being purely microscopic, SUMO represents each vehicle explicitly, which provides the flexibility to analyze how individual vehicles interact with the network and with each other under different traffic conditions. The simulator supports a wide range of traffic management studies, such as congestion analysis, route optimization, traffic

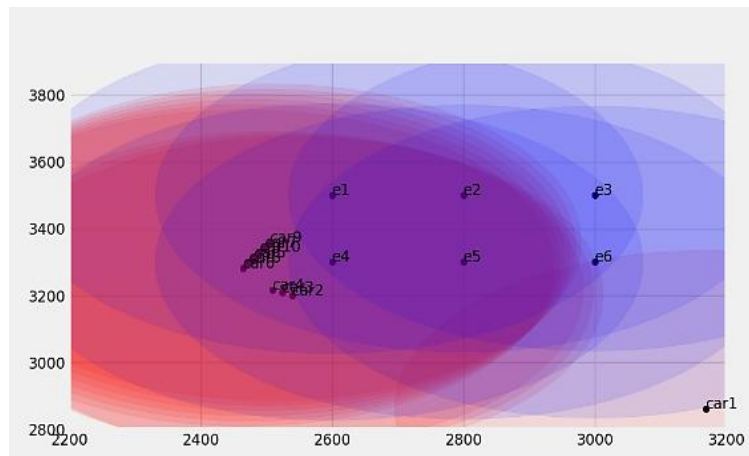
light coordination, and incident management.

By default, SUMO simulations are deterministic, meaning that repeated runs with the same input produce identical results. However, the platform also provides multiple options to introduce stochastic behavior, such as random variations in vehicle departure times, routing decisions, and driver behavior, which allows for more realistic modeling of urban traffic dynamics.

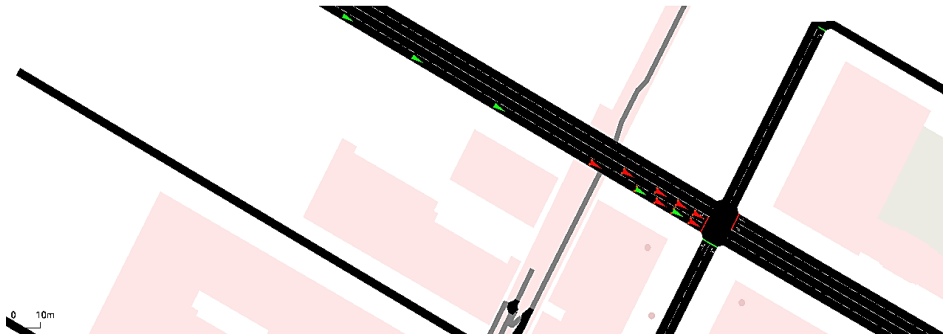
This combination of microscopic detail, multi-modal support, and stochastic flexibility makes SUMO a highly suitable tool for simulating urban vehicular networks and evaluating applications such as video streaming over VANETs, where vehicle mobility patterns directly impact network performance and Quality of Service (QoS).

Table (1): The network parameters.

| Parameter | Value |
|---------------------|--------------------|
| Simulator | Mininet-Wifi |
| Simulation Area | 3200*3200 meters |
| Simulation Time | 900 seconds |
| Node movement model | Random Waypoint |
| Transmission range | 300m |
| Traffic type | Video Conferencing |
| Trajectory | Random |
| Speed | 75km/h |



Fig(3): GUI of Mininet-Wifi

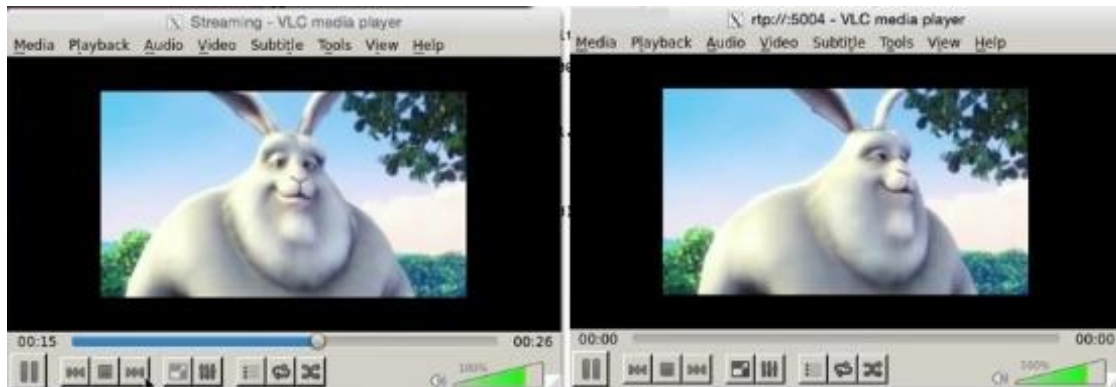


Fig(4): GUI of SUMO.

In this work, video streaming was implemented within a Vehicular Ad Hoc Network (VANET) environment to support communication between vehicles and, where applicable, between vehicles and roadside infrastructure. Video streaming involves the continuous transmission of visual data, either in real-time or non-real-time modes, using available wireless communication links. The main objective of this implementation is to provide useful visual information and enhance passenger experience while maintaining an acceptable level of service quality.

Due to the high mobility of vehicles and the constantly changing network topology, maintaining stable video transmission in VANETs presents several challenges. Frequent link disruptions and variations in network conditions may lead to packet loss and increased transmission delay. To address these issues, the implemented approach focuses on improving communication reliability and reducing delay, which contributes to better Quality of Service (QoS) for video streaming applications. The obtained results indicate that appropriate communication and resource management strategies can significantly enhance video streaming performance in vehicular network scenarios.

Figure (5) is included to visualize the interaction between vehicular nodes during video transmission and to demonstrate the effect of mobility and handoff on network performance.



Fig(5): Video Transmission

```
root@hus-VirtualBox: /home/hus/mininet-wifi/examples
openflow      Templates
Pictures      Videos
Public        wmediumd
ryu
root@hus-VirtualBox:/home/hus# cd mininet-wifi
root@hus-VirtualBox:/home/hus/mininet-wifi# cd examples
root@hus-VirtualBox:/home/hus/mininet-wifi/examples# python3 vanet-sumo.py
*** Creating nodes
*** Configuring Propagation Model
*** Configuring wifi nodes
*** Connecting to wmediumd server /var/run/wmediumd.sock
*** Starting network
Retrying in 1 seconds
*** Running CLI
*** Starting CLI:
mininet-wifi> car1 ping car2
PING 192.168.0.2 (192.168.0.2) 56(84) bytes of data.
64 bytes from 192.168.0.2: icmp_seq=1 ttl=64 time=15.4 ms
64 bytes from 192.168.0.2: icmp_seq=2 ttl=64 time=8.97 ms
64 bytes from 192.168.0.2: icmp_seq=3 ttl=64 time=5.21 ms
64 bytes from 192.168.0.2: icmp_seq=4 ttl=64 time=3.55 ms
64 bytes from 192.168.0.2: icmp_seq=5 ttl=64 time=4.62 ms
64 bytes from 192.168.0.2: icmp_seq=6 ttl=64 time=5.92 ms
```

Fig(6): ping between vehicles

4-Conclusion and Future Work

A number of simulations of real-time video streaming via automotive networks are described in this research. This Research examines how handoffs reduce overall quality. of a video streamed while crossing a road. The packet loss rate increases as video bitrate and vehicle speed do. Despite quick handoff methods that reduce handoffs Blackouts are utilized, although the deployment is limited by packet losses of on-demand video services in mobile networks. because of reason why video analysis can be useful in future studies employing dependable protocols for streaming to prevent

packet loss during the exchange of ideas. The investigation of video streaming across automotive networks will be expanded in future studies to include behavior analysis of the TCP transport protocol's various varieties. Other network mobility strategies to avoid blackouts of video streaming are also being researched in future plans. Instead of focusing on network layer mobility, this mobility proposal will focus on transport layer mobility. It will also include multi-path and multi-homing characteristics, optimize communication data rate during handoffs, and guard against network disconnections.

References

- [1] Paul, Bijan & Ibrahim, Md & Bikas, Md. Abu Naser. (2011). VANET routing protocols: Pros and cons. International Journal of Computer Applications. 20. 28-34. 10.5120/2413-3224.
- [2] Ericson, "Communication and Mobility by Cellular Advanced Radio", ComCar project, www.comcar.de, 2002.
- [3] Online, <http://www.ist-drive.org/index2.html>.
- [4] W. Franz, H. Hartenstein, and M. Mauve, Eds., Inter-Vehicle-Communications Based on Ad Hoc Networking Principles-The Fleet Net 5 Project. Karlshue, Germany: Universitatverlag Karlsruhe, November 2005.
- [5] A. Festag, et. al., "NoW-Network on Wheels: Project Objectives, Technology and Achievements", Proceedings of 6th International Workshop on Intelligent Transportations (WIT), Hamburg, Germany, March 2008.
- [6] Reichardt D., Miglietta M., Moretti L., Morsink P., and Schulz W., "CarTALK 2000 – safe and comfortable driving based upon inter-vehicle-communication," in Proc. IEEE IV'02.
- [7] Morris R., Jannotti J., Kaashoek F., Li J., Decouto D., "CarNet: A scalable ad hoc wireless network system," 9th ACM SIGOPS European Workshop, Kolding, Denmark, Sept. 2000.
- [8] C. Perkins, E. Belding-Royer and S. Das, "Ad hoc on-demand distance vector (AODV) routing", pp. 2070-1721, 2003.
- [9] Elias C. Eze, Si-Jing Zhang, En-Jie Liu and Joy C. Eze, "Advances in Vehicular Ad-hoc Networks (VANETs): Challenges and Road-map for Future Development", International Journal of Automation and Computing, vol. 13, no. 1, pp. 1-18, 2016.
- [10] M.J. Booyen, S. Zeadally and G.-J. Van Rooyen, "Performance comparison of media access control protocols for vehicular ad hoc networks", Networks IET, vol. 1, no. 1, pp. 10-19, 2012.

-
- [11] S. Xu, P. Guo, B. Xu and H. Zhou, "QoS evaluation of VANET routing protocols", Journal of Networks, vol. 8, pp. 132-139, 2013.
- [12] G. Karagiannis, O. Altintas, E. Ekici, G. Heijenk, B. Jarupan, K. Lin, et al., "2011 Vehicular networking: A Survey and tutorial on requirements architectures challenges standards and solutions", Communications Surveys & Tutorials. IEEE, vol. 13, no. 4, pp. 584-616, Fourth Quarter 2011.
- [13] S. Rene, C. Ganan, J. Caubet Fernández, J. J. Alins Delgado, J. Mata Diaz and J. L. Muñoz Tapia, "Analysis of video streaming performance in vehicular networks", 2011.
- [14] P. Hornman, "QoS support for traffic safety applications in VANET communication infrastructures", University of Twente Enschede the Netherlands, 2010.
- [15] S. Singh, P. Kumari and S. Agrawal, "Comparative Analysis of Various Routing Protocols in VANET", Advanced Computing & Communication Technologies (ACCT) 2015 Fifth International Conference on, pp. 315-319, 2015.
- [16] Phakathi, Thulani & Lugayizi, Francis & Isong, Bassey & Gasela, Naison. (2016). Quality of Service of Video Streaming in Vehicular Adhoc Networks: Performance Analysis. 886-891. 10.1109/CSCI.2016.0172.
- [17] G. Karagiannis et al., IEEE Communications Surveys & Tutorials, 2011.
- [18] E. C. Eze et al., IEEE Access, 2020.
- [19] S. Bhoi and P. M. Khilar, IEEE Communications Surveys & Tutorials, 2020.
- [20] Y. Sun et al., IEEE Transactions on Intelligent Transportation Systems, 2020.
- [21] Y. Zhang et al., IEEE Network, 2023.
- [22] T. Phakathi et al., IEEE CSCI, 2016.
- [23] P. Sharma et al., International Journal of Computer Applications, 2015.
- [24] A. Benmir, A. Sahraoui, and R. Bounab, "Comparative Evaluation of Swarm Intelligence Based Multipath Routing Protocols for Video Streaming in Vehicular Ad Hoc Networks," Algerian Journal of Signals and Systems, vol. 10, no. 3, pp. 91–97, Sep. 2025.
- [25] M. A. Labiod, M. Gharbi, F. X. Coudoux, P. Corlay, and N. Doghmane, "Enhanced Adaptive Cross Layer Scheme for Low Latency HEVC Streaming Over Vehicular Ad Hoc Networks (VANETs)," arXiv:2311.02664, Nov. 2023.
- [26] A. Benmir, A. Korichi, A. Bourouis, M. Alreshoodi, and L. Al Jobouri, "GeoQoE Vanet: QoE Aware Geographic Routing Protocol for Video Streaming Over Vehicular Ad Hoc Networks," *Computers*, vol. 9, no. 2, art. no. 45, 2020.
-

-
- [27] “Challenges and Opportunities for Multimedia Transmission in Vehicular Ad Hoc Networks: A Comprehensive Review,” *Electronics*, vol. 12, no. 20, 4310, 2023.
- [28] K. Z. Ghafoor, “Video Streaming Over Vehicular Ad Hoc Networks: A Comparative Study and Future Perspectives,” ARO The Scientific Journal of Koya University, 2025.
- [29] P. Sharma and A. Kaul, “Enhancing Quality of Service of Video Streaming Applications Over Vehicular Ad Hoc Networks,” *Journal of Computer Science*, vol. 21, no. 7, pp. 1565 1575, 2025.
- [30] “Survey on QoE/QoS Correlation Models for Video Streaming Over Vehicular Ad Hoc Networks,” Hrčak ID: 218274, 2019.
- [31] J. Rashid and A. Diyanat, “A Proposed QoE Prediction in Video Streaming Using ITU T Standards and Machine Learning Approaches,” *ISI Journal*, vol. 30, no. 06, 2025.
- [32] Hussein Ali Al-Gboursy and Sahar Abdulaziz Al-Talib 2020 IOP Conf. Ser.: Mater. Sci. Eng. 928 022055
- [33] Al-Gubouri, H. A. (2024). Performance Analysis of Software-Defined Networking in Band Controllers for Different Network Topologies. ADCAIJ: Advances in Distributed Computing and Artificial Intelligence Journal, 13(1), e31674. <https://doi.org/10.14201/adcaij.31674>