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Article

PERFORMANCE ANALYSIS OF WAVE PACKETS IN LOW DENSE VEHICULAR AD-HOC NETWORKS

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Abstract: Communication has reached new heights with the introduction of term wireless in its family. Wireless communication includes the voice, video and data transfer with the help of radio, infrared, satellite, microwave, Wi-Fi, mobile etc. Some of the popular wireless networks include Personal area network with enabled standards like Bluetooth, Local area network with for Electrical and Electronics Engineers (IEEE) 802.11, metropolitan area network with IEEE 802.15 and wide area network with cellular technologies. Many new approaches have been emerged in the networking field due to the up-gradation of technology with the rise in smart cellular based handheld devices. It is a revolutionary phase where people are relying on the technology via tabs, smart phones, laptops and other wireless devices. Among different available wireless technologies like Radio Frequency based, Infra Red (IR) based, Microwave etc. the ad-hoc routing is bringing the interest of researchers to reach new heights in people-centric and opportunistic based routing. The IEEE developed and governs many standards for communication. The wireless standard IEEE 802.11 contains miscellaneous standards for wireless local area network released for the unlicensed use for providing benefits to the society. Mobile Ad-hoc NETworks (MANETs) has been one of the major interested areas of research for people working in networking for a long time. But in the last few years, many researchers have been interested in working with vehicular communications, which is another type of ad-hoc network that can be practically experimented in real-time. Vehicular Ad-hoc NETwork (VANET) is another sort of MANET in which nodes are replaced by moving vehicles. VANET communication differs from MANET in many aspects as the there is no battery issue since the vehicles are acting nodes and can continuously provide power to the installed circuit boards. As vehicles will move with high speed so remain in the network for a very smaller time and follows a predefined path so their movement and location can be predicted. Researchers have many challenges in the implementation of VANET such as high node mobility and continuously changing topology, vehicles follow different routes making the operating environment very dynamic. Such challenges can be resolved by attaining a good Packet Delivery Ratio (PDR) and low delay rates. In this research work, we are analyzing the performance of designed VANET scenario on specified 40 vehicles for a 10 second simulated scenario. The performance metrics Basic Safety Messages (BSM) Packet Delivery Ratio (PDR), Average Goodput, MAC/PHY overhead, packet received, receive rate, and Wireless Access for Vehicular Environments (WAVE) packets are analyzed over four VANET routing protocols- Ad-hoc On Demand Vector (AODV), Destination Sequenced Distance Vector (DSDV), Dynamic Source Routing (DSR), and Optimized Link State Routing (OLSR) in a defined area. The motivation behind to do this research work is to analyze the performance of designed network scenario with lesser number of vehicles . The selection of the best routing protocol is the main motive of this study. The findings showed that DSR performed 29% better in average goodput than other routing protocols, OLSR is 55% better performer in MAC/PHY overhead, OLSR is 1.35% better in safety messages of

PDR. DSR is performed 2.2% better than in receive rate, and 2.27% in packets received. DSDV is the best performer with 12% ratio in Wave packets analysis followed by AODV with 11.8% and OLSR with 11.7%.
Keywords: VANET, Routing Protocols, Performance Metrics, Simluation, Quality of Service, Communication Models.

1. Introduction

Wireless communication has an important technique for communicating between two or more devices without any preinstalled communicating infrastructure known as ad-hoc based routing [1]. Ad-hoc based routing is further based on the single hop and multi-hop communication [2]. Single hop communication means only a single transfer of information between two distinct nodes in a network while multi-hop means the information is passed via many different nodes (this path is known as a hop) in order to successfully communicate with the destination node. The range of communication between two distinct nodes can be raised without using any additional set up in the architecture of the network. Multi-hop ad-hoc routing is used in most of the upcoming new networking approaches. People-centric means technology near about persons using smart handheld devices and opportunistic means involvement of multi-hop ad-hoc routing for designing a stable network. For that, a node seeks opportunities near to it for the successful transfer of information to a distinct node in the wireless network. In MANETs, all the nodes communicate with each other to share the information with them using the Internet and provide services like sharing of internet-based services[3]. MANET is not widely adopted by the industry and users for the following reasons[4]:

i. The lack of technological integration among network components.

ii. Because realistic physical implementation of MANET is not attainable, the inefficiency of performing practical tests causes researchers and users to lose interest in this topic.

However, the advantage of MANET is the advancement of sensor, mesh, opportunistic, and vehicular communications by utilizing several practical approaches [5] such as:

i. Experiments conducted on the basis of real-world scenarios.

ii. Relaxation in the network modeling technique.

iii. Conduct research on network design for specific applications.

MANETs offer a wide range of **applications** in several domains, which has piqued researchers' interest in working with automation-based military operations, sensor network-based activities, e-commerce, and personal area networks[6]. All sorts of wireless technology should be relevant to users, and appropriate research programmes should be done on a regular basis in order to fulfill the desired requirements of the users with the execution of application designed. MANET appears to be losing research interest, and applications are not finding market relevance, however standardization is an issue that can be remedied in the near future. Wireless sensor networks (WSN) are gaining popularity and user attention for a variety of applications in ambient intelligence, monitoring, and controlling. Many opportunities exist for researchers to work on WSN to improve mobility and performance, particularly on underwater and acoustic sensor networks[7]. Another intriguing field that is gaining popularity among both users and researchers is vehicular communication, also known as VANETs [8], which has the potential to improve road safety by reducing accidents or car crashes, improving traffic efficiency by reducing traffic jams, and sharing entertainment features such as music, images, games, and so on while travelling.

Many research areas are still open and require contributions from researchers to improve service quality, routing protocol functionality, and VANET standardization. VANET communication varies from MANET communication in several ways, including the absence of a battery issue because the cars serve as nodes and can continually power the installed circuit boards. Because cars travel at fast speeds, they stay in the network for a very short period of time and follow a predefined course, allowing their movement and location to be predicted. The Relationship between MANET, VANET, and FANET (Flying Ad-hoc Network) is presented in **Figure 1**[9].

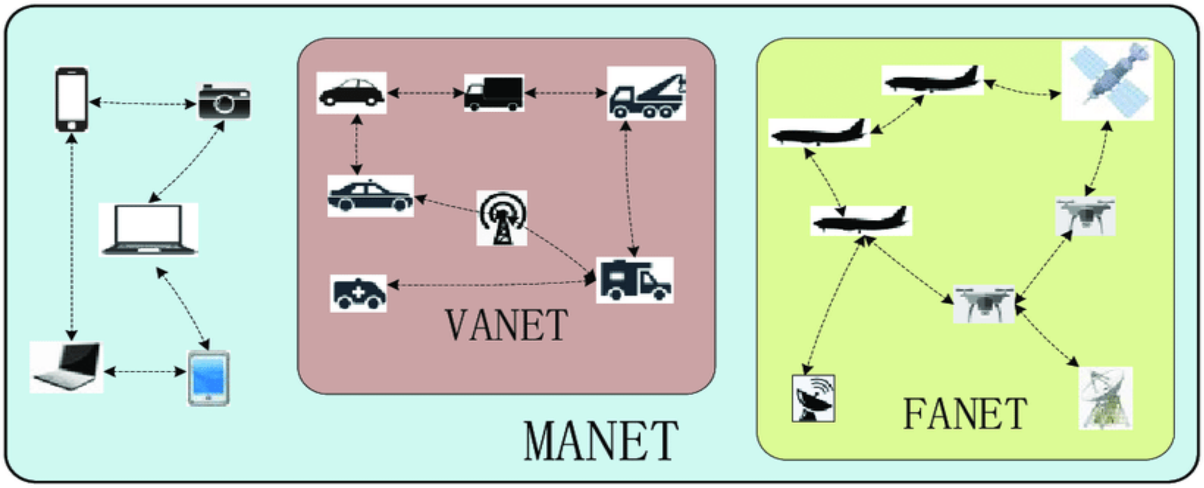

Figure 1: MANET, VANET, and FANET Relationship

A parametric/factors based comparison/relationship between MANET, VANET, and FANET ia tabulated in **table 1.**

Table 1: A Relationship between MANET, VANET, and FANET

Feature/Parameter	MANET (Mobile Ad Hoc Network)	VANET (Vehicular Ad Hoc Network)	FANET (Flying Ad Hoc Network)
Network Type	Self-configuring wireless mobile network	Specialized form of MANET for vehicles	Specialized form of MANET for UAVs/drones
Node Type	Mobile devices, laptops, smartphones	Vehicles, roadside units (RSUs)	Unmanned Aerial Vehicles (UAVs), drones
Node Type	Mobile devices, laptops, smartphones	Vehicles, roadside units (RSUs)	Unmanned Aerial Vehicles (UAVs), drones
Mobility Pattern	Random mobility	Road/path constrained mobility	3D aerial mobility
Speed of Nodes	Low to moderate	High	Very high
Topology Change	Moderate	Rapid	Extremely rapid
Communication Environment	Terrestrial	Urban/highway environments	Air-to-air and air-to-ground
Coverage Area	Small to medium	Medium to large	Large and dynamic
Network Architecture	Infrastructure-less	Infrastructure-less with RSUs support	Infrastructure-less
Routing Complexity	Moderate	High	Very high
Delay Sensitivity	Moderate	High	Very high

Energy Constraint	Battery dependent	Less constrained due to vehicle power	Highly constrained
Position Awareness	Optional	Essential (GPS-based)	Essential (GPS and altitude-based)
Main Objective	General mobile communication	Intelligent transportation and road safety	Aerial surveillance and remote sensing
Typical Applications	Military, disaster recovery, conferences	Traffic management, collision warning, infotainment	Surveillance, rescue missions, border monitoring
Communication Standard	IEEE 802.11	IEEE 802.11p / DSRC / WAVE	IEEE 802.11, LTE, 5G
Mobility Dimension	2D	2D	3D
Scalability	Moderate	High	Moderate to high
Security Challenges	Node authentication, routing attacks	Privacy, safety-critical attacks	UAV hijacking, aerial interference
Relationship	Base network architecture	Derived from MANET	Derived from MANET

Researchers face numerous obstacles when implementing VANET, including high node mobility and constantly changing topology; vehicles take varied routes, making the operational environment more dynamic. Such difficulties can be overcome by achieving a high PDR and low delay rates. As the number of vehicles on the road grows by the day, various challenges arise, and a prompt solution is required to save the lives and money of ordinary people[10]. Such **issues** include an increase in the frequency of accidents resulting in fatalities and serious injuries, economic losses owing to hourly traffic congestion, and environmental damage caused by emissions [11]. Vehicle manufacturers such as General Motors, Toyota, BMW, Honda, Audi, Volvo, and many more are commendable for their participation in the deployment of VANETs, which results in cars with the ability to generate and spread messages. Such communication can take place directly between two vehicles in one hop communication or via another vehicle and other pre-installed infrastructure on the road in multi-hop communication. Because of its vast range of uses, vehicular communication is gaining popularity around the world, and it will improve the travelling experience and road safety. Many **study fields** are open in VANETs [12], including routing protocols, security feature implementation, various application design, hardware design for On Board Unit (OBU) and Road Side Units (RSUs), various types of sensors involved, and so on. Some of the main properties of VANET are dynamic topology, frequently disconnected networks, abundant energy sources, mobility modeling, varying communication environments, robustness, on-board sensors, no network borders, and time bound.

VANETs are categorized into three groups based on communication, as indicated in **Figure 2** [13]:

1. Vehicle-to-Vehicle (V2V) Communication
2. Vehicle-to-Infrastructure (V2I) Communication
3. a hybrid

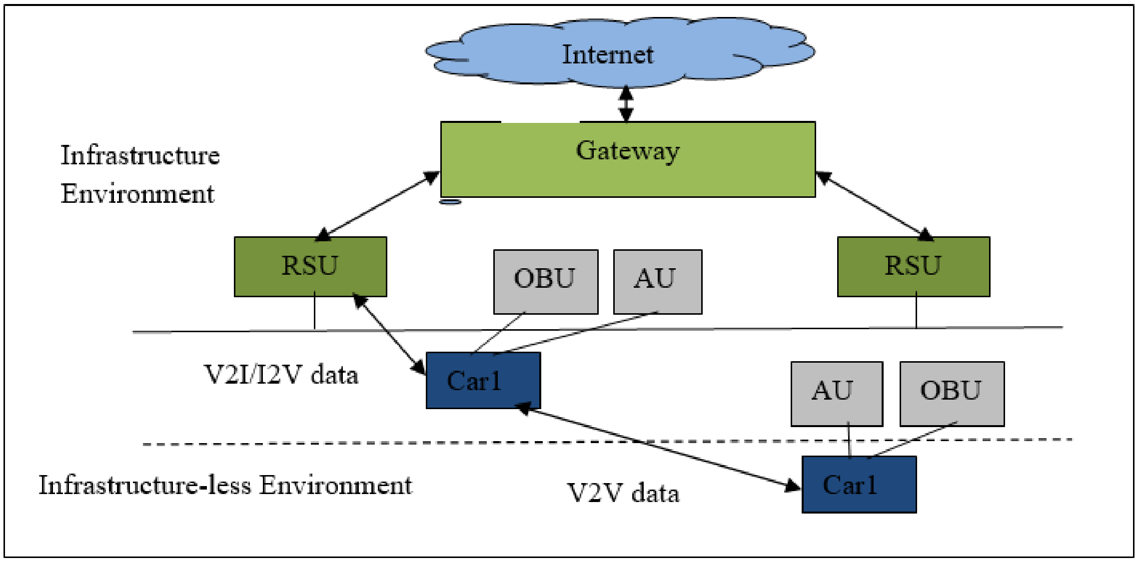

Figure 2: VANET Architecture

Dedicated Short-Range Communication (DSRC) allows each vehicle to communicate with other vehicles using short radio waves [14]. DSRC operates at a frequency of 5.9 GHz and has a range of up to one kilometer. This is an ad-hoc communication, which means that each connected node can move freely without the use of cables. RSUs are the routers that are used, and the RSU is the router that each linked node utilizes. The Vehicular Networks System is made up of a vast number of nodes; with an estimated number of each car has an On Board Unit (OBU), which connects to the RSU via DSRC radios, and a Tamper Proof Device (TPD), which protects the secrets of automobiles. **Figure 2** depicts all of the car's details, including the keys, driver identity, trip specifications, speed, route, and so on.

IEEE 802.11p is built on Wireless Access for Vehicular Environments (WAVE) and other IEEE 1609 versions [15]. WAVE is a modified version of the original DSRC that has fewer network overheads and is in charge of communication between vehicles and RSUs or between vehicles. From an implementation standpoint, it is critical to understand that WAVE operates at both the PHY and MAC layers, hence its implementation on both tiers must be considered. These architectures are known as the WAVE-PHY and WAVE-MAC protocols. WAVE-PHY is made up of numerous communication channels that operate in the wireless spectrum frequency range of 5.850 GHz to 5.925 GHz. WAVE-PHY transceivers use Orthogonal Frequency Division Multiplexing (OFDM) modulation, with a band of 10 MHz allotted to each channel. The Physical Medium Dependent (PMD) sub-layer is in charge of communication with transceivers in WAVE-PHY, while the Physical Layer Convergence Procedure (PLCP) sub-layer is in charge of interaction between the PHY and MAC layers. WAVE-MAC, on the other hand, is primarily in charge of the MAC layer activities that specify resource allocation policies among competing nodes for the wireless medium. Nodes use the IEEE 802.11 standard for collision avoidance, Carrier Sense Multiple access/collision avoidance (CSMA/CA), to avoid congestion. In general, the WAVE-MAC architecture exchanges data using multi-channel operations as defined in IEEE 1609.4. **Figure 3** depicts the WAVE protocol stack.

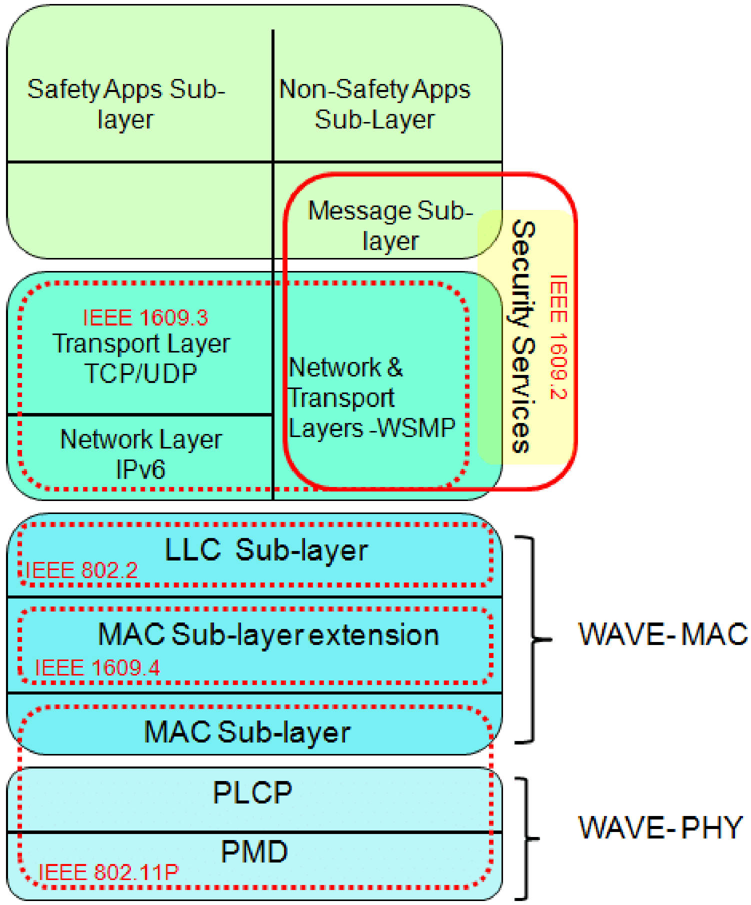

Figure 3: WAVE Protocol Stack for VANET

The organization of the paper is as follows- related work on VANET and its routing protocols are presented in section 2, Evaluated Model and Flow Process is presented in section 3, Performance Evaluation Parameters are discussed in section 4, Performance Analysis of Routing Protocols is presented in section 5 followed by conclusions and future scope in section 6.

2. Literature Review and Objectives

2.1 Literature Review

One of the important difficulties in the design of a vehicular ad-hoc network is the development of a dynamic routing protocol that may help disseminate information from one node (car) to another. Because VANET topologies are more dynamic and constantly evolving than traditional MANET topologies, VANET routing differs from MANET routing [6]. In a VANET setting, only a few older MANET-designed protocols have been tested. **Figure 4** [16] depicts a list of the routing protocols utilized in VANET.

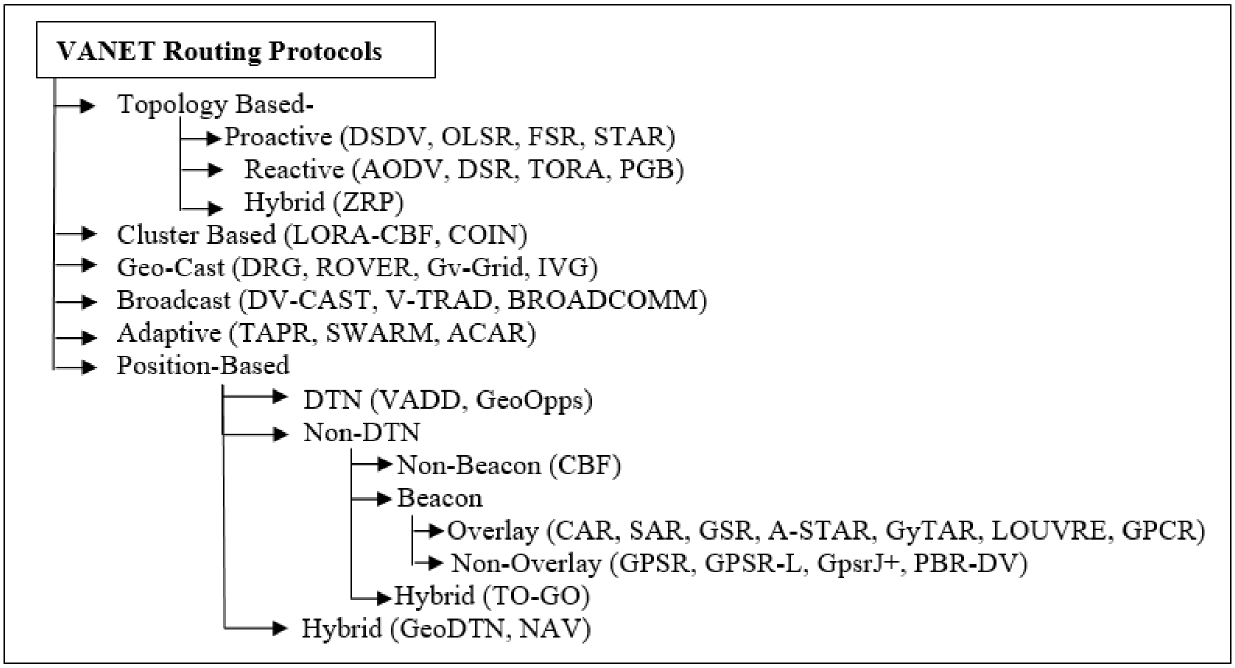

Figure 4: Routing Protocols in VANET

The topology-based protocols operate on the basis of the network's topology. Some of the older existing protocols typically used for MANETs have been updated to make them acceptable and efficient for VANETs in this type of protocol. Topology-based routing systems are further categorized into three types: proactive, reactive, and hybrid [17]. **Position-based routing** differs from topology-based routing in that it has solved some of the restrictions of the former. The sender node uses geographical parameters such as the node location along with the information packet in this kind. Such information can be collected by utilizing a Global Positioning System (GPS) device, which uses satellites to update the node's location on a regular basis. As the node movement is covered, this information about the node's location is very beneficial for constructing a stronger network in terms of packet delivery, throughput, and very little node-to-node delay [18]. **Broadcasting protocols** are involved in the broadcasting of information signals from time to time, such as the node position, speed of the node, traffic conditions, weather conditions, warning signals, and so on. These signals are broadcasted repeatedly to ease the routing mechanism, and the neighbor list is also updated with each broadcast message to reduce overheads in discovering neighbours [19]. **Cluster routing** is utilized when several nodes are moving or joined together to form a cluster. The networking of such a set of nodes is regulated by a cluster head, which is in charge of delivering packets to all nodes in the cluster. It is particularly well suited to automotive networks with a large number of vehicles travelling in a vehicular environment such as a highway, landscape, or city [20]. **Geocast routing** techniques operate on the premise of routing data packets from a single source vehicle to all vehicles in the zone of relevance (ZOR) at the destination. To prevent the geocast message from just flooding from the source to the ZOR, a forwarding area known as the Zone Of Forwarding (ZOF) is utilised to constrain the message sending until it reaches the ZOR [21]. **Adaptive routing protocols,** also known as dynamic routing algorithms, make routing decisions on the fly as data packets are sent from source to destination. These algorithms build routing tables based on network conditions such as network traffic and topology [22].

The research methodology followed to do this research work is as follows:

- Study the research papers relevant to the performance of VANET routing protocols.
- Select some research papers to find out the research gaps and objectives.
- Study the relevant network simulator and mobility generator tool.
- Fulfill the proposed objectives over network simulation tool using experiments.

For the experiment work, we have selected four topology based routing protocols- AODV, DSDV, DSR, and OLSR. Some of the important research paper related to VANET, its applications, issues, challenges, advantages, disadvantages, its routing protocols are covered in literature review as presented in **table 2**. The existing research work did not explore the impact of node density over performance metrics, so this research work is done.

Table 2: Literature Review of VANET

Author's Name	**Technologies / Parameters/ Routing Protocols**	**Objective**	**Research Gap**
M. J. N. Mahi et al. [23] 2022	Big data, fog computing, SDN (Software Defined Networking), and SIoT (Social Internet of Things)	A high-level description of a comprehensive VANET update solution designed to solve future problem management concerns using a variety of acceptable scientific subjects, indications, and combinations.	No experimental work is considered while writing a review.
Nitika Phull et al. [24] 2022	Cluster reformation in game theory approach	Increase the average cluster member life length, the average number of reaffiliation times, throughput, and packet loss rate.	Very much specific to game theory-based energy-efficient clustering approach.
Muhammad Rizwan Ghori et al. [25] 2018	Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication	Study research works related to the applications, protocols and security	There isn't much work done in terms of confidentiality and availability.
Asim Rasheed et al. [26] 2017	Communications, Air-interface, and Long and Medium range (CALM), Car-2-Car Communication Consortium (C2C-CC), WAVE (Wireless Access in Vehicular Environment, Association of Radio Industries and Businesses (ARIB)	A study of existing issues and potential uses for VANETs, including medium access control techniques, routing approaches, hardware and spectrum issues, and security and privacy concerns.	In the VANET environment, there is a lack of in-depth performance evaluation of various systems as well as varied and comprehensive real-life scenarios.
Sahabdeen Aysha Asra [27] 2022	Security issues in VANET	VANET security flaws are investigated. In addition, the study discusses layer-specific attack classification in the VANETS protocol stack.	The study's weaknesses were the quantity of the dataset and the lack of quality characteristics.
Siquan Hu et al. [28] 2017	AODV, DSR, OLSR and AODVUU	AODVUU is chosen and changed for multi-path AODVUU in order to reduce packet loss and routing overhead.	Expanding the network scale and testing on real traffic is missing.
Sumit Pande et al. [29] 2021	AODV, NS-2, SUMO	Examine the presence of the AODV routing protocol and investigate characteristics such as end-to-end delay, throughput, packet delivery ratio (PDR), packet loss ratio, and so on.	Improvement of security, mobility, and reliability is missing.
Santosh Kumar et al. [36] 2020	AODV, SUMO, MOVE, NS2.35	The effective implementation of the AODV has studied and analyzed with various QoS	The performance of AODV has been analyzed for three dissimilar numbers of nodes i.e. 12, 15 and 18

		parameters against different network density.	nodes respectively which is quite low in number.

2.2 VOSviewer Analysis of VANET

For visualizing the bibliometric analysis of VANET, VOSviewer bibliometric analysis tool has been used. On renowned database repository, “Web of Science”, a search term named as “Vehicular Ad-hoc Networks” has been searched. Respectively, 5956 documents has been extracted which includes review article (181), early access articles (30), open access (2212), and enriched cited references (1521). The selected years are from 2001 to 2025. The co-occurrence relation in all the keywords has shown in **figure 5**.

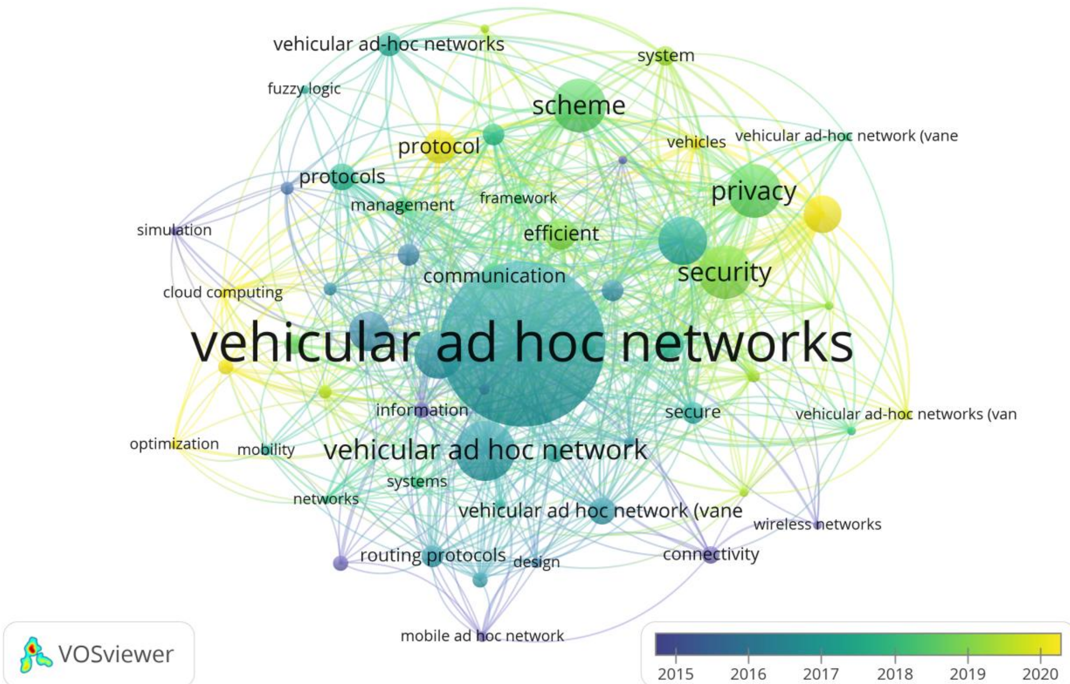

Figure 5: Co-occurrence relation of Keywords on VOSviewer

2.3 Objectives

As per the literature review of VANET and its routing protocols, the following objectives are identified for this research-

- Study the concepts of VANET and its routing protocols.
- Design an evaluated VANET model.
- Simulate the evaluated VANET model over Network Simulator (NS3.27) on platform Ubuntu 20.
- Analyze the performance of evaluated VANET model over four routing protocols.

3. VANET Evaluated Model and Flow Process

The proposed evaluated VANET model is represented in **Figure 6**. For executing the simulation experiment we have taken vanet-routing-compare.cc file as an input. The selected wireless routing protocol is IEEE 802.11p. The input file is executed for four times by selecting different routing protocols. The complete flow procedure of this experiment is represented in **Figure 7**. Once the .cc file is written up, it is imported onto the NS3.27 simulator [30]. The .cc file is executed by using the following command-

```
home~/ns-allinone-3.27/ns-3.27 $./waf - -run scratch/vanet-routing-compare
```

The above-said command is used for default selected protocol. By default, it is executed for OLSR. For selecting another protocol, the command will be changed as

```
home~/ns-allinone-3.27/ns-3.27 $./waf - -run "scratch/vanet-routing-compare –protocol=2"
```

The parameter –protocol is set to value 2 for AODV, 3 for DSDV, and 4 for DSR. Once the file has run successfully, the results have been shown on NETANIM tool. Further, .csv and .tr files have been created.

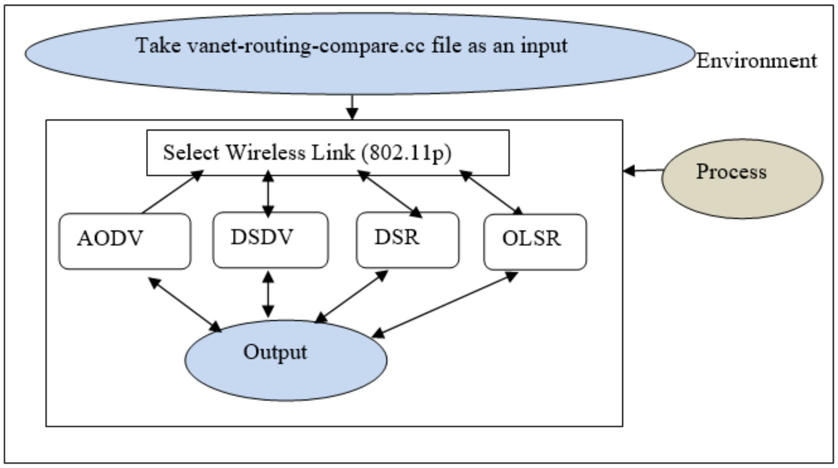

Figure 6- VANET Evaluated Model

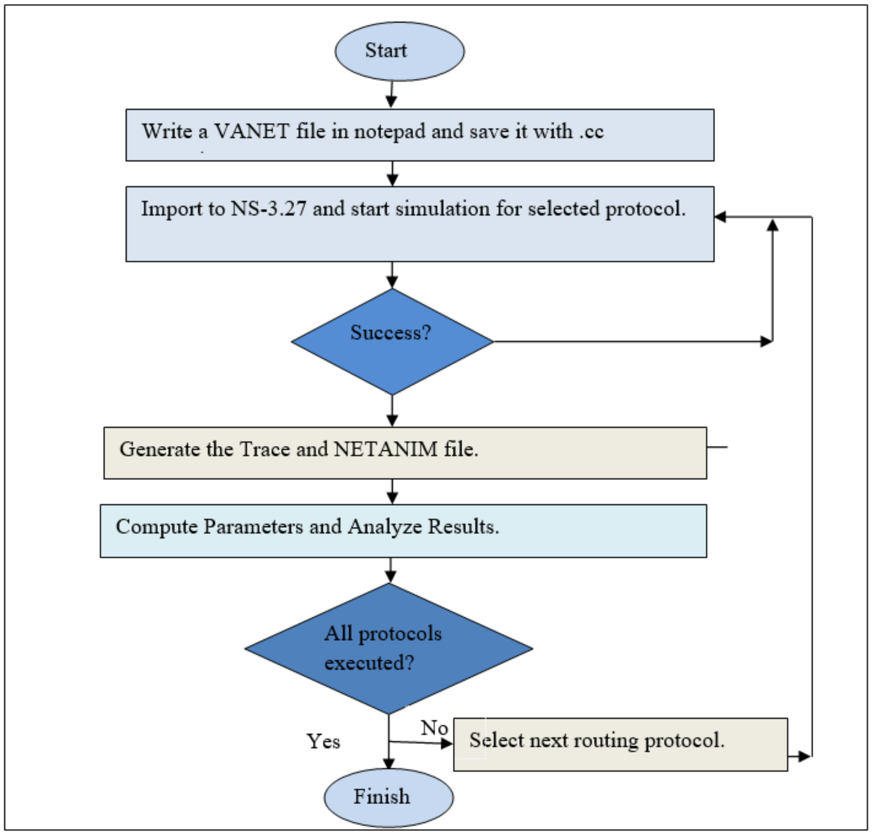

Figure 7: Flow Process of executing VANET routing protocols

3.1 Performance Evaluation Parameters

The literature work put emphasis on various parameters on which the network performance is evaluated. In this research work, the following parameters are considered for evaluation of performance of the routing protocols in the designed VANET scenario [31].

a) Average Goodput: Goodput is used as an assessment parameter over throughput in VANETs since it only evaluates valuable information. It is determined as the ratio of relevant information file size to transfer time. It is referred to as application layer throughput. The rate of data transmission can be measured in bits per second (bps), kilobytes per second (kbps), or megabytes per second (Mbps).

b) MAC/PHY overhead: We employed basic safety messages (BSM) that are broadcasted every second in this work. BSM is a tool for distributing useful information in vehicular ad hoc networks. Routing protocols generate routing packets in order to communicate information about route updates in the network. These packets do not carry any application layer information. Both types of packets (routing and application) share network bandwidth. As a result, routing packets are known as network overheads, and they should be minimized for better routing protocol performance [32]. It is calculated using the equation 1 as:

$$MAC/PHY\ layer\ overhead = (total\ physical\ bytes - total\ application\ bytes)/(total\ physical\ bytes) \quad \ldots (1)$$

c) Basic Safety Message Packet Delivery Ratio (BSM PDR): In this work, each node broadcasts 10 BSMs every second. The overall packet delivery ratio for each BSM is computed for the entire simulation time. It has been discovered that a high PDR promotes more stable network connectivity. It is calculated using the equation 2 as:

$$BSM\ PDR = (Received\ BSM\ Packets)/(Transmitted\ BSM\ Packets) \ \ldots (2)$$

d) Transmitted Packets: The number of packets transmitted from all source vehicles in the simulation time is termed as transmitted packets [33]. These packets are important as many other parameters like lost packets, dropped packet, packet delivery ratio, packet loss ratio etc. are determined from the transmitted packets.

e) Lost Packets: The numbers of transmitted packets that are not delivered to any destination vehicle nor dropped by any vehicles are considered as loss packets in the network. These packets may rise due to some particular malicious vehicle keeps the received packets with it and forwards further in the network. It is an important parameter to study the effect of attack with the loss packets.

f) Drop Packets: The number of packets dropped by any participating vehicle intentionally or due to network failure is considered as drop packets. It also depends on the routing protocol performance how better it routes the packets to the destination so that the number of drop packets remains very less [34].

g) Packet Delivery Ratio: This ratio calculates the number the successfully delivered packets by the destination transmitted from the source [35].

h) Packet Loss Ratio: This ratio is calculated from the loss packets before delivered to the destination vehicle and very helpful in deciding network performance.

i) Speed of Vehicles: With what speed the vehicles will move in the designed scenario is an important aspect for consideration in VANETs during simulations. In VANETs the speed of the vehicles will decide for how long duration these vehicles will remain in communication range. It also depends on the vehicle density which is explained below.

j) Vehicle Density: This is number of vehicles that are taken for consideration in the scenario of VANETs. It is an important parameter on which the performance of the network depends. If number of vehicles is less, then the communication between vehicles will be difficult. In this situation, we need delay tolerant networks that keep the data with them until next communicating vehicle does not arrive. If number of vehicles are high then the congestion in the network increases and we need to increase the transmission power. The selected routing protocol also performs as per the density of the vehicles. It should be considered as a variation parameter for the VANETs simulations.

k) Simulation Time: After designing the VANETs scenario, the simulation time for the scenario is important. If we consider the simulation time to be low in a denser network, then many vehicles would not be able to participate fully in the network thus resulting in an increase in packet loss. It should be also considered as a variation parameter for the VANETs simulations.

l) Packet Received

The total no of received packets by a node is considered as packet received rate. In MANETs, packet receive is the process of successfully delivering packets from the sender to the intended destination. This process includes receiving the packet from the sender, routing the packet through intermediate nodes, and finally delivering the packet to the intended destination. Packet receive in MANETs is important for data communication between mobile nodes, as it ensures that data packets are reliably delivered without any loss. Packet receive in MANETs is a complex process because the topology of MANETs is highly dynamic, and the nodes are mobile. To ensure successful packet receive, the different nodes in the network must cooperate to route the data packets. Furthermore, due to the potential for congestion, the nodes must also be able to identify and avoid packet-dropping nodes. It is calculated by using equation 3 as:

$$\textit{Packet Received} = \textit{Packet Sent} - \textit{Number of Packet Drops} \quad \ldots (3)$$

m) Received Rate

A node's received rate is the number of packets it receives per unit of time. The received rate in a MANET is the total rate of the packets that a node receives from its neighbors, often expressed in bits per second (bps). It can be determined by measuring the amount of data successfully received within a defined period. In a MANET, the received rate is mainly affected by the number of neighbors, the topology of the network and the mobility characteristics of the nodes. The received rate can also be impacted by the quality of wireless signal, the interference caused by multiple networks, and the data transmission rate of other nodes in the network. It is calculated by using equation 4 as:

Received Rate = (Total No. of bits received in measured time period) / (Total No. of bits transmit in measured time period) × 100 … (4)

3.3 Results and Discussions

From the literature review and study of various protocols, AODV, OLSR, DSR, and DSDV have been selected for analyzing their routing performance in a designed VANET scenario. The routing performance of routing protocols has been evaluated on the basis of Average Goodput, MAC/PHY layer overheads, packet received, receive rate, and Basic safety Message Packet delivery Ratio (BSM PDR). For analyzing the performance of the selected routing protocols in VANET, a highway scenario of dimensions 300m × 1500m is designed. The simulations have been performed with consideration of variation in number of vehicles along with the variation in speed of vehicles. The other related detail of scenario is in **Table 3**.

Table 3: Simulation Environment Setup

Parameter	**Specifications**
Platform	Ubuntu20 LTS
Simulation Tool	Network Simulator-3.27
IEEE Scenario	VANET(802.11p)
Mobility Model	Random Way Point
No. of Vehicles	40
Speed of Vehicles	20 m/sec.
Traffic Type	TCP
Path loss Model	Two ray ground
MAC Layer	IEEE 802.11p
Routing Protocols	AODV, OLSR, DSDV, DSR
Transmission Max. Delay (ms)	10
Simulation Area(in meter)	1500×300

Transmission Power (dBm)	20
Channel	Wireless Channel
Simulation Time	10 seconds

The simulations were performed utilizing the routing protocols AODV, OLSR, DSDV, and DSR to determine the average Goodput, packet delivery ratio for basic safety messages (BSM PDR), and MAC/PHY overheads at a constant vehicle speed of 20 m/s. As shown in **Figure 8** the DSR shows highest Goodput of 16.69 kbps followed by DSDV having value of 13.9264 kbps. AODV performs an average with value of 12.39 kbps and OLSR having worst performance with value 5.68 kbps. In the overall comparison of average goodput, DSR performed 29% better than other routing protocols.

The performance of calculating MAC/PHY layer overhead using the same scenario is almost identical to that of Goodput analysis. OLSR routing has the lowest MAC/PHY overheads of any of the four routing protocols, with an overhead value of 0.27. DSR routing provides the maximum MAC/PHY overheads with the highest value 10999. AODV acts as an average performer with overhead value of 0.49. In the overall comparison of MAC/PHY overhead, OLSR performed 55% better than other routing protocols. The MAC/PHY Overhead Analysis at every simulation second is represented in **Figure 9**.

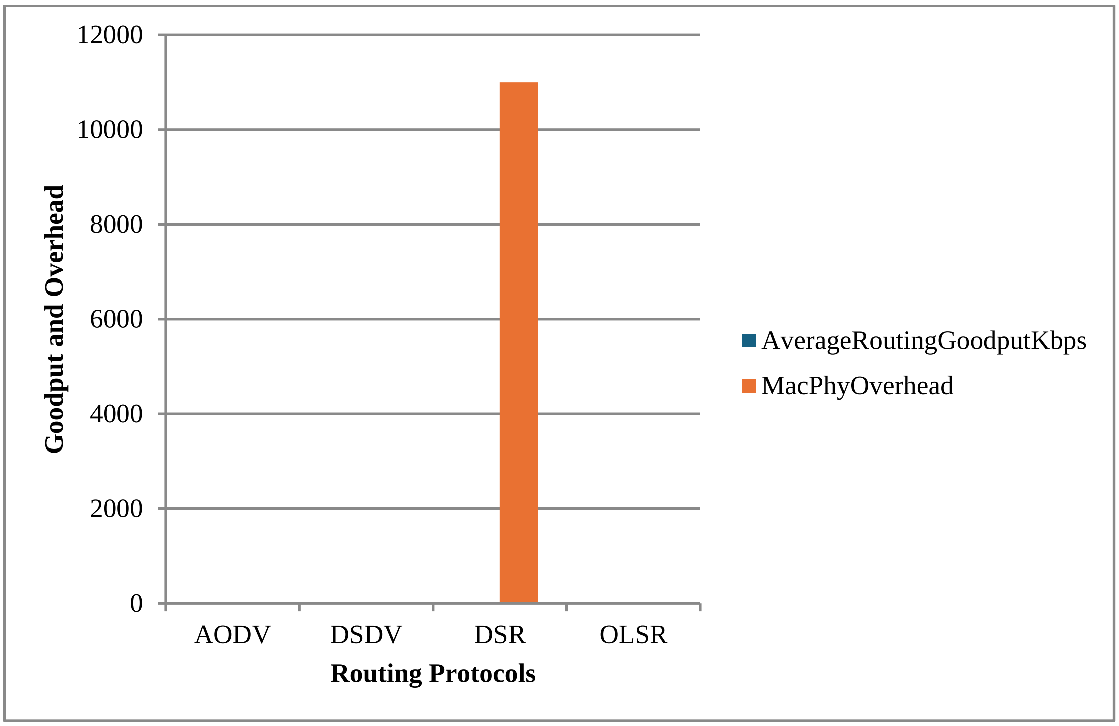

Figure 8: Average Routing Goodput and MAC/PHY Overhead

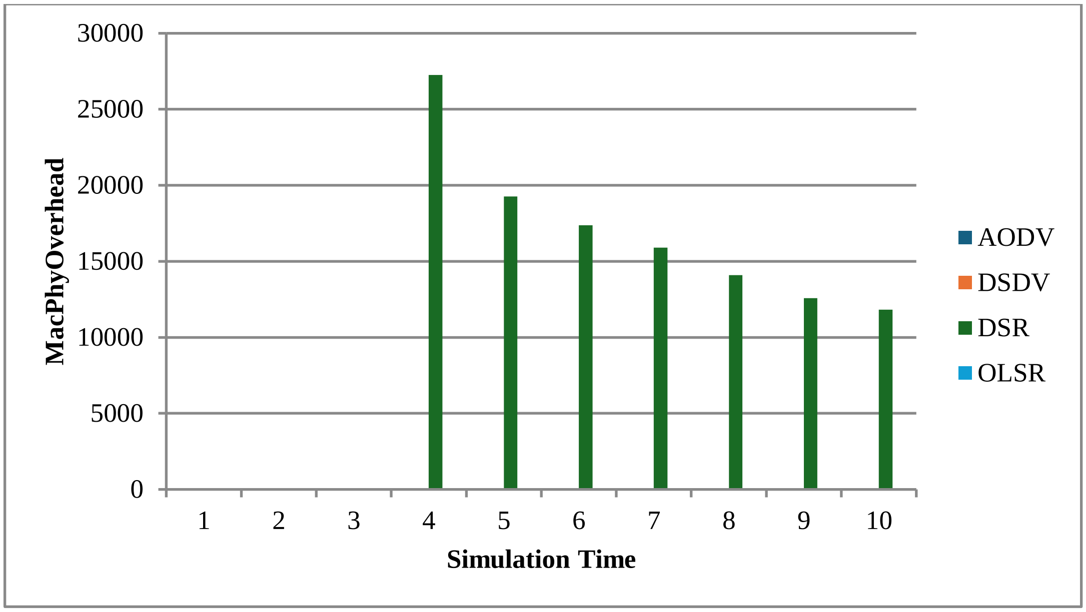

Figure 9: MAC/PHY Overhead Analysis at every simulation second

The BSM PDR is determined for all routing protocols and is illustrated graphically in **Figure 10**. The results demonstrate that for the three routing methods utilised, the PDR for all ten basic safety messages is quite near. The OLSR achieves the highest PDR for all ten messages, whereas the DSR has the lowest PDR. While the performance of DSDV lies between OLSR and AODV. OLSR is 1.35% better than AODV, and 1.31% better than DSDV in safety messages of PDR.

Figure 10: Basic Safety Messages Packet Delivery Ratio Analysis

The receive rate in a VANET refers to the rate at which the nodes in the network receive packets from each other. In the DSR, the received rate is high for 0 to 9 seconds of simulation time. But it is 0 for initial 2 seconds. The received rate value at 5th second is higher most of DSR than the other routing protocols. The received rate is growing when the simulation time is increased from 0 to 1 second. After DSR the AODV is the second highest received rate protocol for 9th second. After AODV, DSDV is the third highest received rate protocol for its 5th second. The received rate value for OLSR is low for each category of simulation time. It is fluctuating for rest of the categories. In the overall comparison, DSR is 1.17% better than AODV, 1.1% than DSDV, and 2.2% than OLSR. The performance metric received rate is represented in **Figure 11**.

The metric packet received, is a control packet sent from one node to another in order to temporarily suspend or pause communication between them. The packet typically consists of a header containing a few bytes of data and is used to inform the other node that it can no longer send data. As the results are shown, In the DSR, the packets received is high for 0 to 9 seconds of simulation time. But it is 0 for initial 2 seconds. The packet received is higher most with DSR protocol when the simulation time is 5th second. The protocol DSDV is performing on second position and giving results in increasing manner from 2nd second onwards. The packet received is higher most with DSDV protocol on the 3rd second of simulation time. After DSR and DSDV, the AODV is the third highest packet received routing protocol. The packet received is higher most with AODV protocol on the 9th second of simulation time. The OLSR is consistently playing low in all categories of simulation seconds. In the overall comparison, DSR is 1.2% better than AODV, 1.13% than DSDV, and 2.27% than OLSR. The performance metric Packet Received is represented in **Figure 11**.

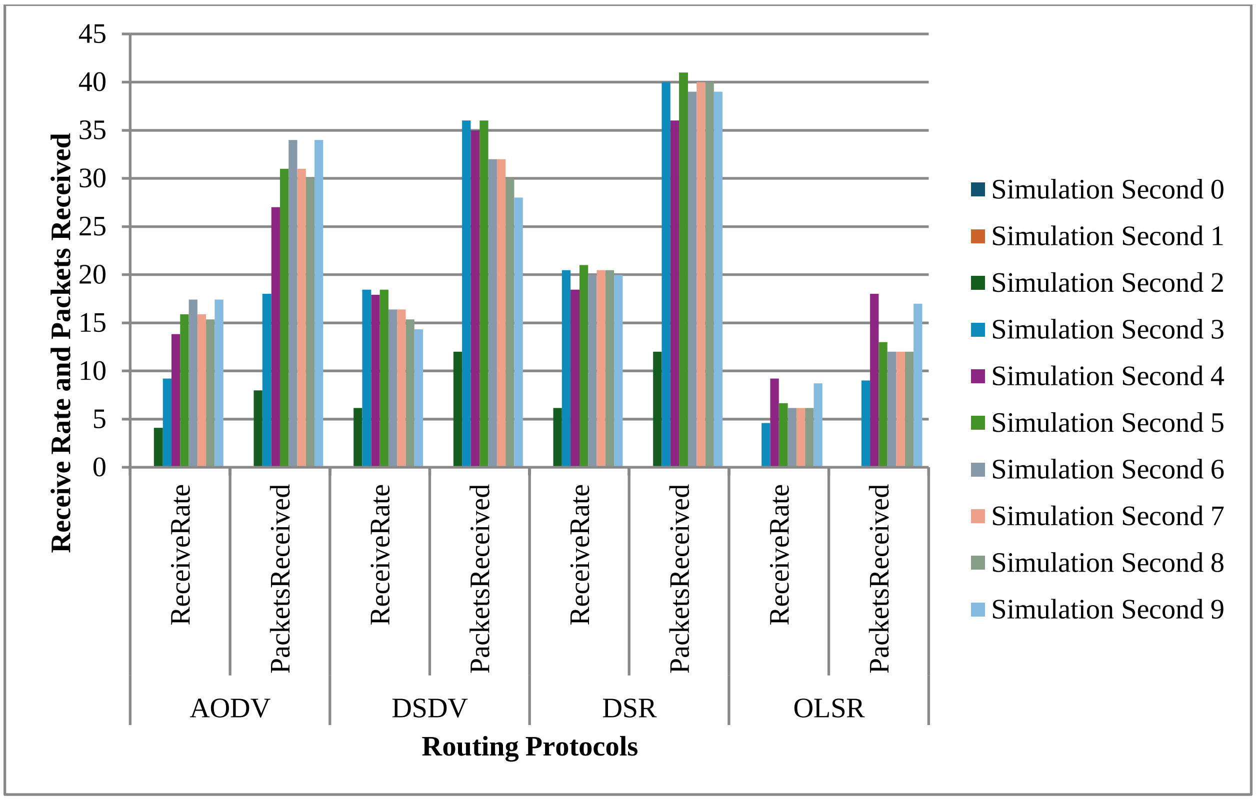

Figure 11: Receive Rate and Packets Received Analysis

The WAVE packet analysis of designed VANET scenario is depicted in **Figure 12**. It covers the analysis of WavePktsSent, WavePtksReceived, WavePktsPpr, ExpectedWavePktsReceived, ExpectedWavePktsInCoverageReceived. The numerical analysis of routing protocols is covered in table 5. The represented analysis is on the basis of simulation time. For initial 0 and 1 second of simulation, all the entries are marked to 0. The sent wave packets from 2nd to 9th second of simulation time is 400 by all routing protocols. The maximum received wave packets for AODV is 4757, for DSDV it is 4805, for DSR it is 0, and for OLSR it is 4721. The maximum ratio of received packets over sent packets is 11.8 for AODV, 12.01 for DSDV, 0 for DSR, and 11.8 for OLSR. The maximum expected received packet value is 358 for all routing protocols. The maximum expected wave packets in coverage area are 323 for AODV, 319 for DSDV, 0 for DSR, and 343 for OLSR. DSDV is the best performer with 12% ratio in Wave packets analysis followed by AODV with 11.8% and OLSR with 11.7%.

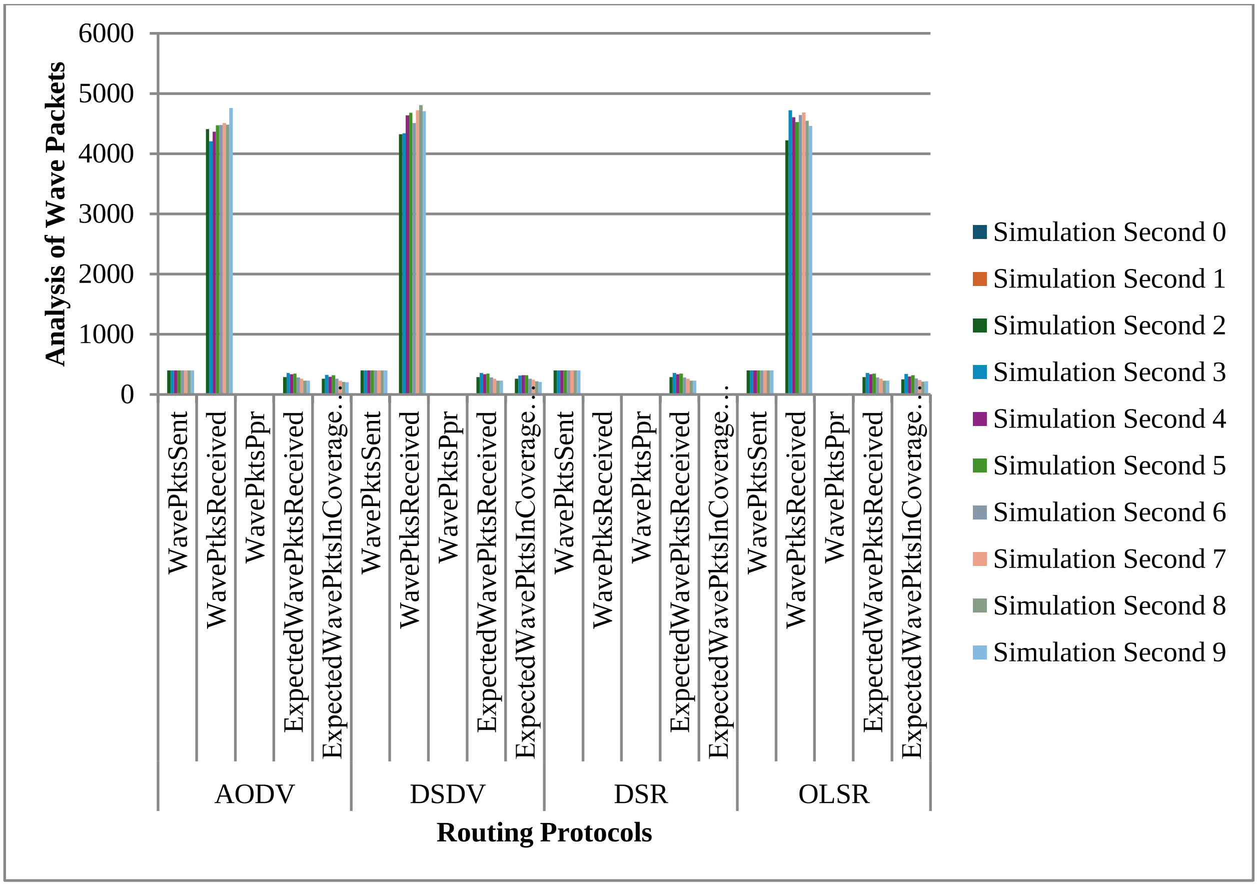

Figure 12: Analysis of Wave Packets

A comparative analysis of all performance metrics on the basis of results is tabulated in **Table 4**. From the table 4, it is clearly indicated that DSR and OLSR is the best performing routing protocols in the designed scenario.

Table 4: Comparative Analysis of VANET Routing Protocols

Performance Metric	Desired Trend	AODV	DSDV	DSR	OLSR	Best Performing Protocol
Average Goodput	↑ Higher is Better	↑ Medium	↑ Good	↑↑ Highest	↓ Lowest	DSR
MAC/PHY Overhead	↓ Lower is Better	↓ Medium	↓ Medium	↑ Highest	↓↓ Lowest	OLSR
BSM Packet Delivery Ratio (PDR)	↑ Higher is Better	↑ Good	↑ Good	↓ Lowest	↑↑ Highest	OLSR
Receive Rate	↑ Higher is Better	↑ Medium	↑ Good	↑↑ Highest	↓ Lowest	DSR
Packets Received	↑ Higher is Better	↑ Medium	↑ Good	↑↑ Highest	↓ Lowest	DSR
Wave Packet Performance	↑ Higher is Better	↑ Good	↑↑ Highest	↓ Lowest	↑ Good	DSDV

Routing Stability	↑ Higher is Better	↑ Medium	↑ Good	↑ Good	↑↑ Highest	OLSR
Dynamic Topology Handling	↑ Higher is Better	↑ Good	↓ Medium	↑↑ Best	↑ Good	DSR
Scalability in Dense Network	↑ Higher is Better	↑ Medium	↑ Good	↑ Good	↑↑ Best	OLSR
Overall Network Efficiency	↑ Higher is Better	↑ Medium	↑ Good	↑↑ Excellent	↑↑ Excellent	DSR / OLSR

4. Conclusions and Future Challenges

Ad-hoc networking is one of the interesting area for researchers since long time. Due to efforts of the of the research community several ad hoc based applications have been invented and many new areas for research are explored. VANETs is one such area that emerged from MANETs but is reaching new heights in its real life implementations. The communication of vehicles is in the starting phase and different projects have been initiated by the United States, European Union and Japan for providing benefits to the society through its numerous applications. VANETs provide real life applications that provide traffic assistance, infotainment, eco-environment, fuel saving to the society. It also faces challenges like dynamically changing topology, frequently disconnected network, varying communication environment and wide network boundaries. In this research work, the overview of the VANETs is presented along with the review of literature. The main goal of this paper is firstly to compare the VANET routing protocols and second, to examine the impact of node density on different performance metrics. The existing routing protocols are classified and some of them are discussed in detail. AODV, DSDV, DSR, and OLSR routing protocols are selected for the performance evaluation in a VANET scenario designed in NS3.27. The results showed that DSR performed 29% better in average goodput than other routing protocols. In the overall comparison of MAC/PHY overhead, OLSR performed 55% better than other routing protocols. The highest BSM PDR is achieved by the OLSR for all the 10 messages and DSR shows the least PDR. OLSR is 1.35% better than other routing protocols in metric BSM PDR. DSR is performed 2.2% better than other routing protocols in receive rate, and 2.27% in packets received. In Wave packets analysis, DSDV is the best performer with 12% ratio. From the result analysis, it is recommended that DSR and OLSR are the best performing routing protocols in the proposed evaluated model.

In Future, the more realistic vehicular mobility generated from traffic generator with traffic situations such as one way road, multi lane, traffic signals, damaged vehicles on road, emergency vehicles etc., can be considered. The IEEE 802.11p can be replaced with the more advanced and security related IEEE 1609.2 standard for obtaining improved results from the designed scenario.

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Conflict of Interest

The authors have no conflict of interest to declare.

References

1. Islam, M., & Jin, S. (2019). An overview research on wireless communication network. Wireless Communication Network, 5, 19–28.
2. Seddiki, N., & Abedsalem, B. (2017). Study of the performance of multi-hop routing protocols in wireless sensor networks. International Journal of Advanced Computer Science and Applications, 8, 378–384.
3. Raza, N., Aftab, M. U., Akbar, M., Ashraf, O., & Irfan, M. (2016). Mobile ad-hoc networks applications and its challenges. Communications and Network, 8, 131–136.
4. Bhatt, D., & Agrawal, B. (2017). Major challenges of mobile adhoc networks. Oriental Journal of Computer Science and Technology, 10.
5. Mobile ad-hoc networks: Applications, advantages & disadvantages. (2018, December 20). Study.com.
6. Alo, R. U., Stanly, N. I., & Onwe, N. F. (2018). Mobile ad hoc network (MANET): Applications, benefits and performance issues in a global positioning system. International Research Journal of Engineering and Technology, 5, 983–987.

7. Pinar, Y., Zuhair, A., Hamad, A., Resit, A., Shiva, K., & Omar, A. (2016). Wireless sensor networks (WSNs). In 2016 IEEE Long Island Systems, Applications and Technology Conference (LISAT) (pp. 1–8). IEEE.
8. Ghori, M. R., Zamli, K. Z., Quosthoni, N., Hisyam, M., & Montaser, M. (2018). Vehicular ad-hoc network (VANET): Review. In 2018 IEEE International Conference on Innovative Research and Development (ICIRD) (pp. 1–6). IEEE.
9. Tarque, M. H., Hossain, M. S., & Atiquzzaman, M. (2015). On the routing in flying ad hoc networks. In 2015 Federated Conference on Computer Science and Information Systems (FedCSIS) (pp. 1–9). IEEE.
10. Deshmukh, M. A., & Dinesh, D. (2014). Challenges in vehicle ad hoc network (VANET). International Journal of Engineering Technology, Management and Applied Sciences, 2, 76–88.
11. Sharma, B., Sharma, M. S. P., & Tomar, R. S. (2019). A survey: Issues and challenges of vehicular ad hoc networks (VANETs). In Proceedings of International Conference on Sustainable Computing in Science, Technology and Management (SUSCOM) (pp. 2491–2503).
12. Cavalcanti, E. R., Souza, J. A. R., Spohn, M. A., Gomes, R. C. M., & Costa, A. F. B. F. (2018). VANETs' research over the past decade: Overview, credibility, and trends. ACM SIGCOMM Computer Communication Review, 48, 31–39.
13. Kugali, S. N., & Kadadevar, S. (2020). Vehicular adhoc network (VANET): A brief knowledge. International Journal of Engineering Research and Technology, 9, 1026–1029.
14. Kenney, J. B. (2011). Dedicated short-range communications (DSRC) standards in the United States. Proceedings of the IEEE, 99, 1162–1182.
15. IEEE. (2019). IEEE draft trial-use standard for wireless access in vehicular environments (WAVE) – Resource manager (IEEE Std P1609.1/D17, pp. 1–66).
16. Yasser, A., Zorkany, M., & Kader, N. A. (2017). VANET routing protocol for V2V implementation: A suitable solution for developing countries. Cogent Engineering, 4, 1–26.
17. Brendha, R., & Prakash, V. S. J. (2017). A survey on routing protocols for vehicular ad hoc networks. In 2017 4th International Conference on Advanced Computing and Communication Systems (ICACCS) (pp. 1–7). IEEE.
18. Kumar, R., & Dave, M. (2011). A comparative study of various routing protocols in VANET. International Journal of Computer Science Issues, 8, 643–648.
19. Abdeen, M. A. R., Beg, A., Mostafa, S. M., Abdul Ghaffar, A., Sheltami, T. R., & Yasar, A. (2022). Performance evaluation of VANET routing protocols in Madinah city. Electronics, 11, 777.
20. Gaikwad, D. S., & Zaveri, M. (2011). VANET routing protocols and mobility models: A survey. Trends in Networks and Communications, 197, 334–342.
21. Gadkari, M. Y., & Sambre, N. B. (2012). VANET: Routing protocols, security issues and simulation tools. IOSR Journal of Computer Engineering, 3, 28–38.
22. Singh, K., Mishra, G., Raheem, A., & Sharma, M. K. (2020). Survey paper on routing protocols in VANET. In 2nd International Conference on Advances in Computing, Communication Control and Networking (pp. 426–429). IEEE.
23. Mahi, M. J. N., Chaki, S., Ahmed, S., Biswas, M., Kaiser, M. S., Shahid, M., Islam, M. S., Sookhak, M., Barros, A., & Whaiduzzaman, M. (2022). A review on VANET research: Perspective of recent emerging technologies. IEEE Access, 10, 65760–65783.
24. Phull, N., Singh, P., Shabaz, M., & Sammy, F. (2022). Enhancing vehicular ad hoc networks' dynamic behavior by integrating game theory and machine learning techniques for reliable and stable routing. Security and Communication Networks, 1–11.
25. Ghori, M. R., Zamli, K. Z., Quosthoni, N., Hisyam, M., & Montaser, M. (2018). Vehicular ad-hoc network (VANET): Review. In 2018 IEEE International Conference on Innovative Research and Development (pp. 1–6). IEEE.
26. Rasheed, A., Gillani, S., Ajmal, S., & Qayyum, A. (2017). Vehicular ad hoc network (VANET): A survey, challenges, and applications. Advances in Intelligent Systems and Computing, 548, 39–51.
27. Asra, S. A. (2022). Security issues of vehicular ad hoc networks (VANET): A systematic review. TIERS Information Technology Journal, 3, 17–27.
28. Hu, S., Jia, Y., & She, C. (2017). Performance analysis of VANET routing protocols and implementation of a VANET terminal. In 2017 International Conference on Computer Technology, Electronics and Communication (pp. 1248–1252). IEEE.
29. Pande, S., Sadakale, R., & Ramesh, N. V. K. (2021). Performance analysis of AODV routing protocol in VANET using NS-2 and SUMO. In WCNC-2021: Workshop on Computer Networks & Communications.
30. Satveer Kour, Singh, M., Sarangal, H., & Singh, B. (2023). Terrain dimensions and node density analysis of MANET using NS2 and BonnMotion. Lecture Notes on Data Engineering and Communications Technologies, 171, 163–175.
31. Satveer Kour, & Singh, J. (2022). Performance evaluation of enhanced Manhattan mobility model over GM, RWP, Manhattan Grid, SLAW, and TLW mobility models in MANETs. Recent Advances in Computer Science and Communications, 15, 992–1000.
32. Kaur, R., Singh, G., Kumar, A., & Satveer Kour. (2022). A review study of VANET, mobility models and traffic generator tools. In Proceedings of 5th International Conference on Contemporary Computing and Informatics (pp. 1055–1060).
33. Satveer Kour, & Singh, J. S. (2019). Performance analysis of mobile nodes in mobile ad-hoc networks using enhanced Manhattan mobility model. Journal of Scientific and Industrial Research, 78, 69–72.
34. Satveer Kour, & Singh, J. S. (2018). A novel approach to predict mobility pattern of mobile nodes in mobile ad-hoc networks. Journal of Scientific and Industrial Research, 77, 629–632.

35. Satveer Kour, Singh, J. S., & Singh, M. (2023). QoS improvement using enhanced Manhattan mobility model on proposed ant colony optimization technique in MANETs. Journal of Scientific and Industrial Research, 82, 616–628.
36. Kumar, S., Kumar, A., Tyagi, V., & Kumar, A. (2020). Impact of network density on AODV protocol in VANET. In 5th International Conference on Computing Communication and Automation (pp. 559–564).