CLUSTER HEAD SELECTION ALGORITHM UNDER TRAFFIC AND MOBILITY CONDITIONS IN VANET

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By:

Manoj Sindhwani

Registration No. 41400715

Supervised By:
Dr. Charanjeet Singh
Professor
LPU, Phagwara

Co-Supervised By:
Dr. Rajeshwar Singh
Director
DGC, Nawanshahr

LOVELY PROFESSIONAL UNIVERSITY

PUNJAB

2021

CERTIFICATE

I certify that **Manoj Sindhwani** has prepared his thesis entitled '**CLUSTER HEAD SELECTION ALGORITHM UNDER TRAFFIC AND MOBILITY CONDITIONS IN VANET**,' for the award of the Ph.D. degree of Lovely Professional University, under our guidance. He has carried out the work at the School of Electronics and Electrical Engineering, Lovely Professional University.

Dr. Charanjeet Singh
Professor
School of Electronics and Electrical Engineering
Lovely Professional University
Jalandhar-Delhi G.T. Road (NH-1)
Phagwara, Punjab, INDIA
Date : 20th July 2021

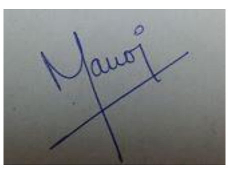
Rajeshwar Singh

Digitally signed by Rajeshwar Singh
Date: 2021.07.09 22:08:21 +05'30'

Dr. Rajeshwar Singh
Professor
School of Electronics and Electrical Engineering
Doaba Group of Colleges
Nawanshahr
Rahon, Punjab, INDIA
Date : 9th July 2021

DECLARATION

I declare that the thesis entitled '**CLUSTER HEAD SELECTION ALGORITHM UNDER TRAFFIC AND MOBILITY CONDITIONS IN VANET**' has been prepared by me under the supervision of **Dr. Charanjeet Singh**, Professor of Electronics and Electrical Engineering, Lovely Professional University, Phagwara and Co-supervision of **Dr. Rajeshwar Singh**, Director of Doaba Group of Colleges, Nawanshahr. No part of this thesis has formed the basis for the award of any degree or fellowship previously.



Manoj Sindhwani
School of Electronics and Electrical Engineering
Lovely Professional University
Jalandhar-Delhi G.T. Road (NH-1)
Phagwara, Punjab, INDIA
DATE: 20th July 2021

ABSTRACT

In both developed and developing countries, a lot of time is consumed due to traffic congestion. This has significant negative consequences, including driver stress due to increased time demand, decreased productivity in the use of personalized and commercial vehicles, and increased emissions of climate-change and air pollution-related gases impacting population health in highly populated areas. Much attention has been paid to reduce environmental emissions and reducing the consumption of fuel in recent years. In an intelligent transportation system, vehicular routing has been commonly used to provide protection, security and reduce traffic jams. However major applications of VANET are related to the safety and security of passengers in vehicles. But the improvement in performance parameters is one of the major challenges in the dense traffic environment. The high-speed requirement of vehicles in VANET causes frequent disconnectivity in the links due to which better efficiency can not be achieved. So to gain improvement in performance parameters, the clustering in VANET plays an important role. Clustering is one of the most powerful strategies for achieving a consistent topological structure. For clustering of the vehicular nodes, some common parameters like distance, location, relative velocity, and point of interest are taken into interest. After clustering of the vehicular nodes, the information is disseminated into the cluster through cluster gateway and in coordination with the cluster head. So routing protocols take care of the communication and routing the data by utilizing routing tables which include information of their neighboring nodes and this routing information is used in finding the best-suited path.

There are various kinds of routing protocols in the vehicular network for transmitting the messages in the network with the best optimal path. So a comparison between various routing protocols is made. It is observed that the proposed technique could give better quality results in terms of multiple parameters like throughput, packet delivery ratio, and delay. As it helps in route discovery methods, AODV DSDV and CBR routing protocols are compared with the proposed technique, which is more efficient than existing protocols, specially CBRP (performs the best in existing protocols) by 6 %, 3 %, and 35 % in terms of throughput, PDR and Delay. Stability and mobility are significant concerns, especially in VANETs.

In this work, the whole network is divided into various clusters, and a cluster head is chosen in every cluster for efficient communication between them. The cluster head provides the time slots to the vehicle to take the channel access in the network for communication purposes. The limitation in the prediction based clustering is the selection priority which is firstly provided to the central nodes, but the possibility is that many vehicles may be present in the center, which increases the delay in the selection of center node, and the limitation in the FoV based clustering is limited sensing range of vehicle nodes. So there is the need to present the clustering techniques which contain the highest degree of nodes to get more connectivity and better throughput. According to this method, the node with the maximum number of neighboring nodes and relatively less speed is considered to be cluster head. The node with minimum neighboring nodes and more speed will be given the least priority, and all these members are named cluster members. The overall results of throughput, delay, jitter, PDR, and packet loss show that the highest degree algorithm performs better than the existing algorithms for the selection of cluster head. For 35 vehicle nodes, the highest degree algorithm performs 44.4 % and 42.8 % in terms of delay, 31.5 %, and 19.3 % in terms of packet loss, 81.5 % and 40.4 % for throughput, 42.8 % and 25.9 % in terms of jitter, 16.6 % and 9.3 % for PDR better than prediction-based and FoV based algorithms. For 50 vehicle nodes, the highest degree algorithm performs 37.2% and 32.8%, 33.3% and 25.3%, 66.3% and 36.6%, 36.5% and 16.1% , 24.3% and 15 % better than prediction-based and FoV based algorithms in terms of delay, packet loss, throughput, jitter and PDR respectively.

A k-means clustering algorithm in which dynamic grouping by k-implies is performed that fits well with the vehicular network's dynamic topology characteristics. The suggested clustering reduces overhead and traffic management. Also, for inter and intra-clustering routing, the dynamic routing protocol is proposed, which increases the overall packet delivery ratio and decreases the end-to-end latency. Relative to the cluster-based approach, the proposed protocol achieves improved efficiency in terms of throughput, packet delivery ratio, and end-to-end delay parameters comparing the situations by taking the different number of vehicular nodes in the network. The simulation results show that the proposed protocol is more effective as compared to CBLTR and AODV-CV protocols. Comparative analysis indicates that the proposed protocol has up to 6.7 % and 9.7 % more throughput, has up to 11.5 % and 18.5 % more PDR, and has up to 32 % and 43 % less E2E delay compared to CBLTR [33] and AODV-CV [34] protocols for a varying number of simulations in the network.

In VANETs, transmission links are incredibly susceptible to interruption; thus, the routing efficiency of these constantly evolving networks requires special attention. To promote reliable routing in VANETs, a novel context-aware reliable routing protocol is proposed which integrates k-means and support vector machine (SVM) in this work. The k-means clustering divides the routes into two clusters named GOOD and BAD. The cluster with a high mean square error (MSE) is labeled as BAD, and the cluster with low MSE is labeled as GOOD. After trained the routing data with SVM, the performance of each route from source to target is evaluated by considering packet delivery ratio, average end-to-end delay, and throughput. The proposed protocol will achieve improved routing efficiency with these changes. The performance of each route from source to target is evaluated by considering PDR, average E2E delay, and throughput. The simulation results of proposed results reveal that it is more effective in comparison to CBLTR and existing protocols. Comparative analysis indicates that the proposed protocol has up to 5 % and 8.4 % more PDR, and has up to 10.5 % and 17.1 % less E2E delay in comparison to CBLTR [33] and Aravindhan et al. [38] for different area sizes.

Wireless communication is adding value to automobile sectors by providing communication between vehicles and infrastructure-based networks. A lot of benefits can be achieved for the society like safe driving, avoiding traffic jams, alert for bad road conditions, intelligent traffic systems, and minimizing road accidents by providing early warning systems. However, the work is focused on the performance evaluation of various network parameters like throughput, packet loss ratio, delay, packet delivery ratio, and jitter. After implementing the proposed algorithms, the results have been improved for these parameters.

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ABBREVIATIONS

ABC	Artificial Bee Colony
ABS	Anti-Braking System
ACO	Ant Colony Optimization
AODV	Ad-hoc On-demand Distance Vector
AWCP	Adaptive Weighted Clustering Protocol
CBLTR	Cluster-Based Life-Time Routing Protocol
CBRP	Cluster Based Routing Protocol
CBVANET	Cluster Based Vehicular Ad-hoc Network
CG	Cluster Gateway
CH	Cluster Head
CM	Cluster Member
CRBP	Cognitive Radio Broadcast Protocol
DSRC	Dedicated Short-Range Communication
E2E	End to End
FA	Firefly Algorithm
FL	Fuzzy Logic
GA	Genetic Algorithm
GPS	Global Positioning System
GyTAR	Greedy traffic-aware routing protocol

I2I	Infrastructure-to-Infrastructure
ITS	Intelligent Transportation systems
MAC	Media Access Control
MANET	Mobile Ad-hoc Network
NN	Neural Networks
OBU	On Board Unit
OLSR	Optimized Link State Routing
PDR	Packet Delivery Ratio
PSO	Particle Swarm Optimization
QoS	Quality of Service
RL	Reinforcement Learning
RSU	Roadside Unit
SVM	Support Vector machine
TD	Transmission Delay
TSR	Transmission success ratio
UMTS	Universal Mobile Telecommunications System
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
VANET	Vehicular Ad-hoc Network
WAVE	Wireless Access in Vehicular Environments
Wi-MAX	Worldwide Interoperability for Microwave Access

CHAPTER 1: Introduction

1.1 History and Motivation

Today's transportation system is an integral component of human activity and has become an indispensable part of everyday human life. In latest years, more residents have become reliant on public transportation [1, 2]. The transportation system faces both opportunities and obstacles. Deaths, accidents, and crashes associated with road travel are caused by nearly driving, with about 1.3 million people dying each year around the world [3]

In a fast-developing country such as India, physical infrastructures such as roads and traffic systems must be geared up to meet the rising tide of vehicles and regulate their movements safely. According to NCRB, a total of 4,73,416 traffic accident cases were reported. Various steps have been taken to increase road safety for vehicles by the automotive industry. Some of them, such as Anti-Braking System (ABS) brakes and airbags, have become a standard feature in most vehicles, while advanced systems such as pre-crash systems are only offered in particular vehicles.

Moreover, in both developed and developing countries, rising amounts of time is lost due to traffic congestion. This has significant negative consequences, including driver stress due to increased time demand, decreased productivity in the use of trucks and other commercial vehicles, and increased emissions of climate-change and air pollution-related gases impacting population health in highly populated areas. Much attention has been paid to reducing environmental emissions and reducing the consumption of fuel in recent years.

The next stage in the evolution of safety-enhancing technologies will likely be in the form of active cooperative systems in which vehicles are fitted with the Global Positioning System (GPS) and can coordinate with each other to avoid collisions. The next generation of vehicle safety-enhancing technologies operating under the flagship of Intelligent Transportation Systems (ITS) seeks to speed up this evolution.

Vehicular communication is a kind of intelligent transport network where it provides more reliability and efficiency in the network. The main aim of the network is to provide safety and security with avoiding congestion. In today's era, the combination of automobile engineering with wireless communication is gaining more popularity because of its several advantages and applications. The motivation behind the study is to provide security for the passengers in the vehicle and to avoid accidents that can save human lives.

1.2 Introduction to VANET

VANET is the sub-branch of MANET and is the node on wheels. VANET is specially designed for communication among vehicles. VANET based nodes are self-organized where vehicles can directly communicate with other vehicles without any need for access points. However, communication is also possible with the help of roadside units (RSU) which makes this network a hybrid network. An IEEE standard is also formed for VANET i.e. IEEE 802.11p which is an approved amendment of IEEE 802.11, to integrate wireless access in vehicular environment(WAVE) to support vehicular communication system. The transport applications are the main feature of the VANET which includes intelligent vehicular communication between vehicles. Vehicular communication is a short-range communication as the vehicles connected are in a dedicated short-range and can communicate under a limited area of a maximum of one thousand meters.

All the automotive private sectors and government agencies are now investing in the emerging field of VANET because of its vast applications and importance [4]. The network can communicate using its mobile nodes and with static roadside units [5]. The cellular network can also participate in vehicular communication for wide coverage and better capacity. VANET's main strength is its adequate storage capacity, no energy limitation, and predicted movement as per the road structure [6, 7].

1.3 VANET Architecture

The main components in VANET are divided into three major categories: roadside unit (RSU), on-board unit (OBU), and trusted authority(TA) as represented in Fig. 1.1. Usually, RSU is installed at various roadside locations, whereas the OBU is mounted inside the vehicular node for communication purposes with installed RSU's [8].

- **RSU:** The roadside unit can send messages to the onboard units on the vehicles and other RSU's. The RSU acts as a hotspot in transmitting safety messages and providing better coverage. The traffic situation alert can be an added advantage to the vehicles before time so that the delay can be avoided.
- **OBU:** To provide internet connectivity to the vehicles, OBU's are installed, using this various information related to the vehicle can be gathered and analyzed.

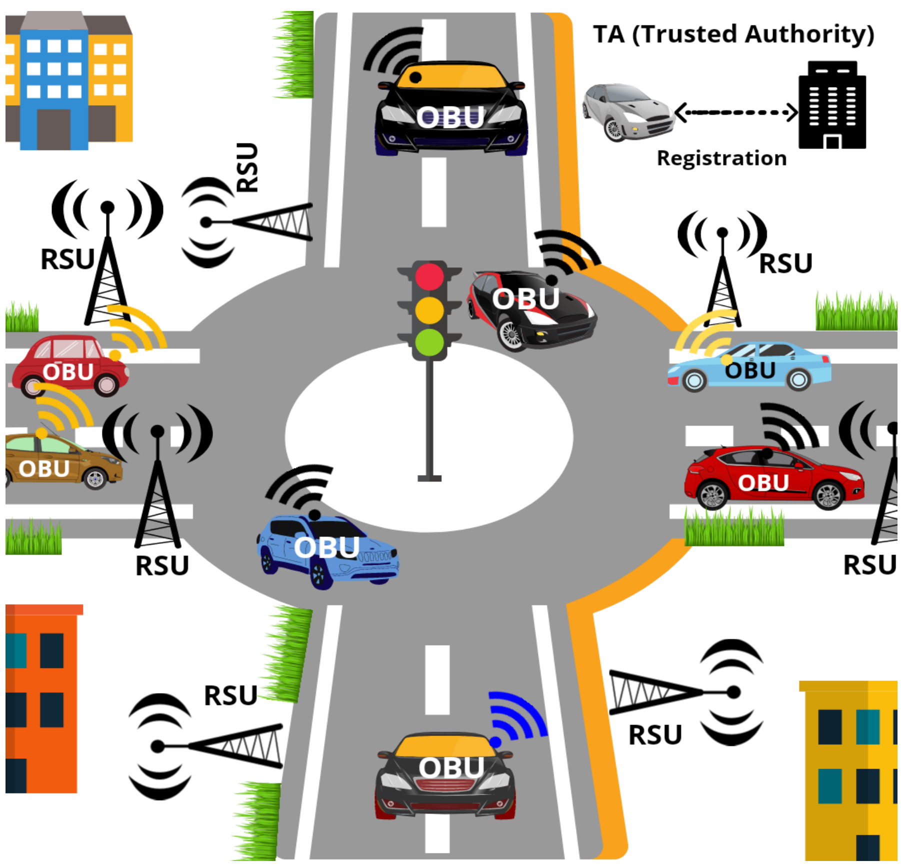

Figure 1.1 VANET Components

- **Trusted Authority:** Trusted authority plays important role in managing the entire system because of its features like security verification of vehicles, authentication, and registration of RSU and OBU.

In VANETs, information can be exchanged using various wireless links as shown in VANET architecture with Fig. 1.2. The possible wireless links are given below:

1. Vehicle-to-Vehicle (V2V): Vehicles can directly exchange the data between them in a self-organized environment without any need for an access point. OBU in vehicles comes into the picture while connecting with another vehicle for communication purposes. All the security alerts can be disseminated between the vehicles using the broadcast feature. Vehicle-to-vehicle communication can be feasible in a dedicated short-range area.
2. Vehicle-to-Infrastructure (V2I) or Infrastructure-to-Vehicle (I2V): The link is a bridge between wired and wireless networks. The OBU mounted on vehicles communicates with static RSU's and vice versa. These links play an important role in collecting traffic-related data, accident information, and route change alerts. Internet access is also provided to vehicles using this connection. As a result, they will obtain up-to-date information on current events and traffic on nearby highways [9]. Infrastructure-based RSU is installed after a particular distance to avoid connection disruption from the vehicles. In short, the vehicles will always remain connected with roadside infrastructure for efficient communication.
3. Infrastructure-to-Infrastructure (I2I): The RSUs can connect over a wired channel to communicate external cellular networks like GSM, UMTS, and 4G. This requires a major cost for the areas where proper connectivity through the infrastructure-based network is still a challenge. It makes a hybrid model for efficient communication, However, in developed areas where infrastructure is already established, the network provides improved efficiency.

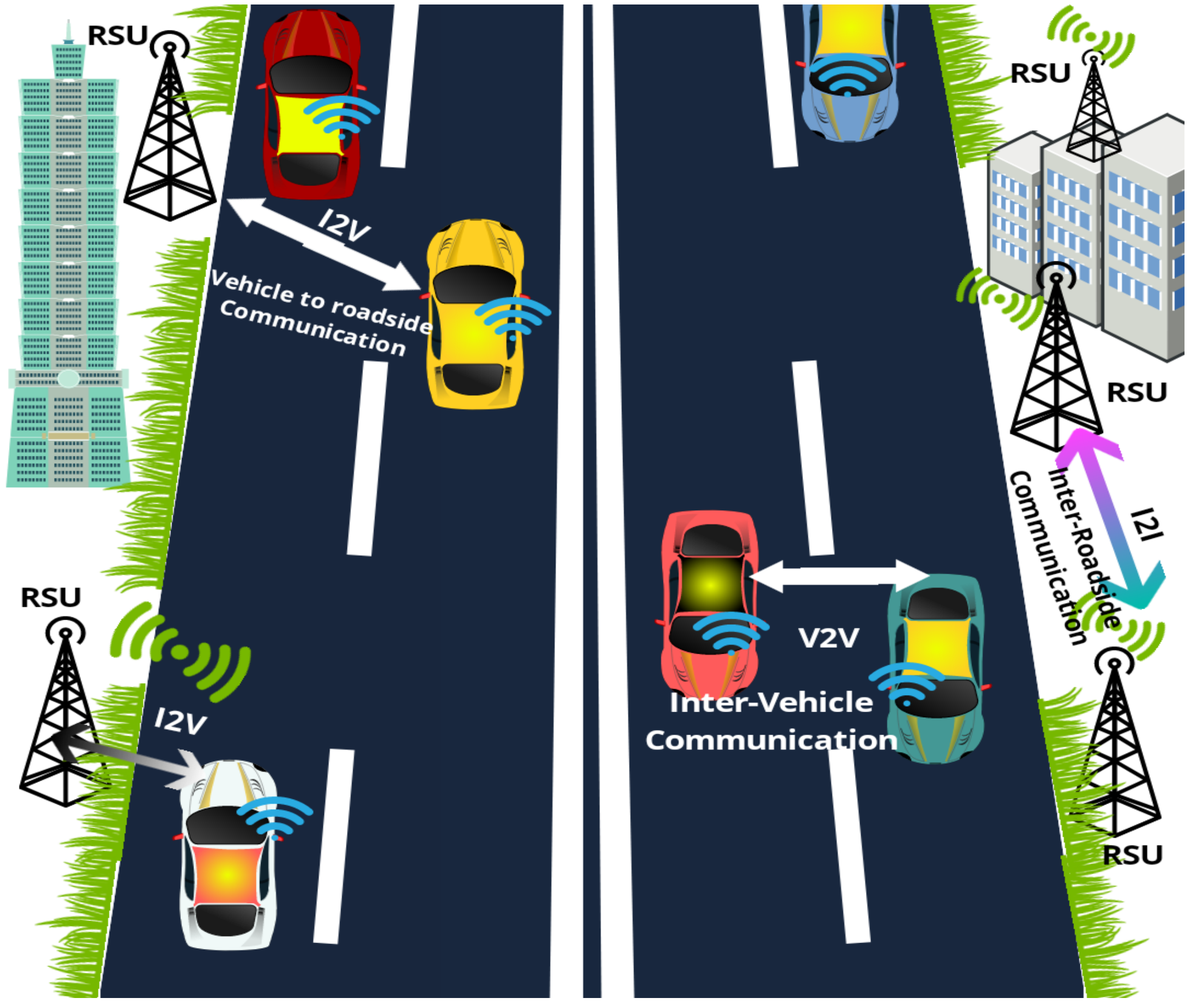

Figure 1.2 VANET Architecture

1.4 Applications of VANET

VANETs have a wide range of applications, which includes traffic management, infotainment, security management, speed management, and congestion control, as presented in Fig. 1.3. They are primarily focussing on the security of the driver and the passengers. However, traffic control is mainly used to disseminate accurate information from source to destination in the vehicular environment. By these applications, the congestion in the network can be avoided that decreases the delay and jitter in the vehicular area network. So overall efficiency of the network is improved. The different kinds of applications are represented below.

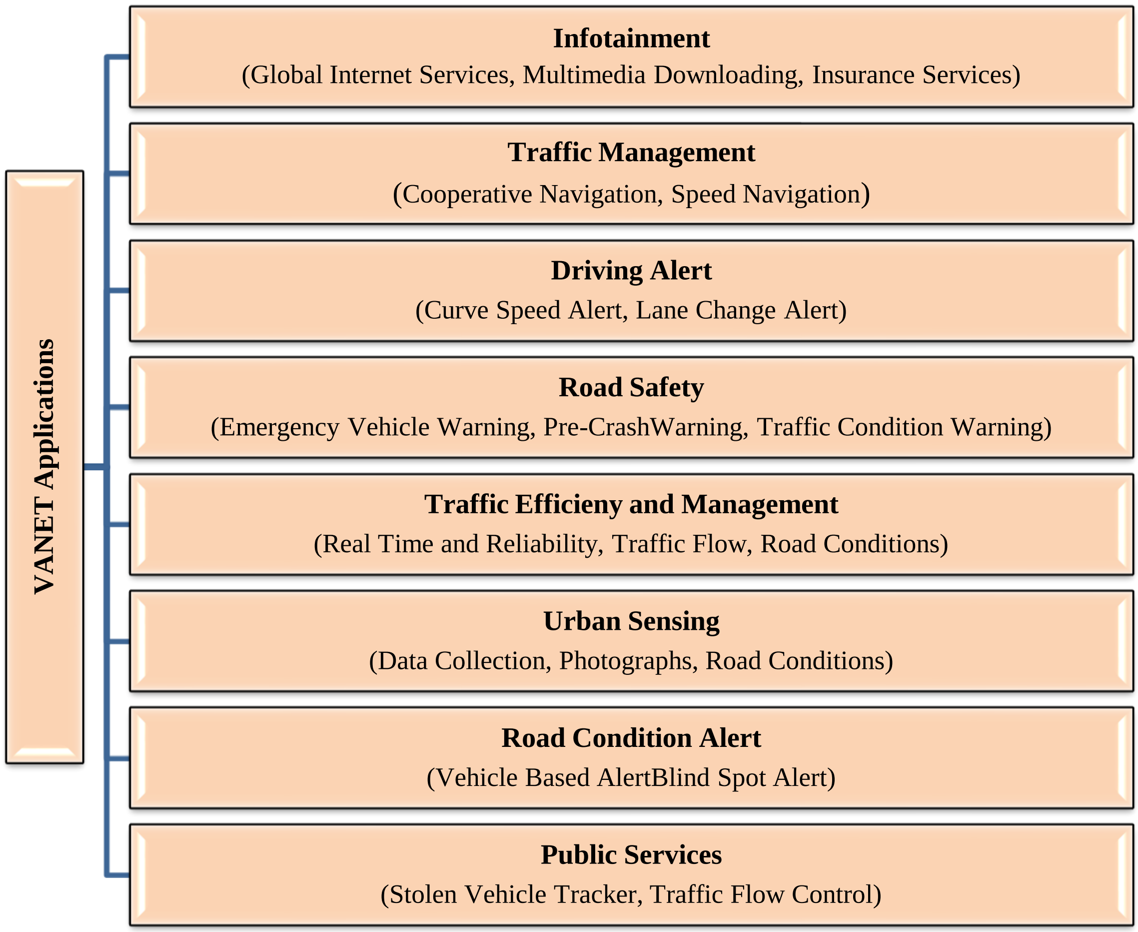

Figure 1.3 VANET Applications

1.4.1 Infotainment

Infotainment offers various entertainment services to passengers in the vehicle, which mostly includes music, gaming, vehicle connectivity, Internet access, insurance services, and multimedia downloads. This application comes under the category of entertainment services for the luxury of the passengers while traveling. These resources provide transferring of files between the vehicles which includes multimedia files such as audio and video for entertainment. Fig. 1.4 depicts how passengers can use video calling applications or stream multimedia files, such as music while driving. MP3 is a digital audio format [10, 11].

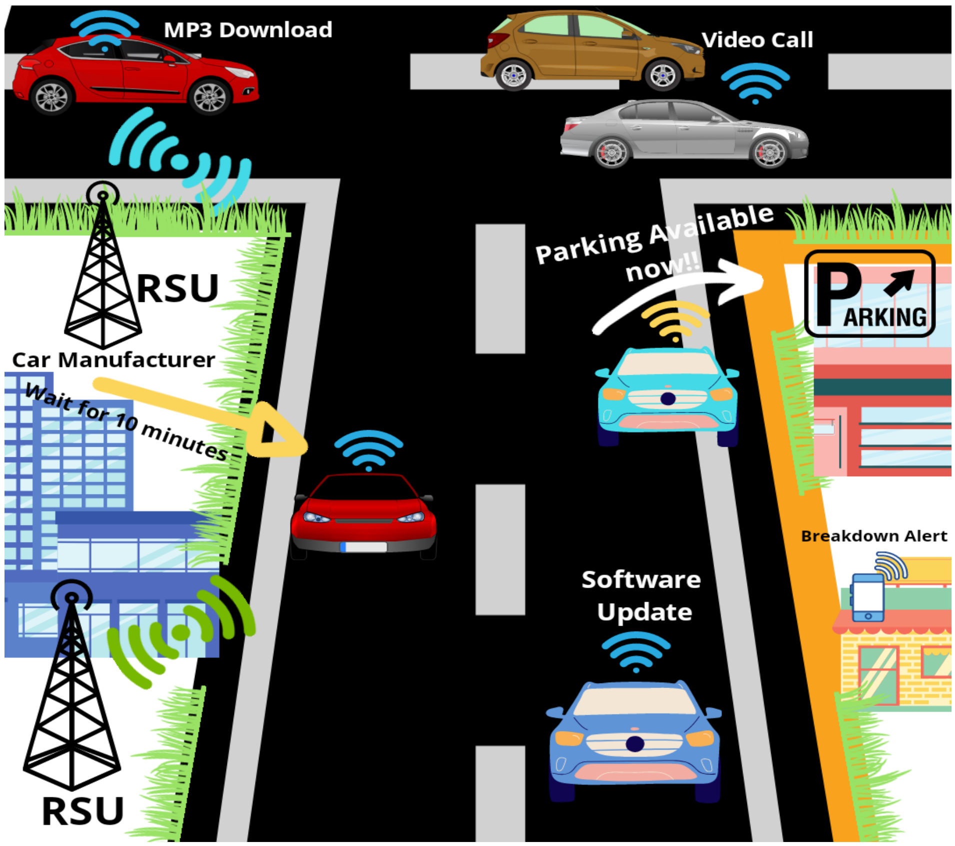

Figure 1.4 Infotainment Application in VANET

1.4.2 Traffic Management

This application keeps track of the velocity of the vehicle and passes the alert message in case of overspeeding as per the speed limit set by the government. The OBU gathers all the data and keeps the information shared with RSU, through which the information is passed to other vehicles in form of traffic alerts. This application is related to the security of the passengers as the alerts can save human lives if informed timely. It also contains value-added services such as cooperative navigation. So traffic management is considered to be the essential application of vehicular area networks.

1.4.3 Driving Alert

Few key features of this application are overlapped with the traffic management services. Driving alert assists drivers on the road by guiding them in road bottlenecks, collisions, traffic incidents, traffic congestion, accidents, and more. It also suggests parking area notification and toll collection. Even in case, assistance is required from a vehicle manufacturer, the communication can be initiated and software can be upgraded if required. Nearest parking and automated maintenance are examples of details that a user of VANET can obtain with high accuracy and a variety of options.

1.4.4 Road Safety

This system is used to improve travel safety and prevent serious accidents. All the legal warnings come under this application for the protection and safety of the passengers. Emergency vehicle alert, lane change warning, emergency brake warning, accident warning, traffic condition warning, and pedestrian crossing warning are among the safety applications shown in Fig. 1.5 [12].

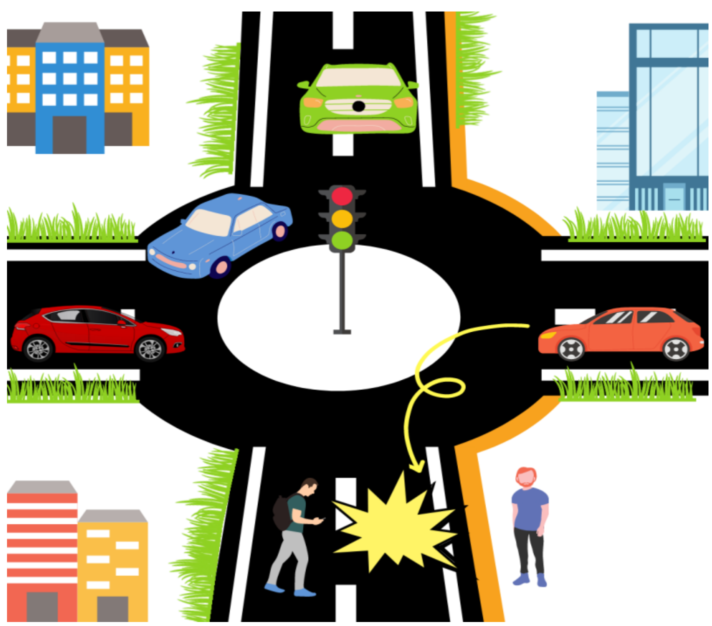

Figure 1.5 Pedestrian Crossing Warning

1.4.5 Traffic Efficiency and Management

In traffic management, the vehicles pass the traffic alerts to all other vehicles in their range so that the vehicles sense the traffic and can change the route for saving time and fuel. Speed control services and cooperative navigation services are two examples of this type of system. The notifications are real-time and reliable for the vehicles to trust upon. It can avoid the usage of speed limit boards on the roads and the speed limit notifications can be passed directly to the vehicle. A traffic control situation at a road intersection is depicted in Fig. 1.6. When a vehicle senses a pathole on the road, it transmits an alert message to nearby vehicles. This mission can be completed by any one of the vehicles or RSU.

Figure 1.6 Traffic Management Application

1.4.6 Urban Sensing

This application focuses on the data collected by sensors so that the information based on the processing of data, can be passed to other vehicles. This system alerts the other vehicles about the curve of the road, accident-prone areas, and existing road situations. The in-vehicle system processes this information to decide the road condition and issue a driver alert to other vehicles. Even when the visibility is poor like in foggy weathers, this application can help to avoid any kind of accident.

1.4.7 Road Condition Alert

The road condition alert is transmitted to other vehicles to warn them and to avoid any kind of mishappening in an unsafe situation. At the intersection, the device collects and processes data, and if a dangerous condition is detected, it sends out alert messages to vehicles.

It can help the drivers going on long routes as timely the route can be changed by getting the notifications of bad road conditions. But sometimes the congestion can be increased on the route having good road conditions. Then traffic management will come into play and alerts will be passed accordingly. The only condition is to avoid any loop in between road conditions and traffic management [13].

1.4.8 Public Services

The application goal is to support drivers and emergency vehicles by reducing traveling time and delivering assistance when an accident occurs, this application also ensures that emergency services can get to their destinations without having to wait in traffic; as this can be achieved by sending warning signals to clear lane for the emergency vehicle. All the information related to emergency vehicle speed, distance, location, and the lane is already passed to vehicles in advance to avoid any mishappening. It also includes traffic flow monitoring and a stolen vehicle tracker.

1.5 Characteristics of VANET

Since VANETs are used in various monitoring and safety applications, they have a number of hardware and communication device characteristics that affect VANET communication. The most important of these characteristics that affect communication in a VANET network are outlined below [14]:

- **Estimate Movement**: The movement of vehicles is limited by the urban structure, like sidewalks, crossings, and roads; thereby, possible vehicle activities can be predictable.
- **Power Constraints:** Because every vehicle is fitted with prolonged battery life, VANETs have no power limitations.
- **Variable Network Intensity**: Traffic stream variance induces variable network density, such that rural regions have low network density, whereas traffic jams have high density.
- **Mobility:** In VANETs, vehicles usually drive at high velocity. A slight delay in V2V transmission can also lead to several problems.
- **Variable Network Topology**: The VANET topology varies quickly because of the extreme velocity of vehicles. This means that VANETs are susceptible to attack, and the detection of malicious vehicles is difficult.
- **Real-time Restrictions**: In VANETs, the communication of data has a fixed time threshold range. This is intended to provide ample time for the recipient to make determinations and take necessary actions quickly.
- **Processing and Storage Capacity**: In VANETs, it is common to manage vast quantities of data between vehicles and infrastructures. Therefore, the ability to compute and store is utterly a daunting problem.
- **Volatility**: It is expected that the interactions among two nodes in VANETs arise only once because of their versatility. The links between nodes will stay within a few wireless hops for a restricted duration of time. Thus, the protection of personal contacts at VANET will be challenging to ensure.

- **High Processing Capacity**: Compared to other mobile nodes, operational vehicles can utilize much higher processing, networking, and sensing abilities.
- **Conventional Mobility**: Vehicles have motions that are more convenient than traditional MANETs. Vehicles travel only on highways. From GPS technology, roadway information is available.
- **Wide-scale**: With several participants, VANETs could span a whole road network. Its area of coverage can vary from a neighborhood to an entire town.
- **Processing Capability with Power and Storage**: Every node is connected to the others. The VANET is nothing more than a vehicle that should be fitted with sufficient processing power to handle data from nearby vehicles. In addition, adequate storage space and energy are needed to store, collect, and send transmission wirelessly. Power production is not a concern when operating the VANET apparatus because they have rechargeable power sources that produce power constantly.
- **Geographical Situation and Transmission**: Vehicles are equipped with GPS, which aid in the provision of position for communication purposes as well as the ability to support interaction in geographic regions for packet forwarding.
- **Many Distinct Communications Situations**: Vehicles are typically driven in cities with a variety of building blocks and structures, as well as highways with heavy, sluggish, or blocked traffic. As a result, different roadblocks for wireless data transmission in VANET can be experienced in each scenario.
- **Delay Restraints and Real-time Communication**: Several applications must produce warnings for drivers when they detect an accident, PreCrash, or sudden brakes. In such situations, the maximum delay is critical since delays that last longer than anticipated result in collisions or injuries. Accidents can be prevented if the information is obtained on time.
- **On-board Devices:** Any vehicle must be fitted with various devices that can be used to make routing decisions and establish a communication channel.

- **Infrastructure Access:** The VANET's smooth contact and connectivity are hard to maintain because of the dynamic environment. In cases where VANET problematic delay constraints applications are running in vehicles and for promoting continuous network connectivity, networking infrastructures along the roadside, such as Roadside units, access points, public hotspots, and so on, will play an important role.

1.6 Challenges of VANET’s

VANET has multiple applications in several fields, but these applications give rise to a lot of challenges [15] which makes VANET a suitable research area. Traditional VANET faces many challenges in network management due to a lot of mobility and frequent disconnectivity, Few challenges are represented below:

- **Bandwidth Limitations:** VANET nodes are self-organizing nodes and do not have a central coordinator as access points. The nodes that can send the safety messages and alerts to other vehicles may be too high for specific areas. So the load sent on the channel should be limited.
- **Delay Constraints:** High transmission mobility in VANET causes frequent disconnections in the network, so the real-time data transmission becomes a challenge which gives rise to delay constraint.
- **Privacy Rights:** Confidential information in vehicular networks is critical to transmitting and should have some privacy rights. A Trust management model should be implemented in the network to make it highly securable.
- **Security Threats:** Because of the open environment of VANETs, different kinds of attacks and threats are possible in the network. Security is a critical issue in VANET which directly affects the safety of the passengers. Therefore, it is a challenge among researchers to design security algorithms to prevent the network from various attacks.

- **High Dynamic and Disconnected Topology:** VANET is a high-speed communication network, and the topology in the network is not stable due to frequent disconnections.
- **QoS:** It is difficult to keep good QoS in the VANET attributing to frequent interruptions, high mobility, connectivity and complex topology etc. QoS can be measured in terms of throughput, delay, PDR, packet loss, and jitter. These network parameters should be improved by using several algorithms to obtain better results. To achieve QoS the routing algorithms are also implemented to find a suitable route for maximizing the efficiency of the network.
- **Standards:** The IEEE 802.11 was not able to fulfill the limitations for the vehicular environment so an amendment was done to propose IEEE 802.11p. As a result, further research on standards is needed.
- **Connectivity:** Connectivity in vehicles becomes a major issue when they are moving at a very high speed. This gives rise to affect various network improvement parameters such as throughput, delay, communication overhead, packet loss, and PDR. So this is considered as one of the main challenges in a vehicular network.
- **High-speed Wireless Communication Techniques:** To support high-speed vehicles in VANET, many wireless communication techniques such as 3G and 4G can be used for connectivity. It is attributed to good infrastructure and throughput. Sometimes these infrastructures are difficult to manage because of high operating costs. However, communication can be improved using this hybrid cellular communication model.
- **Broadcasting:** All types of important announcements are done through broadcasting protocols, such as emergency alerts, traffic information, weather updates, abrupt brakes notification, road condition, and so on. The broadcasting alerts the driver for the kind of notification and immediate action can be taken to avoid these kinds of situations. Although this may cause hidden station problems

in VANET. Furthermore, the protocols should be able to broadcast security information across both low and high-intensity VANETs.

- **Scalability:** Vehicles on roads are increasing day by day so the communication overhead also increases, The scalability should be there to avoid any loss of information. However, the congestion and complexity may increase in this case which may decrease the network performance.
- **Architectural Design:** A hybrid architecture is integrated as it will operate in a mix of technologies such as cellular communication, wifi, radio, and ZigBee, so this kind of flexibility in architecture is difficult to design.
- **Low Latency and High Reliability:** Vehicular nodes must disseminate the information quickly and with reliability. Optimal route selection can be done for less latency however, decreasing the number of hops in the dissemination of information improves the reliability. Achieving both is a tedious task and still a challenge for the researchers to work upon.
- **Resources Management**: Although resources like storage space, energy, and charging capability is easily available in the vehicular networks still the management need to be taken care of as bandwidth management is still one of the biggest challenges in vehicular networks. [16].

1.7 Security Requirements for VANET

Security in VANET is a significant concern because if an intruder will come and attack the system, then the life of a human can be affected. Vehicular Ad-hoc arranges unique instances of specially appointed systems that, other than lacking foundation, imparting substances move with different speed. The pertinent criteria are to set up reliable end-to-end correspondence ways and effective information exchange. In this manner, there are specific system concerns and security challenges in VANETs to get the accessibility of pervasive availability, secure correspondences, and notoriety administration frameworks which influence the trust in participation and arrangement between versatile systems administration substances. All things considered, there are different mechanical issues related to driverless autos, and these impacts fundamentally make issues people in general. Subsequently, it is important to have legitimate safety efforts to make it hurt society and is considered one of the most significant hindering variables for selecting these driver-less autos. Security requirements include confidentiality, integrity, availability, privacy, access control, etc. Some of them are discussed here and also represented in Fig. 1.7.

- **Authentication:** In the security of VANET, authenticity is a significant challenge. Before accessing all the available services, it is necessary to authenticate all the active stations in the network. The process of authentication damages the whole network due to violations or attacks within the network. The main objective of authentication is to protect nodes from outside or inside attacks in a vehicular network. The authorization levels of vehicles are controlled by the process of authentication. The authentication prevents Sybil attacks in VANETs by specifying identity to each vehicle.
- **Message Integrity:** Message integrity is essential as it ensures that there is no transformation in the message between the moment it was sent and received. Hence, the transferred message should match the received message.
- **Message Non-repudiation:** It is easy to identify sender location and its identity which is approved by the special authority. With the help of authenticated messages it sends, it is easy to locate the vehicle.
- **Access Control:** Vehicles haves to perform only those tasks for which they got authorization and must be as per rules. If the working of nodes is according to specified authorization, then access control is ensured and generates messages.
- **Message Confidentiality:** In order to maintain privacy in the system, it is necessary to have confidential property. This privacy is enforced by the law enforcement authority only in order to create privacy between the communicating nodes.

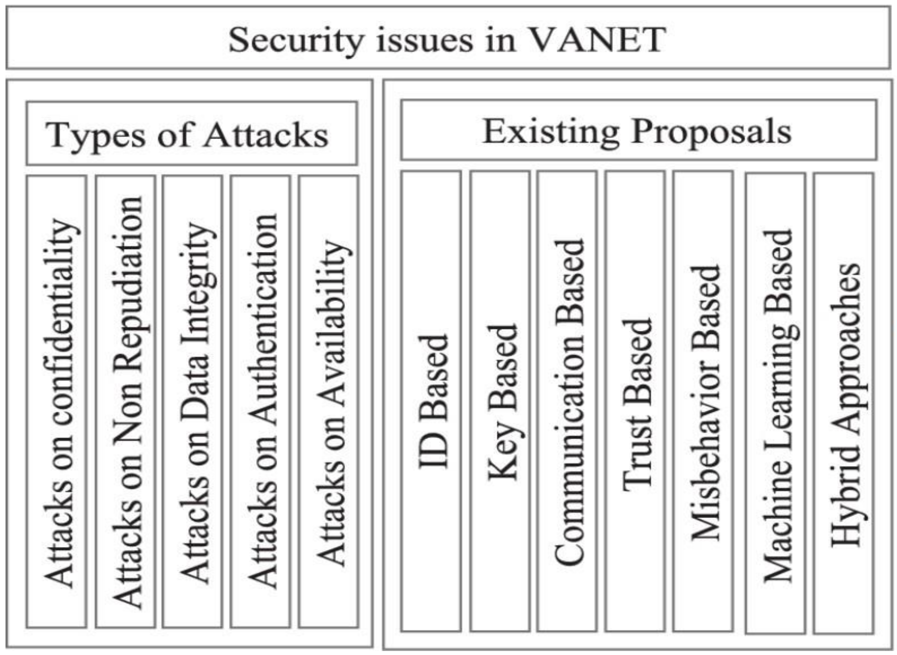

Figure 1.7 Security Issues in VANET

- **Privacy**: It is the system that assures that the information is not leaked to unauthorized people. It is not possible for a third party to track the movement of vehicles as it is a violation of personal privacy. Privacy of location is essential as it hides the past location of vehicles so that no unauthorized person can access it.
- **Real-time Guarantees**: Most of the safety applications are depended upon the strict time guarantees as it plays an essential role in VANET. Hence, this feature has been utilized for the avoidance of collisions in time-sensitive road safety applications.

1.8 Attacks in VANET

The unique characteristics of VANETs have been utilized in the networks for design decisions. Hence, it is necessary to address the issues related to inter-vehicular communications widely deployed in the network. Fig. 1.8 represents the scenario of different kinds of attacks in VANET.

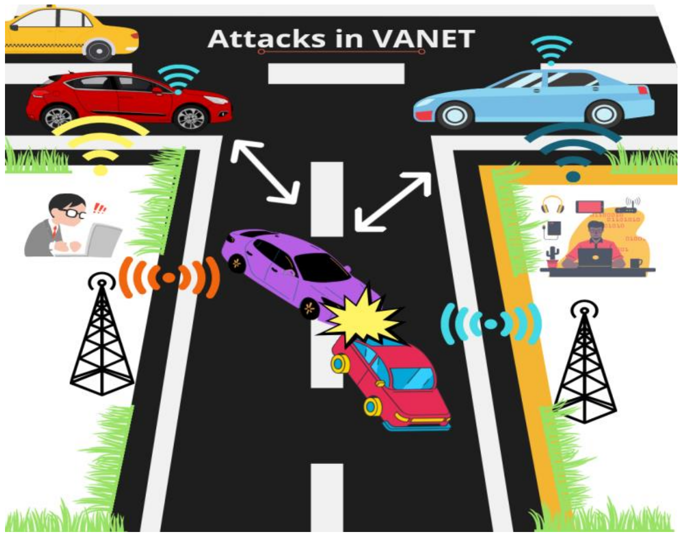

Figure 1.8 Scenario on types of Attacks in VANET

- **DoS Attack**: The network is bringing down due to the DoS attack. A node cannot deny whether it transfers the message or not due to the property of non-repudiation. It is difficult to determine the correct sequence. For the elimination of false messaging, it is required to have a regular verification.
- **Blackhole:** Dark gap assault is the assault in which hubs don't take an interest in the system. The dark opening is framed when a setup hub drops out. All the activity in this is diverted towards the particular hub that really doesn't present because the information is lost. Assailant makes a false picture because of which wastage of information happens.
- **Masquerade Attack:** In this attack, the intruder pretends to be an authorized user of the system. It will provide authority to an intruder for using the system privileges. This attack can be made by stealing login IDs, passwords.
- **Replay Attack:** It is also known as a playback attack because the legally correct data is illegally repeated and transmitted in the system. This is the lower-tier version of the man in the middle attack.

1.9 Clustering in VANET

Generally, VANET's applications are time-crucial. The main constraints of these applications are the rapid propagation of data across the network area in question. Approximately 60% of accidents can be prevented by the prompt distribution of emergency signals to local and remote vehicles. The method of propagation of broadcast messages is distributed into two categories: single-hop and multi-hop transmission. In a flat V2V dense network, a conventional multi-hop broadcast message propagation scheme will result in packet drop, high communication costs, high data packets delivery delay, as shown in Fig. 1.9. We need a stable communication infrastructure for message propagation to address the disadvantages, as mentioned earlier, of a flat V2V network system.

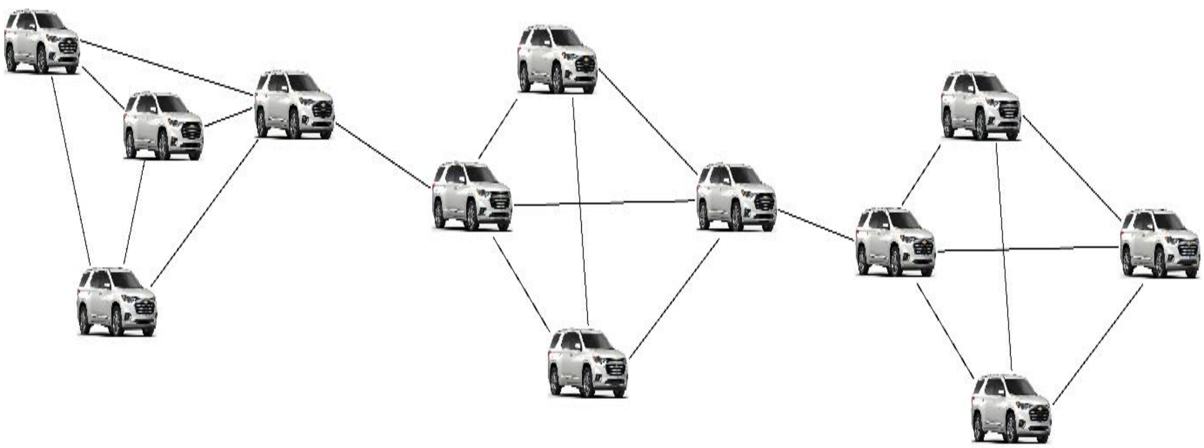

Figure 1.9 Flat VANET Architecture

VANET's cluster-based networking system forms a trusted backbone for the efficient transmission of messages and associated reserves to all vehicles inside the network [17, 18]. The application of VANET, such as security and complex road situation details, needs the extremely static topology of the network, so the enhanced clustering technique is highly required in such instances. The clustering shows an essential way of shaping community vehicles and efficiently coordinating wireless communications. In VANET, clustering routing contributes to decreased network dynamics [19].

Clustering is a strategy for forming a group of vehicles in a geographical area, as demonstrated in Fig. 1.10. A cluster is a logical community that has been created. Vehicles in a cluster can play one of the below roles:

- **Cluster Head (CH):** It performs transmission of information among clusters and intra-clusters in VANETs. At a minimum, one vehicular node that synchronizes data transmission with members and another CHs.
- **Cluster Member (CM):** All other normal vehicular nodes in the cluster which do not have any connection with other clusters.
- **Cluster Gateway (CG)**: The vehicular node offers an inter-cluster connection among two or more clusters.

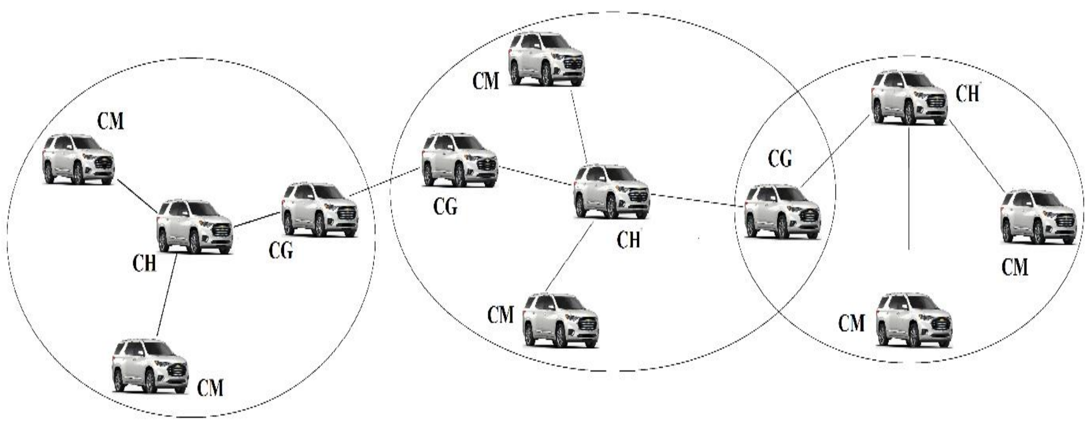

Figure 1.10 Cluster VANET Architecture

CHs are then chosen to achieve optimized network efficiency based on their improved functionality. Clustering protocols aim to deliver facilities with the least overhead and delay. The clustering protocol's execution based on many parameters like the distance of the vehicle from the destination vehicle, previous communication record of CMs, and the spread of the vehicles in the given area, which is also referred to as vehicle density. Vehicle density is also responsible for checking the robustness and scalability of the proposed network architecture. City traffic always results in high traffic congestion and slow movement of the vehicles; therefore, a cluster's formation can remain for a long time. On the highway, vehicles move at high speed; therefore, cluster formation changes very frequently. In an ideal case, each CM communicates to its nearest CH in order to save energy.

In vehicular communication, the clustering process is carried out by allocating each vehicle to an active CH. Therefore, CH needs to handle several CMs. If the handling capacity of CH exceeds the allocated capacity, in that case, CMs may not be linked to the nearest CH [20]. The clustering process is simple, and it states that keep the nodes similar in attribute or behavior. Fig. 1.11 demonstrates the grouping of nodes based on location only.

Since clustering algorithms in VANET are used to communicate between vehicles by partitioning network areas into sub-clusters [21], clustering protocols can ensure appropriate channel access by limiting the channel traffic among CMs. Instead of managing the CH, clustering algorithms are also responsible for better-utilizing network resources like bandwidth [22]. Due to the high mobility, the choice of CH and enhancing the stability in the network becomes a significant challenge.

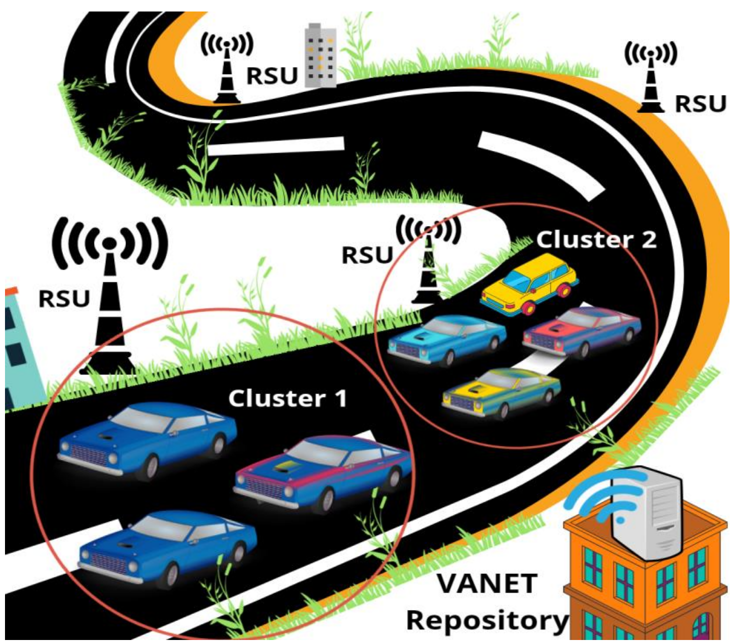

Figure 1.11 Clustering in VANET

1.9.1 Role of Clustering in VANET

For data dissemination throughout the network, the V2V transmission employs two methods: flooding and relaying. In flooding, neighboring nodes that received the source node's packet rebroadcast it to their neighbors. This method aimed to enter the data packet in the destination as many times as possible. Flooding can trigger the broadcast storm problem in a flat, dense network. All nearby nodes receive the packets transmitted by the source node in relaying approaches, but only a few nodes chosen as forwarder nodes are permitted to retransmit. In a multi-hop flat, dense VANET using the flooding method, the possibility of efficient transmission to the destination is reduced [23]. Simultaneously, using a relaying method improved the likelihood of efficient data transmission, but at the cost of increased overhead and delay. Clustering in VANET is, to a large degree, a powerful solution to such problems.

The multi-hop communication standard is commonly utilized to transport data from source to target via one or more intermediary nodes [24]. In a multi-hop communication model, routing is the procedure of determining the most efficient route between source and destination. A routing protocol's main aim is to accomplish the best throughput, PDR, routing overhead possible. The three types of traditional wireless ad hoc routing protocols are proactive, reactive, and geographical. For the vehicular world, they all have some drawbacks. Since VANET's frequent topology changes necessitate high bandwidth, the constructive routing protocol is ineffective. The reactive routing has a long initial delay in establishing contact [25, 26, 27]. Geographic routing [28] makes routing decisions solely according to node location knowledge. The location coordinates of the node can be discovered using a GPS or other location-based technique. It's challenging to locate the exact location of a mobile node in a complex setting like a VANET. We need routing protocols that enhance scalability, reliability and decreased data transmission delay in VANET. Cluster-based routing protocols, to a large degree, focus on these issues. The vast network is partitioned into small sections called clusters in cluster-based routing protocols. Intra-cluster routing is used within the cluster, whereas inter-cluster routing is used between clusters [29]. Instead of all vehicles in a cluster, CH assumes responsibility for all routing work in both groups.

1.10 Objectives

Keeping in mind, all the issues discussed above, the investigation is focused on the following objectives.

- To compare the different cluster head selection algorithms and find out the best-suited algorithm which will give better result in a high mobility scenario.
- To improve the cluster head selection procedure for reducing the time of data transmission.
- To make improvements in the existing MAC protocol, which will increase the transmission efficiency and reduces packet overhead in the network.
- To design an algorithm for achieving maximum throughput by using the adaptive technique to manage cluster size in different traffic conditions.

1.11 Scope of the Work

The Vehicular ad-hoc network is an emerging area of technology and with vast advantages and applications; various issues and challenges are also identified. The scope of the work is to study and resolve the challenges of various network parameters such as throughput, delay, packet loss, PDR, jitter, etc. The traffic scenario from low to high mobility of the vehicles is considered. The main scope is to implement clustering techniques and to choose the best route for the disseminating of the information from the source to the destination. The proposed routing protocol is found to be reliable under dense traffic conditions with high mobility nodes and this kind of routing algorithm performs best under the urban environment. The nodes are also increased to verify the results in high traffic scenarios. The adaptive technique to manage the cluster size is different traffic conditions and areas are implemented. The cluster head plays an important role in coordinating with the cluster members of the network and the information is transferred using the cluster gateway. K-means algorithm is also used for clustering of the nodes and combined with a dynamic routing protocol to obtained better results with the existing techniques with the proposed protocol. Machine learning techniques are implemented to train the data accumulated from produced simulations and train SVM in every iteration with random inputs until the best results are achieved.

1.12 Organization of the Thesis

The first part of this chapter consists of the background: basic principles, history, and applications of the VANETs. The overall schema of the chapters is formulated in the following manner:

Chapter 2 provides a brief literature survey of the various clustering and routing protocols in VANET. This study enables us to understand the basic soft computing routing mechanisms in VANETs and to learn about the behavior of well-known current routing protocols. Clustering algorithms are surveyed for cluster head selection technique which is chosen in terms of stability, relative velocity, location, direction, and various other parameters.

Chapter 3 presents various types of routing protocols in VANET. Performance evaluation of different routing Protocols is done. The algorithms are also proposed for the best route selection in the traffic environment. Challenges in the vehicular network are also addressed which occurs due to the high mobility of the vehicle nodes. An optimal path selection-based routing protocol is implemented. The clustering techniques to overcome issues in the routing are also addressed. Throughput, Delay, and PDR comparison is made using different kinds of routing protocols.

Chapter 4 presents the clustering techniques in VANET. The cluster head selection algorithms are also proposed in this chapter. The cluster head stability increases the efficiency of the network. The finite number of nodes are taken in the vehicular environment and the cluster head is chosen based on the highest degree of connectivity wih a specific cluster node. This approach will decrease the delay, improve the PDR and overall efficiency of the network is increased.

Chapter 5 presents a dynamic enhanced k-means clustering protocol to pick cluster heads, which increases the overall distribution ratio of packets and reduces VANET's end-to-end latency. Firstly k-means algorithm is presented for clustering of nodes and then dynamic routing protocol is implemented to get results of proposed routing protocols which are compared with the results of existing techniques. The obtained results show improvement from the existing techniques.

Chapter 6 presents the proposed context-aware hybrid (k-means + SVM) method for differentiating traffic flows of different context information to minimize the communication overheads. The machine learning techniques are implemented to get the desired results using the support vector machine approach. This section includes implementing the suggested procedure compared to the existing one based on various parameters like throughput, average PDR, average E2E delay, etc.

Chapter 7, in the end, brings the overall work performed in this research work to a close. The conclusive remarks are given considering the strength and the limitation of the proposed research. The research gaps are also identified which is described in future scope for further research.

CHAPTER 2: Literature Survey

2.1 Related Work

The objective of literature survey is associated with the insights of the challenges of the clustering and routing protocols in Vehicular ad-hoc networks.

In Song et al. (2010) [30], a cluster-aware directional routing (DBR) algorithm is suggested where a node sends data to a nearby CH whose moving path is identical to the message's communication direction. The communication path is determined by a node's location and destination location coordinates.

The authors suggested an enhanced greedy traffic-aware routing (GyTAR) in Jerbi et al. (2009) [31], which is a spatial routing procedure centered on the intersection. It uses the idea of clusters among adjacent intersections to transmit the data. The routing protocol for VANETs for vehicle intensity and load-aware (VDLA) was suggested in Zhao et al. (2012) [32], which chooses a set of junctions to create the path to the target. The option is established on the density of the vehicle in real-time, the traffic density, and the distance to the target.

Abuashour et al. (2017) [33] introduced the CBLTR protocol, which is a cluster-aware lifetime routing algorithm with the aim of maximizing route robustness and throughput in a bi-directional sector situation. The CHs are chosen by considering the lifetime of all vehicles in each cluster. According to its current position, destination position, and average throughput, the CHs choose the best path. The proposed protocol also reduces cluster control overhead between member nodes and the CH. According to the simulation data, it significantly outperformed in respect to E2E delay and throughput.

In Louazani et al. (2014) [34], the cluster-based protocol for connectivity maintenance in VANET called AODV-CV is presented, in which the CH is elected based on the nearest definite velocity to the average velocity of all nodes situated within the cluster zone. The AODV-CV protocol outperforms AODV regarding throughput by increasing the velocity.

In Malathi et al. (2017) [35], the authors presented a cluster-based routing protocol that considers the target of the vehicle and the perspective for CH election and routing. However, the proposed work is based on dynamic clustering that maximizes the clustering messages overhead. A new algorithm for the system to sort a cluster architecture and CH election suitable for vehicular networks is suggested in Mohammed et al. (2016) [36]. Moreover, it shows a novel clustering-based routing approach that ensures efficient data communication among vehicles.

Rawashdeh et al. (2012) [17], rationalized a threshold-based system for highway roads, in which the slowest vehicle among the neighbors activates the cluster creation procedure. It is based on relative speed, in which neighbors inside the range travel at a slower rate than the given threshold associates under the corresponding CH. The CH selection is dependent on the vehicle's proximity to its mean location and velocity. The CH does not need the node that starts the formation process.

Willis et al. (2015) [37], proposed the ASPIRE mechanism, which operates in a distributed way and is focused on local fission. It aims to construct massive clusters while maintaining high node interconnectivity. Also, when there are a lot of CH shifts, it provides better connectivity. As two CHs come into range, delaying the reclustering phase for a while improves cluster stability. This eliminates the need for redundant clustering.

In Aravindhan et al. (2019) [38], a hybrid clustering mechanism is presented that merges the geographic- and context-aware clustering methods. Each node calculates a weight according to a specific factor: velocity, distance, residual lifetime, point of interest, and direction. The vehicle with the highest weight is chosen as CH. The hybrid clustering decreases control overhead in the network and the destination-aware routing enhances the PDR and minimizes the E2E delay.

Both of the above-mentioned clustering and routing protocols are part of the traditional computational area of obtaining provably optimal clustering and routing solutions. However, due to their high complexity and low efficiency, these solutions are insufficient for VANETs Soft computing has recently attracted a lot of attention due to its outstanding performance outcomes and excellent abilities to address theoretical issues and its broad applicability [39]. Soft computing aims to find a precise approximation that provides a reliable, computationally efficient, and cost-effective solution that reduces computation time. Soft computing techniques are being used in VANET to provide adaptability and robustness in the face of network failures and changing wireless conditions.

Soft computing offers an effective method that causes intelligent action in a dynamic and complex situation such as VANETs [40]. In recent years, various soft computing techniques like Particle Swarm Optimization (PSO), K-means, Neural Networks (NN), Firefly Algorithm (FA), Fuzzy Logic (FL), Artificial Bee Colony (ABC), Genetic Algorithm (GA), harmony Search Algorithm (HSA), Ant Colony Optimization (ACO), Reinforcement Learning (RL), and Support Vector Machine (SVM) are presented to upgrade the clustering and routing efficiency of VANETs [15]. Such clustering protocols have proven to be successful in the face of VANET-specific challenges like network failures, complex topology, and node flexibility. Providing versatility and strength to network failure, complex network topology, and flexible channel requirements in VANETs is an idea of using soft-computing approaches. This section discusses clustering and routing protocols based on soft computing in VANETs, as shown in Fig. 2.1. However, clustering is done when some common parameter is found in the network like speed, distance, connectivity, etc. Clustering enhances the efficiency of the network by disseminating the information in a common group. Various kinds of challenges are resolved with the clustering techniques in vehicular area networks. MANET protocols are not effective when implementing in a vehicular environment with high speed and dynamic topology.

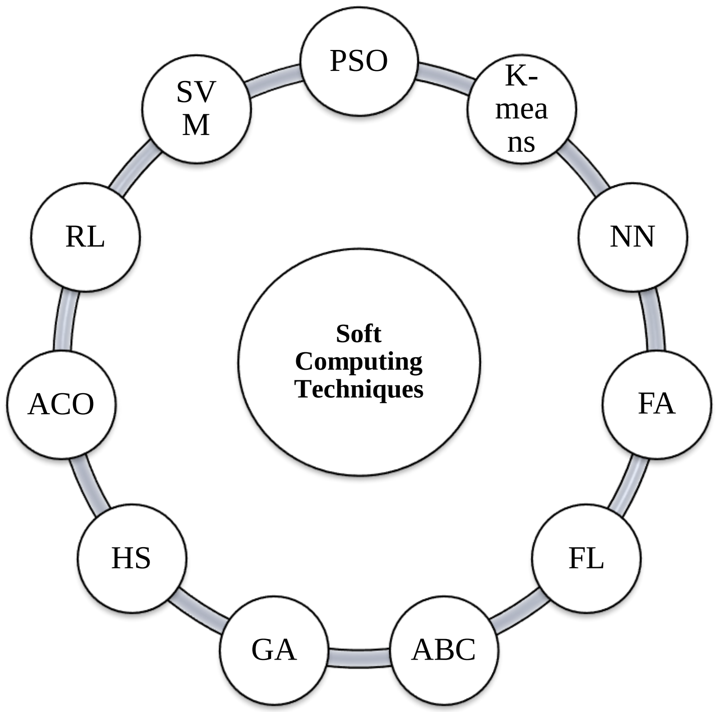

Figure 2.1 Soft Computing Techniques in VANETs

2.1.1 PSO

PSO is replicated by the social habits of bird flocking. It includes a swarm of particles N_P, in which a particle i captures a position $X_{i,d}$ and a velocity $V_{i,d}$ in the global search area. Fig. 2.2 shows how a particle achieves the best optimal solution.

Throughout the search time, each particle displays its own individual best named as $pBest_i$ and a global best named as $gBest$. Later obtaining the $pBest_i$ and $gBest$, particle P_i revises its velocity and position in every iteration by utilizing the given equations:

$$V_{i,d}(t+1)=w\times V_{i,d}(t)+c_1r_1(pBest_{i,d}-X_{i,d}(t))+c_2r_2(gBest-X_{i,d}(t)) \quad (2.1)$$

$$X_{i,d}(t+1)=X_{i,d}(t)+V_{i,d}(t+1) \quad (2.2)$$

where, w suggests the inertial weight r_1, r_2 , show two evenly dispersed random digit and c_1, c_2 suggest two non-negative factors known as acceleration factor generally set to 2.0. After discovering a new location in every iteration, the $pBest_i$ and $gBest$ of particle P_i is updated by calculating the fitness function. This method is repeated till a static amount of iterations is achieved [41].

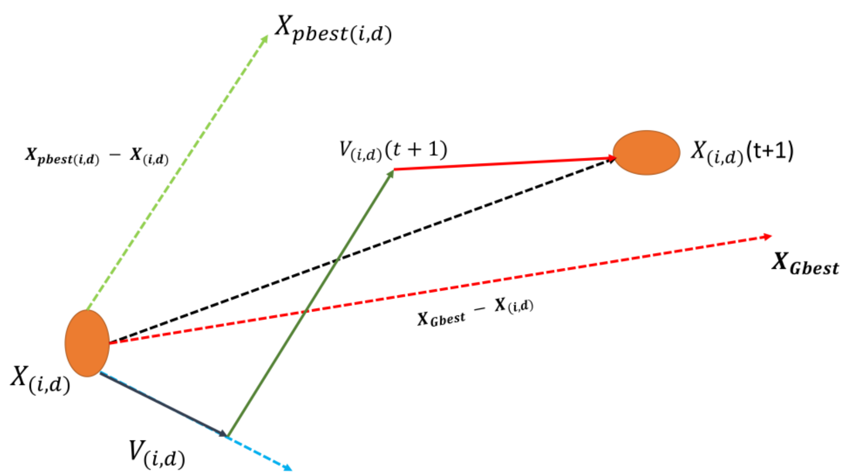

Figure 2.2 Particle Representation in PSO.

Bao et al. (2020) [42] proposed PSO-based efficient clustering V2V routing (CRBP) scheme in VANETs to increase the execution of V2V. The protocol consists of three elements: cluster formation, particle coding of the path, and cluster routing. Initially, vehicles are identified with identical changing routes, and the CHs are chosen. Second, the path particle and its speed, iteration procedures, and fitness functions are intended for optimal routing. Thirdly, methods are suggested that can considerably enhance the effectiveness of routing. In an attempt to create a balanced cluster, the position, velocity, and neighbors of the nodes are gathered, the link fitness is determined so that the optimal route can be found immediately. The simulation results signify that node density, node contact radius, and large hops among the CH and any member node have a significant impact on CRBP performance; CRBP has a 20 % growth in PDR compared to CBVRP and QoS-OLSR and a 47 % decline in delay.

Husain et al. (2020) [43] investigated a geocast routing protocol locating the PSO approach with the next vehicle (NHV) and designed the fitness mechanism to make convergence quick and easy to identify both local and global maximums. The authors used PSO with a fitness function to select an optimal next hop vehicle that extends PDR and reduces delay and routing capacity to forward information to the geocast area in a timely manner. The proposed protocol performs optimal because the fitness feature utilized in PSO decreases latency and improves throughput and PDR because PSO convergence is fast. In less time, local maximums are achieved.

2.1.2 K-means

It is a centroid-based approach in which every cluster is connected to a centroid. The primary goal is to reduce the distances among the data point and their consequent clusters. It takes the simple dataset as input, separates it into k-amount of clusters, and reiterations the procedure until it does not determine the optimal clusters as presented in Fig. 2. The k-means clustering primarily executes two tasks:

- Find the optimal value for K by an iterative procedure.
- Allocates each data input to its nearby k-center and generates a cluster.

Hence each cluster has datapoints with some unities, and it does not belong to other clusters. However, the K-Means clustering method has been utilized effectively to resolve various VANET issues [44].

Elhoseny and Shankar (2020) [45] proposed a clustering-based optimization approach to extend the energy efficiency of V2V communication. This paper introduces the model of K-Medoid to cluster the vehicles, and then energy-efficient nodes are accepted for convincing transmission. The successful node identification of VANETs was presented in this paper, considering at least the energy utilization factor. A k-means algorithm recognizes influential nodes from each cluster with the probability of achieving energy-efficient transmission. In various modifications, the K-medoid process groups the vehicles and selects any nodes in some rounds as CHs. It can decrease the amount of communicated messages from one node to another, saving the network more resources. At that point, through the evolution of the network factor (EC) using the EDA algorithm, the optimal path for V2V transmission was acquired between the vehicles in VANETs.

Ramalingam and Thangarajan (2020) [46] suggested a dynamic grouping that fits well with VANET's dynamic topology characteristics by K-implies. The suggested strategy fits admirably with the number of bunches referred to in advance and even the mysterious number of categories. The user has the opportunity to resolve the number of bunches needed in this method. This measure demonstrates the new focus of the bunch by increasing the unit counter by one in each concentration until the goal work is accomplished. The same can be established, and it is possible to overcome the ideal CHs and the connection between CMs and CHs. There is a dynamic weighting potential for Dynamic K-Means. The detailed analysis shows that the proposed computation produces subtle improvements in main VANET factors. This calculation decreases the number of messages and further increases the proportion of package transport.

Khan et al. (2016) [47] explored a new Triple Cluster Routing Protocol (TCRP) for CH selection utilizing the revised K-Means. The updated K-means divide the vehicle nodes inside their velocity confidence variety into three clusters. For all VANET pairs of vehicles, the Floyd-Warshall algorithm determines the smallest path. A vehicle with the lowest average distance to the other and the smallest velocity variation will be chosen as the CH. The simulation results demonstrate that the TCRP keeps the cluster structure constant and prevents CH reselection incoming rounds, thus creating reasonably stable vehicle clusters. By eliminating message flooding, TCRP gains control over the network's excessive overhead.

2.1.3 Neural Network

A NN is a vast network of interconnected elements formed by human neurons. A neuron performs a small number of processes, and the weighted amount of these is the entire process. A neural network must be conditioned by a well-known set of inputs to generate the desired outputs. Training is usually done by feeding, instilling trends in the method, and allowing the network to alter its weighting function according to specific learning rules previously developed. There may be supervision or unmonitored of the learning. An ANN consists of basically three layers: Input, secret layer, and output, where nodes may have numbers in each layer. This measures the performance of NN against the target output, and the weights among layers are changed, and the procedure is repeated until a very minor fault remains if the results are not as expected [48].

Mohammadnezhad and Ghaffari (2019) [49] proposed a clustering-based routing protocol in which nodes are grouped using an imperialistic algorithm based on motion parameters like node degree and velocity. The CH is chosen based on the quantity of buffer space available and predicted communication count based on the radial base function NN algorithm. A node will be selected as CH in a given cluster if it has the highest free space and the least estimated communication count. According to simulation performance, the proposed protocol improves PDR, throughput, and E2E delay.

Bagherlou and Ghaffari (2018) [50] proposed a clustering-based reliable routing algorithm with stable implementations. In this way, for suitable clustering of nodes, simulated annealing was used, and the parameters like node degree, network coverage, and capacity are taken into account. The radial base function neural network is utilized to choose the CH, and an adequate fitness value based on velocity and free buffer size is employed. Every cluster has two gateways that are being used for the transmission of the packet as the communication interface. The simulation results showed the effectiveness regarding route detection rate and transmission rate of packages.

2.1.4 Firefly Algorithm

FA imitates the characteristics and twinkling behavior of tropic firefly swarms. FA has two essential resources, which becomes it better in comparison to other computational methods. The exceptional characteristics of the FA are local attractions and automatic regrouping. Since light strength and distance are proportionate, based on the absorption coefficient, the attraction among the fireflies tends to be global or regional. This allows both global and regional modes to be visited. FA has the ability to sub-split and regroup on the basis of the neighboring attractiveness; this merit of FA becomes it more acceptable for clustering issue [51].

Joshua et al. (2019) [52] proposed a reputation-based Weighted Clustering Protocol (RWCP). To stabilize the VANET topology, it is enclosed by considering the path of vehicles, location, speed, neighboring vehicles, and the status of each node. The work uses a multi-objective issue that takes the considerations of the RWCP as the feedback and intends to provide an improved cluster lifespan, enhanced packet distribution ratio, and decreased overhead of the cluster. An evolutionary approach, the Multi-Objective FA, is used to optimize the factors of the RWCP. The TETCOS NetSim simulator and MOEA structure have been used to refine simulations. With similar evolutionary optimization methods, the results are tested. The simulation results indicate that the suggested technique for the Mean Cluster Lifespan, PDR, and Control Packer Overhead performs well.

2.1.5 Fuzzy Logic

FL is a numerical tool developed to convey approximate human thought. FL produces intermediary standards centered on inference rules and linguistic variables, as opposed to a conventional set theory in which the outputs are either real or untrue. There are four fundamental components of a fuzzy logic scheme, specifically fuzzification, defuzzification, rule base, an inference engine, as shown in Fig. 2.3. The fuzzification component plans the device responses to the appropriate fuzzy sets. It designates every fuzzy set which is defined by a language word, such as "high," "low," "moderate," "small," and "large" membership degree.

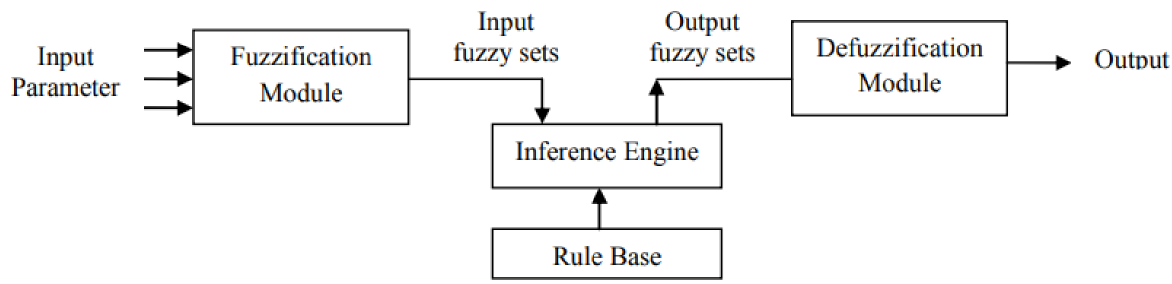

Figure 2.3 Fuzzy Logic System

If-then rules are stored by the fuzzy inference engine, the fuzzified values with the aid of the fuzzy rule are mapped to linguistic output variables. The results obtained from the inference scheme are translated by defuzzification like the averaging technique and the centroid technique into crisp values [53].

Moridi et al.(2017) [54] suggested a stable multilevel clustering routing protocol in VANETs. It is an expansion of the AODV protocol at the first level, strengthened by using fuzzy logic to establish efficient routing between members of the cluster. For routing among CHs and destination, Tabu search was used at a higher level. This approach is used to solve problems with hybrid optimization and utilizes a cost function to choose a resolution from a range of potential solutions. Node size, node velocity, node angle, and reliability are the efficient metrics for selecting the optimal path. The simulation result showed an improved transmission rate of packets and reduced average E2E delays, the number of packet failures contrasted to previous protocols.

2.1.6 Artificial Bee Colony

To optimize the multi-variable function problem, the ABC procedure using the foraging capacity of honey bees. Honeybees forage can be organized into three assemblies in the ABC for food source: working, onlookers, and scout bees. Based on local data, the forager bees take advantage of a food source within their surroundings. Though, if fitness value related to a different food source is improved as compared to the previous one, then bees consider the new location and ignore the previous one. Afterward, the entire quest is completed by every employed forager's bees; they share the food source's fitness details like path, and productivity with onlooker bees, via a waggle dance. It analyses the fitness value and selects a source of nutrition having a more excellent prospect of finding nectar. When existing food supplies run out after a few forages, scout bees start looking randomly around the hive for new food sources [55].

Fekair et al. (2016) [56] suggested a QoS-based unicast clustering algorithm. This protocol considers two methods: a clustering algorithm that arranges and optimizes data transmission according to QoS constraints and an ABC that discovers the best routes based on QoS criteria from a source to a destination. Clusters are built in our approach around cluster-heads chosen based on QoS consideration: usable bandwidth, E2E delay, jitter, and expiration time of the connection. Via simulation, it shows that by selecting routes based on the QoS parameters, the method can greatly improve routing efficiency in VANET. The findings show that optimal route selection enhances PDR, E2E delay, and network overhead.

Bitam and Mellouk (2011) [57] suggested a QoS multi-path routing algorithm termed as QoSBeeVanet. It is centered on the biological bee communication model of the food source. This protocol used scouts and foragers to find network data and carry data to the destination, in which each scout reports his data in a weighing table. Each route in that table has to be weighed by a weighting factor according to its efficiency.

Bitam et al. (2014) [58] introduced hybrid bee swarm routing called HyBR. It is a unicast and multi-path routing algorithm that provides road security through low latency packets and high packet delivery. When the network is densely linked, use a topology-based routing process that utilizes two kinds of network discovery packets: Scout and Forager inspired by bee contact, and use a connected routing method when the network densities are low. Geographic routing is a routing technique in which a GA is used to determine the shortest path between the source and the target.

2.1.7 Genetic Algorithm

It is an evolutionary process that mimics evolution's mechanism in an attempt to generate optimized solutions. It begins with the randomly produced population of people, called chromosomes, according to the problem. An individual chromosome is a set of genes containing a portion of the solution. Based on the specific issue, the fitness value is estimated, and the chromosomes related to large fitness costs are chosen in the next generation for the reproduction process. In the next phase, chromosome recombination is done using a crossover process to replicate original children. To produce new offspring, the crossover process combines the genetic features of two parents. On the chosen chromosomes, a mutation procedure is executed to have children by modifying the genes of particular chromosomes. The process is repeated until an optimal solution is attained [59].

Hadded et al. (2015) [60] proposed an Adaptive Weighted Clustering Procedure (AWCP) to enhance the stability of network topology, which considers vehicle direction, location, velocity, and a number of neighboring nodes. The numerous parameters of AWCP consider this problem as non-trivial. The authors describe a multi-objective problem to optimize the protocol whose goals are: delivering stable cluster architectures, optimizing the rate of data transmission, and minimizing overhead clustering. The authors fix this multi-objective issue with version 2 of the Nondominated Sorted Genetic Algorithm (NSGA-II). The simulation results demonstrate that AWCP attains considerable improvement regarding arrangement, distribution, and inverse generational distance.

Garg and Wadhwa (2016) [61] proposed G-AODV, a reliable on-demand routing mechanism that aims to improve path robustness and reliability in VANET. It is based on enhanced-GA, which improves the AODV principles. After the route discovery process, GA retrieves three delay-optimized routes from numerous existing routes among the source and destination. The GA method begins with redeploying the request routes that describe the initial population's chromosomes, followed by tournament selection and genetic operations to enhance the stochastic optimal solution. If possible, a two-point crossover is placed, The GA flowchart is given in Fig. 2.4 and the mutation operator compares the chromosomes with the best local evaluations to find better solutions.

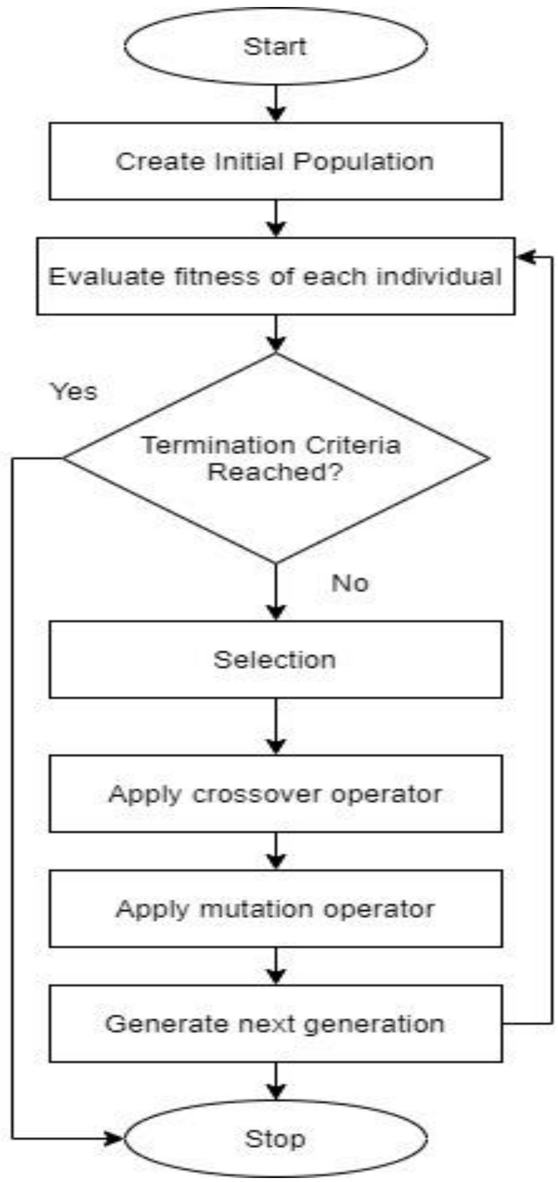

Figure 2.4 Flowchart for Genetic Algorithm

2.1.8 Harmony Search Algorithm

HS is an essential evolutionary approach intended to imitate the process of jazz musicians improvising. HS creates random resolutions that are called Harmony Memory. In each iteration, a new solution is designed and compared with the worst resolution.

It is substituted with the severest resolution if a new resolution is better. The phase continues until the condition of termination is fulfilled. HS algorithm's strength lies in its capability to effectively arrive at a global solution [62].

Chandren et al. (2021) [63] proposed an enhanced HAS mechanism that considers the configuration of OLSR factors by embedding two common selection methods, namely, roulette wheel selection and tournament selection, in its memory. According to the simulation results on a highway scenario, the improved HSO outperforms the OLSR regarding packet distribution ratio and routing overheads.

2.1.9 Ant Colony Optimization

The foraging nature of real ants in nature influenced ACO. The ants communicate with one another via pheromone, which acts as an intermediary. It's a flammable substance created by ants as they hunt for food. However, the pheromone trail's focus is to find the smallest route from their habitation to the food source.

ACO is made up of two types of functioning insects: forward and backward ants. Forward ants use two factors to create probabilistic solutions: pheromone and heuristic data. The probability of the k_{th} ant choosing point j from point i is determined as below.

$$P_{ij}^{k} = \left\{ \frac{\left[\tau_{ij}\right]^{\alpha}\left[\eta_{ij}\right]^{\beta}}{\sum_{j=1}^{N}\left[\tau_{ij}\right]^{\alpha}\left[\eta_{ij}\right]^{\beta}} \right. \quad (2.3)$$

where pheromone τ_{ij} specifies previously achieved potential result, the heuristic η_{ij} signifies the previous data of auspicious solution, α and β are weight constraints which regulate the influence of pheromone and heuristic.

When all of the forward ants have arrived at their food source, they turn to backward ants and fully revise the pheromone strength along the route while moving in the direction of the nest, as shown below.

$$\tau_{ij}(t+1)=(1-\rho)\tau_{ij}(t)+\rho\Delta\tau_{ij}(t+1) \tag{2.4}$$

where ρ signifies pheromone vaporization level, τ_{ij} signifies the amount of pheromone left on edge (i, j) and $\Delta\tau_{ij}(t+1)$ signifies pheromone amount accumulated on edge (i, j) in existing iteration. Fig. 2.5 describes the function of the ACO algorithm [64].

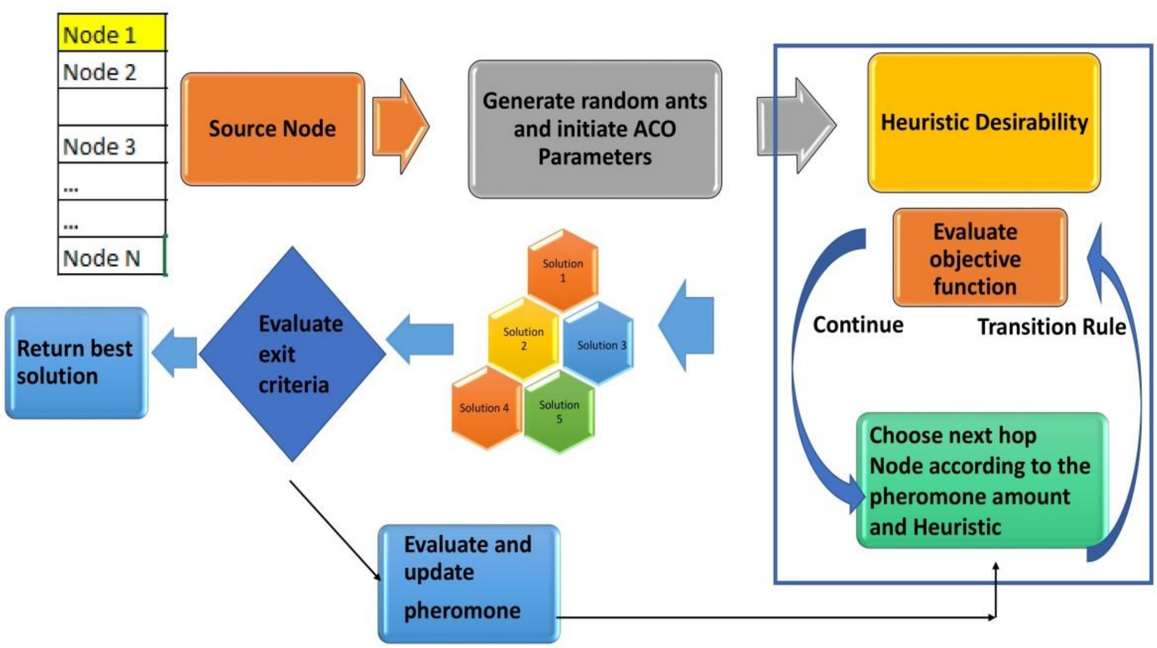

Figure 2.5 Operation of ACO

Rana et al. (2013) [65] suggested a solution known as MAZACORNET for finding multiple routes among network nodes, where they created a hybrid, multipath ACO-based routing procedure. Where the network is separated into many areas, a proactive method is utilized to identify a path in the area, and a reactive way is used to locate a path from one area to another using local knowledge stored in each area. This algorithm is scalable as well as resistant to connection failures. If connection failures do not occur, the stability in the vehicular network will increase. The stability parameter is crucial for any kind of network as with this efficiency of the network will also increase. Multiple routes in the network help to forward a message in the congested network. So the clusters can be made from different areas of the network.

2.1.10 Reinforcement Learning

RL allows an agent to conduct reasonable actions according to previous interactions and rewards to achieve its goals. The agent accepts the status of existing states and intends to take action based on its cumulative information at each point, as shown in Fig. 2.6.

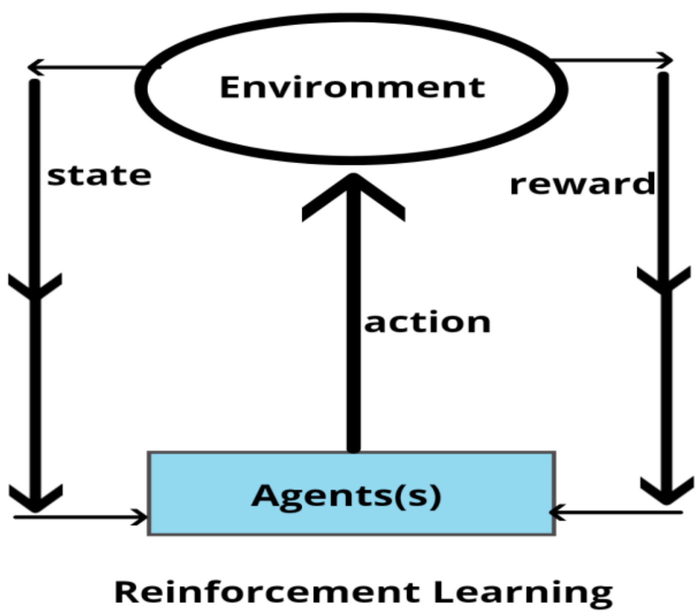

Figure 2.6 RL Model

A scalar RL reward, r, is used to send this state change information to the agent node. This reward denotes that performing an action when in a particular state is appropriate. The learning agent associates every state-action set with maximum reward according to its previous knowledge over time, resulting in optimal performance evaluation [66].

Yang et al. (2020) [67] propose HQVR, a heuristic Q-learning-based routing for VANET. The protocol chooses a hop according to the reliability of the connection. The learning process in HQVR is focused on the information gathered through the sharing of beacon packets, and it is a distributed algorithm. According to the authors, the rate of beacon messages affects the convergence of the Q-learning algorithm, causing convergence to be slower. The relation length ratio determines the learning rate in HQVR. The rate of learning defines the level of convergence according to the characteristics of the Q-learning protocol. As a consequence, the need for discovery decreases with a higher relationship. The source, therefore, has the right to select the optimal path from the alternatives available. Then the best optimal path is selected and the packet is routed in the network.

In Bi et al. (2020) [68], the authors proposed RL based routing protocol called RLRC in VANET. To create cluster between vehicles, the authors used an enhanced edition of K-Harmonic Means. The CH will be required to share a large number of packets with other CHs and the CMs of its own cluster as RLRC creates clusters to minimize the number of state spaces. As a consequence, RLRC considers the vehicle's energy parameter when selecting CH. To ensure seamless connection, bandwidth is chosen as the next factor when selecting a CH. The least distant node is chosen as the CH according to relative distance. In the RLRC protocol, the SARSA (λ) version is utilized to refine the routing procedure and reduce learning time. Compared to protocols in which each node is a state, RLRC decreases the amount of the state space by building clusters, and the convergence time is faster.

2.1.11 Support Vector Machine

SVM is a vector-oriented method that can perform pattern recognition and regression based on the principle of statistical study and the structural risk minimization principle. SVM provides a number of training examples, each one of which is designated as one of the various categories; an SVM training algorithm constructs a model that forecasts the category of the new examples. It separates two groups by a wide margin in order to keep them as far apart as possible, as shown in Fig. 2.7. It is done through the transformation of small input space into significant inputs, which turns non-distinguishable classes into discrete classes. Kernelized SVM is a common method for addressing classification problems. The use of the SVM classifier in applications like clustering, multi-class grouping, and ranking, on the other hand, adds to the computational load. As a result, SVM is often suggested for binary categorization.

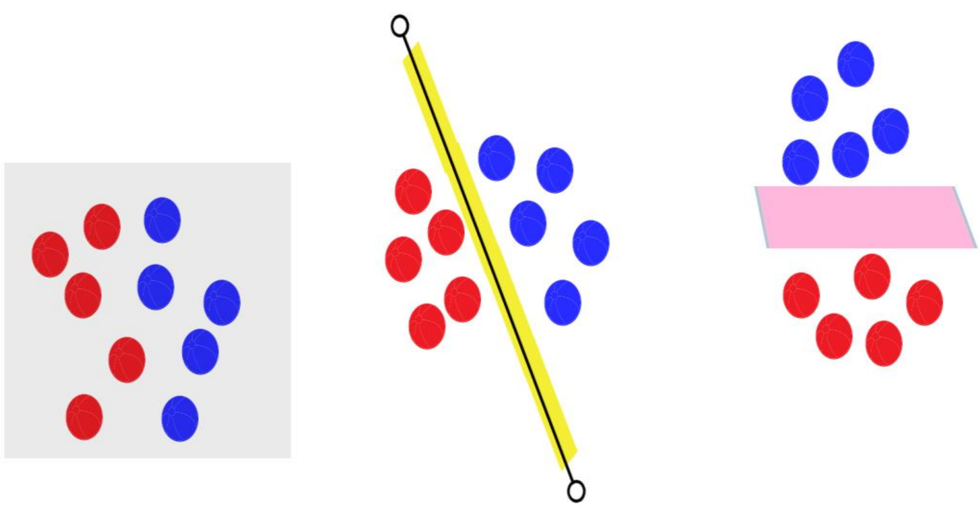

Figure 2.7 Principle of SVM

Zhao et al. (2016) [69] suggested a greedy forwarding routing procedure in VANET based on the SVM technique. The SVM in the proposed approach is used to manage vehicle information and produce routing parameters in order to improve routing efficiency. By applying a large amount of classified data (features including the distance among forwarding and next-hop nodes, moving direction of next-hop nodes, acceleration of next-hop and forwarding nodes), the model is obtained by training such dataset in SVM. The simulation results show better reliability and communication efficiency are achieved.

2.2 Comparative Analysis

This section describes the comparative evaluation of surveyed soft computing-based clustering and routing protocols employed in VANETs. Table 2.1 emphasizes the proposed soft computing approach; issues addressed, and performance parameters of the reviewed clustering and routing protocols in VANETs. This section also enables the researchers to evaluate numerous soft computing techniques discussed in this chapter and select the suitable computing technique according to merits and limitations as demonstrated in Table 2.2 to deliver efficient clustering and routing in VANET.

Table 2.1 Evaluation of Surveyed Protocols

Paper	**Proposed Approach**	**Issues Addressed**	**Performance parameters**
Bao et al. (2020) [42]	PSO	Routing efficiency in VANET	PDR, E2E delay
Husain et al. (2020) [43]	PSO	Scalability and overhead for routing	Delay, the routing load, dropped packets, throughput, and PDR
Elhoseny and Shankar (2020) [45]	K-means	The energy efficiency of V2V communication	Energy consumption

Ramalingam and Thangarajan (2020) [46]	K-means	Adaptability towards dynamic network topology	PDR
Khan and Fan (2016) [47]	K-means	Eliminate message flooding	Energy consumption, Delay
Bagherlou and Ghaffari (2018) [50]	NN	Dynamic clustering in VANET	Route discovery rate, PDR
Mohammadnezhad and Ghaffari (2019) [49]	NN	Ensure reliability in VANET	PDR, Throughput, E2E delay
Joshua et al. (2019) [52]	FA	Maximize cluster lifespan	Mean Cluster Lifetime, PDR, Control Packet Overhead.
Moridi et al. (2017) [54]	FL	Effective routing in multi-level clustering	PDR, E2E delay, and Packet loss rate
Fekair et al. (2016) [56]	ABC	Decide the best route based on QoS criteria.	PDR, E2E delays, and the network Overhead
Bitam et al. (2011) [57]	ABC	QoS in VANET routing	E2E delay and PDR
Bitam et al. (2014) [58]	Hybrid bee swarm	Timely dissemination of messages to improve road safety	Average E2E delay and PDR.
Hadded et al. (2015) [60]	GA	Stability of network topology	Data delivery rate and Clustering overheads
Garg and Wadhwa (2016) [61]	GA	Improve route stability and reliability	PDR, throughput, and delay

Chandren et al. (2021) [63]	HS	Flexible routing due to the dynamic nature of VANET	PDR and network overhead
Rana et al. (2013) [65]	ACO	Effective bandwidth utilization, scalability, and robustness	E2E delay and PDR
Yang et al. (2020) [67]	Q-learning	Unreliability of the link due to vehicle movement	PDR and E2E delay
Bi et al. (2020) [68]	RL	Multi-hop reliability and efficiency	PDR
Zhao et al. (2016) [69]	SVM	Generate routing metrics to enhance reliability	Packet loss and network delay

The comparison of different soft computing techniques with their merits and limitations are represented in Table 2.2, however, various other techniques are there but in this work, few of them have been highlighted.

Table 2.2 Comparison of Soft Computing Techniques

Soft Computing Techniques	**Merits**	**Limitations**
PSO	• PSO is used due to its simplicity to implement on software and extremely optimum resolution. • PSO based clustering algorithms indicate considerable progress in	• PSO's iterative nature precludes it from being used in graphical applications.

	terms of strength and flexibility	
K-means	• Comparatively easy to implement. • Guarantees convergence	• Difficult to approximate K-value • It didn't suit properly with a global cluster.
NN	• NNs deal with incomplete sets of data. • NNs are useful in prediction.	• In complex ANN systems, excessive training can be needed.
FA	• For determining the fitness function, the FA has relatively fewer parameters.	• It is not successful in defining the high-performing regions in search space for complicated issues.
FL	• The least system improvement cost, design time, and computing memory are needed to execute FL.	• Fuzzy laws do not conform to the complexities of the network and need to be re-learned under difficult network circumstances.
ABC	• It achieves global optimization via discovery by artificial scouts and local optimization by exploiting onlookers and employed bees.	• Because of the random solution, ABC has a sluggish convergence issue.
GA	• The inherent parallel environment makes GAs appropriate for the process of data collection.	• GA has a slow speed of convergence that limits its execution in real-time applications.
Harmony search	• It has relatively fewer parameters to calculate the fitness value • It has the capability to detect areas with improved results.	• For complex issues, HS is not effective in detecting the global solution in a large search space.
ACO	• It has the capability to resist an extremely vigorous environment.	• It initially requires the necessary information to find optimal routes.

RL	• No specific network state information is needed for optimal path allocation.	• It requires adequate time to learn network topology.
SVM	• It is pretty efficient in large dimensional spaces. • It is comparatively memory effective.	• It is not appropriate for large data sets. • It does not perform properly when the data sets are overlapping.

CHAPTER 3: Routing Protocols in VANET

3.1 Routing Protocols

The routing protocol in VANET is an attractive and promising area of research where routing protocol helps nodes in generating routing tables. In the high mobility scenario of VANET, the disseminating of the messages is quite difficult. So routing protocols take care of the communication and routing the data by utilizing routing tables which include information of their neighboring nodes, this routing information is used in finding the best-suited path [70]. There are various categories for the routing protocols, which are as follows and represented in Fig. 3.1.

- Topology Based Routing Protocols
- Location driven Routing Protocols
- Cluster-based Routing
- Geo-cast Routing
- Broadcast Routing

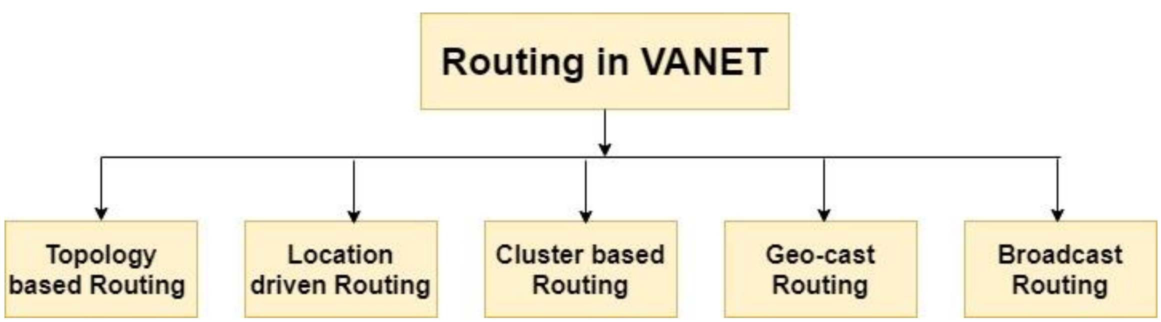

Figure 3.1 Routing Protocols in VANET

The VANET is a network where frequent disconnections occur and with various applications in intelligent transportation systems. There are several routing protocols for setting up a path between a source node and a destination node. AODV protocol [71, 72] which broadcast the route query to all neighboring node, and then those nodes will forward the request to their neighboring nodes. This process helps in selecting the path from sender to receiver. AODV protocol is the best performing routing protocol when the number of nodes for communication is more in number. The path which is established using reactive routing protocol [73, 74] has high chances of congestion in the network and also consumes a large amount of network bandwidth. This research is based on establishing a path from sender to receiver using a multicasting approach and also reduce the chances of congestion in the network. It will generate a path with the shortest distance and leads to improve throughput, reduce packet loss and delay when compared with the existing protocol.

This protocol provides assistance in the dissemination of information from one vehicular node to another vehicular node. There is a difference between the traditional ad-hoc network and the routing in VANET due to utilized topologies is highly dynamic as compared to the former. All the developed protocols for the Mobile ad-hoc network environment were tested on the vehicular area network. Hence, it remains a challenge that how to reduce the associated delays from the passing message from one node to another node. The primary role in VANET is to find out and maintain the desired path for communication purposes. There are different routing protocols for every situation.

3.1.1 AODV Protocol

Due to the high mobility of the vehicle nodes, there are various issues that reside in this network, such as routing, quality of service, and vehicles nodes movement. To achieve secure and efficient path from sender to receiver, routing protocols are classified into reactive, proactive, and hybrid. The AODV [75] is the reactive type of routing protocol in which the source will flood the route request packets, and nodes that are adjacent to the destination respond with the route reply packets.

In the AODV protocol, the algorithm selects the best path from source to destination based on hop count and sequence number. The path will select from source to destination on the basis of hop count and sequence number. The path which has been selected is the shortest and reliable. Due to high node mobility, there are very few chances of link failure, which reduces the quality of service. The information is gathered by the source node in the reactive routing protocol so that they can generate a path to the destination when they desire. AODV protocol is one of the examples of this protocol by which a path is established between sender and receiver [76, 77]. AODV will generate a route between nodes whenever a request to transfer data packet is generated; that's why it is known as on-demand distance vector routing.

Along with links, it does create any additional traffic. Routes are active at every node till the transmission is not fully completed and till the time source needs these routes. AODV forms trees for connecting with the multicast group members. It uses the sequence number to ensure that the path established is active or not. AODV is a self-initializing protocol and starts path establishment whenever the source wants to transmit data. In AODV, no communication is done till the path establishment process is done. Source node when need connection, it will broadcast route request message for a connection. The node is receiving the request messages stores a route towards the requesting node. All the entries which were not used in path establishment will get erased and are re-entered after some time. If any route failure occurs, the routing error message is sent back to the route-initiated node, and the whole process of establishing the route is repeated from starting [78].

Generally, the source will initiate the route request for establishing the path from origin to the target node. So here the algorithm 3.1 is proposed for selecting the best route selection from source to destination. The root node will also be selected in the vehicular network and the source node sends the route request message to the root node in the network.

The proposed protocol takes into the account coverage area, stability, and buffer size of the nodes to select an optimal route. While the coverage area ensures that as and when a node having higher coverage is chosen in the optimal path, it has enough neighbors for route maintenance in case there is any issue related to link breakage in the path. Secondly, the focus has also been given to the stability of the nodes which is being computed based on the speed of the nodes. The nodes moving with higher speeds tend to have poor link stability. Since such nodes have a higher probability of getting chosen in the optimal paths, it may also lead to congestion over it. Therefore, buffer size has also been included as one of the parameters while selecting the optimal path.

Therefore, the proposed protocol aims at maximizing the throughput as well as PDR by selecting the node having higher stability and buffer size (it can store more packets which eventually will lead to higher packet delivery rate and throughput); minimizing the delay (as higher coverage area will lead to quick route rebuilding in case of path breaks). The objective function is thus defined as:

$$f = \alpha * f_{cov} + \beta * f_s + \Upsilon * f_b \quad (3.1)$$

$$f_{cov} = N_{nei} \quad (3.2)$$

$$f_s = V_i - Mean(V) \quad (3.3)$$

$$f_b = B_s - P_b \quad (3.4)$$

Where f is the objective function which needs to be maximized; f_{cov} , f_s and f_b are the fitness functions related to the coverage, stability, and buffer size; α, β, Υ are constants with the sum equaling to 1.

N_{nei} is the number of neighboring nodes; V_i is the velocity of the node and $Mean(V)$ is the average velocity of the neighbors, B_s is the buffer size; P_b is the number of packets in the buffer.

Algorithm 3.1: Best Route Selection Algorithm

Input: Vehicle nodes

Output: Best path Selection from source to destination

1. Deploy network with a finite number of vehicles nodes
2. Select root node ( )
    a. For i to number of nodes
    b. if (coverage area , stability and buffer size of node(i) > coverage area and stability of node(i+1))
    c. Root node=Node(i)
    d. Else
    e. Root node=Node(i+1)
3. Source sends a route request message to the root node
4. if(destination is the range of root node)
5. Reply to a source with a route reply packet
6. Else
7. Forward route request to next root node
8. Repeat step 4 to 7 until destination found
9. Source start sending data to the destination

While the existing protocols such as AODV, DSDV, and CBRP ignore these parameters, the inclusion of these parameters in the proposed routing protocol makes it novel in comparison to the above-mentioned techniques.

The distance is calculated between each node, and pheromones are updated, which has the least distance from source to destination. The approach which is discussed so far uses broadcasting techniques. The path established using reactive routing protocol has high chances of congestion in the network and consumes a large amount of network bandwidth [79]. The process of initialization, path establishment, and setting root node and communication process is shown in the various figures shown below.

As represented in Fig. 3.2, a finite number of vehicular nodes have been taken in the network. Also, the roadside units are established in the network, which is also finite in numbers to satisfy the situation. The vehicular nodes are also finite in numbers, and their movement is limited in the vehicular environment to achieve the results in traffic conditions as the network deployment, source, and destination, path establishment, communication and formulation of new root nodes is also shown in the figures below.

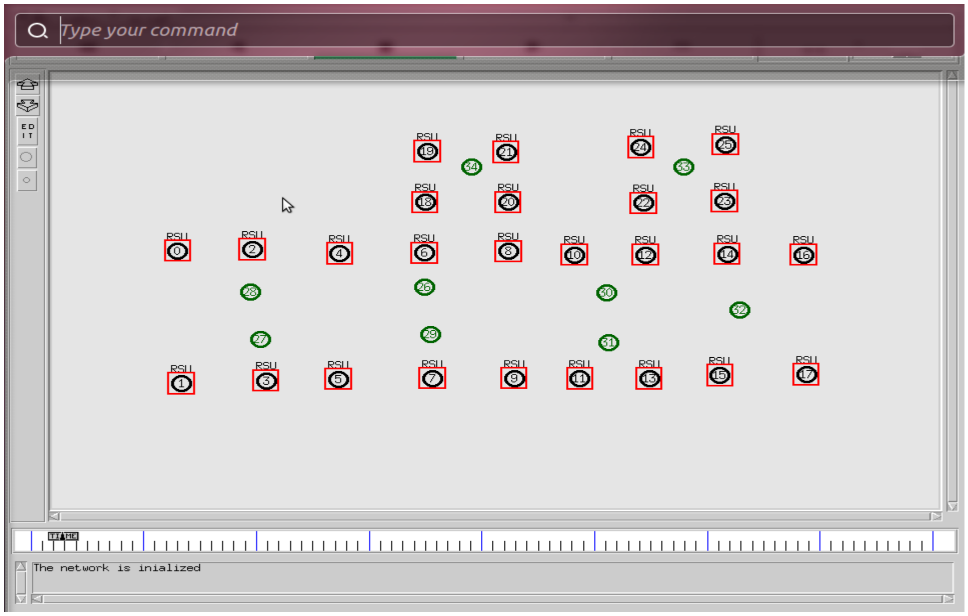

Figure 3.2 Network Deployment

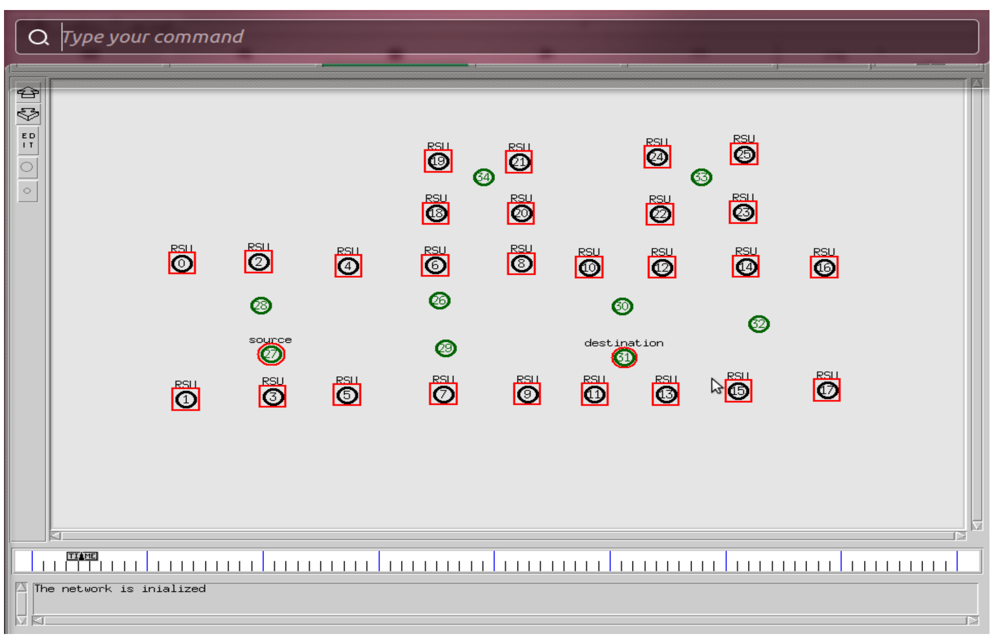

Figure 3.3 Define Source and Destination

As represented in Fig. 3.3, the source node and destination node are also defined for setting up the path between sender and receiver nodes.

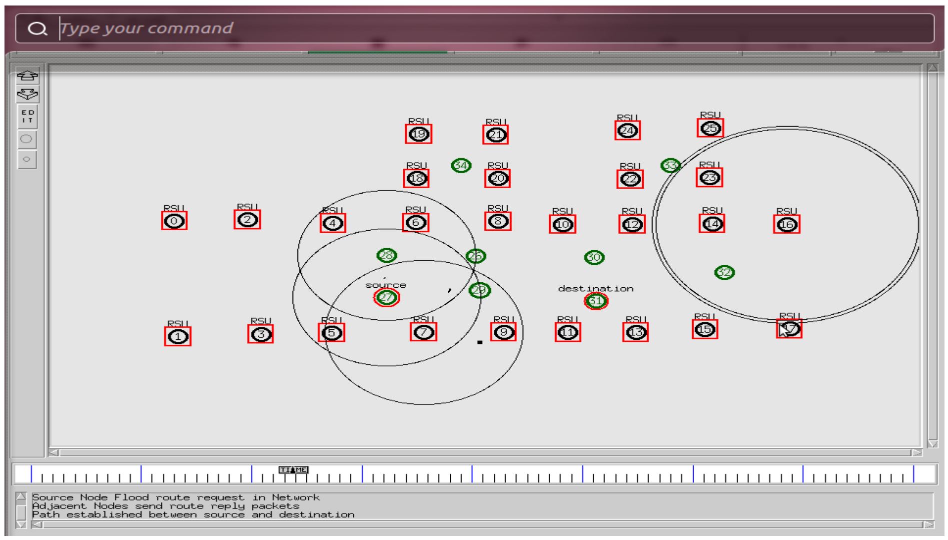

Figure 3.4 Path Establishment Process

The path establishment is represented in Fig. 3.4, Here the route request and route reply messages will be exchanged in between the network. Route reply messages are acknowledgment messages.

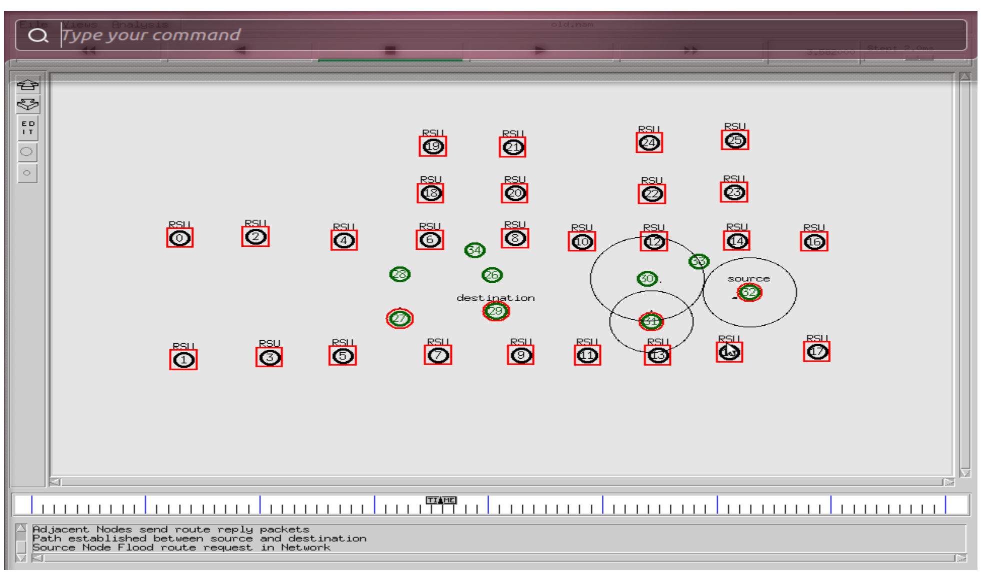

Figure 3.5 Communication Starts

Using any algorithm based on hop count, sequence number or any other priority parameter, the communication will start between the vehicular nodes as represented in Fig. 3.5; here again, the route reply messages will be acknowledged.

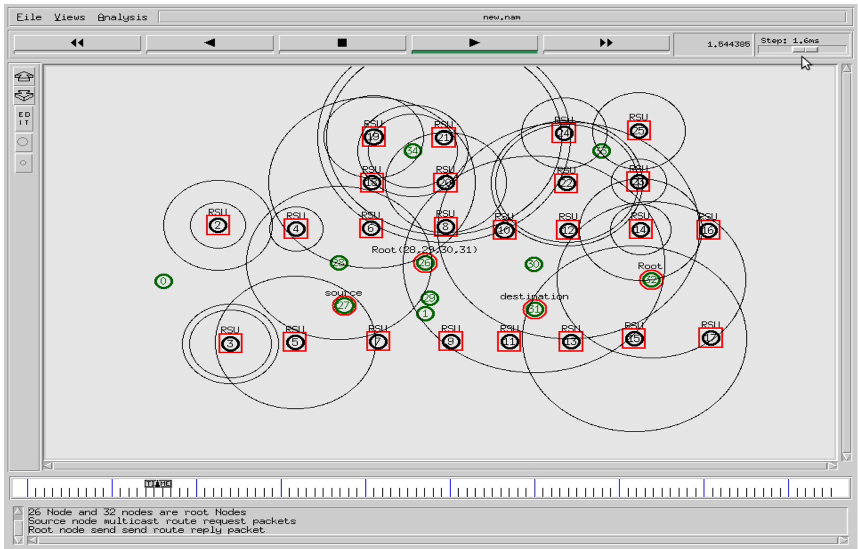

Figure 3.6 Defining Root Nodes

The root node is selected on the parameters of stability and coverage area, as shown in Fig. 3.6.

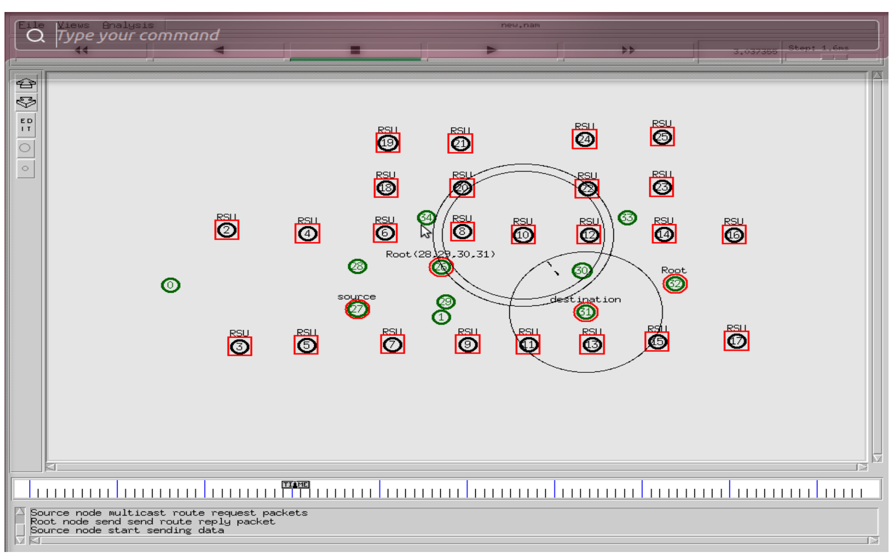

Figure 3.7 Path Establishment

So it’s essential to select the root node in the network for setting the priority and for communication with the nearest root node.

Generally, all the paths from sender to receiver are established, taking the root node into the picture. Also, the path establishment is represented in Fig. 3.7.

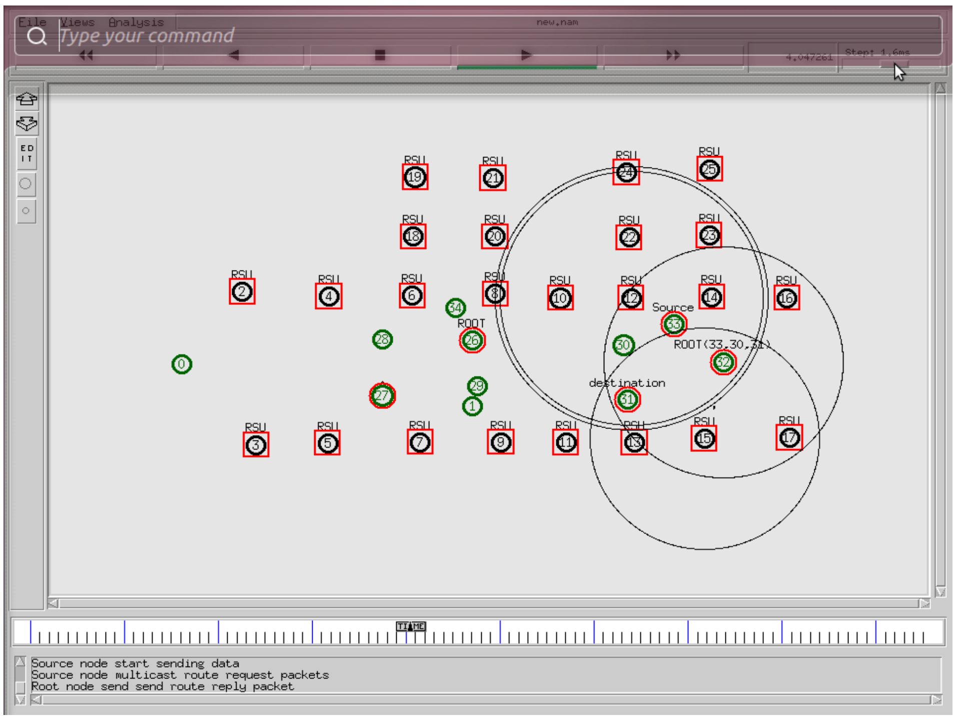

Figure 3.8 Formulation of New Root Node

Using the same parameter to select the root node like stability and maximum coverage area, the new root node is selected to transfer the message from sender to receiver [80, 81]. Fig. 3.6 shows the all the possible candidate nodes which can be selected as the optimal ones for formation of the best route. From these candidate nodes, various paths are formulated from source to destination node. While these paths represent all the possible solutions, the fitness function is then computed for all these paths. The path having the best fitness function is selected as the optimal route which has been shown in Fig. 3.7. The data transmission is continued over such a path and in case the link gets broken, the link repairing is done using the new node. This has been then shown in the Fig. 3.8.

The CBR protocol is a cluster-based protocol that partitions the coverage area geographically into grids to transmit the data packets efficiently [82, 83], where every grid comprises clusters.

3.2 Performance Metrics:

Packet Delivery Ratio (PDR): PDR is the ratio of the number of packets received by the receiver to the number of packets sent by the sender.

$$PDR = \frac{Number\ of\ packets\ received}{Number\ of\ packets\ sent}$$

Throughput: Throughput defines the output of the network. It is the measure of successful data delivery over a communication link.

$$Throughput = \frac{Total\ Number\ of\ received\ byte}{Total\ no.of\ transmissions}$$

Delay: Delay measures the amount of total time consumed by the packets to reach to the destination from the source.

$$Delay = \frac{\sum(arrival\ time - send\ time)}{no.of\ connections}$$

A vehicular ad hoc network comprises nodes (source and destination vehicles), clusters, and cluster heads. Supposedly, it will choose the one which will be closest to the grid as the CH. One vehicle transfers data packets to the other vehicle, which is the CH of another cluster. Similarly, in every transmission, the nodes will transmit the data packets to CH vehicles. An optimal CH is selected to route the packets to the final destined node.

The total number of nodes taken and the search for the fittest CH goes on in every cluster.

- According to the CBRP, the communication network has been partition into four parts, each making a cluster of seven nodes.
- The Source node S1 will transmit the packets with the help of CH of C1. C1 will interact with cluster C2 to route the packet to the destination node D1.
- Similarly, inter- cluster and intra- cluster communication can take place. This protocol will result in reduced OH. Furthermore, the CH selection algorithm can be understood as given below.

Clustering Algorithms [84] are a boon for the issues existing in routing protocols, leading to better cluster lifetime and stability. The studied algorithms are clubbed in the Table 3.1, which illustrates various parameters such as:

- Metrics
- Clustering Parameter
- Algorithm Base
- Issues resolved
- Clustering
- Evaluation Parameters
- Roadside Scenario
- Vehicle Speed
- Cluster Stability
- Efficiency

Where Road Clustering provides a better end-to-end delay, their static geographical-based clustering algorithm provides throughput improvement. However, scalability is always a big concern in VANETs, which is achieved in Content-Based clustering, Decentralized Clustering but is required more scalability in the network, which is still a big challenge to overcome.

After the achievement of the best clustering algorithm, further work has been carried out with the Routing Protocols such as AODV, DSDV, and CBRP, which uses the clustering technique to overcome issues in routing. Since VANET is itself a subset of MANET, so

MANET routing protocols does not suits for VANETs due to high dynamicity and mobility. A routing protocol is helpful in the management of information exchange by establishing a route and making decisions of data forwarding, route maintenance, and recovery of failed routes.

The three routing protocols have been implemented, and the performance has been compared on the basis of:

- Throughput
- PDF
- Delay

The output conclusion we get after the simulation of the protocols is shown in Table 3.1:

Table 3.1 General Comparison of Routing Protocols

Issues resolved	AODV	DSDV	CBRP	Proposed Protocol
Unstable routes and link breakage	Uses hop count as the basis for path selection which may have nodes moving at higher speeds.	Uses the proactive approach in path building. This leads to usage of non-existent routes.	Uses the cluster based approach for routing of the packets. CH is selected based on location.	Uses fitness function based approach to select optimal routes. The fitness function considers the number of neighbors, velocity and free buffer space.
Highway Scenario				

Evaluation Parameters Under Highway Scenario*	AODV	DSDV	CBRP	Proposed
Throughput	235 Kbps	175 Kbps	250 Kbps	275 Kbps
PDR	0.871	0.865	0.88	0.90
Delay	170 ms	182 ms	150 ms	110 ms
Road Side Scenario				
Evaluation Parameters Under Roadside Scenario*	AODV	DSDV	CBRP	Proposed
Throughput	164 Kbps	143 Kbps	172 Kbps	198 Kbps
PDR	0.751	0.746	0.76	0.83
Delay	151 ms	179 ms	142 ms	123 ms
Clustering				
Parameter	AODV	DSDV	CBRP	Proposed Protocol
Clustering Used	No	No	Yes	No

AODV is the routing protocol of wireless ad hoc networks, which set up a route to the desired destination on-demand and uses unicast and multicast routing. AODV itself is an alteration of DSDV. Since several challenges occur while routing the packets for which CBRP comes out, be a better part that outperforms AODV and DSDV. It geographically divides the area into the grid where a CH is to be selected per cluster. Routing is considered to be an essential factor as the vehicular nodes change the topology rapidly.

The proposed protocol should be reliable under dense traffic conditions with high mobility nodes; these kinds of protocols perform best in an urban environment. For a smart, intelligent transportation system (ITS), the design factors should be taken into consideration. But the main problem is that the MANET protocols could not be used in the dynamic environment of VANET. So different sets of routing protocols need to be used for VANET. To avoid this kind of situation, we propose a protocol based on position and coordinates in vehicular networks. But the main challenge is that not all vehicles have installed GPS in their systems. It will also create difficulty in routing the packets without knowing the coordinates of another vehicle. Some vehicles do not allow sharing of their coordinates due to privacy and security issues. Also, another challenge in routing is to forward the packets in dense traffic conditions due to congestion in the network. So, sometimes multi-hop communication is preferred in the vehicular network to improve the routing techniques as it routes the packets in the multi-hop environment at the same time. This may create many routes between sender and receiver nodes and also helps in selecting the best possible routes through which the packet will be sent from sender to receiver node in the dense traffic environment. It is not possible to shift to a complete infrastructure-based model for the smooth transmission of packets. However, this gap gives ample opportunities to researchers for proposing efficient routing algorithms for the dissemination of information in vehicular networks. The proposed routing protocol has included various features like GPS, proper line of sight, and known lane model of vehicular networks into account. This will easify the process of implementing and designing algorithms in dense traffic environments [85].

Considering the scenario of taking two vehicular nodes with limited distance in an urban environment. Let x and y be the two nodes with limited speeds S_x and S_y, L is the acceptable LOS distance between nodes x and y. (A_x,B_x) and (A_y, B_y) being their corresponding co-ordinates with β_x and β_y velocity angles. The lifespan of the link in between the nodes x and y is analyzed by the mathematical equation as:

$$\text{Path Expiration} = \frac{-(ij+km)+\sqrt{(i^2+k^2)L^2-(im-jk)^2}}{i^2+k^2} \tag{3.5}$$

Where

$$i = S_x\, cos\beta_x - S_y cos\beta_y \tag{3.6}$$

$$k = S_x\, sin\beta_x - S_y sin\beta_y \tag{3.7}$$

$$j = A_x - A_y \tag{3.8}$$

$$m = B_x - B_y \tag{3.9}$$

The algorithm 3.2 represents the cluster head selection technique for disseminating the information in the clusters.

Algorithm 3.2: Cluster Head Selection

---

1. Begin;
2. CH (V_2)→ Broadcast INI
3. INI → (G, Loc)
4. If (V_1→ unable to receive INI)

   Wait till (T_1)
5. Then (Broadcast REQ)

   Wait till (T_2)
6. If (No Response)
7. Assignment of self as CH // CH leaves the grid
8. CH (V_2)→ Broadcast LEAVE
9. LEAVE→ G
10. $V_1, V_2, \ldots, V_n$→ REQ;
11. Select new CH;
12. End;

3.3 Results and Simulations:

The communication between members of one cluster to another cluster can be done through cluster head. Also, RSU intersection points will be available so as to increase the coverage; here proposed protocol improves the parameters like throughput, packet delivery ratio, and delay. Table 3.2 represents the simulation parameters for the research proposed in this work.

Table 3.2 Simulation Parameters

Channel Type	Wireless Channel
Network interface type	Physical
Protocol	802.11
Interface Queue type	Queue/ Droptail
Link layer Type	LL
Maximum Packets	500
Number of nodes	22
Simulation Time	5ms
Routing Protocol	AODV/ DSDV/ CBRP

3.3.1 Throughput

The results have been obtained for AODV, DSDV, CBR, and the proposed work in Fig. 3.9. The represented graph is of the comparative study of performance based on throughput. No doubt that AODV outperforms the DSDV routing protocol, but CBR has greater throughput than both conventional protocols. Now here comes the proposed protocol giving a higher throughput than all three existing protocols. The throughput of the proposed work is improved by 29%, 9%, and 6% while comparing with AODV, DSDV, and CBRP.

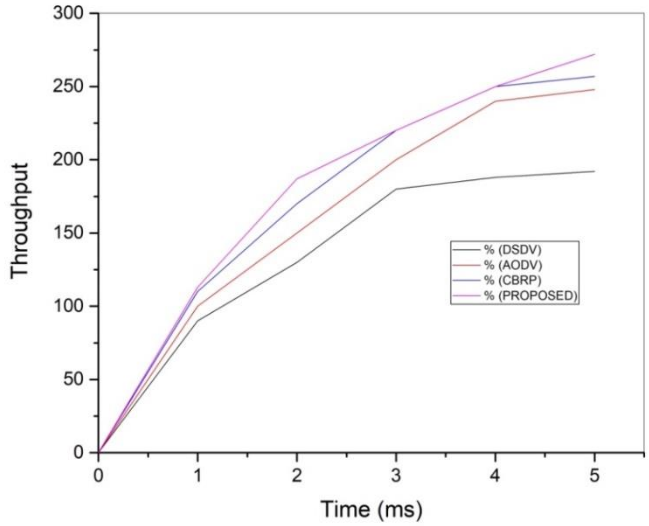

Figure 3.9 Throughput Comparison

3.3.2 Packet Delivery Ratio:

The graph shown in Fig. 3.10 is the comparative analysis of PDR performance where our proposed scheme has a lesser number of packet drops and a better PDR. Initially, the performance of the protocols is closely related but as the time and cluster size increases, the performance of CBRP with the proposed values become better. Hence the performance has been enhanced. The PDR achieved in the proposed protocol is improved by around 3% from AODV, DSDV, and CBRP as all three protocols are showing the same performance at a later stage. But it is clear from the result shown below in Fig 3.10 that even at a later stage, the proposed protocol has improved PDR.

At the start of the simulation, all the channels in the network are idle and free. So as and when the first few packets are sent in the network between any two nodes, they get properly delivered at the other node. This eventually leads to a higher value of PDR. Subsequently, as the simulation progresses, the number of packets sent in the network increases which leads to a bit of congestion. This leads to few packet drops in the network thus causing lesser PDR at a later stage.

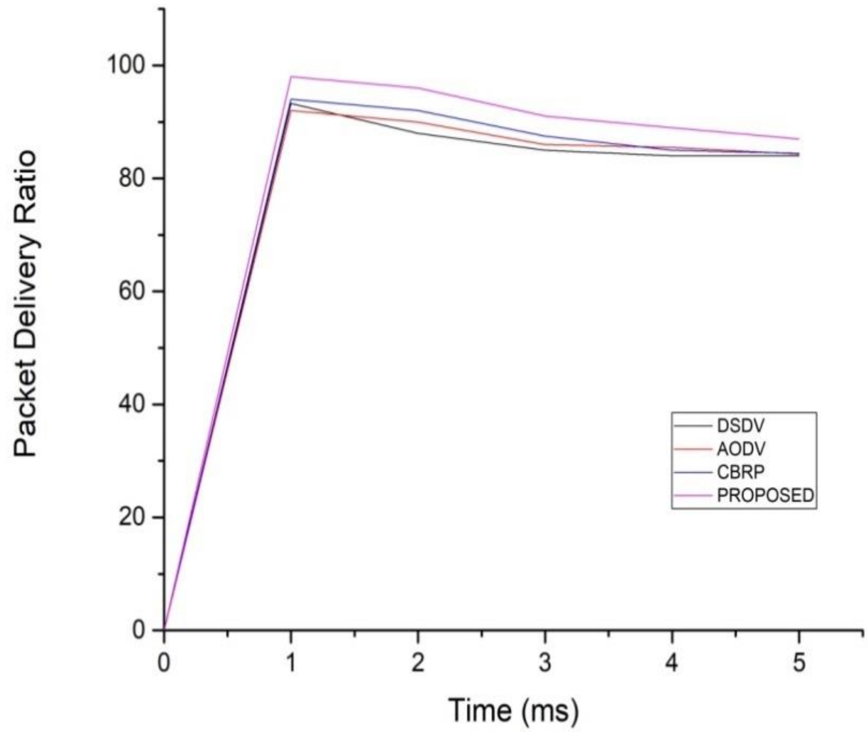

Figure 3.10 Packet Delivery Ratio Comparison

3.3.3 Delay:

The result obtained by comparing the average delay of all three protocols with the performance enhancement has been shown in Fig. 3.11, from which it is clear that the performance improvement is achieved using the proposed protocol against AODV, DSDV, and CBRP. Lesser will be the delay, and better will be the performance. Delay can occur due to the peculiar traffic conditions in the vehicular ad hoc network in the real-time traffic, but the performance of the proposed protocol proves to be better than all discussed in the work. The delay of the proposed protocol is reduced by 63%, 47%, and 35% while comparing with AODV, DSDV, and CBRP.

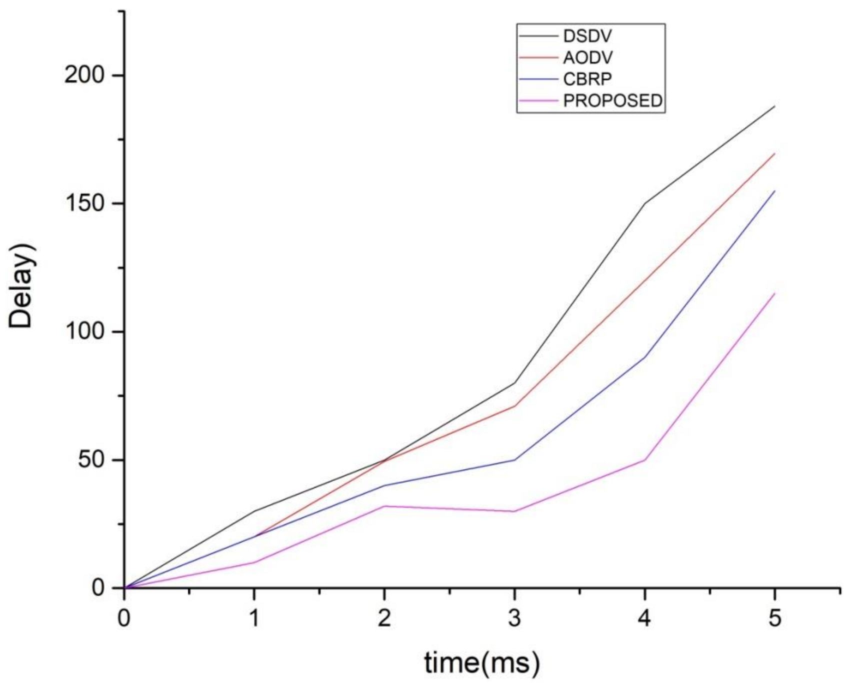

Figure 3.11 Delay Comparison

3.4 Summary

The work carried out till date has primarily focused on the study of various traditional clustering algorithms, but the proposed model can give better quality results in terms of various parameters like throughput, packet delivery ratio, and delay. As it helps in route discovery methods, AODV DSDV and CBR routing protocols are compared with the proposed technique, which is more efficient than existing protocols, specially CBRP (performs the best in existing protocols) by 6%, 3%, and 35% in terms of throughput, PDR and Delay. Stability and mobility are major concerns, especially in VANETs. Furthermore, the conventional routing protocols could not provide an optimal route in VANETs due to several reasons such as the network size, clustered pitch, etc., so there is a requirement for different routing protocols. So the stability algorithms stood to be more useful and required in the dynamically unpredictable environment as in the prime objective.

CHAPTER 4: Clustering Techniques in VANET

4.1 Clustering in VANET

Clustering is an important concept where the vehicles can make a group based on some common parameters [86]. The researchers proposed the unique idea of clustering in vehicular networks to increase the efficiency of the network. A cluster is formed to make the communication between the cluster members (CMs) or between the cluster head (CH) and the cluster members. The cluster head is the node chosen on the basis of various cluster head selection algorithms. Also, the cluster head's purpose is to coordinate the communication among the members present in the cluster. There are number of clustering algorithms designed for the purpose of choosing the cluster head for achieving stability in the network. Fig. 4.1 is a general description where the dynamic topology serves as an issue, and stable clustering is used to resolve it. Various mobile nodes make a cluster using clustering techniques like autonomous clustering, context-aware clustering, decentralized clustering, and dynamic clustering [87, 88].

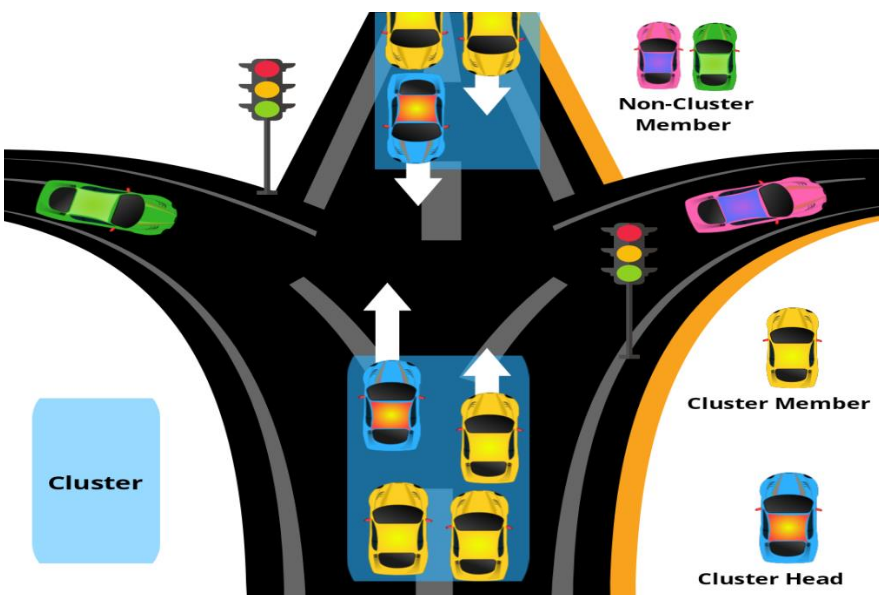

Figure 4.1 Clustering in VANET

The clusters are bounded with rules and regulations so as to follow the safety parameters in a vehicular environment. The cluster head is selected on various metrics like distance, location, point of interest, and the relative velocity of the vehicles. In this work, connectivity is considered one of the significant parameters in which the node with more connectivity takes charge as a cluster head. However, in the dynamic topology of VANET, there are frequent disconnections, so the connectivity does not stay for a long time. This is considered one of the main issues and challenges of communication in VANET. The common metrics used for the algorithm design is the relative velocity between the vehicles, i.e., the vehicles moving with generally the same velocities make a cluster, and the node moving with less relative velocity is considered to be the cluster head. A message is broadcasted when a new vehicular node is entered into the network, and the routing tables are updated accordingly. The members are continuously monitored and analyzed until a suitable cluster head is not obtained. If all the cluster members leave the cluster, then the loop is started again for choosing the appropriate cluster head according to the new cluster based on the selected metric [89, 90].

Clustering increases efficient message broadcasting and transmission. Clustering eliminates overhead signaling since the connections within the same cluster between the vehicular nodes are more secure. Clustering improves the usage of limited resources, like bandwidth, and enhances data transmission performance. The clustering method is useful in network management in large-scale complex and distributed networks by breaking the network into small segments that are scalable. The benefits of using clustering systems are reducing the number of messages transferred within the network, minimizing V2R or V2V communication congestion, increasing network scalability by creating small sections of the network [91], minimizing problems with contention and hidden station, enhancing the effectiveness of the routing service [92]. In addition to these, advantages such as handling evolutionary nature in topology and volume are also essential for the VANET system. For all clusters, the cluster size is not the same, and the difference relies on the wireless communication device's routing path. The communication between clusters is shown in Fig. 4.2.

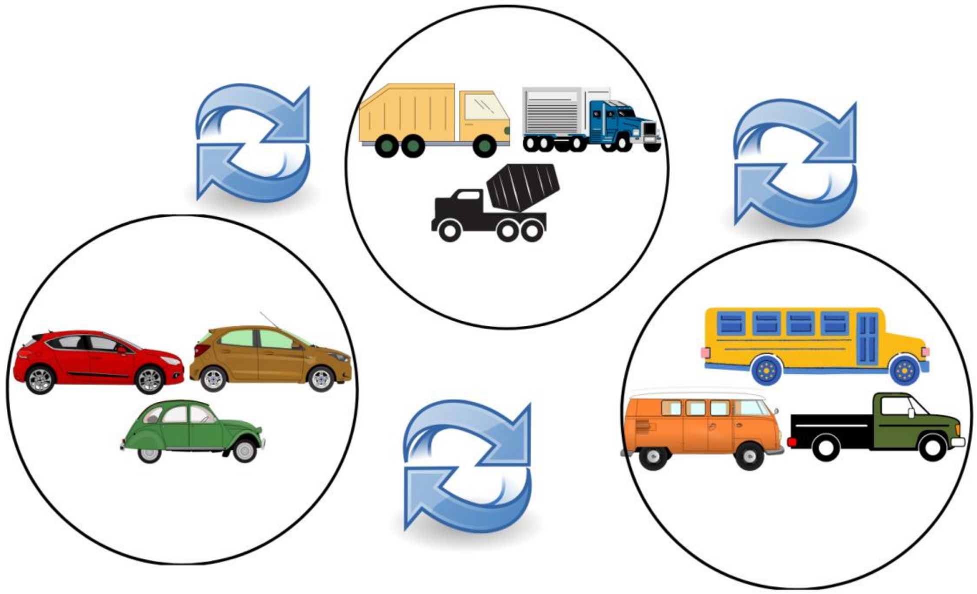

Figure 4.2 Communication in Clusters

The consistency of the cluster could be represented as the number of times the CHs change and the CM associated with their CH [93, 94]. Many clustering methods need to regard the integrity of the cluster as a performance metric. It is considered to be an essential objective that any cluster protocol attempts to accomplish. Clustering systems significantly simplify routing, distribute resources efficiently, control networks, and make the network security for every node in the cluster. In order to boost network ability and increase spatial channel retention, CHs help promote inter-cluster and intra-cluster transmission. In VANET, not only does a successful clustering method have low overhead cluster management, but it also offers stability during dynamic topology control.

4.1.1 Advantages of Clustering in VANET

Hybrid existing methods are CBR protocols that guarantee a highly stable network. There are some benefits:

- Increase power ratio of packets
- Reduce overhead in routing

- Less network traffic could be reduced to cluster head and gateway nodes and inter-cluster communication.
- Scalability of contact for a broad set of nodes
- Support with path construction and reducing of routes
- Minimum knowledge in the system that is processed and transmitted.

Table 4.1 Clustering Algorithms

Application	Name of Algorithm
General Purpose	• k-hop • Fuzzy-logic Based Approach • Mean Collection Time Clustering • Aggregate Local Mobility
Routing	• Passive Clustering • Mobile Infrastructure in VANET • Cellular Automata Clustering • Vehicular Passive Clustering
Security	• Vehicle Weighted Clustering Approach • Clustering-based Public Key Approach
QoS	• Cluster Configuration method • Stability-based Clustering approach
Traffic Safety	• Cluster-basedRisk-Aware Cooperative Collision Avoidance

4.2 Cluster Head Selection

Clustering is a kind of control technique used in vehicular networks to make the frequent topology changes (because of more speed of vehicles) less dynamic. A number of clustering techniques are proposed by various researchers to easify the formation of clusters by applying different clustering algorithms. Fig 4.3 is a general description where the dynamic topology serves as an issue, and stable clustering is used to resolve it. The vehicles start forming a cluster using clustering techniques, and the nodes in the cluster are called Cluster Members (CM), among which one node is chosen as the Cluster Head (CH) with the help of clustering algorithms [95, 96].

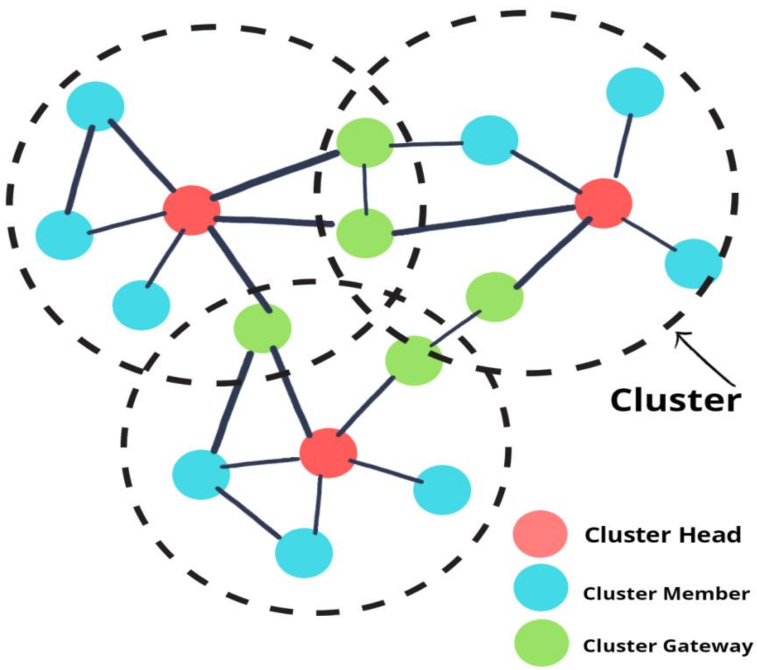

Figure 4.3 Clustering Mechanism

4.2.1 Prediction-based Algorithm

This is one of the cluster head selection algorithm techniques [97]. According to the prediction-based method, the cluster-head is selected randomly with respect to the location of the node in the cluster. Generally, the central node is chosen as CH, and other members in the corners are elected as Cluster Members. The example is shown in Fig. 4.4.

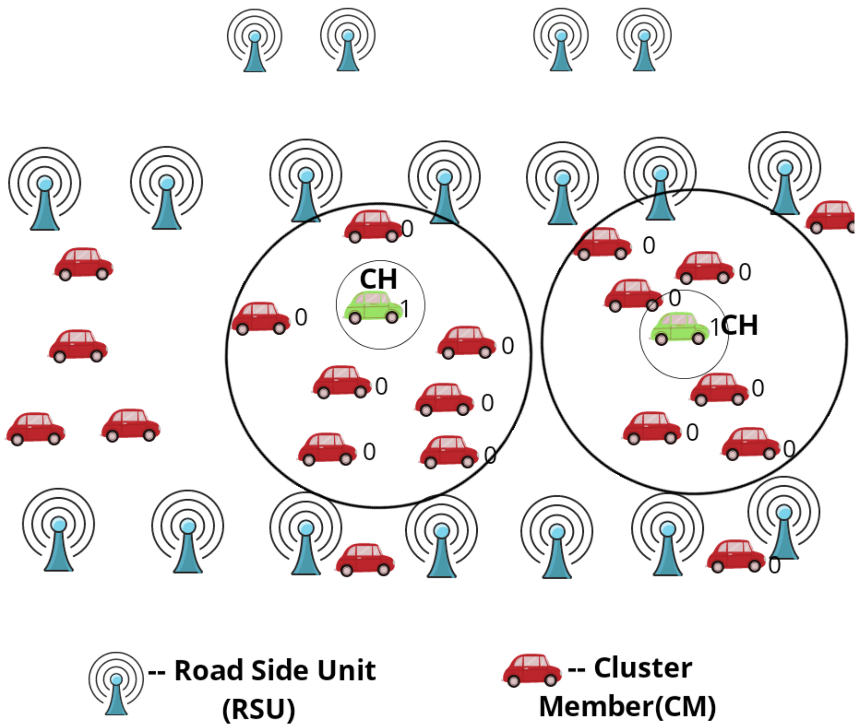

Figure 4.4 Model of Prediction-based Algorithm

4.2.2 FoV based Clustering Algorithm:

This is the method used for clustering of multimedia nodes, these nodes are having the directional sensing region called the field of view (FoV) and can only sense data within that region. In this approach, the overlapping area between FoV of multimedia nodes is mainly considered. If the overlapping area of the FoV of two nodes is wide enough then they can be selected as the members of one cluster. Each node is assigned as a cluster member based upon their FoV [98, 99]. Same cluster members coordinate with each other to perform the assigned task. The example is as shown in Fig. 4.5.

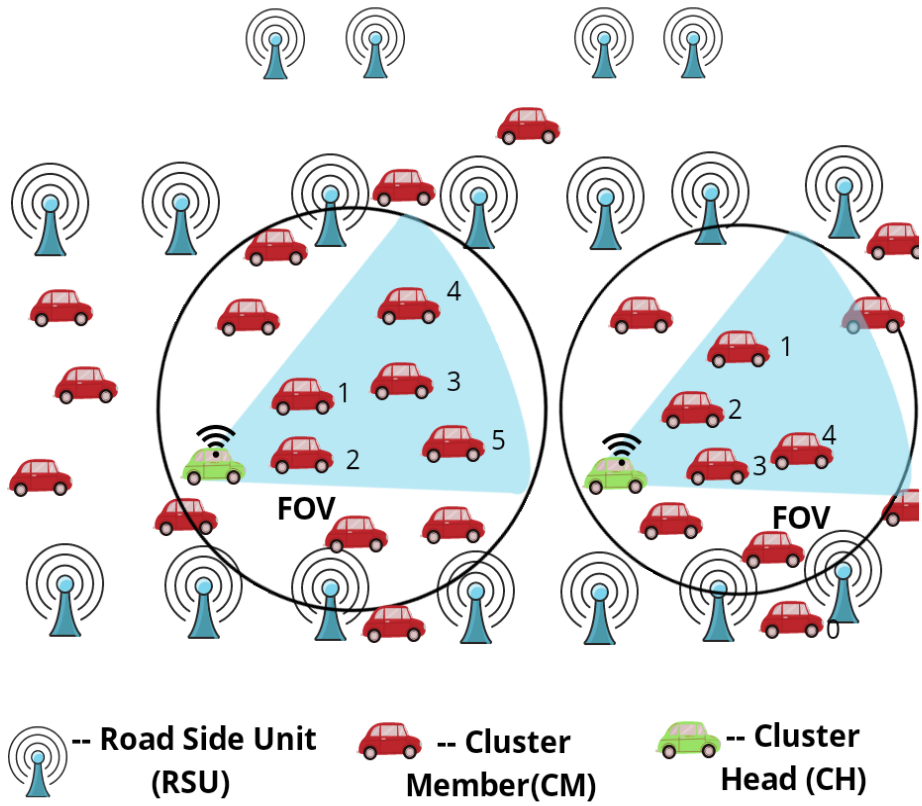

Figure 4.5 Model of FoV based Algorithm

4.2.3 Highest- degree Algorithm:

This algorithm is based on the connectivity of the vehicles called the degree of vehicles. According to this method, the node with a maximum number of neighboring nodes and relatively less speed is considered to be a cluster head. The node with minimum neighboring nodes and more speed will be given the least priority, and all these members are named as Cluster Members. The cluster members forward all their routing queries through the cluster head in the network. After the cluster head, some priority nodes are also defined with more connectivity called as leadership nodes. After the cluster head, the leadership nodes will take the charge of cluster head in the network maintaining the link stability of the network. The example is shown in Fig 4.6.

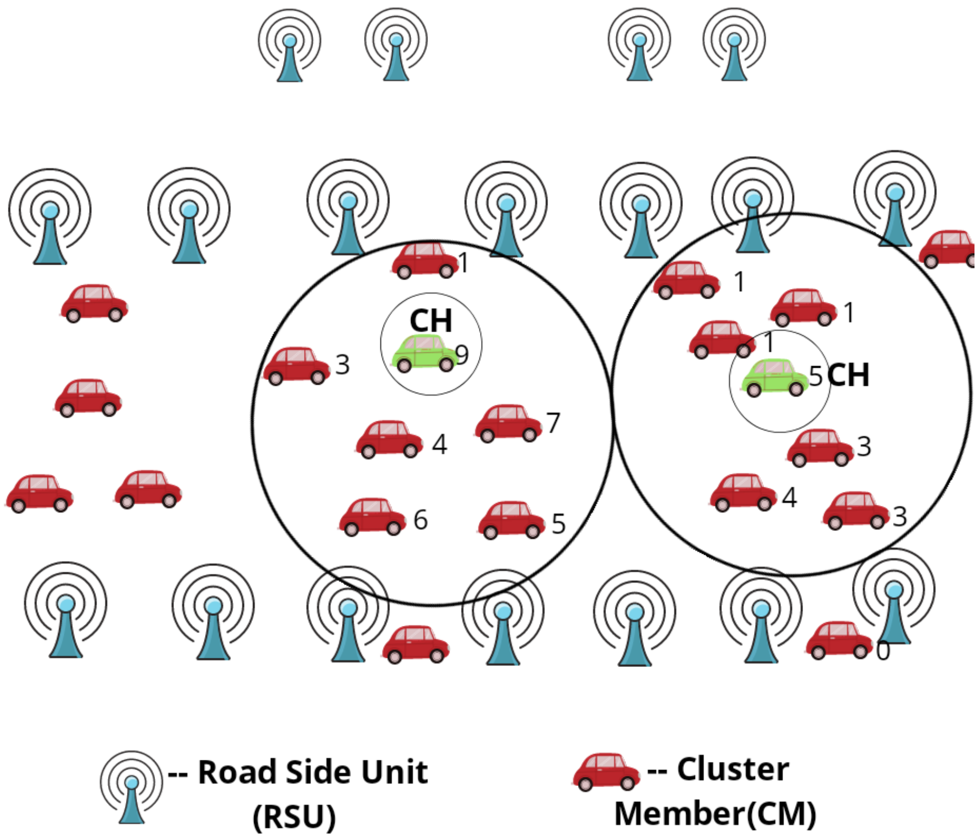

Figure 4.6 Model of Highest-degree Algorithm

The presented work is shown in the form of the flow chart in Fig. 4.7, the whole network is divided into various clusters, and a cluster head is chosen in every cluster for efficient communication between them. In the prediction-based algorithm, the cluster head is selected using the neighboring nodes and their locations whereas in FoV based algorithm the nodes are covered in the directional sensing region. The limitation in the prediction based clustering is the selection priority which is firstly provided to the central nodes, but the possibility may be that many vehicles may be present in the center, which increases the delay in the selection of center node, and the limitation in the FoV based clustering is limited sensing range of vehicle nodes. So highest clustering algorithm outperforms the existing techniques.

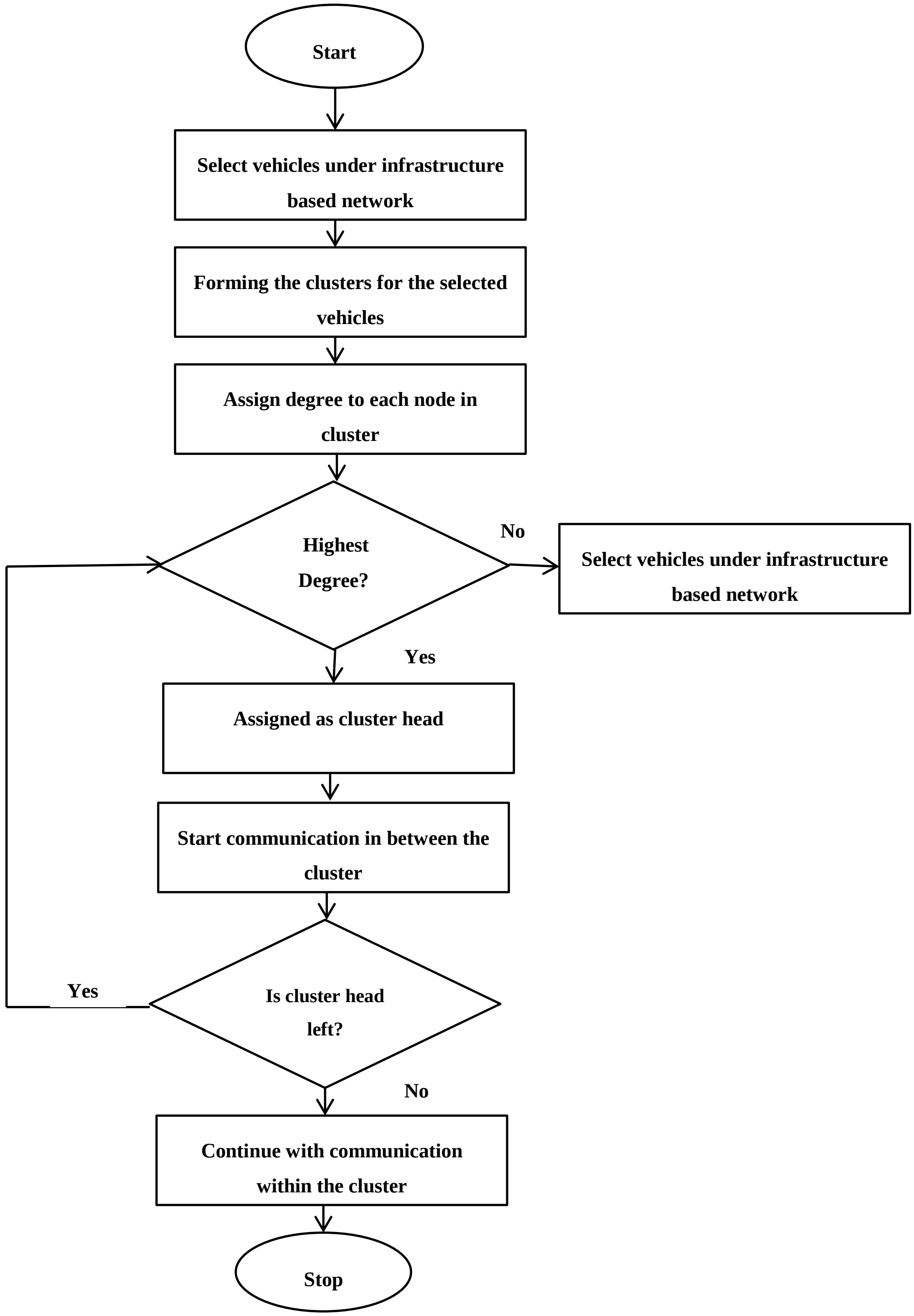

Figure 4.7 Flow Chart of Highest Degree Algorithm

The results are simulated and compared in various networking parameters comparing prediction-based, FoV based clustering techniques with the highest degree algorithms in the desired VANET scenario. The flow chart represents the scenario of choosing the cluster head from the various nodes in the network. Also, the algorithm is given as:

Algorithm: 4.1. Highest Degree Algorithm for Cluster Head Selection

```
1. Input: 'n' // number of vehicles
2. cluster [n]; no = 0; ind
3. dist [n] [n-1] = Hold the distance matrix
4. for (i = 0 to n; i = i+1)
5. for (j = 0 to n-1; j = j+1) {
6. dist [i] [j] = sqrt((x-x1)^2+(y-y1)^2) }
7. min = dist [i] [0]
8. for (j = 1 to n; j = j+1) {
9. if dist [i] [j] < min {
10. min = dist [i] [j]
11. ind = j }
12. if (i_th vehicle && ind_th are not present in any cluster) {
13. cluster [no] = i , ind
14. no = no+1 }
15. else
16. cluster [where i or ind_th vehicle already present] = i or ind
17. // Time t random simulation
18. speed [n] [n-1] = to hold the speed matrix; prior := n*n
19. for (i = 0 to n; i = i+1) {
20. for (j = 0 to n-1; j = j+1)
21. speed [i] [j] = dist [i] [j]/time }
22. for (i = 0 to n ; i=i+1) {
23. for (j = 0 to n; j = j+1)
24. for (k = 0 to n-1; k = k+1) {
25. if (speed[j][k]<min)
26. speed[j][k] = prior
27. prior--
28. }
29. } //For each cluster find the maximum priority points and define cluster heads
30. Output: Selection of cluster heads and efficient data transmission
```

4.3 Results and Simulations

A lane model is designed for prediction-based, FoV based, and highest degree algorithms. The selected parameters and the output values are used to design the whole scenario are shown in Table 4.2.

Table 4.2 Simulation Parameters

Parameters	Value
Medium	Wireless Channel
MAC Protocol	802.11
Model of Propagation	Two Ray Ground Propagation
Antenna Type	Omni-Directional Antenna
Vehicular Nodes	35 and 50
Routing Protocol Used	AODV Protocol
Queue Type	Drop Tail Queue
Length of Queue	500
Area Covered	3000x500 m^2
Scenario	Highway Scenario
Transmission Power	0.3
Receiving Power	0.15
Traffic Pattern	CBR
Size of Packet	512 bytes

4.3.1 Delay

The performance of the communication between the sender and receiver depends on various parameters, where one of the critical factors is a delay. Delay refers to the time taken from point A at the source node to point B node at the destination node. Considering the delay parameter, the comparison is made between the algorithms as shown in Fig. 4.8. The highest degree algorithm not only selects the cluster head based on the connectivity and speed but also leadership nodes as well. In case the cluster head moves out of the cluster, the leadership nodes take the charge as cluster head. This process avoids the re-clustering in the network and reduces the delay. It is observed that for 35 vehicle nodes, the highest degree algorithm performs 44.4 % and 42.8 % better than prediction-based and FoV based algorithms. For 50 vehicle nodes, the highest degree algorithm performs 37.2 % and 32.8 % better than prediction-based and FoV based algorithms.

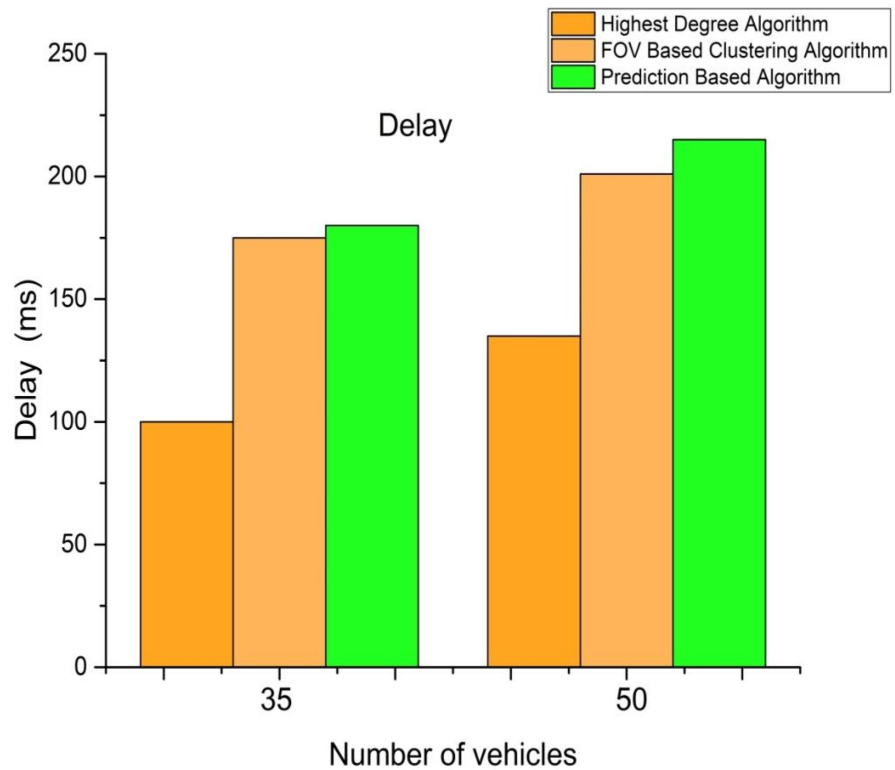

Figure 4.8 Comparison of Delay

4.3.2 Packet Loss

Packet loss occurs due to congestion in the network as few packets are lost in the network. Considering the delay parameter, the comparison is made between the algorithms, as shown in Fig 4.9. It is observed that for 35 vehicle nodes, the highest degree algorithm performs 31.5 % and 19.3 % better than prediction-based and FoV based algorithms. For 50 vehicle nodes, the highest degree algorithm performs 33.3 % and 25.3 % better than prediction-based and FoV based algorithms.

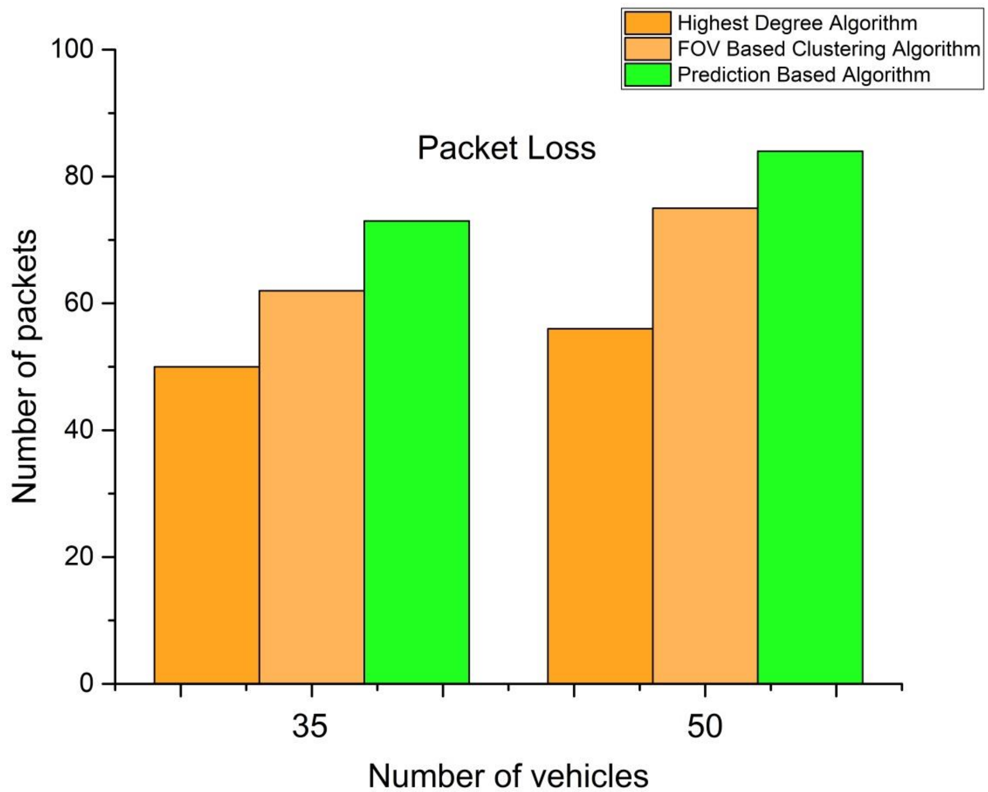

Figure 4.9 Comparison of Packet Loss

4.3.3 Throughput

For every network, throughput is considered to be the most important factor for the transmission of packets from source to destination. It defines the rate of the successfully received packet by the receiver. Considering the throughput parameter, the comparison is made between the algorithms, as shown in Fig 4.10. It is observed that for 35 vehicle nodes, the highest degree algorithm performs 81.5 % and 40.4 % better than prediction-based and FoV based algorithms. For 50 vehicle nodes, the highest degree algorithm performs 66.3 % and 36.6 % better than prediction-based and FoV based algorithms.

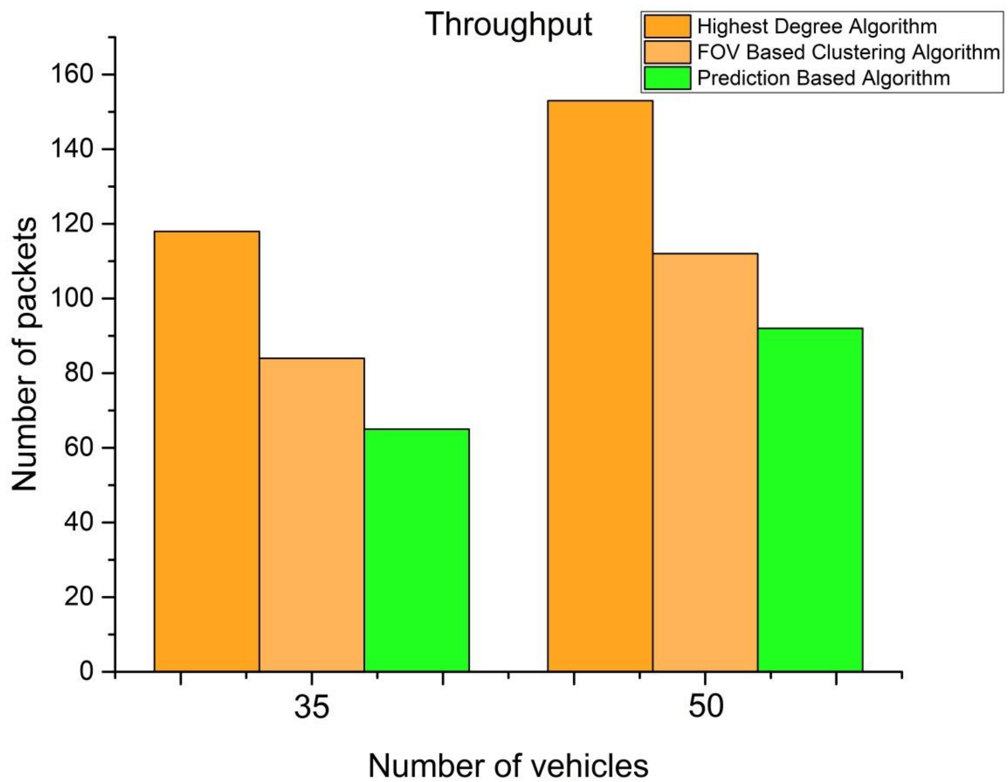

Figure 4.10 Comparison of Throughput

4.3.4 Jitter

Jitter is defined as a delay in the variation of packets from a sender node to a receiver node. The receiver node is responsible for the jitter factor, as the leading cause of variation in received packets is queuing size and congestion in the network. Considering the Jitter parameter, the comparison is made between algorithms, as shown in Fig 4.11. It is observed that for 35 vehicle nodes, the highest degree algorithm performs 42.8 % and 25.9 % better than prediction-based and FoV based algorithms. For 50 vehicle nodes, the highest degree algorithm performs 36.5 % and 16.1 % better than prediction-based and FoV based algorithms.

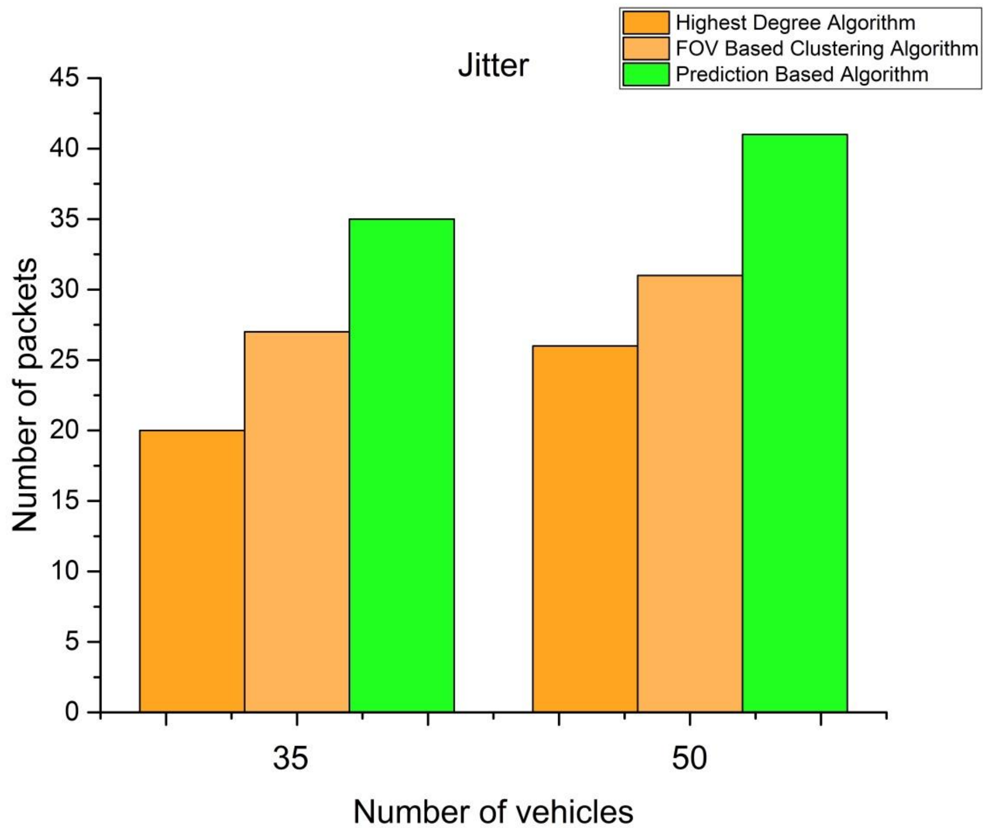

Figure 4.11 Comparison of Jitter

4.3.5 Packet Delivery Ratio

Packet Delivery Ratio (PDR) is also an essential factor in measuring the performance of the vehicular network. PDR is a ratio of received data packets by the transmitted data packets. Considering the PDR parameter, the comparison is made between algorithms as shown in Fig. 4.12. It is observed that for 35 vehicle nodes, the highest degree algorithm performs 16.6 % and 9.3 % better than prediction-based and FoV based algorithms. For 50 vehicle nodes, the highest degree algorithm performs 24.3 % and 15 % better than prediction-based and FoV based algorithms.

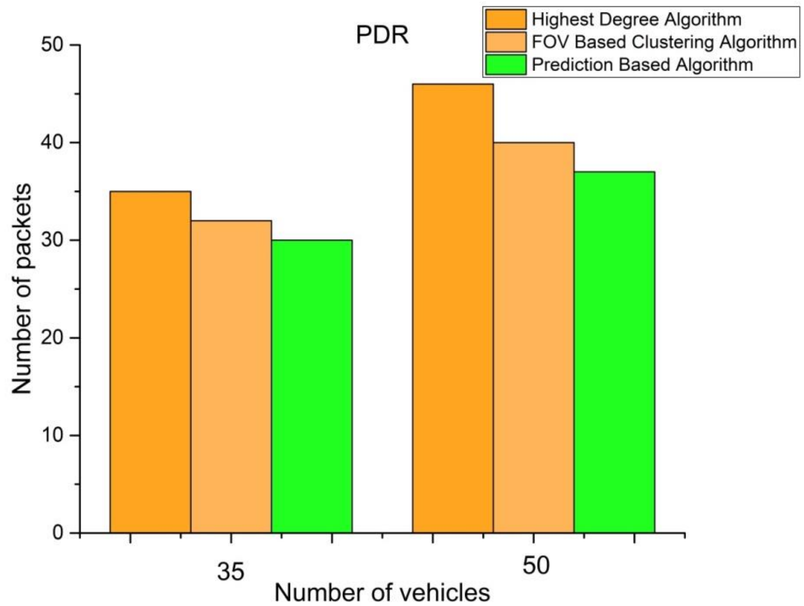

Figure 4.12 Comparison of Packet Delivery Ratio

4.4 Summary

The overall results of delay, packet loss, throughput, jitter, and PDR show that the highest degree algorithm performs better than the prediction-based algorithm and FoV based algorithm. For 35 vehicle nodes, the highest degree algorithm performs 44.4 % and 42.8 % in terms of delay, 31.5 %, and 19.3 % in terms of packet loss, 81.5 % and 40.4 % for throughput, 42.8 %, and 25.9 % in terms of jitter, 16.6 % and 9.3 % for PDR better than prediction-based and FoV based algorithms. For 50 vehicle nodes, the highest degree algorithm performs 37.2% and 32.8%, 33.3% and 25.3%, 66.3% and 36.6%, 36.5% and 16.1%, 24.3%, and 15 % better than prediction-based and FoV based algorithms in terms of delay, packet loss, throughput, jitter, and PDR respectively. The work done have considered the mentioned parameters but there can be other algorithms that are not being compared such as fuzzy logic-based, artificial neural network, and deep learning-based algorithms which select cluster head based on other parameters, complex input conditions, and optimization techniques.

CHAPTER 5: Enhanced K-means Clustering and Dynamic Routing

5.1 Introduction

Clustering is one of the most powerful strategies for achieving a consistent topological structure. In order to achieve efficient communication, CH's selection is therefore necessary. In [100, 101], a few stable clustering-based mechanisms were suggested in VANETs. However, in all this literature, it is concluded that they do not sustain the quality of the CH due to high vehicle growth and the constantly varying topology of vehicles.

For overcoming the challenge of high-speed vehicles network in VANET, an enhanced K-means clustering algorithm is presented in which dynamic grouping by K-implies is performed that fits well with VANET's dynamic topology characteristics. The suggested clustering increases the overall distribution ratio of packets and reduces VANET's end-to-end latency. The clustering of K-means divides the region into four segments, and each segment has a number of CHs k. The objective function is then determined using key vehicle parameters, such as position, speed, direction, and point of interest (POI). The measured objective function value not only helps to create more stable clusters but also takes advantage of the data transfer process by choosing more stable routes. Each cluster has specific interests through this clustering, such as parking data, accident alerts, and overcrowding information. When a message is received by a CH, it tests whether or not the vehicles within the cluster are involved in the message. If they are interested in the vehicles within the cluster, CH will transmit the data to its members. Else, the data would be transmitted to the next CH. This will decrease the non-relevant distribution of data in the network. And, for hybrid-based clusters, dynamic routing is proposed for successful inter-cluster communication. The data is transmitted via the nearest neighboring CHs in this path, which is established from the position of the vehicles. The dynamic routing increases the overall PDR and decreases the E2E latency.

5.2 Enhanced K-means

K-means is a very effective procedure in data extracting [102] among clustering algorithms, mainly as a result of its simplicity, scalability, and because it is ease to adjust to different scenarios and domains. There are some well-known shortcomings in k-means, however. To be exact, the amount of clusters, k, is required as an input. For request for data clustering, Influential k is answered. Input is given as the number of clusters; then, an improved k-means is utilized to split the vehicles into clusters. The process follows a minimal method for categorizing a specific data group into a different number of clusters. The operation of the clustering algorithm is as follows:

1. Build k cluster centers or centroids $c_1, c_2, c_j, \ldots\ldots c_k$ by using random sampling and the locations of each centroid and some initial values known as seed points.
2. Then, between vehicles and centroids, the objective function is computed. The objective function depending on the location, direction, speed, and point-of-interest of vehicle nodes which are defined as follows:
    - *Location:* As a significant parameter, the location of the vehicle is considered and can be calculated using GPS. This GPS supplies OBU with information that decides its current position.
    - *Direction*: A vehicle's path is calculated by measuring the difference among the last two places obtained by the GPS.
    - *Speed*: The speed of the vehicle is measured via OBU. There should be the least difference in velocity for vehicle nodes present in the same cluster.
    - *Point-of-Interest list*: There are certain interests in any car. Some vehicles are concerned about parking, restaurants nearby, and some are only concerned with information about incidents and overcrowding, etc. A

vector is used to describe a vehicle's interests. Each " k " vehicle maintains an interest vector in the way of:

$PI(K)_I = (PI(K)_1, PI(K)_2, ...PI(K)_n)$

In order for vehicles present in the same cluster, the vehicles' POI should be the same.

Let a vehicle i such that $1 \le i \le N$ and centroid k such that $1 \le k \le K$, in which (x_i, y_i) and (x_k, y_k) are their positions, v_i and v_k are their speeds respectively. The objective function of K-Means(KM) is specified as below:

$$f_{KM}(i,k) = c_1 \times D_{ik} - c_2 \times \Delta S - c_3 \times dist(i,k) + c_4 \times PI_{ik} \tag{5.1}$$

where D_{ik} represents the angle of direction among vehicle i and centroid k, ΔS represents velocity variation among vehicle i and centroid k which is defined as below:

$$\Delta S = \left| S_k - S_i \right| \tag{5.2}$$

And $dist(i,k)$ is the distance among vehicle i and centroid k, which is defined as below:

$$dist(i,k) = \sqrt{(x_i - x_k)^2 - (y_i - y_k)^2} \tag{5.3}$$

c_1, c_2, c_3 and c_4 indicate the relative importance of D_{ik}, ΔS, $dist(i,k)$ and PI_{ik}

3. The cluster center is modified based on the outcome of the partition. Until the predefined iterations are attained, this method continues to loop. The outcomes are acquired at the end of the iteration.

The clusters are formed based on the above parameters. If a vehicle joins any cluster at any unit of time, it joins the related cluster and transmits a CH-REQ to the corresponding CH. Each cluster has a threshold level (TL), and it begins the procedure of a new CH election when a CH extends the TL.

5.2.1 CH Selection

A weight-based CH selection algorithm is suggested for optimal CH selection, where each node calculates a weight according to specific parameters, and the highest weight node is selected as the CH. The total duration required for the CH collection to be finished is *T*. This is split into four sub-hours. The following measures are involved in CH selection:

1) Each vehicle acquires its clustering factors from its onboard component: position, path, velocity, and POI, and the time required for this is $T1$.
2) After locating nearby vehicles, each vehicle recognizes vehicles whose POI is close to its own; each vehicle transmits its clustering factors to its nearby nodes.
3) If a node obtains the clustering factors from its neighbors, a list for each nearby is preserved. (N_{List}). The time undertook to achieve this is $T2$.
4) A list comprises the ID of the neighboring car, its location, speed, destination, POI, and compatibility with the POI.

   $N_{List} = (N_1, N_2, ...N_n)$

   Three parameters, which are cosine similarity and soft cosine similarity, are used to compute Point-of-interest compatibility (PC). For instance, the PC is calculated using the following equation between vehicle "a" and vehicle "b":

$$PC_{ab} = \underbrace{\frac{\sum_{k}^{n} pa_k \, pb_k}{\sqrt{\sum_{k=1}^{n} pa_k^2 \sum_{k=1}^{n} pb_k^2}}}_{Cosine\ Similarity} + \underbrace{\frac{\sum_{i,j}^{N} s_{ij} a_i b_j}{\sqrt{\sum_{i,j}^{N} s_{ij} a_i b_j} \sqrt{\sum_{i,j}^{N} s_{ij} a_i b_j}}}_{Soft\ Cosine\ Similarity} \tag{5.4}$$

   Here s_{ij} =similarity ($feature_i$, $feature_j$).

5) Next, the mean Euclidean distance (AED) between the " a " vehicle and each of its " b " neighbors is measured using the following equation:

$$AUD_{a,b} = \frac{\sum_{k=1}^{n} \sqrt{(x_{a_k} - x_{b_k})^2 + (y_{a_k} - y_{b_k})^2}}{n} \tag{5.5}$$

here $(x_a, x_b)(y_a, y_b)$ signify position coordinates of nodes ‘‘a’’ and ‘b’’, and ‘‘n’’ represents the number of neighbors. The time duration for this process is $T3$. $T4$ is static, and it is identical for all vehicle nodes.

6) Each vehicle determines the waiting time ‘‘Tw’’

$$Tw = \frac{1}{\alpha |N_{List}(k)|} \times T4 \times R \tag{5.6}$$

Here, α signifies the number of times the vehicle ‘‘k’’ selects as a CH earlier. $|N_{List}(k)|$ is the nearby nodes of node ‘‘k’’. R represents a random number among 0.1 and 0.2. The node awaits for ‘‘Tw’’ and determines the Weight Value (WV). If any CH request is accepted with in this ‘‘Tw’’, the vehicle does not compute the WV. It agrees that vehicle is a CH.

7) Every node computes WV after ‘‘Tw’’. The node sends out the CH advertising message immediately after measuring WV. Because of R., each node has different waiting times. The WV is determined using the equation below:

$$WV_k = \frac{APC_k}{AED_k . AV_k} \tag{5.7}$$

In order to enhance the WV of a vehicle, AED_k and AV_k should be lowest. Algorithm 5.1 explains the operation of the proposed protocol based on enhanced K-means.

Algorithm 5.1: Enhanced K-means Clustering

Input Parameters:

a) Set of Vehicle nodes $V = \{v_1, v_2, v_3, ... v_N\}$

b) Initial number of clusters K

c) Direction, Velocity, Location, and POI of each Vehicle node

Output Parameters:

a) Optimal clusters

Choose a k centroid from the vehicular nodes

CH to be selected from a centroid

For $i = 1$ to N do

  Calculate f_{KM}

  Assign nodes to specific clusters considering f_{KM}

End for

For $K = 1$ to k do

  Calculate the weight value WV of nodes to specific clusters

  Choose CH as per higher WV

End for

If all selected vehicles are either CHs or CMs Then

  End

Else

  $K = K + 1$

End if

5.3 Dynamic Routing Protocols

If the network clustering structure has been created, when the cluster member demands that the packets be transferred to the designated destination, the packet will be sent to the CH. By using the dynamic routing protocol to the destination, the CH forwards the packet. The dynamic protocol is split up into two protocols:

- Intra-sector routing
- Inter-sector routing

5.3.1 Intra-sector Protocol

The suggested routing protocol intends to disseminate the data packets via the chosen CHs within the section. Every CH constructs its routing table and saves the neighboring CH ID and its related places in it to maintain the path of routing data. When the nearby CH gets data, it chooses the candidate CHs which are situated near the destination regardless of the location of the CH in its routing table, and after that sends the data to the nearest CH. If there are no nearby CHs to the destination node, the local CH uses a store-and-forward procedure as a recovery procedure. It saves the data in a particular buffer and keeps going until another CH relay is located. Algorithm 5.2 describes the steps taken to propagate the data inside the sector. If a node receives data at any point during the simulation, it first double-checks the routing table. And afterward chooses the CHs with the least distance to the destination. Lastly, if the routing table contains no entries, then a store-and-forward method follows the current CH.

5.3.2 Inter-sector Protocol

The protocol proposed seeks to disseminate the packets across the sector via the selected CHs as described as follows:

1. If a source vehicle "s" wishes to pass on data to the vehicle “d,” the "s" sends the message including the destination location ($Tloc(x_{tl}, y_{tl})xy$) to the corresponding CH ‘‘k.’’
2. After that, the direction of communication (DC) is computed. DC is related to the path of CH ‘‘c’’ if the cosine similarity (CSM) is more than 0. The connection between DC and velocity Vector (V_c) is calculated utilizing the following equation.

$$CSM = \frac{DC.V_c}{|DC||V_c|} \tag{5.8}$$

where DC is the distance between the vehicle and the target position, is DC. There is a velocity vector in each CH "c" that can be defined as

$$V_c = v_c \hat{i} + v_c \hat{j} \tag{5.9}$$

Also, every CH ‘‘c’’ has a certain target (x_{dest}, y_{dest}). For selecting the forward node, the distance between the target position and CH's target is also carried.

3. To choose the next forwarding CH node, a CH 'c' utilizes the targets and directions of its nearby nodes, CH. Initially, it determines a DC post's communication route. Then, it tests CSM by CH node 'c' for every neighbor with velocity.
4. Subsequently evaluating CSM and ΔD_c for every nearby CH ‘‘c’’, a CH ‘‘k’’ defines the routing metric (RM) for each neighbor CH ‘‘c’’:

$$RM = \frac{CSM}{\Delta D_c} \tag{5.10}$$

5. A neighbor CH in another sector whose RM is highest is chosen as the next hop CH.
6. Then, the next CH tests whether $Tloc$ within the cluster is located or not. The message is forwarded to $Tloc$ if $Tloc$ is located within the cluster. Otherwise, the next-hop CH is selected again using RM, and the process repeats itself.

5.3.3 Operation of proposed routing protocol

a) It sends the message to its CH when a source "S" receives a message.
b) The CH first tests whether or not the $Tloc$ is located within the cluster.
c) If yes, the message is sent to $Tloc$.
d) Else, it will verify that the $Tloc$ is in the segment.
   - If so, the intra-segment packet forwarding protocol is utilized, where the next CH node is selected from its forwarding table.
   - If not, the inter-segment protocol is utilized where the next CH node centered on the RM is chosen in the other sector. The next CH tests $Tloc$’s accessibility within its cluster again. If $Tloc$ is not identified, the next hop CH is chosen again, and

the procedure repeats until the data Reaches its *Tloc* node. Algorithm 5.2 represents the intra-sector routing protocol as shown below.

Algorithm 5.2: Intra-Sector Routing Protocol

Input Parameters:

a) Set of Vehicle nodes, and CHs

b) Distance of each vehicle CH

c) direction of each Vehicle CH

Output Parameters:

a) Best next forwarding node

1. For Each data packet obtained by the CH
2. If data obtained by CH, then
3. Check forwarding table of corresponding CH
4. If forwarding table of CH Not empty, then
5. Save the CHs which are closest to the target in the candidate CH table
6. Next forwarding node = CH near the destination
7. End If
8. Else
9. Store and forward
10. End If

11. End For

5.4 Results and Simulations

Two types of simulators are used to assess the execution of the proposed protocol: the traffic simulator that replicates the vehicle mobility and the network simulator that creates the vehicular area. The SUMO is the most used traffic simulator in VANET. A 1000 x 1000 area segment is applied to test the proposed protocol; the segment is split into clusters. The simulation parameters for the aforesaid area and number of vehicles are shown in Table 5.1.

Table 5.1 Simulation Parameters

Simulation Parameter	Simulation Value
Simulation Time	1000 -5000 sec
Area Covered	1000 x 1000
Vehicular Nodes	50-100
Range of Communication	250 units
Speed Range for Vehicles	(10-60) kmph
Size of Packet	1024
MAC	802.11p

Firstly, 100 vehicles are allocated by uniform distribution to the segment, and constant velocity is assigned to each vehicle. As simulation results, the output of the proposed protocol is compared to the CBLTR [33] and AODV-CV [34] regarding PDR, throughput, and E2E delay. Table 5.1 provides a detailed list of parameters for the simulation. The throughput relation between the proposed protocols, CBLTR [33], and

AODV-CV [34] for 50, 60, 80, and 100 nodes is shown in figures 5.1, 5.2, 5.3, and 5.4. Figures show that throughput increases with the number of nodes increasing, which results in increasing the efficiency of the vehicular network. With throughput, many other network parameters are taken into account like PDR and delay. The average throughput is also represented with the help of the graph. The proposed technique is showing improvement in the implementation. Fig. 5.1 is representing the graph of throughput comparison of 50 nodes.

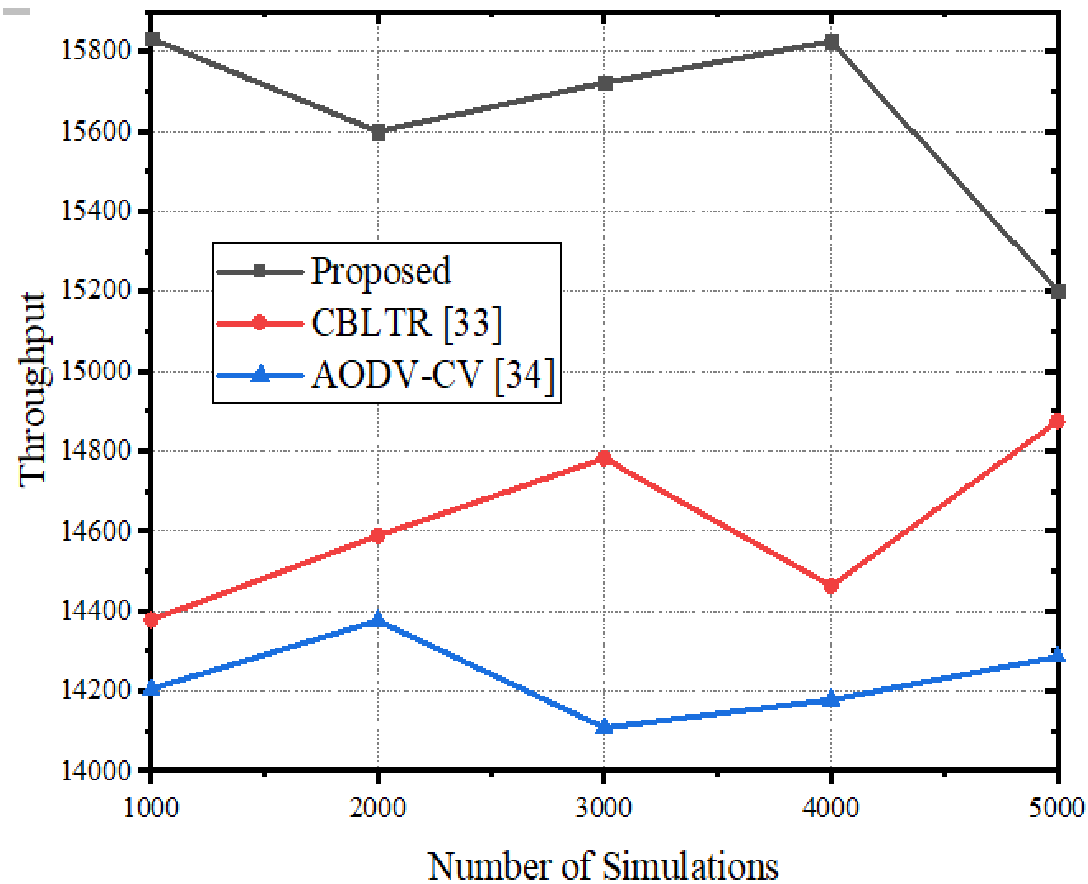

Figure 5.1 Throughput Comparison for 50 nodes

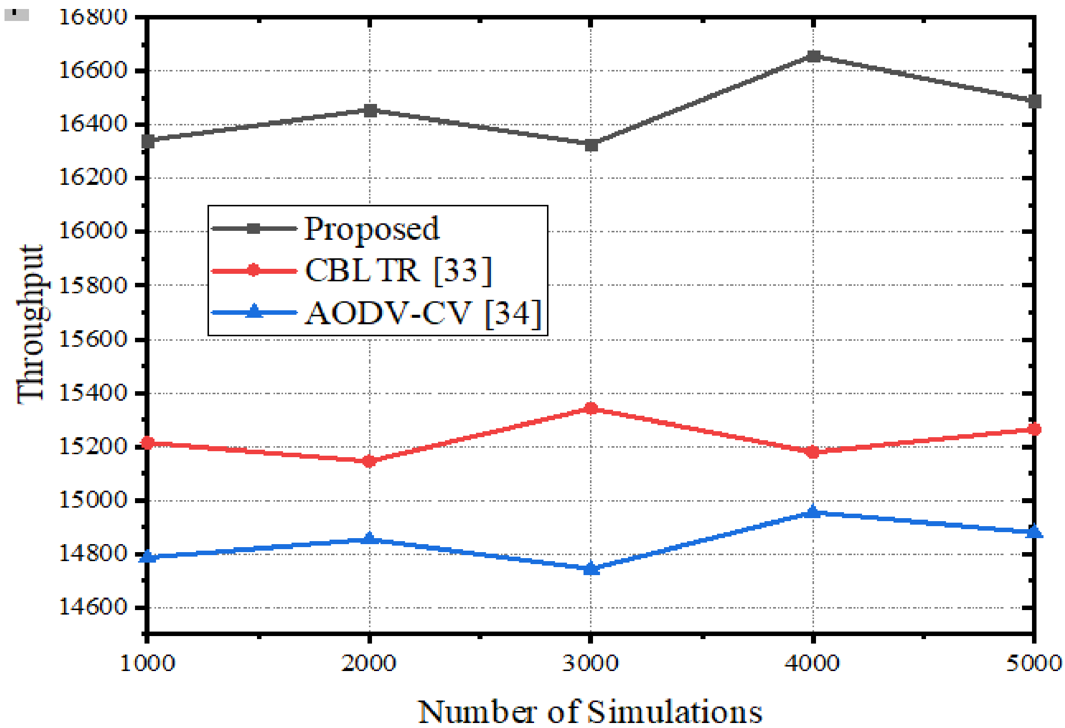

Figure 5.2 Throughput Comparison for 60 nodes

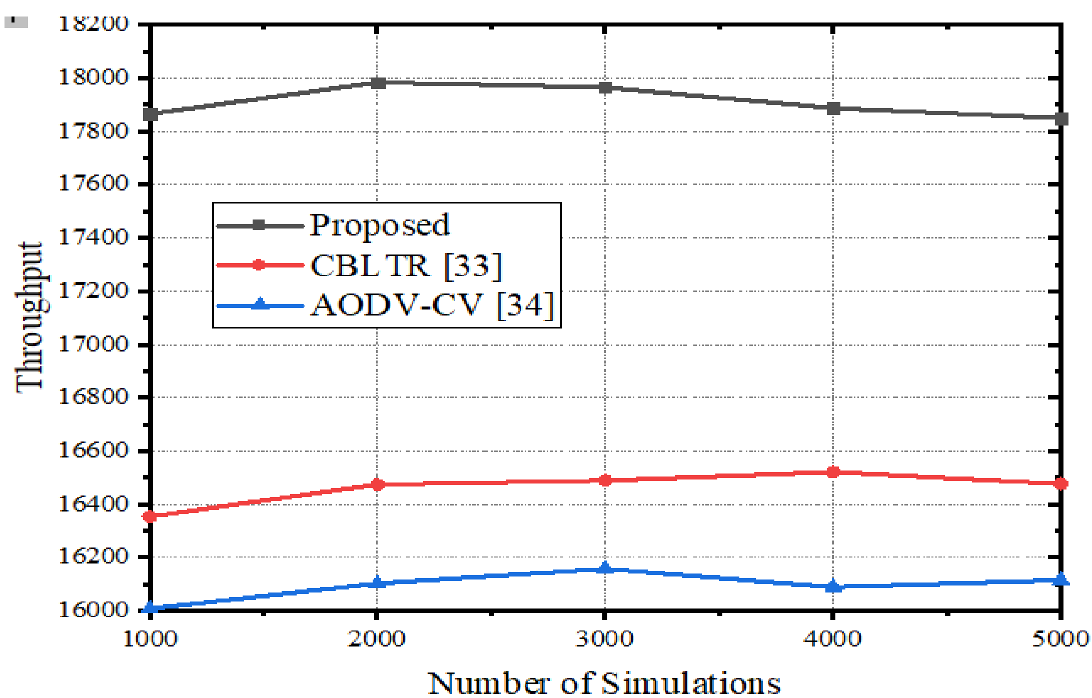

Figure 5.3 Throughput Comparison of 80 nodes

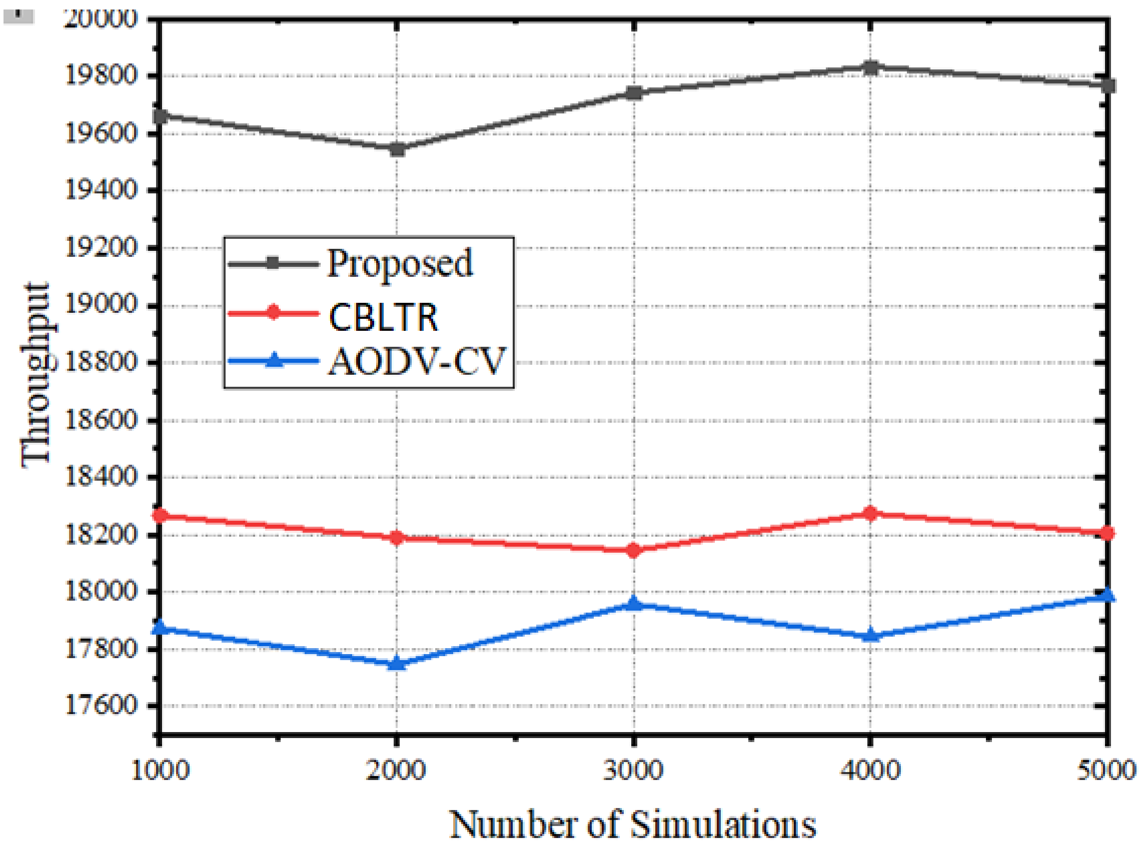

Figure 5.4 Throughput Comparison of 100 nodes

Fig. 5.5 depicts an average comparison of throughput for the proposed CBLTR [33] and AODV-CV [34] protocols with varying vehicle nodes. The AODV-CV [34] has the least throughput in comparison to all other protocols as it declined to manage the network changing aspects efficiently as compared to CBLTR [33] and proposed protocols. When compared to the existing protocol, the proposed protocol shows an increase in throughput, CBLTR [33] and AODV-CV [34], because of dynamic clusters creation using K-means and stable CH election using location, direction, velocity, and POI as the key parameters. The throughput in the proposed protocol is increased by 6.7 % compared to CBLTR [33] protocol and 9.7 % compared to AODV-CV [34] protocol for 50 vehicle nodes in the network.

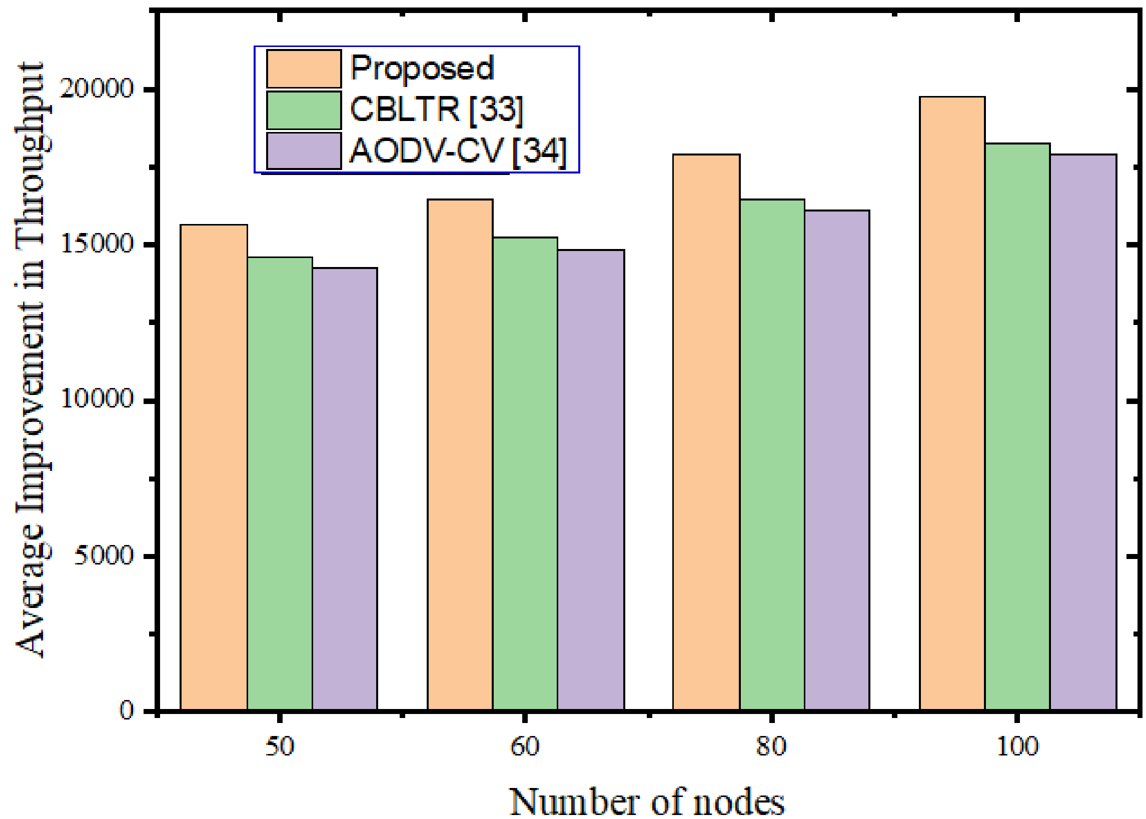

Figure 5.5 Average Improvement in Throughput

In Fig. 5.6, the PDR is computed for the proposed CBLTR [33] and AODV-CV [34] protocols over a various number of simulations. It is found that PDR remains constant by increasing the number of nodes because PDR is independent of packet injection rate. The PDR in the proposed protocol is improved by 11.5 % compared to CBLTR [33] protocol and 18.5 % by AODV-CV [34] routing protocol.

In Fig. 5.7, E2E delay in distribution of packets is computed for the proposed CBLTR [33] and AODV-CV [34] protocols. It is found that the proposed protocol has less delay as compared to CBLTR [33] and AODV-CV [34]. This is because the link among the nodes varies as the velocity of vehicles varies. The E2E delay in the proposed protocol is reduced by 32 % compared to CBLTR [33] protocol, 43 % by AODV-CV [34] routing protocol.

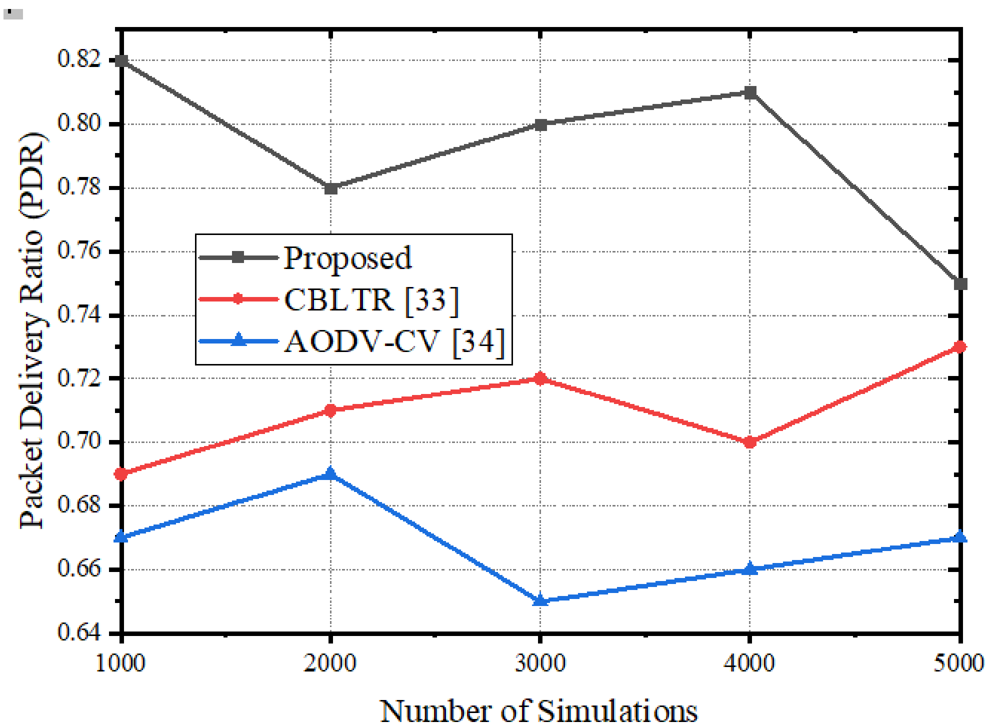

Figure 5.6 PDR Comparison for 50 nodes

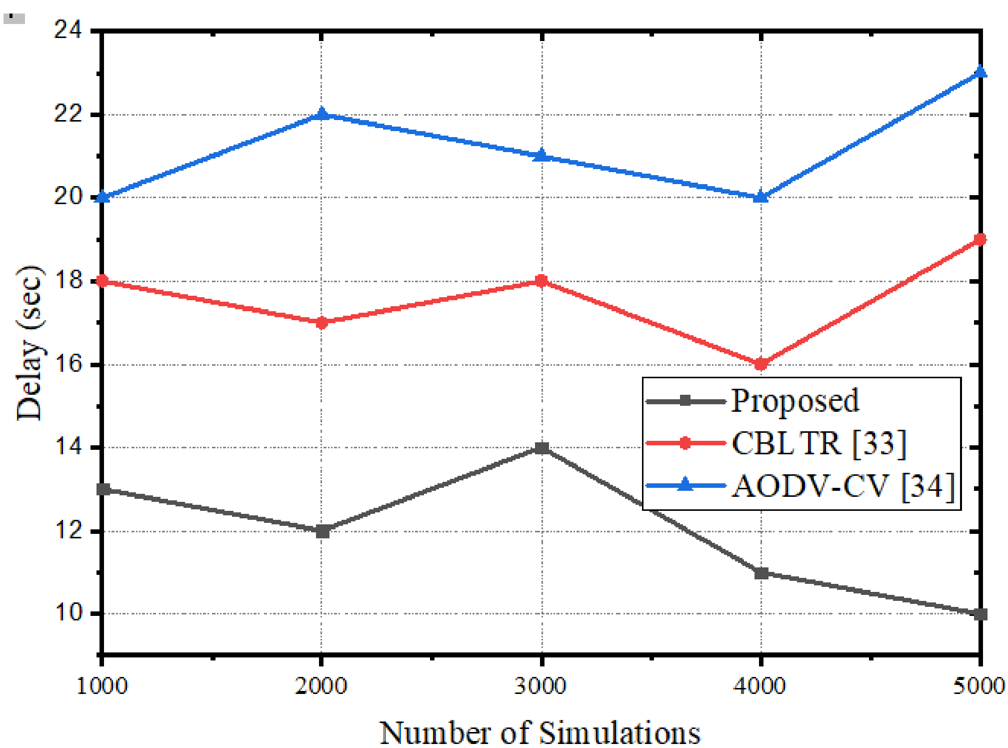

Figure 5.7 Delay Comparison for 50 nodes

5.5 Summary

In this chapter, a new clustering architecture is proposed that comprises of two algorithms: First, a k-means clustering scheme is suggested, which incorporates regional clustering techniques to minimize overhead and traffic management in VANET. Second, to choose the next-hop node for inter-clustering routing, a dynamic routing protocol is presented that considers the destination of a node, which increases the overall PDR and decreases the E2E latency. According to the simulation results, the proposed protocol outperforms the CBLTR [33] and AODV-CV [34] protocols. Comparative analysis indicates that the proposed protocol has provided 6.7 % and 9.7 % more throughput, 11.5% and 18.5 % more PDR, and 32 % and 43 % less E2E delay compared to CBLTR [33] and AODV-CV [34] protocols for a varying number of simulations in the network.

CHAPTER 6: Proposed Context-aware Reliable Routing Protocol

6.1 Introduction

In a VANET, the routing issue implies the various operational functions that have an effect on enhancing the performance of data transmission among sender and receiver in terms of a variety of QoS metrics like E2E delay, data packet distribution ratio, and so on. The key challenge of VANETs is to define the behavior of routing approaches in determining routes for data transmission with persistent mobility of vehicular nodes.

In the literature, routing schemes for VANET have been extensively studied. Routing protocols can be categorized into five groups based on how constructive, reactive, hybrid, adaptive, and context-aware they are. The proactive routing protocol sends a route discovery request to every node, increasing control overhead, energy consumption, and E2E latency. In order to reach only the intended destination, a source initiates a discovery process in the reactive routing protocol, but it still requires the path discovery process to find a route for each new node [103]. The constructive and reactive approaches are combined in the hybrid routing protocol. Clusters are areas where the nodes in a hybrid network are clustered together. Through using constructive intra-cluster routing and reactive inter-cluster routing, the clustering architecture improves network scalability. As a result, VANET environment scalability is improved, and overhead control messages are reduced. Despite the fact that clustering techniques reduce routing control overhead, regular CH selections enhance the re-election process's control overhead [104]. Because of the interference and mobility, the adaptive routing protocol can deal with varying network topology, node mobility, and complex wireless conditions. To address the problem of heavy congestion, context-aware routing integrates external resources of information like maps, location facilities, or even public transportation programs [105].

When developing a routing protocol, it's critical to consider the problems and characteristics of the infrastructure on which it'll be used. Some of the challenges are high mobility of nodes, dynamic changing topology, scalability, reliability, fault tolerance, energy consumption, uneven traffic density, neighborhood discovery, delay constraints, and real-time transmission [106]. In highly complex networks like VANETs, reliability is the most challenging problem to solve. A valid route can become invalid after a brief period because vehicle communication breaks down frequently due to the high speed at which vehicles travel. Using the shortest route for data communication between network nodes without considering route reliability may be an expensive solution. This occurred because these paths could become unacceptable shortly, interrupting data transmission frequently [107].

6.1.1 Reliability in VANET

To deliver safe communication among vehicles, a reliable routing approach is required. Because of the excessive mobility and frequent variation in network topology, establishing a reliable routing for VANETs is a challenging job. In VANETs, transmission links are extremely vulnerable to interruption; as a result, the routing efficiency of these constantly evolving networks requires special attention. In VANET, there are two types of reliability, which are mentioned below:

- **Link Reliability**: The likelihood that a direct connection among two vehicles will remain uninterruptedly accessible over definite time duration is known as link reliability. Assumed a prediction time T_P for constant accessibility of a particular link l among two vehicles at t, the link reliability $r(l)$ is specified as below:

$$r(l) = P\{\text{to continue to be available until } t + T_P \,|\, \text{available at } t\} \tag{6.1}$$

- **Route Reliability***:* In VANETs, various possible paths could occur among the source node s_r and the destination node d_e, where each path is a set of links among the source and the destination. For every provided path, the number of its established links by $\Omega: l_1 = (s_1, n_1), l_2 = (n_1, n_2), \ldots l_\Omega = (n_\Omega, d_e)$. The route reliability $R(P((s_r, d_e))$ for path P is described as follows:

$$R(P((s_r, d_e)) = \prod_{\omega=1}^{\Omega} r_t(l_\omega) \tag{6.2}$$

Where $r_t(l_\omega)$ is the link reliability as calculated in Equation (6.1).

In previous years, with the rapid development of soft computing techniques and machine learning techniques, routing protocols based on PSO, ABC, GA, SVM, and k-means have been extensively adopted by researchers to recognize and route packets among nodes in an improved way [108, 109]. Soft computing is a collection of predictive mathematical models that can be used to make predictions and decisions based on a vast quantity of data. This ability to predict and make choices may be critical in the VANET [110, 111]. However, in route selection, background details like communication type, E2E link-dependency, and packet load size can boost the performance of the VANET system. All these observations encourage the adoption of machine learning techniques to deliver the routing problem in VANET. Thus, to promote reliable routing in VANETs, we propose a novel context-aware reliable routing protocol which integrates k-means and SVM in this chapter. The K-means clustering divides the routes into two clusters named *GOOD* and *BAD*. The cluster with a high mean square error (MSE) is labeled as *BAD*, and the cluster with low MSE is labeled as *GOOD*. After trained the routing data with SVM, the performance of each route from source to target is evaluated by considering PDR, average E2E delay, and throughput. The proposed protocol will achieve improved routing efficiency with these changes.

The key contribution of the proposed protocol is as below:

- Introduces a context-aware method to distinguish the traffic flows with distinct context information in an attempt to minimize the communication overheads.
- Design a machine learning techniques-based routing which considers k-means and SVM approaches for optimal route selection in order to deliver reliability and

robustness against system malfunction, active topology, and varying mobility in VANET.

- Adopts PDR and E2E delay as routing metrics guarantee that the most reliable route is selected during transmission [112].

6.2 Preliminaries

This section primarily discusses the two machine learning techniques, k-means and SVM which are used in the proposed protocol.

6.2.1 K-means

It is a centroid-based approach in which every cluster is connected to a centroid. The primary goal is to reduce the distances among the data point and their consequent clusters. It takes the simple dataset as input, separates it into a k-amount of clusters, and reiterations the procedure until it does not determine the optimal clusters as presented in Fig. 6.1. The k-means clustering primarily executes two tasks:

- Find the optimal value for K by an iterative procedure.
- Allocates each data input to its nearby k-center and generates a cluster.

Hence each cluster has datapoints with some unities, and it does not belong to other clusters. However, the K-Means clustering method has been utilized effectively to resolve a variety of VANET issues.

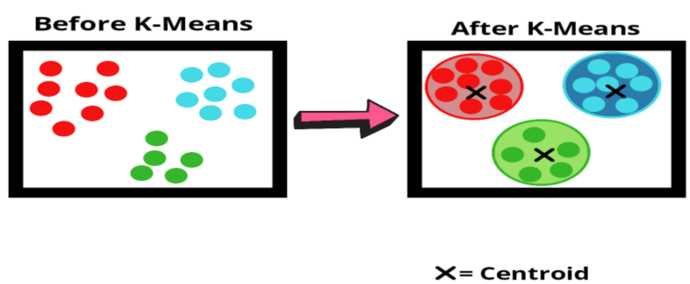

Figure 6.1 K-means Clustering Approach

6.2.2 SVM

SVM is a vector-oriented machine learning method that can perform pattern recognition and regression based on the principle of statistical study and the structural risk minimization principle. SVM provides a number of training examples, each one of which is designated as one of the various categories; an SVM training algorithm constructs a model that forecasts the category of the new examples. It separates two groups by a wide margin in order to keep them as far apart as possible. It is done through the transformation of small input space into large inputs, which turns non-distinguishable classes into discrete classes. Kernelized SVM is a common method for addressing classification problems. The use of the SVM classifier in applications like clustering, multi-class grouping, and ranking, on the other hand, adds to the computational load. As a result, SVM is often suggested for binary categorization. Fig. 6.2 represents the support vector machine approach.

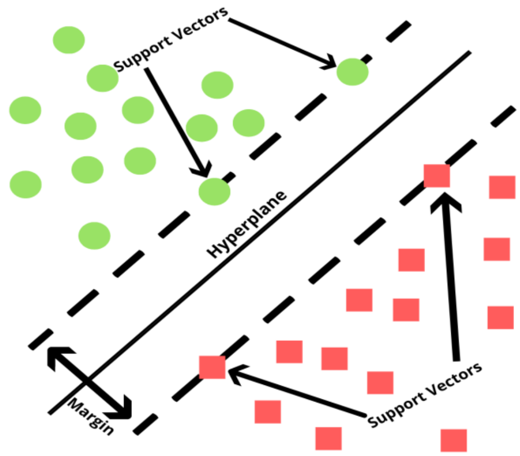

Figure 6.2 Support Vector Machine Approach

6.3 Proposed Hybrid (K-Means and SVM) Routing Protocol

The operation of the proposed protocol is defined as follows:

1. K-means clustering divides the input routes into k clusters or centroids. It evaluates the Euclidean distances among the data points and centroids and allocates points to the closest centroid. A process for grouping N data inputs $x_1, x_2, ...x_N$ into k clusters $C_i, i = 1,....k$, every comprising n_i data points, $0 < n_i < N$, reduces the subsequent mean-square-error (MSE) value:

$$J_{MSE} = \sum_{i=1}^{k} \sum_{x_t \in C_i} \left\| x_i^{(j)} - c_j \right\|^2 \tag{6.3}$$

where x_t is a vector signifying the t-th input and c_i signifies the geometric centroid of the cluster C_i. In order to minimize an objective value, a squared error function is used, where $\left\| x_i^{(j)} - c_j \right\|^2$ represents the distance between the data point x_t and the cluster center c_i.

$$I(x_i, j) = \begin{cases} 1 & if \;\; i{=}arg\ min(\left\| x_i - c_j \right\|^2)\ j = 1,......k \\ 0 & otherwise \end{cases} \tag{6.4}$$

Here $c_1, c_2, c_j, ...c_k$ are known as cluster centers which are acquired by the subsequent steps:

- Set k cluster centers $c_1, c_2, c_j, ...c_k$. For each input x_t and k cluster, perform stages 2 and 3 till all clusters congregate.
- Evaluate cluster membership value $I(x_i, j)$ using equation (6.4) and determine the membership of each input in every k clusters whose center is nearest to that centroid.
- For each k cluster, establish ci as a center of all data inputs in cluster Ci.

Consequently, K-means clustering divides the routes into two clusters named *GOOD* and *BAD*. The cluster with high MSE is termed as *BAD*, and the cluster with low MSE is termed as *GOOD*. The pseudo-code has been explained in Algorithm 6.1.

2. In this step, SVM is utilized to address the classification problems by converting an input vector into the n-dimensional feature set. To increase the space in

between the two classes, SVM is used which maximize the margin principle. SVM provides various kernel functions for mapping the vector to n dimensional data. Out of the given kernel function, the radial basis function (RBF) is being used for this kind of mapping. The expression for Gaussian RBF is given below.

$$K(c_1, c_2) = \exp\left(-\gamma \|c_1 - c_2\|^2\right) \tag{6.5}$$

where $K(c_1, c_2)$ represents the kernel function for two classes c_1 and c_2, $\gamma > 0$ and represented

$$\gamma = \frac{1}{2a^2} \tag{6.6}$$

3. The training and testing data accumulated from the produced simulations will train SVM in every iteration with random inputs until the best result is reached. The input data are normalized before training in each iteration. As a result, an SVM detects malicious activity in the network and sends the results to the response module with its own rules for a final decision.
4. After trained the routing data with SVM, during the execution, the following parameters of each route from source to destination are evaluated:
   - *PDR:* It is the average proportion of all data messages profitably obtained at the destination across all the packets created at the source node by the application layer.
   - *Average E2E delay:* The average duration time among sending and receiving for received packets.
   - *Throughput:* It indicates the number of packets transported in a specified duration of time from source to destination.

Determine the routes with low PDR, high E2E delay, and low throughput and determine the corresponding nodes frequently in these routes.

5. After determining the nodes which occur frequently in the non-optimal routes, the proposed approach eliminates the routes which consist of nodes from BAD cluster

and shift the load of the malicious nodes to its nearby node in order to maintain reliability.

Algorithm 6.1: K-means Clustering-based VANET Routing

Input Parameters:

a) Set of Routes $R = \{r_1, r_2, r_3, ...r_N\}$

b) Initial number of clusters K

c) Direction, Velocity, and Location each Vehicle node

Output Parameters:

a) Optimal clusters: GOOD and BAD

1. Randomly initialize K centroids in space
2. For $i = 1$ to N do
3. Calculate the membership function $I(x_i, j)$
4. Assign routes to convenient clusters according to $I(x_i, j)$
5. End for
6. If all routes are assigned to cluster, then
7. End of the algorithm
8. Else

9. $K = K + 1$

10. End if

11. If MSE of cluster = high, then

12. Cluster = GOOD

13. Else

14. Cluster = BAD

15. End if

6.4 Simulations and Results

Two types of simulators are used to assess the execution of the proposed protocol: the traffic simulator that replicates the vehicle mobility and the network simulator that creates the vehicular area. The SUMO is the most used traffic simulator in VANET. A 1000 x 1000 area segment is applied to test the proposed protocol; the segment is then split into clusters. Firstly, 100 vehicles are allocated by uniform distribution to the segment, and constant velocity is assigned to each vehicle. As simulation results, compared with the performance of the proposed protocol CBLTR [33] and AODV-CV [34] regarding PDR, throughput, and E2E delay. Table 6.1 provides a complete list of parameters for the simulation.

Table 6.1 Simulation Parameters

Simulation Parameter	Simulation Value
Simulation Time	1000 -5000 sec
Area Covered	1000 x 1000

Vehicular Nodes	50-100
Range of Communication	250 units
Speed Range for Vehicles	(10-60) kmph
Size of Packet	1024
MAC	802.11p

Initially, in order to test the protocol proposed, 100 vehicles are distributed on a uniformly distributed segment, and each vehicle is randomly selected constant velocity from predefined speed ranges as follows: 57 hours, 27 hours. The output of the proposed algorithm is presented and compared with (Aravindhan and Dhas) [38] and CBLTR [33] in terms of packet delivery ratio and packet transmission delay. Due to the unpredictability of network speed and density between vehicles, the key reason to consider various simulation speed and density factors was the lack of contact and connection between the vehicles. In reality, the connectivity and the quality of routing between vehicles play a major position in the lives of these two factors.

In PDR, the percentage of data packets reaching destinations is compared with the total number of packets sent to the destination. The PDR is shown in Table 6.2 based on the various vehicle speeds. The vehicle nodes often shift as the speed increases, i.e., the knots reach their static limits very often. The delivery ratio is decreasing with an increase in vehicle speed.

Table 6.2 Packet Delivery Ratio versus Mobility

Maximum Speed (km/h)	Packet Delivery Ratio		
	PDR Proposed	(Aravindhan and Dhas) [38]	CBLTR [33]
10	0.956	0.921147	0.881252

20	0.94114	0.91254	0.830825
30	0.89547	0.83254	0.776322
40	0.88471	0.85541	0.831066
50	0.831148	0.82146	0.731932
60	0.82114	0.80189	0.743047

The reason behind the increase of dropped packages at higher speeds was the faster shift of vehicle positions. The node nearest to the destination is chosen as the next hop in CBLTR [33] by using the weighting mechanism. Such nodes are typically near to the communication range's edge and can exit it in less time when the speed is higher. In order to increase the reliability, failure probability as well as corresponding end-to-end parameter will be reduced at different speeds and when selecting the link, take into consideration several parameters.

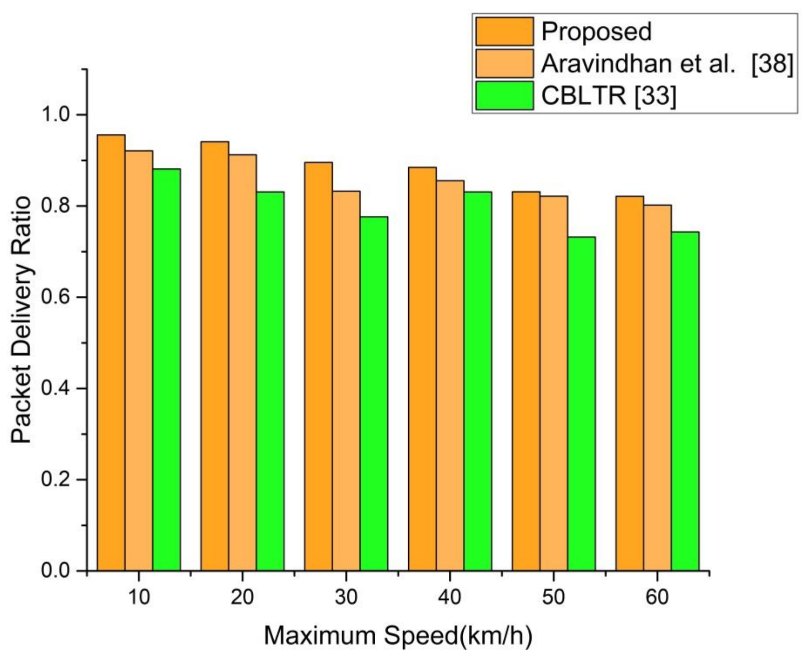

Figure 6.3 Packet delivery Ratio versus Mobility

Fig. 6.3 displays the percentage improvement in PDR in the proposed protocol as compared to (Aravindhan and Dhas [38] and CBLTR [33] protocols with varying mobility. It should be noted that in protocols such as Aravindhan and Dhas [38] and CBLTR [33], increased velocity results in a lower packet delivery rate. Connection failure likelihood is reduced in the proposed protocol because K-means was used for the most reliable connection, and the lowest cost node was selected between the CHs.

Table 6.3, 6.4, and 6.5 show the comparison of PDR with varying the vehicle nodes for the proposed, Aravindhan and Dhas [38] and CBLTR [33] protocols network areas 1000 x 1000, 1200 x 1200, and 1500 x 1500, respectively. It demonstrates that as the amount of vehicles increases, so does the distribution rate. That's because of the fact that when there are few vehicles on the route, it may be challenging to locate nearby forwarding vehicles, and therefore messages are dropped after the wait time. CBLTR [33] has the least PDR in comparison to all other protocols as it declined to manage the network changing aspects efficiently as compared to the proposed protocol. Furthermore, before sending the message, CBLTR [33] must first explore the route. Since the clusters in CBLTR [33] change regularly, the established route must be maintained on a regular basis and may be invalid when the actual message is sent. Unlike CBLTR [33], Aravindhan and Dhas [38] only sense the next available message forwarder and thus adapts much better than CBLTR [33] to the complex existence of the VANET network topology.

Table 6.3 Packet Delivery Ratio versus Vehicular Nodes in Area (1000 x 1000)

Total Number of Vehicles	Packet Delivery Ratio (1000x1000)		
	PDR Proposed	(Aravindhan and Dhas) [38]	CBLTR [33]
50	0.92114	0.901458	0.84759
60	0.92847	0.89554	0.853078

70	0.93145	0.882145	0.861486
80	0.93259	0.87452	0.871304
90	0.942234	0.86325	0.872346
100	0.95112	0.923541	0.876269

Table 6.4 Packet Delivery Ratio versus Vehicular Nodes in Area (1200 x 1200)

Total Number of Vehicles	Packet Delivery Ratio (1200 x 1200)		
	PDR Proposed	(Aravindhan and Dhas) [38]	CBLTR [33]
50	0.92181	0.90114	0.847996
60	0.927007	0.910982	0.856946
70	0.932966	0.882145	0.857473
80	0.940004	0.87452	0.860932
90	0.943054	0.86325	0.868258
100	0.951186	0.923541	0.871627

Table 6.5 Packet Delivery Ratio versus Vehicular Nodes in Area (1500 x 1500)

Total Number of Vehicles	Packet Delivery Ratio (1500 x 1500)		
	PDR Proposed	(Aravindhan and Dhas) [38]	CBLTR [33]
50	0.92114	0.901458	0.850015

60	0.92847	0.89554	0.850314
70	0.93145	0.882145	0.857059
80	0.93259	0.87452	0.860566
90	0.942234	0.86325	0.868399
100	0.95112	0.923541	0.876087

Figures 6.4, 6.5, and 6.6 show the improvement in PDR with varying vehicular node density in the network areas 1000 x 1000, 1200 x 1200, and 1500 x 1500, respectively. The proposed protocol indicates the PDR improvement compared to CBLTR [33] and Aravindhan and Dhas [38] because of effective route selection using K-means and SVM approach. The average PDR in the proposed protocol is increased by 5 % as compared to Aravindhan and Dhas [38] protocol, and 8.2 % compared to CBLTR [33] protocol for vehicular nodes in the network area of 1000x1000, as shown in Fig. 6.4.

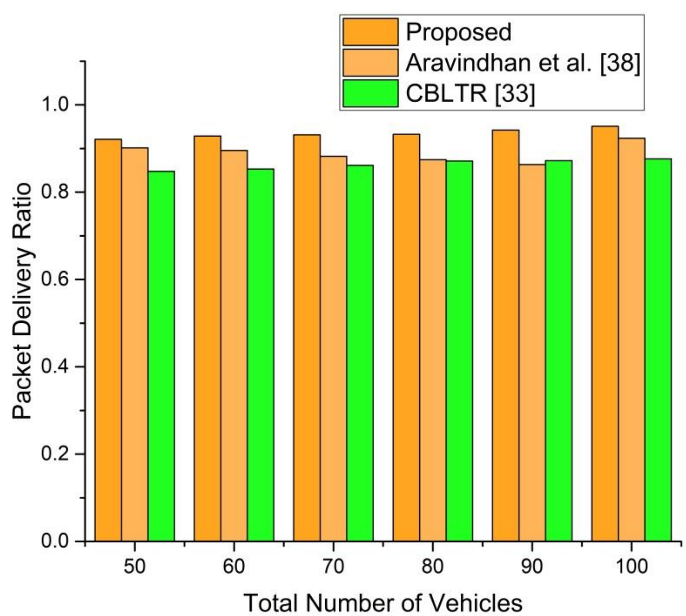

Figure 6.4 Packet delivery Ratio versus Vehicular Nodes (1000x1000)

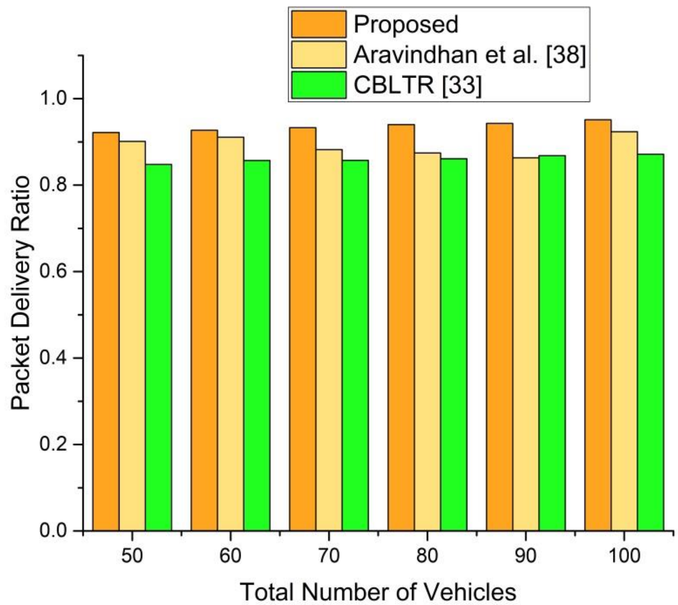

Figure 6.5 Packet Delivery Ratio versus Vehicular Nodes (1200x1200)

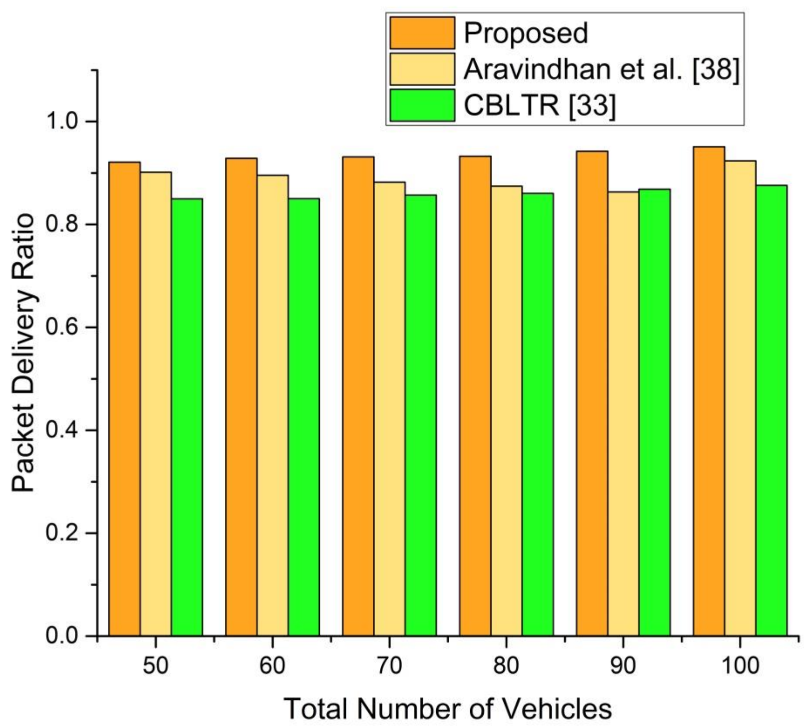

Figure 6.6 Packet Delivery Ratio versus Vehicular Nodes (1500x1500)

Figures 6.7 and 6.8 show the improvement in delay with varying vehicular node density in the network areas 1000 x 1000 and 1500 x 1500, respectively. It has been observed that as traffic density rises, so does end-to-end latency. The CBLTR [33] protocol has the longest end-to-end delay.

The typical end-to-end delay is the amount of time a data packet takes to travel in the middle of its origin and destination. Table 6.6 and 6.7 display the comparison of delay with varying the vehicle nodes for the proposed, Aravindhan and Dhas [38] and CBLTR [33] protocols in network areas 1000 x 1000, and 1500 x 1500, respectively. Increased node distance increases the likelihood of connection and packet delay in VANETs. Since the proposed solution uses secure paths, fewer connections are broken when transmitting data, resulting in less end-to-end latency. Figures 6.7 and 6.8 show the delay vs vehicular nodes in network areas 1000x1000 and 1500x1500.

Table 6.6 Delay versus Vehicular Nodes in Area (1000 x 1000)

Total Number of Vehicles	Delay (1000 x 1000)		
	Proposed	(Aravindhan and Dhas) [38]	CBLTR [33]
50	55.74125	61.7025	68.9633
60	53.65745	61.62673	66.95025
70	52.68301	59.20148	64.20894
80	50.44252	57.73666	63.06623
90	50.27617	53.77705	61.147
100	48.32444	50.89118	58.76468

Table 6.7 Delay versus Vehicular Nodes in Area (1500 x 1500)

Total Number of Vehicles	Delay (1500 x 1500)		
	Proposed	(Aravindhan and Dhas) [38]	CBLTR [33]
50	54.221	61.047	66.235
60	51.7447	60.74139	64.15697
70	51.63957	59.68256	62.36491
80	51.44708	57.30921	60.98239
90	50.36123	56.52751	58.08472
100	49.92715	54.16984	55.1998

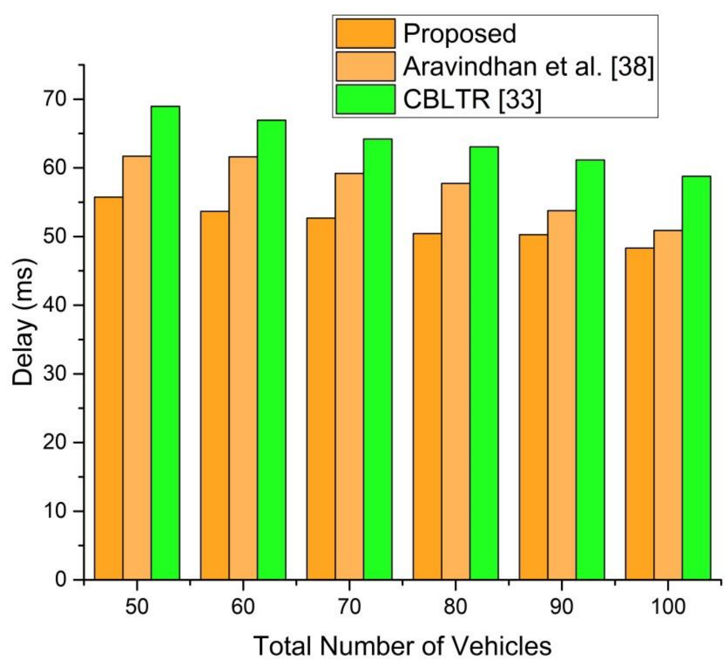

Figure 6.7 Delay versus Vehicular Nodes (1000x1000)

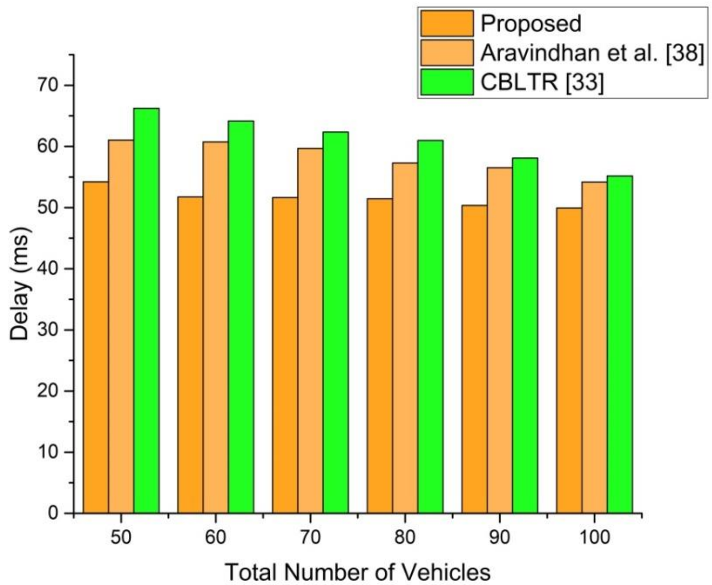

Figure 6.8 Delay versus Vehicular Nodes (1500x1500)

The key explanation for this delay is that in CBLTR [33] protocol, only a single variable is chosen for adjacent nodes, which is invariably the nearest neighbor. This issue was overcome in the proposed protocol by using K-means and taking into account a number of parameters. The average end-to-end delay of dissimilar densities of vehicles for the proposed protocol reduced at a firm pace, as shown in the figures above.

6.5 Summary

To promote reliable routing in VANETs, a novel context-aware reliable routing protocol has been proposed which integrates k-means and support vector machine (SVM) in this work. The performance of each route from source to target is evaluated by considering PDR and average E2E delay. The simulation results of proposed results reveal that it is more effective in comparison to CBLTR [33] and Aravindhan et al. [38] protocols. Comparative analysis indicates that the proposed protocol has up to 5 % and 8.4 % more PDR, and has up to 10.5 % and 17.1 % less E2E delay in comparison to CBLTR [33] and Aravindhan et al. [38] for different area sizes. The benefit of the technique is that even after increasing the number of nodes the throughput is improved and delay is reduced.

CHAPTER 7: Conclusion and Future Scope

7.1 Conclusion

In this work, clustering algorithms and routing protocols are implemented to improve performance parameters in VANET. Clustering is one of the control mechanisms for dynamic topology in the high-speed environment of VANET. This converts an automobile system into an intelligent transportation network that benefits society. In the fast-moving world, the vehicle's speed ranges increases day by day due to better infrastructure in developed countries. This caused the issue of link stability in the network due to frequent disconnections. So it was important to work on the performance parameters for better efficiency of the network. The proposed VANET clustering algorithms are used to group similar vehicles in communication networks. Via clustering technology, the channel contention between cluster members can be effectively restricted, and fair channel access ensured. The new context-conscious cluster algorithm for effective and reliable transmission of data in VANET is proposed in this report.

The various algorithms like prediction based, FoV based, Highest degree algorithm, AODV-CV, CBLTR are focussed and compared in different input conditions to measure the performance parameters in traffic conditions and suitable results are obtained for comparison which serves the first objective of the work.

In the 2nd objective, there is the need to reduce the time of data transmission in the vehicle nodes so the delay should be reduced. In chapter 3, the proposed protocol takes into the account coverage area, stability, and buffer size of the nodes to select an optimal route. It minimizes the delay (as a higher coverage area will lead to quick route rebuilding in case of path breaks). AODV, DSDV, and CBR routing protocols are compared with the proposed technique, which is more efficient than existing protocols, specially CBRP (performs the best in existing protocols) by 35% in terms of delay.

Whereas in chapter 4 highest degree algorithm is presented in which, for 35 vehicle nodes, the highest degree algorithm performs 44.4 % and 42.8 % better in terms of delay than prediction-based and FoV based techniques. And for 50 vehicle nodes, the highest degree algorithm performs 37.2% and 32.8% better in terms of delay than prediction-based and FoV based techniques. In chapter 5 dynamic routing protocol is proposed which has up to 32 % and 43 % less E2E delay compared to CBLTR [33] and AODV-CV [34] protocols for a varying number of simulations in the network. A novel context-aware reliable routing protocol that integrates k-means and support vector machine (SVM) is presented in chapter 6 which has up to 10.5 % and 17.1 % less E2E delay in comparison to CBLTR [33] and Aravindhan et al. [38] for different area sizes.

The 3rd objective demands to increase the efficiency of the network by improving in PDR and reducing the overhead by reducing the packet loss and delay. In chapter 3, AODV, DSDV, and CBR routing protocols are compared with the proposed technique, which is more efficient than existing protocols, specially CBRP (performs the best in existing protocols) by 3% in terms of PDR. Whereas in chapter 4 highest degree algorithm is presented where for 35 vehicle nodes, the highest degree algorithm performs 16.6 % and 9.3 % better in terms of PDR and 31.5 %, and 19.3 % in terms of packet loss, than prediction-based and FoV based techniques. And for 50 vehicle nodes, the highest degree algorithm performs 24.3 % and 15 % better in terms of PDR and 33.3 %, and 25.3 % in terms of packet loss, than prediction-based and FoV based techniques. In chapter 5 dynamic routing protocol is proposed which has up to 11.5 % and 18.5 % more PDR, compared to CBLTR [33] and AODV-CV [34] protocols for a varying number of simulations in the network. A novel context-aware reliable routing protocol that integrates k-means and support vector machine (SVM) is presented in chapter 6 which has up to 5 % and 8.4 % more PDR in comparison to CBLTR [33] and Aravindhan et al. [38] for different area sizes.

The 4th objective is focused on increasing the throughput in different traffic conditions. So in chapter 3, AODV, DSDV, and CBR routing protocols are compared with the proposed technique, which is more efficient than existing protocols, specially CBRP (performs the best in existing protocols) by 6% in terms of throughput. Whereas in chapter 4 highest degree algorithm is presented where, for 35 vehicle nodes, the highest degree algorithm performs 81.5 % and 40.4 % better for throughput than prediction-based and FoV based techniques. And for 50 vehicle nodes, the highest degree algorithm performs 66.3% and 36.6% better in terms of throughput than prediction-based and FoV based techniques. In chapter 5, the dynamic routing protocol is proposed which has up to 6.7 % and 9.7 % more throughput, compared to CBLTR [33] and AODV-CV [34] protocols for a varying number of simulations in the network.

7.2 Future Scope

To meet the need for applications, this section discusses research gaps in which the science is either not studied or not completely utilized with maximum ability:

- **Location Prediction**: In VANET, due to high-speed network situations, the location of vehicles often changes. The role of the cluster protocol in an uneven vehicle density scenario for precise location prediction should be comprehensively analyzed.
- **Trustworthiness:** In the trustworthiness verification process, vehicles require to discover the requested data. It is hard to handle both trust and user privacy for such procedures. Therefore, to guarantee the trade-off between privacy and trust, a need for a robust cluster-based architecture.
- **Hybrid Scenario**: The latest proposal on clustering protocols has taken into account urban or highway situations in the literature. For a hybrid road scenario, a special investigation is needed.
- **QoS Provisioning**: VANET has several unique characteristics, including a complex topology and repeated link breaks, which cause numerous routing issues in the transmitting phase. As a result, maintaining QoS in this setting is a difficult task.
- **QoS-adjusted Backbone Structure**: Providing QoS-aware broadcasting channels for V2I and V2V communications is one of the hottest research areas. Developing

consistent and flexible roadside structures with sequential functionality is also expected to be the subject of a lot of research in the future.

- **Bandwidth Constraint**: The increased bandwidth demand can result in band overloading, resulting in service degradation. As a result, ensuring QoS assistance in these circumstances will be simpler if IEEE 802.11p range shortage occurs. In light of this, we assume that more research into communication standards could lead to more effective QoS broadcasting approaches for VANET.
- **Delay Constraint**: In the future, the selection of cluster head can be done using some metaheuristic algorithm as well. Also, roadside units can be incorporated into the network to perform clustering in a centralized way. This will reduce the overhead of the network as well.

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List of Publications

List of Journals:

[1] M. Sindhwani, C. Singh and R. Singh, “Implementation of K-Means Algorithm and Dynamic Routing Protocol in VANET,” Computer Systems Science and Engineering. **(SCI Indexed: Paper Accepted)**

[2] M. Sindhwani, R. Singh, A. Sachdeva, and C. Singh, "Improvisation of optimization technique and AODV routing protocol in VANET," Materials Today: Proceedings 2021. https://doi.org/10.1016/j.matpr.2021.03.727 **(Elsevier-Scopus Indexed)**

[3] M. Sindhwani and C. Singh, "Comparative Study of Cluster Head Selection Techniques in VANET under traffic conditions," International Journal of Emerging Technologies and Innovative Research, ISSN: 2349-5162, Vol.6, Issue 2, page no.66-78, February-2019. **(UGC Care listed)**

[4] M. Sindhwani and C. Singh, “VANET Applications and Characteristics under Dynamic Traffic Conditions,” International Journal of Emerging Technologies and Innovative Research, ISSN: 2349-5162, Vol.6, Issue 1, page no.1186-1189, January-2019. **(UGC Care listed)**

List of Conferences:

[5] M. Sindhwani and C. Singh, "Cluster Head Selection With Dynamic Clustering Technique Using Mobility And Stability Parameters," Intelligent Circuits and Systems, ICICS 2020. **(Scopus indexed: accepted and presented)**

[6] M. Sindhwani, C. Singh and R. Singh, "Enhanced Study on Security Major Issues And Challenges In Vehicular Area Networks," Global Emerging Innovation Summit, GEIS 2021. **(Scopus indexed: accepted and presented).**

[7] M. Sindhwani, C. Singh and R. Singh, “Enhanced Study on Components, Challenges and Applications In Vehicular Area Networks,” International

Conference on Recent Innovations in Computing (ICRIC-2021). **(Scopus indexed: Paper Accepted)**

[8] M. Sindhwani, C. Singh and R. Singh, "Multi-Objective Gravitational Search Algorithm Based Clustering Scheme in VANET," International Conference on Recent Innovations in Computing (ICRIC-2021). **(Scopus indexed: Paper Accepted)**

List of Book Chapters:

[9] M. Sindhwani, C. Singh and R. Singh, "IOT Forensics meets VANET: Challenges and Opportunities," Digital Forensics and Internet of things: Impact and Challenges. **(Book Chapter, Scopus Indexed: Accepted)**

[10] M. Sindhwani, C. Singh and R. Singh, "Blockchain Technology based System in Vehicular Ad-hoc Network," Cross- Industry Blockchain Technology: Opportunities and challenges in industry 4.0. **(Book Chapter, Scopus Indexed: Accepted)**

List of Research Articles under Review:

[11] M. Sindhwani, C. Singh and R. Singh, "Soft computing techniques aware clustering-based routing protocols in Vehicular Area networks: A Survey" International Journal of Information and Communication Technology. **(Scopus Indexed: Paper under Review).**

[12] M. Sindhwani, C. Singh and R. Singh, "UAV meets VANET: A Hybrid Model for Performance Enhancement in Smart Cities," Recent Advances in Computer Science and Communications. **(Scopus Indexed: Paper under Review).**