

An emergency vehicle prioritization protocol for VANET based on QoS

by

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Abstract

Since supplying passenger safety is the fundamental purpose of establishing vehicular ad hoc networks, researchers are mainly concerned with giving a strategy to ensure meeting this demand. Rescue services vehicles are one of the primary components of VANET, and the messages they broadcast play a vital part in delivering safety. As a result, offering a routing protocol algorithm that prioritizes their messages and guarantees QoS is one approach to meet the core purpose of VANET, or in other words, safety. Grouping the vehicle nodes, also known as clustering, is one of the appropriate solutions for improving the performance of the routing protocol. Most traditional cluster-based topologies in VANET solely consider the mobility to pick the cluster head. While cluster head speed fluctuations can affect the number of cluster head choices and improve the VANET QoS. Furthermore, the fast movement of vehicles exposes clustering links to vulnerability and directly impacts reliability. In this research, we proposed a new efficient multi-hop cluster-based routing protocol that prioritizes emergency vehicles' messages and provides stable and reliable communications to ensure emergency messages are delivered effectively. The number of neighbors, the distance between the vehicle and BS, and the S/N power received by the base station (BS) are the criteria for selecting a cluster head (CH) in our proposed model. Each CH is in charge of transmitting data from other cluster members to the infrastructure directly or indirectly through the qualified adjacent cluster heads. The epigenomic workflow approach is employed in our design to establish efficient resource management in RSU computing nodes and decrease transmission latency. The transmitted messages from vehicles are divided into two separate queues (q1 and q2), while the priority message queue uses the TDMA protocol to disseminate. In this thesis, experiments and simulations were carried out utilizing the NS-2 tool with VanetMobisim integration to assess the efficacy of the suggested approach. Achieved results indicate that the proposed technique increases communication reliability and stability while improving QoS for messages provided by rescue services.

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Chapter 1

Introduction

As the number of vehicles on the road increases, so does the possibility of accidents and congestion, which has become a significant concern for passengers, healthcare organizations, and the vehicle industry. As a result, the Vehicular Ad hoc network (VANET) has evolved to alleviate these concerns, enhance driving quality, and provide essential entertainment and information to drivers and passengers. Furthermore, wireless transmission platforms such as WiFi, Bluetooth, and WiMAX have been adopted to create connections and transport data among devices with variable radio transmission ranges. A vehicular ad hoc network (VANET) is a type of mobile ad hoc network (MANET) in which vehicles, such as cars, actively participate in system communication with no infrastructure, such as routers or phone towers, to manage them [2]. Though VANETs are a subset of MANETs, with both being self-organized, they differ significantly in network architecture, mobility behavior, energy resources, power consumption, and application configuration. Driver behavior, mobility restrictions, and high-velocity cause VANETs to have distinguishing characteristics such as quick but relatively anticipated changes in the network topology, unbalanced network load, and regular breakage[1].

1.1 Vehicular Ad Hoc Network

Since more vehicles are outfitted with computing technology and wireless communication devices, inter-vehicle networking is becoming a fascinating field of study, standardization, and progress. Each vehicle in a VANET network can play one of three roles: transmitter, receiver, or router [3]. Therefore, vehicles must be equipped with devices such as communication modules, transceivers, and internal sensors to transmit information such

as vehicle status, road conditions, and other pertinent data. All equipment is attached to the onboard unit system (OBU), one of the fundamental components of the VANET.

Vehicles can communicate directly with one another through onboard units (OBUs) to send messages, which is known as vehicle-to-vehicle (V2V) communications. V2V communications are supported by a reliable wireless technology known as dedicated short-range communication (DSRC). However, given the features of fast-moving vehicle nodes, unequal distribution, and constantly varying VANET topology, relying entirely on V2V to perform technical communication is unfeasible. Therefore, the fixed-based infrastructure in heterogeneous architecture, which is employed the fourth-generation cellular system LTE (Long Term Evolution), is used to enhance VANET capabilities. The communication between vehicles and infrastructure is referred to as V2I. VANET architectures employ Base Stations (BS) to efficiently communicate between vehicles and service providers such as cloud storage, servers, the Internet, etc. The employment of LTE technology is motivated by its broad transmission range (100km) in the radio access network (RAN) and low transmission latency (less than 5ms) [4].

In addition to the BS as a fixed infrastructure, there are Road Side Units (RSUs) installed along the roadside or in specific areas such as crossroads or near parking spots to extend vehicle communication coverage. The DSRC protocol is also used for communication between vehicles and RSUs, which have a less extensive coverage range than BSs.

The DSRC standard provides the services to transmit messages from a vehicle every 100-300 ms over a range of 300 meters. With growing traffic congestion in this communication range, each car has to keep between 1000 and 10000 messages per second in the buffer and verification queue [5]. This queue severely affects the computing power and storage of vehicles and leads to disruption of delivering services. On the other hand, although LTE offers a faster transfer rate and a broader communication range, the frequent handover due to the interaction between individual cars and fixed stations consumes a large portion of the network's bandwidth. In addition, overhead is especially significant in the case of high car densities, which can be decreased by using the self-organized nature of V2V technology. Another notable challenge is that V2V connectivity only provides local knowledge of the vehicular network, whereas V2I provides more detailed city-wide information. Since V2V and V2I communication have their advantages and disadvantages and complement one another in various ways, we could obtain additional benefits by combining these technologies. The mixed network design completely incorporates the benefits of lower system overhead and longer connectivity time of V2V with

the advantage of shorter transmission latency, powerful processors, vast storage, and extended dissemination scope of V2I.

Another technique for decreasing handover and ensuring more consistent connectivity is to divide the vehicular network into smaller clusters based on similar features [6]. By clustering vehicles, some of them assume the position of a leader known as cluster heads (CHs) based on the defined criteria, whereas the remainder act as followers that are referred to as cluster members (CMs). Followers or CMs exchange their packets to base stations solely through the cluster heads, reducing the number of handovers between cars and base stations and, as a result, network overhead. Moreover, real-time and effective data distribution, efficient data management, scalability [7], as well as improved security are the other benefits of the VANET clustering approach [8]. Despite these benefits, the clustering technique is not without its challenges. Clustering stability is a critical factor that influences clustering performance and network QoS. In the absence of cluster stability, clustering overhead, transmission delay, and medium congestion worsen, wasting bandwidth, and increasing packet loss, ultimately lowering QoS and network disruption. In addition to stability, clustering should guarantee reliability by providing link reliability. However, due to the fast speed and unpredictable topology, establishing a reliable link in a vehicular network is challenging. These obstacles must be addressed while building a clustering algorithm for a vehicular scenario.

On the other hand, it should be highlighted that some vehicles, such as ambulances, fire engines, and police cars, emit signals that convey critical information about human life and health. If the signals on these vehicles are missing, late, or faulty, they could cause detrimental consequences. The timeliness and accuracy of these communications, which carry warnings or notifications, become particularly critical when an emergency occurs. As a result, we must devise a method to deliver their message with minimum delay and maximum reliable transmission rate. Adopting the efficient and scalable routing protocol in VANET, which considers the priority of rescue services while maintaining the QoS standard and reliability, becomes the main task of this thesis.

To process data and conduct calculations in the VANET project, we must employ computing resources that can be embedded in vehicles, RSUs, BSs, or any other node in the network. If the computing nodes are too far from the vehicles, a significant delay is imposed on the network, reducing network efficiency. Using the vehicle's resources to conduct essential calculations also is not a good approach in most cases where we need to perform sophisticated computations and have a large amount of data. RSU is one of the acceptable choices that are closer to vehicles and capable of outperforming

vehicles. RSU is one of the acceptable choices that are closer to vehicles and capable of outperforming vehicles. Although RSUs are far less powerful than BSs, it is feasible to use their capabilities and outsource certain network operations to them. However, their computing resources are limited and should be managed to facilitate the flow of data as well as serve various users' sent communications. In fact, computing nodes must schedule their jobs such that they do not impose an excessive burden on the available resources responsible for executing complex computations, which might cause the servicing to slow down or fail outright. Slow service delays response, which is unacceptable, particularly in an emergency.

1.2 Motivation

VANET applications are designed with aims such as improved traffic management, road safety, and accident avoidance, and they have a direct impact on the lives of those who commute by vehicle. To achieve the aim, vehicles must broadcast and receive messages such as road safety, traffic, and information services in real-time via vehicular networks. Consequently, criteria such as network overhead, packet delivery ratio, transmission delay, and resource management that represent the quality of service (QoS) in VANET are received a large amount of importance. Reducing the QoS range from a specific amount might generate a lot of latency and overhead on the network, and in the worst scenario, can prevent vehicles from communicating with each other.

Establishing and maintaining appropriate QoS in vehicular networks is essential to network stability and efficiency. QoS support contributes to more predictable network communication behavior, allowing network-driven information to be more effectively balanced and network resources to operate more efficiently [9]. Therefore, finding a solution to the trade-off between improving QoS and high-speed mobility restrictions has become very appealing to technology users.

Using the cluster-based architecture is one of the proposed solutions for improving network management and QoS, including network overhead and scalability. Although different algorithms were implemented in VANET utilizing the clustering approach, the unstable linkage between nodes caused by the vehicles' quick and fluctuating movement still makes it challenging to discover a decent algorithm to determine the appropriate CH. Choosing unstable cluster heads can harm network performance by lowering packet delivery ratio (PDR) and throughput while increasing overhead and latency. Therefore, by providing an appropriate algorithm for creating clusters and selecting stable cluster

heads, which increases cluster stability, we achieve an acceptable level of QoS in vehicular networks.

Large-scale metropolitan environments have a heavy influx of vehicles in VANETs, especially during rush hours, and their communication exchange can readily overload the wireless channel with high traffic loads. Prioritizing messaging can prevent data from being transmitted over the network at the same time and improve traffic prediction, hence avoiding regional congestion. On the other hand, the routing reliability of vehicles that exchange emergency communications, such as ambulances and fire trucks, is especially vital. As a result, a reliable data distribution strategy is required to minimize packet loss while still ensuring appropriate packet delay and overhead [10].

As previously indicated, we can delegate a portion of the computing process to RSUs that are close and more powerful than vehicles. However, employing them has its series of challenges. Assigning RSU as a computing node deploys computer resources near cars, saving time while serving data. This attribute is perfect for latency-sensitive communications. At the same time, the primary concern of employing them is limited resources to execute sophisticated processes and data storage. As the VANET applications have an Adhoc characteristic, they must be aware and intelligent about their surrounding, making them more fault-tolerant in the presence of topological changes. Accordingly, applying RSU with improved resource management could be the best suggestion for gathering encompassing information. A thorough review of the relevant literature revealed that there is no substantial study to evaluate the influence of prioritizing vehicles on enhancing the quality of service (QoS) in vehicular networks utilizing the clustering approach and with the help of a task scheduler. Therefore, developing an algorithm in a cluster-based VANET that employs a task scheduler in RSU while considering the priority of emergency vehicles and systematically comparing its performance with different clustering approaches implemented in vehicular networks can be a novel method for improving the system QoS.

1.3 Problem statement

Distinctive aspects that arise in the vehicular ad-hoc network owing to unexpected driver behavior, vast size, dynamic topology, high mobility of nodes, and fluctuating vehicle density on the road have faced inherent obstacles. Transmitting the emergency messages through the VANET application needs strict restrictions on latency, packet delivery ratio, and delivery distance shown in table 1.1. The Generating Rate describes the

pace at which packets are generated by the nodes; the Distribution Range represents the maximum radius over which the safety signal must be propagated; finally, the MAX Lag indicates the maximum allowable delay for data supplied for potential dangers. As shown in table 1.1, the required coverage area for dissemination of safety signals is 400m -1000m, whereas the WAVE standard has a limited radius scope of roughly 300 meters. As an alternative solution[4],[1], researchers replaced fourth-generation wireless communications with higher distribution coverage and faster transmission speed. One of the drawbacks of this alternate technology, named long-term evolution (LTE), is the frequent handover between vehicles and stationary BS along the roadway.

Amenity	Generating Rate	Distribution Range	Max Lag
Safety Recall Notice	-	400 m	5 s
Vehicle Diagnostic and Maintenance	10 Hz	500 m	5 s
Wrong Way Alert	10 Hz	500 m	1 s
Emergency Vehicle Signal	1 Hz	1000 m	1 s
Approaching Rescue Services Warning	-	1000 m	1 s

Table 1.1: VANET Safety Application Requirements [1]

Clustering of the networks is employed to relieve some of the challenges, such as minimizing the complexity of flat networks, enhancing scalability, and reducing the number of handovers; However, several obstacles must be overcome, which are as follows:

- One of the most complicated aspects of clustering network architecture is determining the optimal technique to transport data across clusters while adhering to QoS and reliability restrictions.
- Another challenge with clustering methods is the high generation of clustering overhead as an outcome of the exchange of high-speed control messages for the construction and maintenance of cluster heads and cluster structures. In addition to the extra clustering overhead, end-to-end latency due to failure to identify the optimum cluster head may occur in cluster-based architectures.
- On the other hand, transferring a significant number of data from high-mobility vehicles to centralized and distant servers for analysis and storage takes considerable time and energy. To maintain optimal QoS, creating computing resources close to the edge is necessary, which cannot be as powerful or massive as the central servers.

Although this technique minimizes the latency of remote server access, limitations on these nodes' processing and storage capacity increase the latency and packet loss.

Therefore, designing the routing protocol for VANETs should satisfy all of these prerequisites while being constrained to the appropriate use of the wireless channel. Hence, to deal with the existing challenges, finding a routing protocol with the capability of providing a comprehensive solution while maintaining QoS is essential.

1.4 Thesis Objectives

The initial objective of this study is to create a priority-based routing protocol that detects topological changes promptly and reacts quickly while also reducing network congestion and effectively sharing resources in computing environments. The second objective is to implement CH selection in a new way to reduce the frequency of CH changes, thereby lowering latency and clustering overhead while also achieving stable clustering and guaranteeing link reliability. This thesis focuses on the following relevant work to accomplish this objective:

- A comprehensive study of current priority-based, QoS-based, and cluster-based routing with QoS provisioning over VANET communications: This study demonstrates how these techniques affect QoS requirements concerning the packet delivery ratio, delay, and reliability. The advantages and disadvantages of different topologies will be presented in a table summarizing and comparing their aspects. In addition, the impact of various clustering and CH selection strategies on QoS is assessed in our research.
- An novel efficient cluster-based routing protocol considering emergency vehicle prioritization (NCBR) for VANET: NCBR approach will address the concerns of allowing rescue service messages quick access to servers, responding quickly to topological changes, and controlling computational resources in RSU nodes. Furthermore, it will improve the packet delivery ratio, reduce delays, and ensure the reliable transmission of safety packets. This technique optimizes clustering by lowering clustering overhead and the number of cluster head changes while boosting cluster head duration time.

- Performing performance evaluation for NCBR: NCBR will be compared with three other current clustering algorithms. All three other tactics will be implemented in the same scenario, and the results will be observed, compared, and discussed in detail.

1.5 Research Contribution

The following are the primary contributions of this thesis:

- Prioritizing emergency messages based on the rescue services and non-rescue services
- A multi-hop novel clustering algorithm with an IEEE 802.11p-LTE hybrid architecture is called NCBR, in which the CH selection method is based on the distance criterion from BS, the S/N ratio criteria obtained from BS, and the number of neighbors.
- Using an epigenomic workflow to optimize resource management in RSU's computing nodes

This thesis presented a new cluster-based routing protocol that prioritized communications from rescue services in heterogeneous VANETs. This novel approach is based on the combination of V2V and V2I infrastructure and manages the messages assigned while employing the epigenomic process to improve resource management in the RSU's computing servers. Using the TDMA-based MAC architecture for priority-based messages reduces channel congestion and, as a consequence, packet loss and latency. The novel cluster head selection strategy, on the other hand, increases clustering stability and reliability while minimizing clustering overhead. This new technique is compared with three different validated cluster-based algorithms and their impact on the VANET QoS.

1.6 Thesis Outline

The following is the structure of this thesis reminder:

- Chapter 2 presents a background assessment of available strategies for preserving QoS over vehicular networking, focused on clustering, prioritizing emergency messages, and resource management with diverse architectures. These techniques are compared based on their specific characteristics.

- Chapter 3 provides an overview of the cluster-based routing protocol considering emergency vehicle prioritization in VANET. This chapter is followed by a detail-oriented discussion of the proposed protocol, covering its architecture, data types sent, clustering, picking cluster head techniques, and determining route reliability.
- Chapter 4 goes into great length about the performance evaluation process and the findings achieved. The simulation tools, mobility models, and other measures used to assess NCBR are all extensively presented. NCBR protocol performance has been represented in terms of packet delivery ratio, delay time, and delay time variations with and without priority status, reliability, clustering overhead, period of being in CH state, and the number of transitions from CH mode to other modes. The results are also compared to current cluster-based architectures in VANET.
- Chapter 5 finishes the thesis with a conclusion, outlining the study's prospects and future view.

Chapter 2

Background and Related Work

At the outset of this chapter, we'll go over several fundamental concepts that will help us better grasp the problems ahead and outline the current metrics that affect routing QoS in VANETs. In the following subsections, we discuss many reasonable ways that have been presented to provide effective routing protocols for enhancing performance with or without clustering techniques. This chapter will highlight the benefits and drawbacks of existing literature in order to provide a comprehensive solution with the highest efficiency and lowest failures for sending emergency messages within vehicular networks by leveraging the strengths and finding a way to mitigate the weaknesses of existing algorithms.

2.1 Introduction

The primary goal of VANET technology is to transmit safety and non-safety signals via V2I and V2V communication to establish passenger safety and convenience. Therefore, the most salient characteristic of a VANET is the exchange of the latest information among vehicles. Packets must travel through the network from one node to the next, which is a complex process in networks with considerable mobility and no centralized authority. Furthermore, wireless communications have been employed as a medium for data transmission via the VANET, imposing additional limitations on the network. Therefore, the routing protocols optimized for VANETs have evolved, finding updated pathways between fast-moving nodes to facilitate data flow. In the lack of an efficient routing strategy, vehicles may don't have the ability to trade data and will forfeit all the benefits presented by developed VANET technology.

Many different routing strategies have been suggested in the publications to deal with the dynamic nature of VANET. In these researches, metrics such as transmission latency, packet loss or packet delivery ratio, throughput, and so on are monitored, revealing the network's overall QoS to evaluate the efficiency of the proposed routing protocols. However, transmitting warning messages over VANET networks for safety reasons requires a more strict assessment for finding the optimal route considering QoS requirements. One of the optimal solutions for sustaining delay-sensitive safety applications in vehicle ad hoc networks is QoS-aware routing strategies, which execute route discovery depending on the quality of service of the path. In some existing QoS-based scenarios, safety messages are prioritized.

Because of the dynamic topology feature, intermediary nodes may be missed to transfer data in an extended network during the routing procedure. This issue makes the considerable network overhead and the high probability of data congestion in a large density of vehicles. Therefore, dividing the network into smaller structures can alleviate some VANET difficulties. Thus, clustering algorithms emerged as a new technique for improving network performance in the vehicular context.

Reviewing the current QoS-based and cluster-based routing strategies provides us with a perspective on the existing issues, benefits, and drawbacks, consequently leading us to a comprehensive solution that tackles some of these shortcomings.

2.2 Definition

Several wireless technologies have been employed, each with its performance and features, to facilitate vehicles in VANET to convey their messages to other cars or fixed infrastructure along the route. Each of these wireless approaches must comply with standards that have been tailored for them based on transmission range, coverage area, data speed, data traffic type, node distance, mobility, energy, and so on. In the following subsection, we will go over the wireless technology and the associated protocols that have been developed for vehicle contexts in more detail.

2.2.1 DSRC/WAVE

One of the reliable wireless technologies that support V2V and certain V2I communications in heterogeneous networks is known as Dedicated Short Range Communications (DSRC). The Wireless Access in Vehicular Environments (WAVE) standard governs

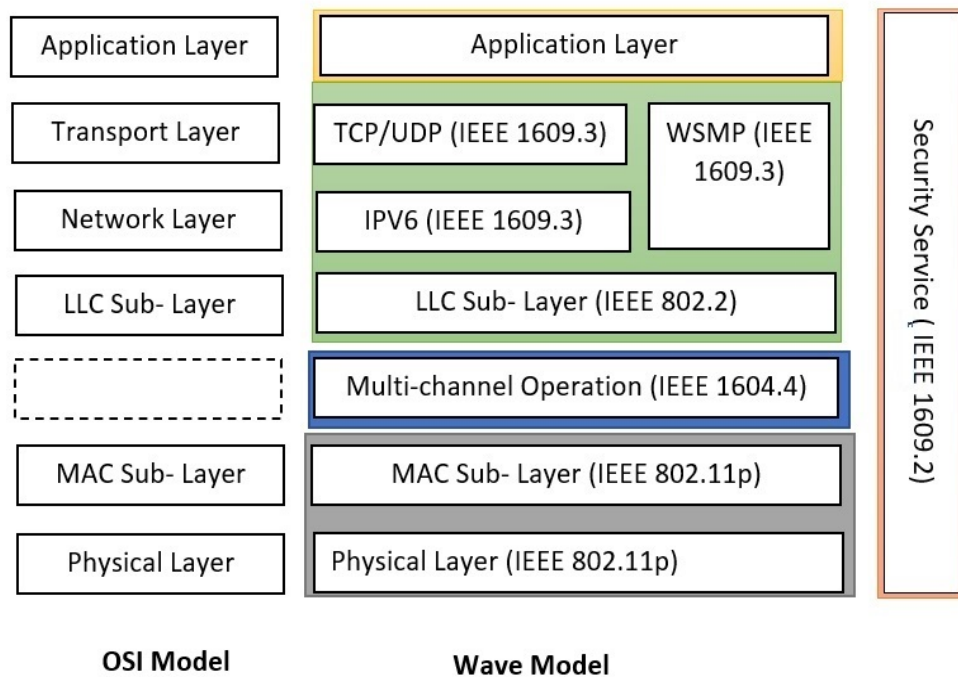


Figure 2.1: OSI model vs WAVE model.

DSRC communications and enables a vehicle to interact with its surroundings at a high data rate and minimal latency.

In the United States, the Federal Communications Commission (FCC) has allocated a frequency band of 5.850 to 5.925 GHz (75 MHz bandwidth) to the DSRC to standardize the vehicular ad hoc network [11]. The granted frequency range is partitioned into seven channels, each with a bandwidth of 10 MHz. Two channels are assigned to the safety broadcaster, one for control operations, while the others can be allocated for other applications, both safety and non-safety related.

On the other hand, the OSI protocol has been applied as the foundation paradigm for designing standard WAVE layers in a vehicle scenario. The WAVE protocols for each layer are shown in parentheses in Fig. 2.1. As illustrated in Fig. 2.1, several of the layers of the WAVE architecture have no counterpart in the OSI model. For example, multi-channel operation and security services are not included in the OSI protocol architecture.

According to the most recent version of ITS standards, the WAVE standard, a member of the IEEE 1609 family, provides a collection of structures, facilities, and specific procedures for safely transferring messages via V2V and V2I communications[12]. Many

VANET applications, such as traffic control, automated tolling, vehicle safety, etc., are designed using the WAVE protocol [12].

Because the DSRC communication range only covers a small area surrounding the cars, some VANET systems use the fourth-generation cellular technology LTE (Long Term Evolution) to connect vehicles to cloud servers or Internet providers. For V2I communication between cars and base stations, LTE technology is employed, which delivers a broader transmission range and lower data latency. Networks that utilize two or more wireless transmission technologies at the same time are referred to as heterogeneous networks.

In order to maintain network QoS, one of the concerns in heterogeneous VANET is the frequent handoff between cars and base stations, which increases network overhead, channel congestion, packet loss, and network disturbance in general. With the growth in the number of vehicles, this difficulty has grown much more significant, and it may make it impossible to convey information over the network. Employing the clustering algorithm in a vehicular environment is one of the approved strategies for reducing the number of handoffs and enhancing scalability. In a hierarchical system, clustering occurs when two or more neighboring vehicles with certain common qualities form a group. Clustering is a concept utilized in data mining and machine learning frequently.

2.2.2 IEEE 802.11/ IEEE 802.11p

To adapt the WAVE protocol to vehicular networks in the physical and medium access layers (MAC), the IEEE 802.11p standard, a modified version of the IEEE 802.11 standard, has been adopted [11]. The IEEE 802.11p protocol uses an Enhanced Distributed Channel Access (EDCA) MAC sublayer protocol founded over the IEEE 802.11e standard with certain transmission parameter modifications. The physical layer is identical to the IEEE 802.11a standard. [13].

The WAVE stack follows the IEEE802.11p standard, which supports the vehicular network's quality of service (QoS) requirements by using carrier sense multiple access with collision avoidance CSMA/CA [14]. The CSMA/CA methodology has easy and inexpensive channel allocation strategies to deploy; moreover, it does not enforce strict time limitations on the radio channel. This approach is appropriate for vehicular ad hoc networks with nodes that move quickly in a dispersed and decentralized setting.

2.3 Routing in VANET

The primary concern of routing algorithm design and development is the delivery of messages from the source node to the destination with the highest reliability and lowest latency. Therefore, numerous routing protocols that satisfy these characteristics have been presented thus far. However, when it comes to mobile nodes in a wireless environment, the challenges and constraints are significantly different. Finding a mechanism to broadcast a message with confidence that it will be received when the nodes are not static and the transmission channels are influenced by changing environmental conditions and node density poses different obstacles. As a result, after a period, the concept of routing for mobile nodes such as vehicles appeared in the literature in which node mobility and the network's changing topology are considered, and different broadcasting methods are suggested.

Broadcasting is a popular method for disseminating communications from one mobile vehicle to another. Once a vehicle broadcasts a message, all nodes within its communication range instantly seek to transmit the message via rebroadcasting [15]. Flooding broadcast [16] is one of the most basic approaches among the numerous broadcasting strategies for ensuring a high packet delivery ratio while being reliable and robust. However, one of the critical issues that should be addressed in flooding broadcasting is a broadcasting storm, which occurs when there is a large volume of data present due to high vehicle traffic density in the vehicular environment. Because of the increased number of cars attempting to transmit simultaneously, this phenomenon significantly increases packet latency and the frequency of collisions at the MAC layer. Furthermore, the broadcasting storm wastes radio resource consumption.

Several methodologies have been developed to cope with the broadcasting storm and reduce data collisions in communications. These popular tactics include MAC-based protocols [17], messages prioritization [18], clustering approaches [19], or a combination of two [20] or more of them.

The ultimate aim of all of these studies is to preserve or improve the QoS of VANETs, which ensures the efficacy of proposed routing protocols.

2.3.1 MAC-Aware Routing protocols

The responsibility of medium access control (MAC) is to share the access channel among multiple users simultaneously by using their predetermined agreements to transfer messages successfully. These mac-based protocols aim to reduce the possibility of data

collision, consequently boosting the delivery ratio, utilizing bandwidth efficiently, and minimizing delay. Time-Division Multiple Access (TDMA) is one of the MAC-based techniques in which the channel is shared for intermittent broadcasting, mitigating the identified transmission challenges while improving network performance. Signals in TDMA-based MAC protocol are split into the timeframe. Each timeframe contains the same length of time slots. Vehicles can use the assigned timeframe to access the channel and broadcast their signals synchronously. [21]. The length of the timeslot may differ depending on the demands of the vehicle to which it is assigned. The packets will be sent in quick succession, each with its timeslot.

The main benefits of using a TDMA-based protocol over IEEE 802.11p can be divided into three categories: (i) fairness in access to the transmission channel; (ii) employing a predictable time frame for each node, reducing packet collisions, and optimizing channel resource utilization; (iii) enhancing packet transmission reliability.

2.3.2 Message Prioritization

Data in a vehicular network broadcast via the routing protocol can be divided into time-sensitive messages (e.g., emergency messages) and non-time-sensitive communications (e.g., e-map or entertainment-context messages). Emergency messages are transmitted to all drivers and pedestrians approaching the crash scene to alert them about the incident and prevent further accidents. Hence, some research concentrated on identifying routing protocols whose primary goal is to disseminate emergency signals with the minimum delay, the highest delivery ratio, and reliability. For instance, Hassan et al. [22] focused on enhancing vehicular network reliability and packet delivery ratio by adopting a "blind" retransmission strategy for emergency communication. Daxin et al. [18] allocated a safety message broadcast to the vehicles involved in a collision with nearby cars. This approach reduces the number of redundant rebroadcasts of emergency signals, thereby reducing transmission delay and emergency data collision.

Prioritizing emergency data originating from vehicles is one strategy for avoiding traffic congestion in access channels and consequently prevents transmission collisions and wastes bandwidth. The author of the reference [23] suggests a multi-hop broadcasting approach in which critical messages are prioritized in communication channels in the first mechanism by using distributed interframe space (DIFS). In the second mechanism, a trinary partitioning technique that divides the communication range into smaller sectors is designed to allow for further nodes to broadcast their emergency signals faster with

the minimum number of passed hops. The advantage of this strategy is that it decreases the jitter time frame in the contention window despite the traffic volume, keeping the contention period steady. However, severe contention during simultaneous transmissions causes the network to endure considerable latency.

In addition to prioritizing emergency signals from regular cars, priority should be given to messages emitted by emergency vehicles to facilitate their movement on the road. Researchers proposed many strategies, such as giving precedence to the emergency vehicle traffic lane [24] and managing traffic lights in cities by detecting emergency vehicles to smooth their flow[25]. In sharma2013traffic, some virtual traffic lights with Radio Frequency Identification (RFID) readers are set at each junction, and two joint lights are deployed at opposite ends of the road. These RFIDs capture the whole traffic flow that passes across these intersections. If rescue services need to pass through certain intersections, RFID sends a signal to the traffic light to switch on the green light, allowing the vehicle to cross the junction without interruption. When an emergency vehicle leaves the road, it sends a signal to the intersection to restore its normal state. Nonetheless, the suggested approach has no noticeable effect on the time required for rescue services.

In [26], the author designed a central traffic control station to provide a green path for ambulances from the event location to the hospital. An antenna is mounted on the ambulance to link with the WiMAX control station in order to send and receive route and traffic alert information. Therefore, the central station can send a warning signal ahead of time to clear the way for passing ambulances. RFID technology determines the detection of ambulances, the path from source to destination, and the location of rescue services. However, this strategy is not appropriate for short-range communication.

These proposed solutions only provide a priority-based algorithm by identifying emergency vehicles and providing a clear road for them via managing traffic signals or a central station. However, the impact of prioritization on emergency services' communications is not considered in this existing research on improving QoS. Low-priority vehicles may clog data and waste bandwidth if vehicles are extremely dense.

In addition to MAC-based protocols and prioritizing to enhance QoS in VANETs, other researchers have used alternative methodologies such as finding the shortest path or finding the route with the highest quality to transport data to the target node, which are classified as QoS-based routing approaches.

2.3.3 QoS-aware routing protocols

A QoS-aware data distribution strategy is dependent on a variety of elements and must contend with severe restrictions [27]. Criteria such as network overhead, packet delivery ratio (PDR), and data latency should be considered when evaluating the QoS-based performance network.

To evaluate the packet delivery ratio, we have to calculate the ratio of received packets at the destination to the transmitted packets from the source node, which is influenced by numerous aspects such as node speed, packet size, transmission range, etc. [27].

On the other hand, transmission delay can be determined by subtracting the time difference between sending a specific packet from the sender and receiving the same one from the receiver. The transmission time delay is a significant metric to consider while transmitting and receiving a data packet since it allows the throughput rate to be computed.

Another factor that played into measuring QoS is the network overhead, which is the extra data added to the payload to regulate and manage data transfer. In the following, we will look at some of the recommended procedures for improving QoS in VANET.

In reference [28], the author has developed an intelligent routing approach based on the reward and punishment system. The main objective of this methodology is to increase the PDR with minimum overhead during the shortest time. In this scheme, a weight is allocated to each link from source to destination. Reward and punishment are calculated based on link stability, distance, speed, and density.

Different strategies have been proposed to achieve the shortest possible message delivery latency for routing protocols, and some of them have been standardized for network simulation tools. One common approach is the Dijkstra algorithm, which employs graph theory to find the shortest distance between two nodes [29]. At the start, to discover the shortest path, this technique produces a tree structure with roots from the originating node to the target node. The vertices in this tree graph are divided into included and non-included vertices, and the algorithm will seek the shortest route across nodes in each iteration.

Dua et al. [28] employed a modified Dijkstra algorithm that considered the weight of the links to choose the optimum route to satisfy the quality of service. The protocol solves the broadcast storm and grey zone issues that plagued most previous solutions. In addition, to avoid the problem of fault tolerance, the suggested system recovers fast in the event of connection failures. A common barrier with this strategy is the possibility

of generating an acyclic graph and failing to discover the optimum path.

Another QoS-Aware protocol for improving QoS in VANET was proposed by Fathy et al. [30] in 2012. Multi-Protocol Label Switching (MPLS) is employed in this protocol, which operates on any layer two technology, and routers forward packets based on the packet's label rather than scanning the routing database for the next hop. The MPLS method can employ Traffic Engineering (TE) to find the optimal path that fits the demands of the packet, although it may not be the shortest path. Vehicles not only wirelessly transfer data to base stations, but they also establish an MPLS domain within the wired infrastructure. This proposed structure, in which roadside units are wired together, is called the Roadside Backbone Network (RBN). Reducing packet loss and end-to-end delay and improving throughput compared to conventional ad hoc protocols are the main achievements of this proposed protocol. However, the reliance on a high density of roadside units and the unreliability of V2V communications are the defects of this technique.

Li et al. [31] presented a VANET adaptive QoS routing strategy (AQRV). Based on the Ant Colony Optimization (ACO) approach, AQRV determines the best route between two terminal intersections, which are nearby intersections with the origin and destination vehicles. This technique does have certain drawbacks. Initially, connection probability and transmission latency were utilized as the assessing factors for discovered routes using AQRV. Each intersection in this method uses the predefined global pheromone to transmit information dynamically. Each intersection in this technique delivers data dynamically utilizing the designated global pheromone, increasing the latency between the two terminal nodes. Another downside of this approach is that whenever the transmitter or receiver nodes change, the search algorithm is triggered to give a new route to convey data, which increases the complexity of the computations and the time required to send data.

The leading conventional methods in mobile network routing strategies that are the fundamental methodology for many of the existing schemes are Destination-Sequenced Distance Vector (DSDV), Dynamic Source Routing (DSR), and Ad Hoc On-Demand Distance Vector (AODV).

The Destination-Sequenced Distance Vector (DSDV) routing protocol maintains a next-hop table that each node shares with its neighbors, which is beneficial for loop prevention. The Dynamic Source Routing (DSR) protocol employs a secure routing system. In this approach, a sender is conscious of the entire path to the destination and stores it in the route cache. The source route is carried in the header of the packets,

which affects the routing overhead. The failed connection in this method is not repaired locally by the route maintenance activities, demonstrating a limitation of this protocol.

Ad hoc On-Demand Distance Vector (AODV) is a process similar to DSR in that the node remains silent until a link is required. Once the request is announced, other intermediates forward this packet to their neighbors while setup a reverse path entry for the sender in its route table. The destination node uses a reverse route table to respond to the source node after receiving a request packet from the node. A source node may receive multiple reply messages, holding only one with the fewest hops to route its packets and discarding the others. In the event of topology changes and connection failures, routing table information is continuously updated. In general, an on-demand routing protocol is divided into two phases: routing in the absence of routing information and route maintenance in the event of a connection failure. The most widely used routing protocol in VANET architecture is AODV, but due to the poor performance of conventional structures, optimization is needed to improve its quality.

The crucial challenges in employing conventional AODV in VANETs are high mobility and topology in motion. Furthermore, under the contention-based MAC protocol, as the density of vehicles in a usual wireless media attempting to transmit simultaneously increases, packet delay and data collision escalate drastically, degrading service quality [32].

2.3.4 Cluster-Based algorithms for VANET

Adopting the cluster-based routing protocol can be one of the most effective strategies for decreasing data congestion and supporting QoS across wireless networks. VANET clustering has been implemented in the research for a variety of objectives such as load balancing, quality-of-service aid, and data transmission in high-density vehicular networks [33]. As a result, using optimized AODV in cluster format may be a good solution for adoption in the vehicular world.

The research on routing protocols relies on the clustering approach, demonstrating that they significantly improve reliability and extensibility in vehicular networks [34],[35]. Real-time and effective data distribution, network consistency, efficient data management, as well as improved security are the other benefits of the VANET clustering approach [8].

Members of the cluster are somehow related to one another, and network clustering can be classified based on the similarities in participants' characteristics. Each cluster

inter-vehicle communication (IVC), known as the COIN algorithm. Unlike the traditional cluster-based approach, this scheme chooses the cluster head based on vehicle dynamic and driver purpose rather than an ID or relative mobility. The primary goal of this strategy is to retain scalability while being inspired by various MANET protocol versions. Although the proposed approach improves the VANET's stability and scalability compared to other traditional schemes, it incurs additional network overhead.

Another structure that leans on the geographic place of the vehicle was introduced by Wang et al. [42] in 2008. The cluster head is chosen based on the priorities assigned to each node. The authors define a qualifying mechanism in which nodes with the estimated longest travel time and lowest speed deviation have the precedence of leading the cluster. Lue et al. [43] proposed another clustering algorithm based on position discrepancy, in which cluster heads are selected on square grids separated by IP or MAC address, regardless of direction or speed, which are significant considerations in-vehicle network specification. With a spike in the volume of vehicles, the key benefits of this system are reduced average routing overhead and decreased average end-to-end latency jitter. However, the proposed scheme suffers from the time-consuming discovery of qualifying cluster heads and is not well suited for dynamic topology.

Because of constrained bandwidth availability, some literature has explored the MAC-based clustering strategy for fair channel access. Yang et al. [20] presented a broadcast-specific cooperative TDMA MAC scheme by clustering structure. The author began his study by categorizing all vehicles that drive in the same direction into one cluster and selecting one of them as a cluster head. The mac-based cooperation among cluster members to send failed messages to one of the members is the main feature of this single-hop cluster-based approach. To identify failures in message reception, each cluster member and the head receive an ACK, which is included in their hello packet headers. This ACK should be heard by all nodes in the vicinity.

Song et al. [44] provided a cluster-based directional routing protocol in which cluster heads work together to forward messages in the direction of vehicle motion. This protocol has low latency for safety applications, a high packet transmission ratio, and high connection stability in the event of a node-to-node link failure. However, it does not provide adequate efficiency over long distances.

All of the preceding clustering algorithms rely on single-hop clustering, which necessitates the selection of more cluster heads and a smaller coverage area. Therefore, multi-hop clustering techniques have grown in popularity in recent years. In such a scheme, the maximum number of cluster members should be set to restrict the size of

clustering and avoid extra overhead. Furthermore, the max hop from a CM to CH is not to be permitted to exceed a preset threshold to prevent widening the distance between CH and other members.

One of the multi-hop clusterings in VANET is suggested by Zhang et al. [6] with a focus on the variability in packet delay. In this approach, each vehicle broadcasts two successive hello packets to neighboring nodes, allowing them to determine the relative mobility of the vehicle along its journey. To select a cluster head, in the first step, the aggregate mobility (AM) of each vehicle is calculated by summing all their relative mobility. The vehicle with the smallest AM value will then be picked as the cluster head. The chosen cluster head is disseminated to vehicles within the n-hop coverage region. However, this approach suffers a high control packet overhead and is ineffective in terms of energy efficiency.

Hassanabadi et al. [45] proposed another multi-hop clustering approach in a dispersed manner using an affinity propagation (AP) scheme that is carried out using the velocity and location data of the vehicles. In general, an affinity propagation process necessitates infinite repeated loops that increase the delay in order to create clusters.

To ensure the stability of the clustering duration of CH lifespan and the number of CH changes should be considered. These two critical parameters affect clustering overhead as well as QoS requirements. Ucar et al. in [46], which is known as VMaSC, calculate each node's relative mobility based on the mean difference in speed between the node and its neighbors. Due to its lesser mobility, the vehicle with the lowest relative speed is chosen as the CH because it retains the node position for a longer duration of time than its neighbors. The Max-hop limitation is participated in this technique to mitigate network flooding, so the hello packet is rebroadcast by the CM as long as the hop counter is less than or equal to the MAX-hop value. Rebroadcasts will be canceled otherwise. Ucar enhances the VMaSC technique in [1] by integrating the cluster structure with an LTE base station to distribute data across the network.

Due to the difficulty of determining the precise speed of the vehicle nodes in order to pick cluster heads, Zhang et al. [4] proposed a priority-based technique in which the cluster head is chosen based on the nodes' following degree. To ensure the stability of this method, preference is given to nodes with the highest following degree, strong connection reliability, and a high expected transmission rate. This multi-hop approach is divided into three stages: cluster generation, CH selection, and cluster merging.

Several solutions have been devised specifically to preserve the balance between rapid vehicle mobility and QoS requirements in the clustering strategy. Wahab et al. [47]

offered a new QoS-based clustering method that considers a balance between QoS requirements and high mobility restrictions. The proposed algorithm aims to create and maintain stable clusters during data transfers while meeting QoS requirements. The primary drawback of this suggested protocol is that massive network resources are required to maintain routing pathways due to frequent network topology changes. End-to-end routes, on the other hand, may not exist when the density is insufficient.

The authors of [48] consider priority in the suggested QoS-based transmission scheduling mechanism known as "QoS-TDMA." This protocol employs clustering centered on the vehicle velocity and directions to accomplish one-hop scheduling. CH serves as the coordinator, allocating slots depending on the necessary QoS. Because the proposed protocol uses one-hop communication in intra-clustering, the incidence of cluster overlapping is higher, network performance is worse, and the coverage area is less.

Abuashour and Kadoch [49] developed a routing system with a clustering architecture in which cluster regions are static while selecting cluster heads are dynamic. This method's achievements include delivering routing stability and average throughput in a bidirectional segment. Because the area of each cluster is static and predetermined, the frequent change of cluster heads caused by vehicle mobility imposes a significant overhead on the network.

Some scientists have concentrated on distribution optimization to guarantee fast data propagation specific to safety messages. Dua et al. [28] suggested a QoS-aware data distribution strategy appropriate for dense locations to manage high data rates in upcoming 5G network applications. A hybrid backbone clustering algorithm (HBCA) is introduced by Singh et al. [50] in 2015. The number of linkages and the vehicles' mobility concept are considered for cluster creation and cluster head selection. During the cluster formation process, nodes with more number connections than the specific threshold first establish a backbone, known as leadership. The leadership then takes part in cluster head elections and cluster rearrangement based on vehicle aggregate relative velocities. However, if the number of nodes is lower than the specified threshold, the cluster has to be reformatted, making it unstable.

Another criterion that confronts difficulties owing to vehicle features is reliability in clustering. To improve QoS, the author in [35] presented a cluster-based reliable low-latency routing (CRLLR) strategy in which vehicles determine their path using the ant colony technique based on link reliability. Reduced route request messages boost connection reliability in this scheme. Zahid et al. [34] designed the cluster-based VANET evolution graph (CVoEG) to assure reliability, in which CH selection and cluster for-

mation are reliant on link reliability. This paradigm improves end-to-end latency and network throughput, in addition to reliability. Table 2.1 compares some of the proposed cluster-based algorithms which are implemented in VANET.

Table 2.1: Several cluster-based routing in VANET

Ref.	Purpose of clustering	CH life time	CH Changes	Delay	PDR	Clustering overhead	stability	Reliability
COIN[41]	Mobility management in intervehicle communication	Moderate	Not Defined	Not Defined	Not Defined	Moderate	Moderate	Not Defined
PPC[42]	Control topology	Not Defined	Not Defined	Not Defined	Not Defined	Not Defined	Moderate	Not Defined
CBR[43]	Position-based Routing protocol	Not Defined	Not Defined	Moderate	Not Defined	Moderate	Moderate	Not Defined
CCB-MAC[20]	MAC -based safety message dissemination	Not Defined	Not Defined	Not Defined	High	Not Defined	Not Defined	High
CBDRP[44]	Routing protocol	Not Defined	Not Defined	Moderate	Moderate	Not Defined	Moderate	Moderate
Multi-hop clustering[6]	Reduce delay and packet lost in handoff stage	Moderate	Moderate	Not Defined	High	Moderate	Not Defined	
Asynchronous APROVE[45]	Mac-based data dissemination	High	Low	Not Defined	Not Defined	High in low density and Low in high density	High	Not Defined
VMasc[46]	Data dissemination	High in single-hop and moderate in multi hop	low in single-hop and moderate in multi hop	Moderate	Moderate	Low	Moderate	Trade off between reliability and LTE usage
VMasc-LTE[1]	Data dissemination and improve VMasc strategy	High in single-hop and moderate in multi hop	low in single-hop and moderate in multi hop	Low	High	Low	High	Trade off between reliability and LTE usage
PMC [4]	Routing	High	Low	Low	High	Low	High	Moderate

Continued on next page

Table 2.1 – *Continued from previous page*

Ref.	Purpose of clustering	CH life time	CH Changes	Delay	PDR	Clustering overhead	stability	Reliability
VANET QoS- OLSR [47]	Data dissemination. Security purpose and Improve QoS-OLSR model	Not Defined	Not Defined	Low in sufficient density	High	Not Defined	High	High
LORA- CBF extension [48]	TDMA-based routing with QoS provisioning	Not Defined	Not Defined	Low	High	Not Defined	High	High
CBLTR [49]	Eliminate the route discovery procedure	High	Low	Low	Not Defined	Low	High	Not Defined
QoS- DDD [28]	QoS- based Safety message dissemina- tion	Not Defined	Not Defined	Low	High	Not Defined	Not Defined	High
CRLLR [35]	Data dissemination	Not Defined	Not Defined	Low	High	Not Defined	Not Defined	High
HBCA [50]	Data dissemination	moderate	moderate	Not Defined	Not Defined	Not Defined	High	Not Defined
CVoEG [34]	Routing	Not Defined	Not Defined	Low	High	Moderate	Moderate	High

2.4 Resource Management In VANET

Access to computing servers for data processing and computational operations is another barrier that complicates the VANET scenario. Cloud servers with high computational capabilities, availability, and massive storage are the most suitable selection for data processing and storage. However, their biggest problem is their distance from cars, which causes severe network delays, and wastes energy and resources. One solution for avoiding long-distance data transport and achieving real-time response is to use close nodes to vehicles that have computational capabilities. The primary challenge that these edge computing nodes encounter is a shortage of computing resources. As a result, some studies provide strategies for managing these finite resources.

In [51], Qafzezi et al. developed a combination of Software Defined Networking (SDN) and Fuzzy Logic (FL) techniques to deal with resource constraints in VANET with a fog-cloud architecture. An SDN controller manages the tiered structure of compute nodes

in this technology, and fuzzy logic is used to make decisions on the VANET's processing layer.

[52] employs the RSU Cloud Resource Management (CRM) scheme to decrease latency, reconfiguration overhead, and service deployment expenses in the VANET environment.

A key challenge in workflow essence applications with computing resources is identifying the optimal number of resources required for process execution to decrease financial expenses for consumers while maximizing resource utilization for resource providers [53]. Scheduling workflow is a method that attempts to assign workflow tasks to the most appropriate collection of computer resources to achieve specified goals [54].

Therefore, the author in [55] proposed a Cost-Makespan aware Scheduling (CMaS) protocol to make an opportunity for the workflow model of the directed acyclic graph (DAG) to execute offload schedule tasks in the fog-cloud platform. The main objective of this heuristic method is to strike a balance between the expense of using a cloud platform and the application's efficiency.

Another verified solution for improving resource management is to use scientific workflows such as Epigenome, Montage, and so on. We will discuss in more depth the Epigenomics scientific workflow in the following.

In a vehicular context, if we view requests from vehicles as a data workflow and RSUs as edge/fog computing nodes, we can use a validated scientific workflow schedule in our suggested model to develop an efficient and cost-effective computing processor.

Fig 2.3 illustrates fog structure with RSUs, distributed under a cloud server in a VANET scenario. It develops a distributed computing framework for VANET components to handle data processing and storage. In other words, RSUs can be regarded as close-edge computing nodes having a topology similar to fog nodes, as depicted in Fig 2.3.

2.5 Epigenomics scientific workflow

One of the drawbacks of using edge nodes is the limited resources available to run data-intensive applications. As a result, we require effective resource management that adheres to time and budget limitations. Workflow technologies are one of the techniques that have been merged with cloud/fog platforms to manage their computational complexity. The scientific workflow's primary role is to schedule computational tasks on distributed resources, manage task relationships, and stage datasets into and out of execution loca-

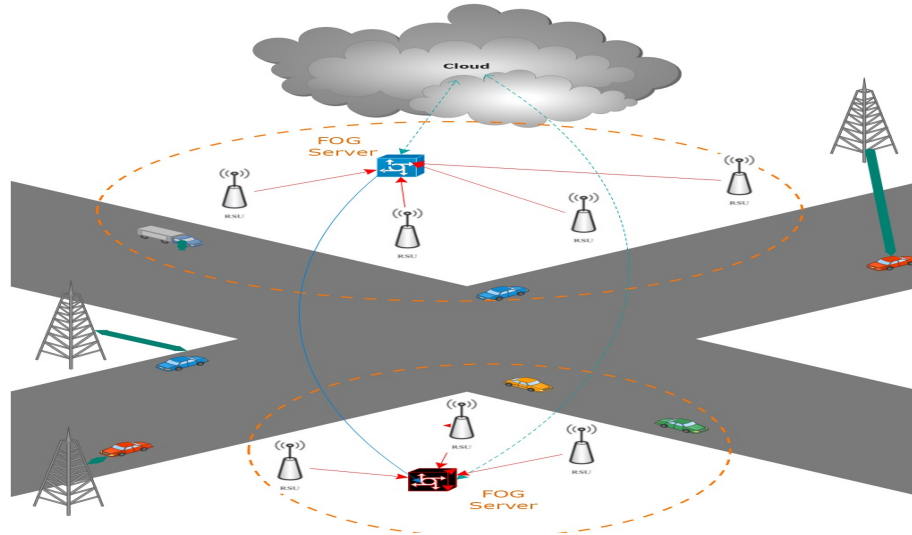


Figure 2.3: RSUs with the Fog structure

tions [56]. The successful implementation of scientific workflow is related to the optimum approach for assigning workflow tasks to available computational resources. This technique is known as workflow scheduling [57].

There are many well-known scientific workflows, each with its own structure and computational characteristics [58]. Depending on the design of the user application, science workflows may be memory, CPU, or I/O intensive [56]. In a distributed environment, fog computing is opening up new opportunities for workflow scheduling. The Epigenomic workflow is a CPU-intensive data-processing pipeline that contains collection pipelines that operate on distinct pieces of data in parallel. [59]. The link between the tasks in the Epigenomic workflow application is represented by eight levels, each of which contains tasks that execute certain functions [60]. The process structure of the Epigenomics workflow application is depicted in Figure 2.4.

2.6 Summary

The vehicular network's primary mission is to provide safety-related messages, alerts, news, entertainment, and information services. Because safety-related communications are more vital, we must prioritize them so that they are both shorter time needed in using service than other messages and do not get lost owing to network congestion. Because of the strict criteria for risk awareness communication and the fast-changing topology of the

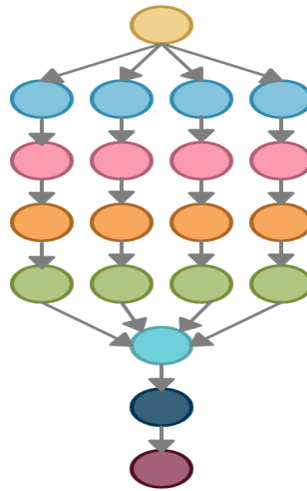


Figure 2.4: Epigenomic workflow

vehicular environment, designing an effective protocol for the transmission of high-quality safety messages across VANETs becomes exceedingly difficult.

This chapter provided background knowledge by establishing essential terminology, ideas, and assessment criteria for routing protocols in the vehicular context. A review of current clustering and QoS-aware techniques provides a clear view of each methodology's benefits and drawbacks. Furthermore, knowing this information assists us in identifying alternatives that offer a high-performance clustering routing protocol with QoS consideration.

In addition, this chapter will be followed by a literature analysis of resource management and workflow scheduling technologies in VANET and will explain the benefits of employing them in VANET to address resource restrictions.

Chapter 3

Methodology

This chapter outlines cluster-based routing protocol with prioritizing emergency vehicles in detail. It is started by outlining the problems behind our research, then is walked through the system architecture, prioritizing, type of transmitted information, and proposed algorithm to create clustering and select cluster heads. Next, the final section describes how to discover the optimal QoS-based routing employed in our method.

3.1 Introduction

The following issues have been found that should be considered when creating an effective routing system for vehicle communications.

- Prioritize signals transmitted by rescue vehicles owing to their critical role in emergencies. According to the research reported in Chapter 2, no solid study on the prioritizing signals sent by rescue services to improve QoS has been conducted.
- Improving the QoS of the vehicle network entails lowering the average routing overhead, lowering the average transmission latency, and raising the PDR despite the dynamic topology, high mobility, and massive size of these networks.
- Establish conscious and intelligent networks in the presence of rapid topological changes. In the case of a node entrance or loss, the designed network should be notified instantly and make a fast decision.
- Manage the RSU's computing resources since they have storage and computing limitations.

- Ensure reliable transmission even in the event of a medium conflict. In the case that the channel becomes congested, a flexible alternative should be devised. Otherwise, potentially lifesaving information goes missing.

These requirements drove us to develop a cluster-based routing protocol considering the priority of rescue services using a close-to-edge computation architecture for VANETs willing to address these problems while outperforming previous VANET routing techniques. However, the employment of clustering techniques raises issues such as verifying cluster stability, minimizing local overhead, and assuring route reliability, which should be considered in designing routing protocols with a clustering architecture. The instability of the clusters and the frequent replacement of the cluster heads harm the network's QoS, which is the opposite of the study's aims.

3.2 System Modeling

This section presents a new proposed priority-based clustering routing protocol with QoS provisioning. Our proposed network architecture is illustrated in Fig. 3.1. We equipped the RSUs in our model with a workflow scheduler in order to provide cost-effective resource management with the least amount of delay in service processing. In our presented model, to avoid data migration to distant locations to conduct process and calculation activities, which is a time-consuming procedure, we delegate some of the responsibility to RSUs, which are closer to the network edge and more powerful than vehicle computing equipment.

This proposed protocol selects the optimal QoS-based routing in the clustering structure and prioritizes messages received from rescue vehicles, all while employing RSU's computing resources to satisfy VANET's real-time essentials. In addition, this protocol takes advantage of the heterogeneous architecture, clustering, and workflow scheduling capabilities to improve the network overhead, reliability, and scalability, and optimize the end-to-end delay.

As previously stated, several protocols concentrating on disseminating emergency messages with priority while improving QoS requirements over vehicular networks have been presented. Moreover, some solutions are developed to provide a clear path for rescue services. However, none of them has suggested a methodology to prioritize the distribution of signals provided by emergency vehicles. In addition, research on VANETs that uses workflow scheduling in an RSU's computing structure to optimize QoS and the

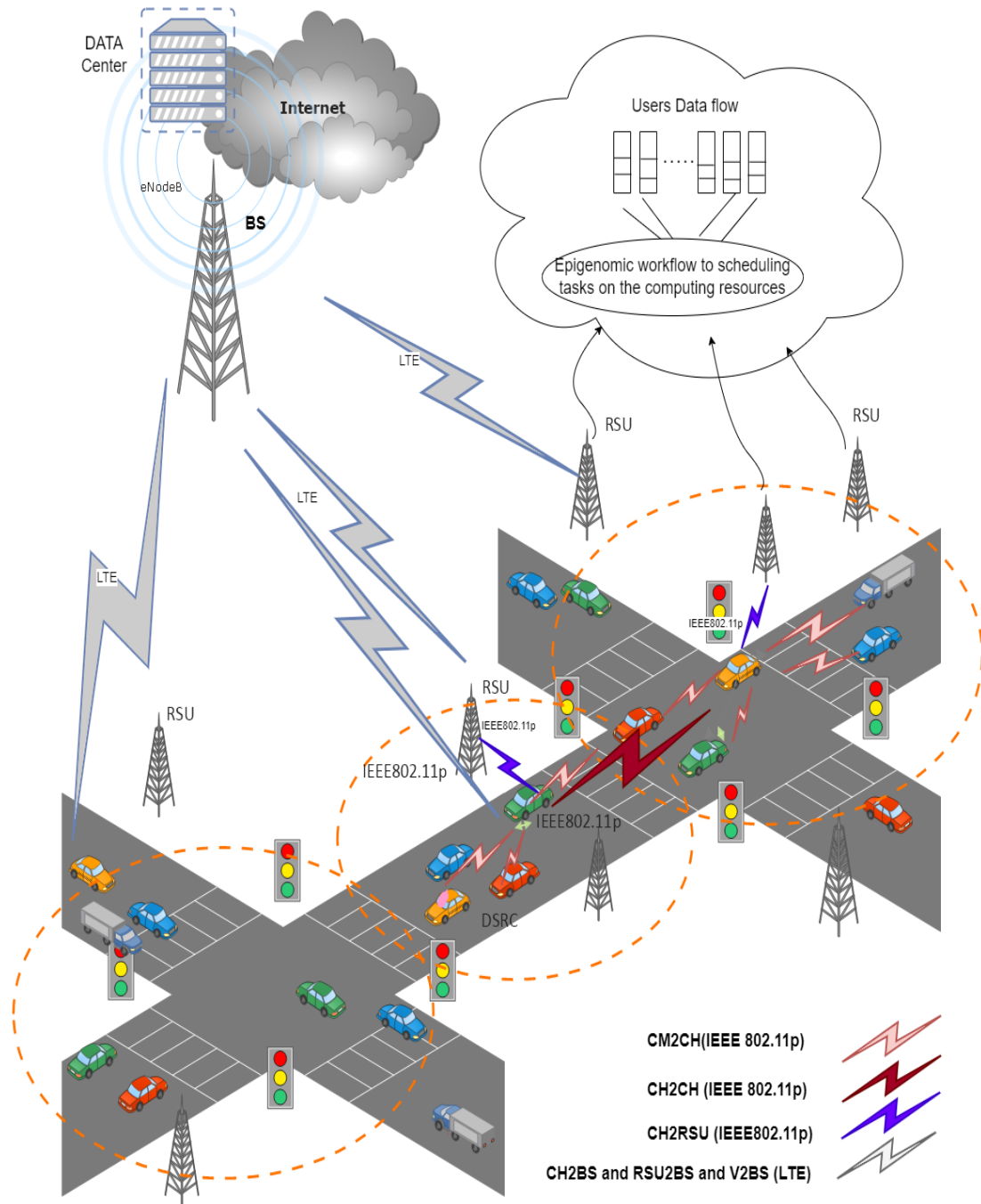


Figure 3.1: Network Architecture.

network efficiency is limited.

The essential components that comprise our suggested model are:

- Vehicles: Vehicles may function as senders, receivers, or routers in the vehicular ad hoc network. In our proposed system, they are classified as priority or non-priority. Vehicles used by rescue services, such as ambulances and fire engines, are given priority, while other vehicles are allocated to non-priority categories.
- BS: Base stations are fixed infrastructures that provide lower transmission latency, strong processors, substantial storage capacity, and a wide distribution range via LTE technology.
- RSU: Roadside units are positioned along the roadside or at specified sites such as crossroads or close parking zones to expand vehicle communication coverage. In our approach, RSUs are considered close-edge computing devices, and some of the functions of cloud servers are delegated to them.

Since our framework is built on a clustering architecture, some of the vehicles serve as cluster heads while others serve as cluster members. All packets delivered between vehicle nodes and infrastructure are routed through the cluster heads in the clustering arrangement. Our proposed model is implemented in heterogeneous VANET, in which a hybrid architecture is employed to enable connectivity between vehicles with each other and with RSUs through IEEE 802.11p, and interconnection between vehicles and RSUs, with BSs via LTE.

3.2.1 Model of Multi-Hop Cluster Architecture

The number of nodes that must be traversed to convey a message from the sender to the CH distinguishes multi-hop clustering from single-hop clustering. Therefore, in a multi-hop design, each cluster member interacts with its cluster head directly or indirectly. To avoid extending the distance between CMs and CH, we must determine the maximum hop count ahead of time (MAX-HOP). On the other hand, because each CH is responsible for monitoring and managing the members in its cluster coverage area, we need to define the maximum number of members (MAX-CM) that can join the cluster for the leaders to function effectively.

Figure 3.2 illustrates the multi-hop clustering model. Vehicles 1 and 6 functions as cluster head models, interacting directly with the BS, RSU, and each other to exchange

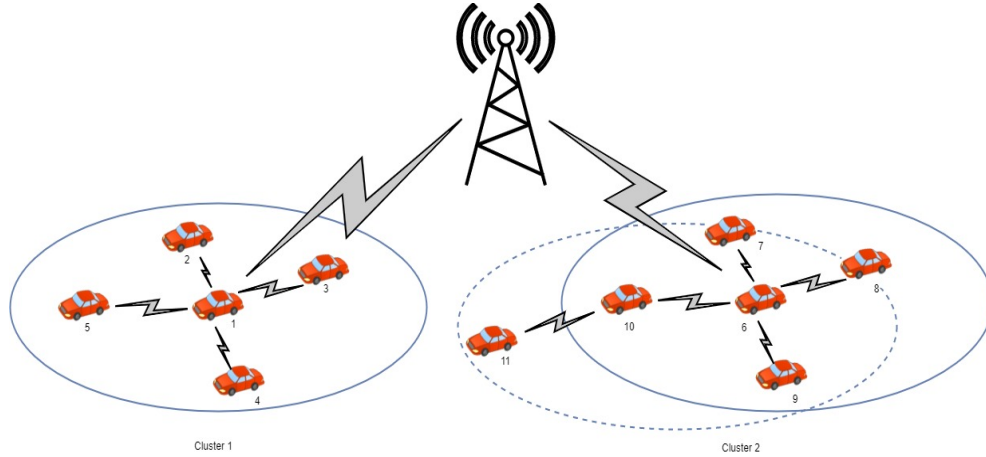


Figure 3.2: Multi-hop Clustering model.

packets. Cluster 1 employs the traditional clustering paradigm, with each CM linked directly to the CH and no intermediary nodes. Whereas, for cluster 2, we can observe vehicle number 6 followed by vehicle 11 by two-hop distances. Because vehicle 11 cannot communicate directly with the cluster head vehicle 6, vehicle 10 maintains the required information about node 11 and manages node 11. As a result, vehicle 11 is considered a member of Cluster 2. Connecting vehicles to the CH indirectly not only increases the cluster's coverage area but also reduces the number of chosen cluster heads in the network.

3.2.2 Priority Scheduling Mechanism

The number of nodes that must be traversed to convey a message from the sender to the CH distinguishes multi-hop clustering from single-hop clustering. Therefore, in a multi-hop design, each cluster member interacts with its cluster head directly or indirectly. To avoid extending the distance between CMs and CH, we must determine the maximum hop count ahead of time (MAX-HOP). On the other hand, because each CH is responsible for monitoring and managing the members in its cluster coverage area, we need to define the maximum number of members (MAX-CM) that can join the cluster for the leaders to function effectively.

Prioritization in conventional clustering models has traditionally been dependent on the type of message, with emergency messages taking precedence over other communications. We opted to emphasize all communications received by emergency service vehicles in this study since they are critical in the event of an accident or crisis. Depending on the

type of vehicle, some need more rigorous security and should experience minimum delays in processing, responding to, and servicing messages in general. As a consequence, we divided vehicles into two categories based on their purpose: the first category includes the rescue services such as ambulances, police cars, and fire trucks, which have priority in receiving services from server devices, while the second group composes of the majority of the non-priority vehicles.

Vehicle-distributed data is allocated to two distinct queues, q1 and q2. Priority vehicle data is forwarded to q1, while other communications are redirected to q2. Since the period of waiting for a packet in the queue is the primary determining feature, we should minimize this time to reduce the packet's delay time [61]. In addition to dividing the received messages, we applied the traditional TDMA strategy for the priority-based queue, which provides fair access for rescue service messages to the communication channel.

3.3 Mechanism Algorithm

The flowchart model 3.3 depicts all of the stages of cluster creation and joining to clusters in our suggested technique. Although they differ significantly in detail, this technique is somewhat extended to the PMC algorithm [4].

3.3.1 Definition of Status

In the cluster design, each vehicle has a status. By changing its condition, the vehicle alters its function in the cluster. All of the vehicle's statuses are defined as follows:

- Initial mode (IN): When a vehicle is first joined to the network, it is in this condition.
- Decision mode(DS): After joining the vehicle to the network, it enters the decision mode. Furthermore, this state will be triggered when the vehicles switch from CH to CM or vice versa.
- Cluster head mode(CH): The cluster head position, which is similar to the leader's role for other members.
- Cluster Member mode(CM): Cluster members are other participants in the cluster architecture who have a single-hop or multi-hop distance less than the MAX-HOP from the CH.

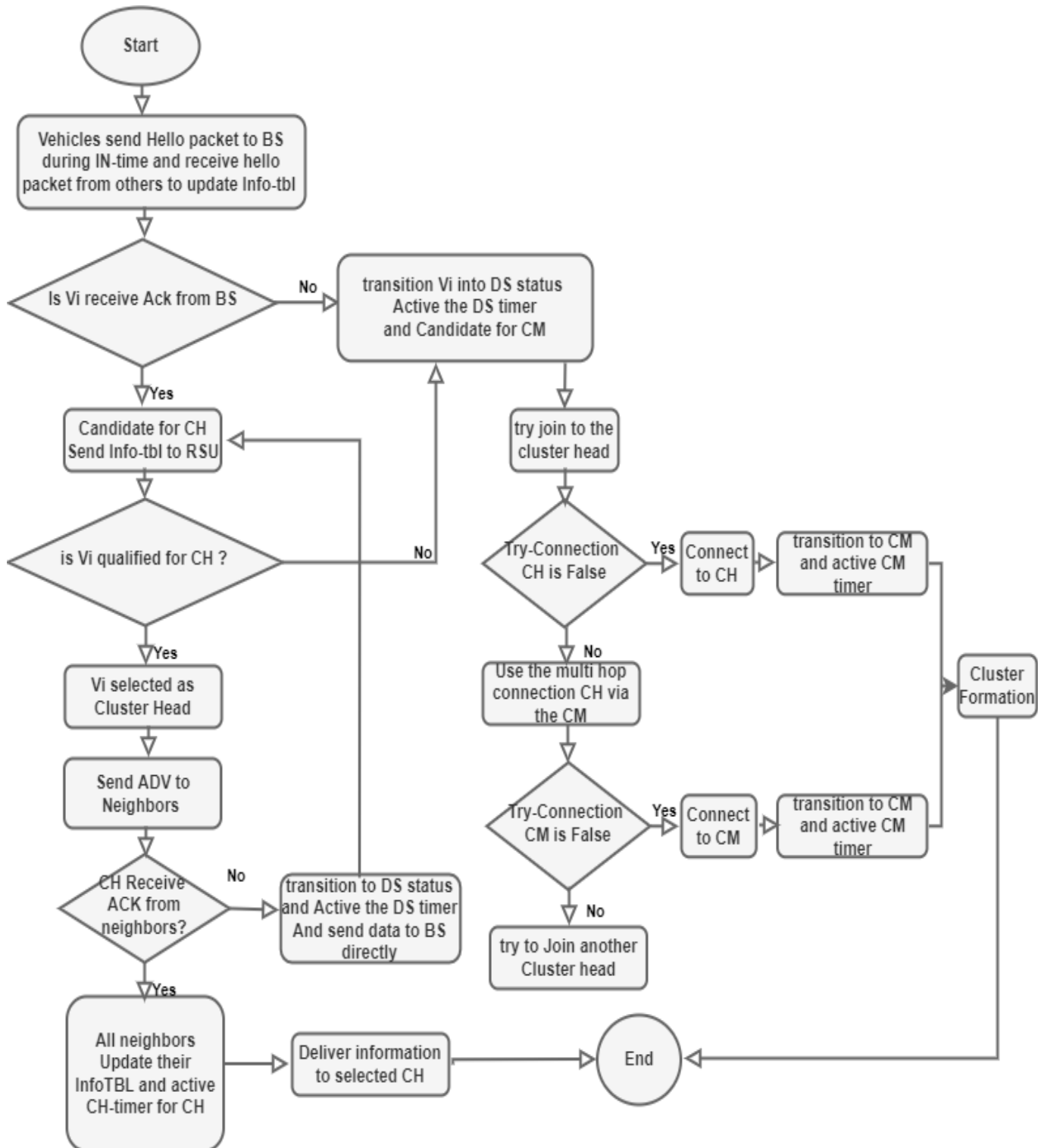


Figure 3.3: Proposed model flowchart

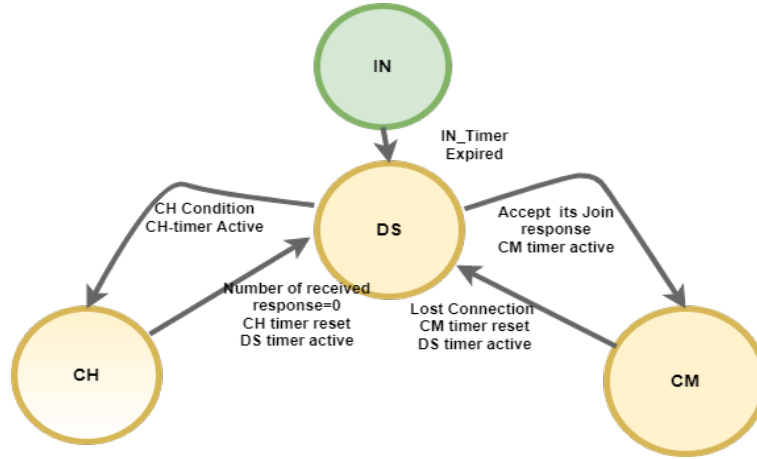


Figure 3.4: Status Transition Diagram

Fig. 3.4 shows the possible changing status transition in our proposed paradigm. As seen in Fig. 3.4, CHs and CMs cannot transition to one another's status without returning to DS mode. In the following, we explain more details about the cluster transition mode.

3.3.2 Creation and Updating of INFO-TBL

Each vehicle in the network carries an information table called INFO-TBL that contains information about itself and its neighbors within the MAX-HOP range. Table 3.1 displays all of the routing entries information kept by the vehicle. As previously stated, the vehicle's condition is defined by the vehicle's instant position (before or after joining the cluster), which might be IN, DS, CH, or CM. The location information part contains information regarding direction, speed, and position. Hop to CH Number represents the number of nodes that a message should be traversed to reach from the source to the cluster head. The number of vehicles directly connected to the cluster head is enumerated in the "Neighbor Node Numbers" section and cannot exceed the MAX-CM value. CH_Id represents the cluster head ID number of the cluster to which the vehicle belongs and can be set to -1 before joining the clusters, and Time-stamp indicates the appropriate and efficient time to enter the route. Furthermore, the Epi is a flag that shows whether or not the vehicle is a rescue service. The modification of INFO-TBL is associated with altering the vehicle statuses or receiving the hello packet from adjacent nodes.

The Hello packet contains the vehicle ID, CH identification, mobility speed, node hop to reach the CH, and movement direction, which is broadcast by neighbor nodes. In the

Vehicle.Id	Epi	Vehicle.State	Location Information	Hop to CH Number	Neighbor Nodes Number	CH.Id	Time-Stamp
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Table 3.1: InfoTbl Routing Entries

event that a vehicle obtains no hello beacons from neighbors within the period provided, the route record is removed when the time-stamp expires.

3.3.3 Algorithm Implementation

When the vehicle initially enters the network, it remains in the IN state for a duration defined by the TIME-STAMP. Each vehicle frequently broadcasts and receives beacons from neighbor nodes during the interval. Info-TBL will be updated based on the information gathered. After the countdown has ended, the IN state shifts to the DS. Each vehicle transmits a hello packet directly to the BS through the RSU as a gateway. Vehicle nodes that successfully receive a response from BS are chosen as candidates to be cluster heads in our proposed approach, while others must join the clusters as cluster members. Potential CHs send their information to the RSUs in their coverage area.

RSUs evaluate the condition of the CHs relying on the information received and determine the cluster head based on the criteria specified in the cluster head selection procedures, sending the CH_Id to the vehicles and BS. Selected vehicles immediately send advertising signals to other neighbors and wait for a set time to receive their response. If they do not receive any acknowledgment from other neighbors after the timer expires, they will return to the CH selection cycle. Otherwise, the chosen car switches from DS to CH and triggers the CH timer. On the other hand, if the vehicle does not meet the CH conditions, it becomes a candidate as a member of the cluster.

Vehicles that failed to deliver their messages straight to BS are excellent candidates for cluster membership. The alignment of these vehicles' motion with the head of the selected cluster is the first factor to examine when determining if these vehicles can join a CH to form a cluster. Each vehicle includes two flags. The first one is the TRY-connection-CH, in which the false state of this flag indicates that the vehicle can connect to CH. The vehicle then transmits its request to CH. If the MAX-CM requirements are satisfied and the response from CH is received, the car enters the cluster, and the CM timer is triggered. Otherwise, the flag is set to true, it signifies that the CH does not accept it as a member. Therefore, the vehicle will request another CM neighbor

to connect to CH through it. TRY-connection-CM is another flag that is considered when the vehicle attempts to connect to the CH through the intermediate CMs. The vehicle will be approved as a member of the cluster when the MAX-HOP and MAX-CM requirements are satisfied and the car request is answered by target vehicles. If none of the preceding parameters are met, the vehicle should attempt to connect to other CHs. Flowchart 3.3 depicts the phases involved in cluster creation and member selection.

If the CM loses its connection, it enters DS mode, and the CM timer expires. Similarly, when the number of acknowledgment packets received by CH equals zero, CH returns to the DS status, and the CH timer will be disabled. All these states are illustrated in Figure 3.4. Cluster head conditions will be explained in depth in the Cluster head selection method.

3.3.4 Cluster Head Selection Procedure

The vehicle that joins the network scene initiates the cluster forming if there is no appropriate cluster in its range. All adjacent nodes in the same orientation try to build a primitive team focused on the vehicle's initial data, which is transmitted through hello packets. Selecting an appropriate CH for each clustering algorithm contributes to improving cluster stability.

To determine the most qualified CH, all the vehicles broadcast their general information, known as the hello packet. The hello packets contain information such as the vehicle's ID, direction, and velocity that can assist participants in making the clustering formation decision [8].

In our proposed technique, the cluster head is selected based on the measured signal-to-noise ratio (SNR), the vehicle's distance from the base station (which can be calculated dependent on the time gap between delivering the message and receiving the response) within the coverage area of the base station, and the number of neighbors. Because wireless channels suffer from different difficulties such as physical barriers and noise, including signal attenuation and fading, a high SNR implies a good quality access channel. As a result, data communicated over this channel has lower latency and a greater transmission ratio, ensuring the channel's reliability. On a different note, when a vehicle is surrounded by more neighbors, it will have a lower relative speed than the other members of the cluster, which can ensure clustering stability.

To prove the relationship between the number of neighbor nodes and the node's stability, assume that N_e is the number of neighbors, L is the length of the vehicle, R is

the communication radius of the car, and all vehicles move in one direction in a straight line. The average inter-vehicle distance d_{Avg} is formulated as

$$d_{Avg} = \frac{2R}{Ne} \quad (3.1)$$

If we consider the driver response time as a constant value of t , the relative speed v is calculated by :

$$v = \frac{d_{Avg} - L}{t} \quad (3.2)$$

According to this equation, when the number of vehicles increases, the average inter-vehicle distance and, consequently, the relative speed of the vehicles decreases.

The lifespan of CH is another aspect that influences cluster stability. Because in our proposed model, the CHs work together to deliver data to the BSs, the energy consumption of the CH nodes is lower than if each cluster head sent its data individually. As a result, chosen cluster heads can remain in their state for a longer time.

Algorithm 1 illustrates the key steps in choosing the cluster head, and algorithm 2 establishes the route for data to be forwarded to the infrastructure. These two algorithms are executed sequentially. Algorithm 2 steps are explained in detail in the subsection "Discovering the Optimal Routing."

Table 3.2: Variable in Algorithm1

Symbols	Description	Symbol	description
V_i	Vehicle i	D_i	Distance V_i from base station
R_m	BS Transmission coverage	BS_m	The base station m
p_i	The packet i	q1	The pro queue
C_m	The cluster m	q2	The non-pro queue
CH_m	The cluster head m	pro	The priority of packet
NN_i	Number of Neighbor V_i	EP_i	Vehicle pro status

After assessing the desired metrics (SNR, distance, and the number of neighbors) and deciding the proper CHs based on the given information, other adjacent vehicles that can not send their data directly to the BS, with similar direction in the same coverage

Algorithm 1 Select Cluster head

Input V_i, R_m, NN_i
Output CH_h, CH_m
Start

- 1: **procedure** (SELECT CLUSTER HEAD)
- 2: **if** More than one vehicle is the BS_m coverage area at the same direction **then**
- 3: Calcualte SNR_i and SNR_j and distance of vehicles i and j from BS_m and NN_i and NN_j
- 4: **if** $SNR_j > SNR_i$ and $D_j < D_i$ and $NN_i > NN_j$ **then**
- 5: V_j selects as a Cluster Head $C_m = CH_m$
- 6: **else**
- 7: V_i selects as a Cluster Head $C_m = CH_m$
- 8: **end**
- 9: **else**
- 10: V_i Remains in DS status until the timer expires
- 11: **end**
- 12: **if** Vehicle i is not member of cluster C_h but in the coverage area of CH_h **then**
- 13: Join C_h ▷ Based on the flowchart model 3.2
- 14: Calcualte SNR_i and SNR_h and distance of vehicles i and h from BS_h
- 15: **if** $SNR_h > SNR_i$ and $D_h < D_i$ and $NN_h > NN_i$ **then**
- 16: C_h remain as a Cluster Head
- 17: **else**
- 18: V_i selects as a Cluster Head $C_h = CH_h$
- 19: **end**
- 20: **end**

Algorithm 2 Message dissemination

Input $SNR(CH)_k, SNR(CH)_f, D(CH)_k, D(CH)_f, p_i, pro$

Output Path, Assign packet to the q1 or q2

Start

procedure (CREATE ROUTING)

2: **if** $SNR(CH)_k > SNR(CH)_f$ and $D(CH)_k < D(CH)_f$ **then**
 CH_k send data directly to BS_m and CH_f sends data to the CH_k

4: **else**
 CH_f send data directly to BS_m and CH_k sends data to the CH_f

6: **end**

 ▷ Cluster Heads broadcast beacons which can include the priority flag ▷ The path has already been created for priority and non-priority messages

if $pro=1$ **then**
 8: $E_{pi}=1$ and p_i assigned to the q1
 else

10: $E_{pi}=0$ and p_i assigned to the q2

end
end

area of the nearest CH join the cluster as the CM (explained in the previous section). The status of the CHs and the CMs is tracked on a regular basis, and appropriate action is taken as a result.

The resource management for processing data collected in RSU's computing nodes requires intensive CPU processing, which we handle by utilizing the epigenomic workflow approach. In this method, with the asset of the workflow scheduling technique, we allocate available resources to tasks as efficiently as possible. By implementing this strategy, we minimize processing time and lower processing costs as much as feasible.

Finding the perfect cluster head will result in positive outcomes such as increased network stability and efficiency.

3.3.5 Discovering the optimal routing

Following the creation of vehicle clusters and the choice of CH, vehicles in various groups share their information with their cluster heads to transmit effectively in the network. As previously explained, after RSUs in the base station's coverage area choose cluster heads, they announce the selected CH_Ids to BS and vehicles. After receiving the CHs selected by BS, it proceeds to determine which CH signal has a stronger signal and travels a shorter distance than the others. The selected CH_Id is subsequently sent to the CHs by the BS.

After receiving information from BS, other cluster heads begin sending requests to the selected CH to establish a connection. If the chosen CH accepts their request, they will send their communications to it; otherwise, they will send their data directly to the BS. The CH selection and message dissemination steps are illustrated in the flowchart 3.5.

Following the establishment of an appropriate routing, CHs deliver their data based on priority and route it through two independent queues in the channel. Messages with prioritization in q1 are conveyed using a standard TDMA-based MAC protocol that is more appropriate for delay-sensitive communication, whereas those in q2 are delivered using the conventional MAC method.

3.3.5.1 Calculating Route Reliability

The level of reliability in the routing technique is one of the criteria that determines the efficiency of that approach. Reliability plays an essential role in determining the QoS of a network because PDR, transmission latency, and routing overhead are improved

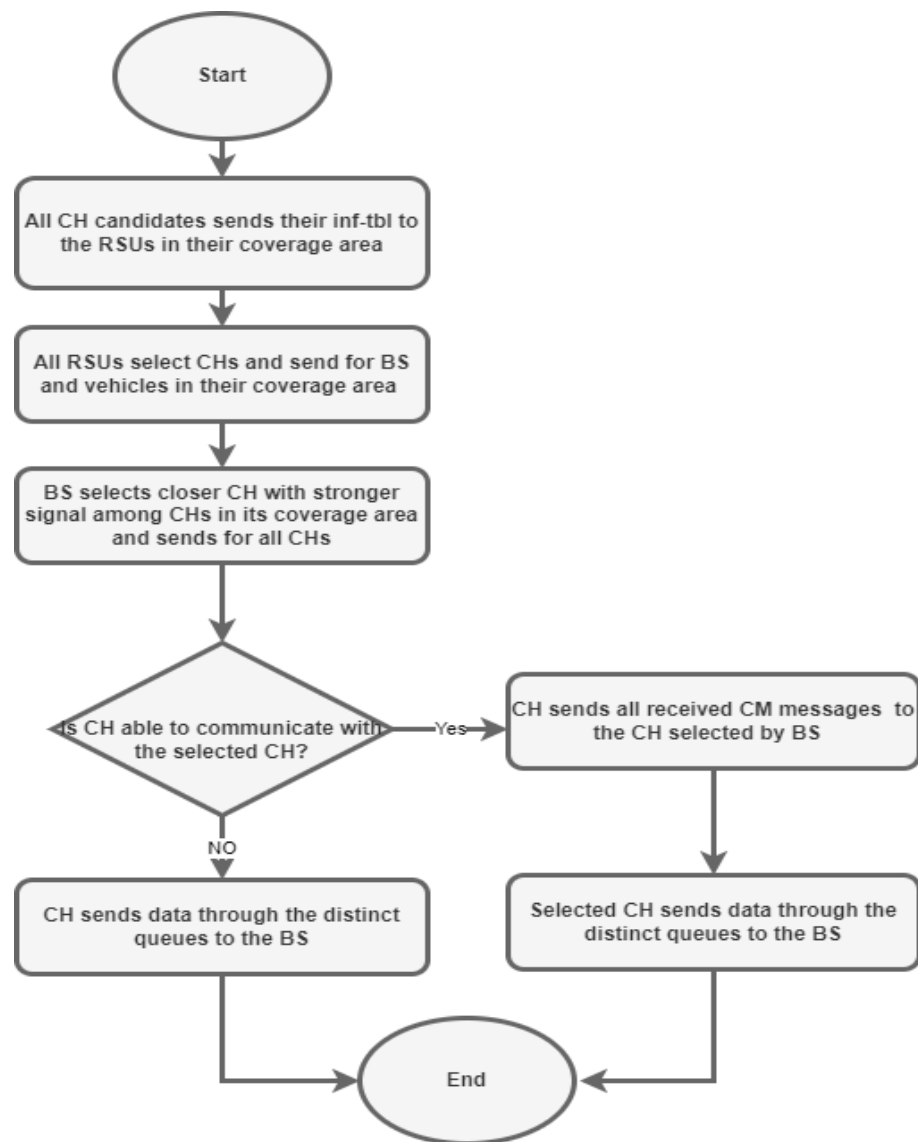


Figure 3.5: CH selection and data dissemination through the Cluster heads to BS

as reliability increases. In a different research, several approaches for calculating route reliability have been proposed.

We calculated the routing reliability in our suggested approach using the mathematical technique provided in [34] and then compared it to the other three clustering techniques [34],[62], and [4].

The author of the CVoEG approach first calculates the reliability of each link. According to the writer's definition, the probability that a direct communication link between two vehicles V_i and V_j will be maintained over a particular time t is referred to as link reliability [63]. If l represents a link between vehicles V_i and V_j at time t , then $r_t(l)$, considering the estimated availability time T_{est} is :

$$r_t(l) = \{\text{link between } V_i \text{ and } V_j \text{ is available until } T_{est} \mid \text{exist at } t\} \quad (3.3)$$

The value of link reliability at time t is calculated by computing the probability density function (pdf) throughout the connection period T between V_i and V_j , as demonstrated in [34], using the following equation:

$$r_t(l) = \int_t^{t+T_{est}} f(T) dt, \text{ if } T_{est} > 0 \quad (3.4)$$

Because each source vehicle may have multiple links, the route reliability value can be calculated by multiplying the reliability of intermediate links individually for each route.

3.4 Summery

This chapter describes the methodology and characteristics of the novel cluster-based protocol referred to as NCBR. The introduced routing protocol is based on prioritizing the rescue service communication in the vehicular network. This novel multi-hop cluster-based routing protocol incorporates a heterogeneous architecture to mitigate VANet challenges and improve the QoS. Applying the RSU's computing ability is closer to the vehicles than BS, and central servers provide networks with consciousness and intelligence. This method employs an info table and beacon packet to measure distance, priority status, and SNR, all of which are necessary for cluster head selection and routing. In addition, it guarantees QoS by prioritizing rescue service messages above data messages when allocating the medium. Furthermore, by adopting the epigenomic workflows technique, NCBR mitigates the difficulty of RSU's resource constraints. When these characteristics are integrated, it makes the NCBR mechanism appropriate for VANETs.

Chapter 4

Performance Evaluation Of Proposed Novel Cluster-Based Routing Protocol

Prioritizing and improving the QoS of routing communications generated by emergency vehicles enhances vehicular network safety. To verify our proposed new routing method, we analyzed the performance of this scheme while comparing it with three validated cluster-based techniques. The chapter is organized as follows: The first section defines the criteria for evaluating the proposed model's QoS, reliability, and stability. The techniques used to experiment, including the intended values of the parameters, the software used to simulate the vehicle mobility model, and how to evaluate the priority-based clustering routing protocol by QoS provisioning, will be discussed in the next section. Then, the final section validates the proposed algorithm's performance by comparing it to comparable multi-hop clustering techniques.

4.1 Simulation Metrics

We reviewed relevant works to determine the metrics that impacted the QoS modification, reliability, and clustering stability. According to Eiza et al. [64] study, the routing decision to convey data to the target nodes is determined by considering the QoS of each link and selecting Device-to-Device (D2D) intermediate nodes. The bandwidth capacity, end-to-end (E2E) latency and durability of the link between two intermediate nodes in the route are all elements that contribute to QoS requirements. Packet drop

percentage and packet delivery ratio (PDR) is measured in this research to assess the network throughput.

[65] evaluated the quality of service (QoS) in four distinct topological routing protocols in VANETs. In addition to the packet delivery ratio and average end-to-end delay, this suggested scheme's throughput is determined by normalized routing overhead, which is calculated relative to vehicle speed and density.

The author of [66] provided an analysis of performance in VANETs which applies clustering structure over vehicle-to-Internet communication. Message Delivery Ratio (MDR), Message Delivery Latency (MDL), and average Clustering Overhead are three primary metrics used in this study to validate the improvement of this method's performance.

Khan et al. [34] evaluated the QoS and reliability of their proposed method by examining the effects of transmission range and vehicle velocity on reliability, overhead, PDR, E2E time, and throughput. In addition, the effectiveness of clustering is assessed in a study conducted by Zhang et al. [4] by analyzing the number of transitions from CHs to non-CH modes, the average duration of remaining in CM mode, the average time of CH stability, and clustering overhead.

Given the metrics used in other studies, we opted to investigate the following criteria to evaluate the proposed model QoS, reliability, and clustering stability.

- Packet Delivery Ratio (PDR): This criterion represents the average percentage of packets successfully received by the target vehicle relative to the total number of packets supplied by the source vehicle.
- Delay: This indicator refers to the travel time of the packet from the sender to the receiver through the media.
- Average Time Of Cluster Head Duration: This indicator displays the period the nodes have been in the CH state. The amount of this time is calculated using the timer activated when the vehicle is selected as the cluster head until it switches to another mode.
- Average Cluster Head Changes: This indicator is measured by calculating the number of vehicles that served the function of CH in the clusters and then switched to other modes.
- Ratio of Clustering Overhead: This indicator is the proportion of the number of control packets spent during the cluster creation and maintenance stages to the total number of packets.

- Link Reliability: The possibility of an existing link between two mobile nodes remaining operational throughout a given lifetime is referred to as link reliability.

Furthermore, since we prioritize messages sent from secure services, we compare latency between priority and non-priority vehicles, which is calculated similarly to the E2E delay.

4.2 Experiments Setup

This section is categorized into mobility pattern and network simulator, which describes the simulation parameters, mobility model, and broadcasting strategy utilized in our experimental environment.

4.2.1 Mobility Scenario

We utilized the VanetMobiSim simulator to simulate genuine mobility in a vehicle environment. We also employed a map of New York City with actual road design and structure to validate our proposed algorithm. The mobility model in this platform is the Intelligent Driving Model-Lane Changing (IDM-LC), which in addition to managing the stop sign and traffic light conditions, allows vehicles to change lanes and overtake one another.

In the simulation experimental environment, the total simulation time is 300s, the speed is restricted to 35 to 60 m/s, and the vehicle's transmission range changes from 100 meters to 300 meters. Most of the parameters in Table 4.1 are obtained from article [4].

Table 4.1 contains the specific characteristics for the mobility scenario and simulation parameters considered in this research.

4.2.2 Network Simulator

Following the determination of mobility characteristics and a broadcasting strategy, choosing the proper tools is the next step to simulating the real-traffic environment, implementing routing protocols, and measuring the QoS criteria. Among the most prominent and popular simulators, we can refer to VEINS [67] accompanying OMNET++ [68] and a combination of VanetMobisim [69] or SUMO[70] with Network Simulator (NS) [71].

Parameter	Value
Simulator	NS2
Mobility simulator	VanetMobisim
Mobility Model	IDM-LC
Transmission Range (m)	100-300
Radio Propagation Model	Two-way Ground Model
MAC Protocol	IEEE 802.11/IEEE 802.11P
Antenna	OmniAntenna
Simulation Time (sec)	300
Simulation Runs	50
Number of Nodes	100
MAX speed (m/s)	35 ~ 60 (126 km/h ~ 216 km/h)
The sending interval of Beacon Packet (ms)	300
Beacon Packet size (Byte)	64

Table 4.1: Simulation Parameter Value

In this research, we delegated the task of designing the network environment to NS2 [71] and the traffic generator to VANETmobisim [69], which supplies all of the functionalities required for this experimental research. VanetMobiSim is a CANU Mobility Simulation (CanuMobiSim) system modification, a versatile framework for simulating user mobility [69]. This French lab mobility simulator incorporates both macroscopic and microscopic levels. All characteristics of each vehicle, such as speed and acceleration, are investigated at the microscopic level, while the macroscopic level determines the road structure and topology. We implement the clustering architecture and other processing models such as SNR calculation, distance computing, and executing epigenomic workflow using the VanetMobiSim library and import XML and jar files in our simulation dynamically.

VanetMobisim adopted the flooding-based broadcasting method in which when a vehicle generates and transmits a packet, it is relayed once by all recipients. In a flooding-based technique to avoid multiple processing and disseminating, each vehicle must keep a duplicate table that includes all of the IDs of the received packets[15].

4.3 Experimental Results and Interpretation

The proposed model in this thesis is compared with the HBASMV [62], CVoEG [34], and PMC [4] algorithm respectively. The HBASMV [62], presented WSN, is made up of BS, CH, ordinary, and end-user nodes. Base station nodes are trusted agents that manage other entities' authentication and trustworthiness as well as process, analyze, and store critical transmitted data. Cluster head nodes are equipped with powerful processors and storage space, and they are in charge of transmitting data from ordinary nodes in their coverage area to base stations as gateways. Each ordinary node is a member of only one cluster and one wireless sensor network. Ordinary nodes can typically detect and transfer basic packets. Their processing capability and storage space are restricted, as is their energy, preventing them from performing various functions and data analysis. Finally, end users typically have ample processing and storage power, while they are not energy-constrained.

Another novel passive multi-hop clustering (PMC) method [4] proposed the multi-hop clustering methodology by selecting more stable cluster members and cluster heads, which enhances cluster design stability. The suggested technique chooses the cluster head based on the number of direct and indirect following vehicles, ensuring a reduction in the frequency of switching cluster heads and improved bandwidth usage.

In [34], one new cluster-based VANET-oriented evolving graph (CVoEG) model has been presented. In this technique, the selection of cluster members and cluster heads is closely connected to link reliability.

Therefore, to evaluate the cluster's stability, two criteria are examined in this study: the average time of CH duration and average CH changes. In addition, packet delivery ratio, delay, and clustering overhead are our primary metrics for demonstrating enhanced QoS and link reliability in the proposed technique.

We obtain the following experimental findings by comparing the six indicators:

4.3.1 Packet Delivery Ratio (PDR)

This criterion is calculated by measuring the average percentage of successful incoming packets to the target vehicles to the entire generated packets by the origin vehicle. PDR is one of the primary indicators for analyzing network QoS requirements. Figure 4.1 depicts the successful packet delivery ratio during the life of the simulation.

As shown in Figure 4.1, the packet delivery ratio fluctuates during the simulation time because it is affected by several factors, such as the number of nodes, network

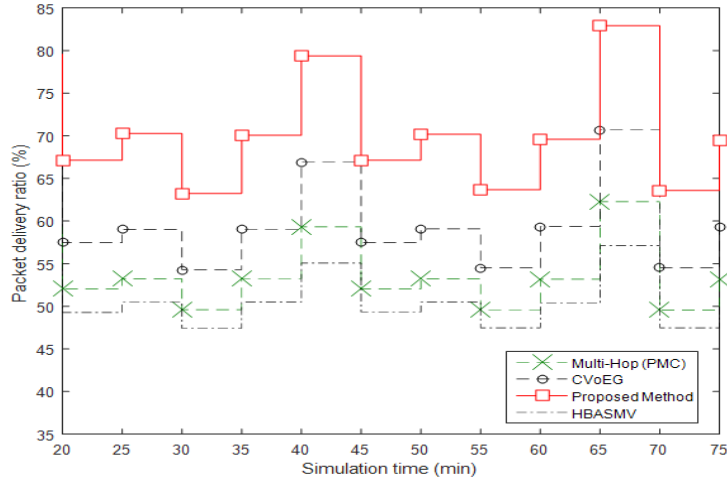


Figure 4.1: Packet Delivery Ratio

reliability, node-to-node link stability, and so on.

Despite the fluctuations, the position order of all four algorithms stays consistent, and HBASMV[62], PMC[4], CVoEG[34], and our suggested model have the lowest to the highest percentage of packet delivery, respectively.

4.3.2 Delay

A delay is a time required for a packet to travel from the source to the target vehicle via the transmission media. Raising the speed of the mobile node increases the average latency. Therefore, we see an upward trend in the delay charts as the speed increases.

To analyze the simulation results, we assessed the delay for each of the four algorithms using a varied number of vehicles, such as 30-50-80 and 100, at speeds ranging from 35 to 60 m/s. While a random number of tasks for nodes ranging from 300 to 1500 have been uploaded.

As demonstrated in Figure 4.2, our suggested model has less delay than conventional techniques, with PMC [4], HBASMV [62], and CVoEG [34] coming in second, third, and fourth place, respectively. Figure 4.2 shows the notable delay behavior when the number of vehicles is set to 80. Given the theory that the amount of delay should rise with the number of vehicles, we can observe that the amount of delay in the number of 80 is significantly greater than when the number of cars is considered 100. This trend might be explained by the experiment's random assignment of tasks to nodes.

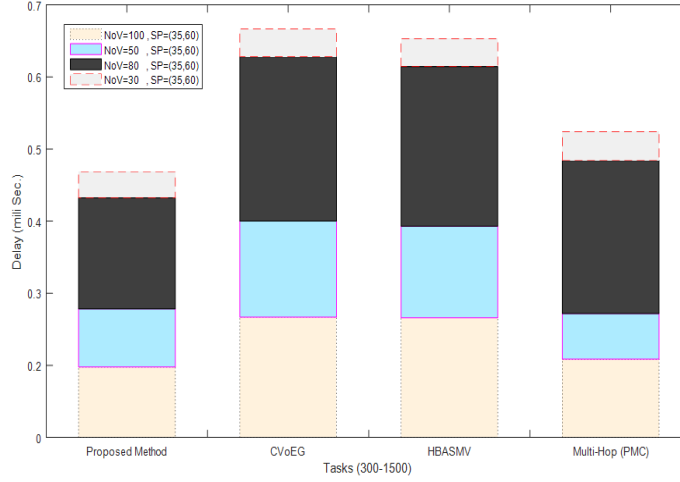


Figure 4.2: Average Delay

4.3.3 Average Delay in priority and non-priority vehicles

Figure 4.3 compares the average delay between receiving messages supplied by rescue services and messages produced by other vehicles that do not have priority. As seen in the diagram, the latency of non-priority vehicles grows faster than that of priority vehicles as their speed increases. Delay in non-priority vehicles increase slowly and steadily from 0.25 (milliseconds) in 20 (m/s) to 0.27 (milliseconds) in 30 (m/s), after reaching a speed of vehicle to 35 (m/s), it increases significantly from 0.32 (milliseconds) to 0.55 (milliseconds) at 50 (m/s). While the message transmission delay in secure services is around 0.26 (milliseconds) up to a speed of 35(m/s), after that, this delay gradually rises to 0.34 (milliseconds) at 50 (m/s).

4.3.4 Average Cluster Head Duration

Cluster head duration time refers to the time spent by nodes in the CH state before transitioning to a non-cluster head state. This percentage is obtained by dividing the total cluster heads' lifetime by the number of CHs chosen [34].

$$AvgLT_{CH} = \frac{\sum_{i=1}^n LT_{CH}(i)}{n} \quad (4.1)$$

The $AvgLT_{CH}$ indicates the average lifetime of the cluster head, LT_{CH} represents the

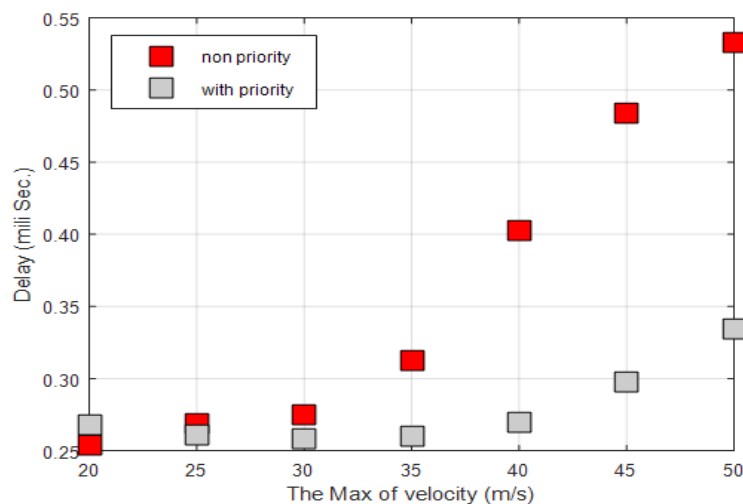


Figure 4.3: Average Delay in priority and non-priority vehicles

duration time of the cluster head, and n refers to the number of chosen CH during the simulation time.

Figure 4.4 illustrates the experimental results obtained by simulation for the maximum transmission range. The change in the lifetime of the cluster head for each node in proportion to the speed of the node for all algorithms is depicted in this figure.

As can be observed from the findings, the average cluster head time reduces as the vehicle's velocity increases. Obviously, frequent topological changes caused by speed variations increase the probability of connection loss. Figure 4.4 shows that the suggested approach and the PMC methodology had longer cluster head lifetime periods than the others, despite the overall result exhibiting a downward pattern.

HBASMV[62] and CVoEG [34] algorithms have shorter cluster head duration times, despite the fact that CVoEG uses the appropriate mobility measure as a cluster head selection criterion.

4.3.5 Average Cluster Head Changes

This criterion is measured by determining the number of vehicles that function as CH and shift to the other states during the simulation cycle.

Figure 4.5 depicts the experimental results, which indicate a connection between the average CH change number and vehicle velocity. It shows how the number of cluster heads grows as the vehicle speed increases.

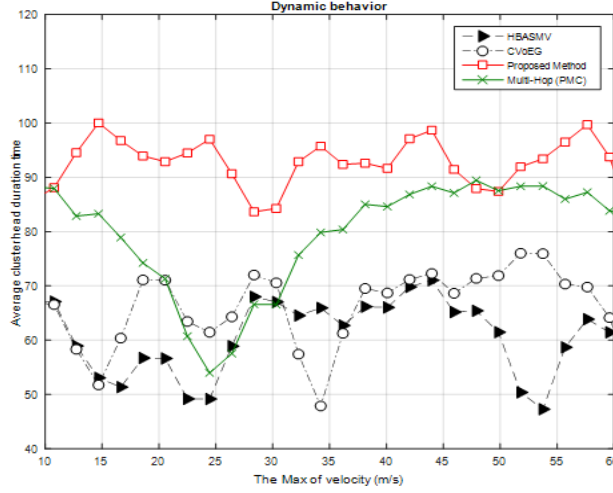


Figure 4.4: Average Cluster Head Duration Time

Because of the cooperation among the cluster heads to transmit data and select the CH based on the QoS and distance, our proposed algorithm has a minimum change in cluster head transition. As shown in fig 4.5 in the other three techniques, these changes encounter a substantially higher rise with increasing speed than our suggested method. Although the PMC approach employs more stable nodes as cluster heads, the average number of CH changes relative to velocity in this strategy is at the third level, following CVoEG, and before HBASMV.

In 40(m/s), the cluster head change in the suggested technique had increased to just over 100. Although this appears on the graph to be a gentle growth, it is, in fact, a rise of almost 50%. CVoEG and PMC also rose by nearly 90%, respectively, from 150 to under 300 and 230 to 420.

As indicated in the diagram, the switching frequency of the cluster head in HBASMV more than doubled with the speed change and reached roughly 550.

4.3.6 Clustering Overhead

The clustering overhead is obtained by calculating the percentage of all control packets devoted in the cluster establishment and maintenance conditions to the total number of produced packets [4].

$$OVH_{cls} = \frac{\sum_{i=1}^n Packet_{ctl}}{\sum_{i=1}^n Packet_{tot}} * 100\% \quad (4.2)$$

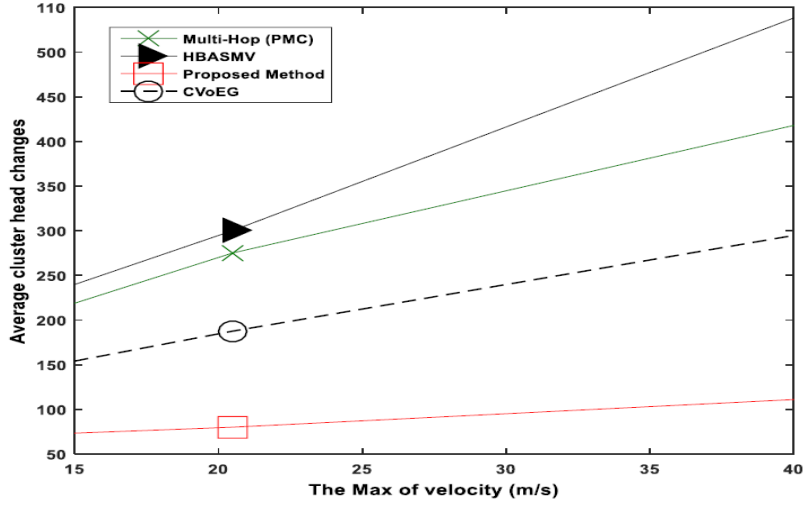


Figure 4.5: Average Cluster Head Change

where the OVH_{cls} in Eq. (4.2) refers to the clustering overhead.

Figure 4.6 shows the ratio of the cluster overhead in relation to the vehicle velocity while MAX-HOP takes 3, MAX-CM takes 10, and the vehicle's broadcasting range is set to 300m. The number of clustering formations increases related to the vehicles' speed.

HBASMV has the lowest overhead compared to the other three techniques at low speeds, while when the speed increases and more clusters are created, our suggested method and PMC impose a lower overhead ratio on the network, and HBASMV and CVoEG are in the second and third place, respectively. It should be noted that the graph only depicts the average percentage of clustering overhead achieved from four different schemes.

4.3.7 Impact of different transmission range on reliability

The possibility of an existing link between two mobile nodes remaining operational throughout a given lifetime is referred to as link reliability. To analyze the experimental results, we take 300 sec for simulation time and 35 to 60 m/s for the speed of the vehicle. In Figure 4.7, we compared the provided model to existing approaches while considering transmission ranges varied from 100 to 300 m.

We can see the behavior of the suggested method when the cluster forms at 90 m, which has a significant rise, while other strategies show a slow and steady increase between 100 to 300 m transmission range.

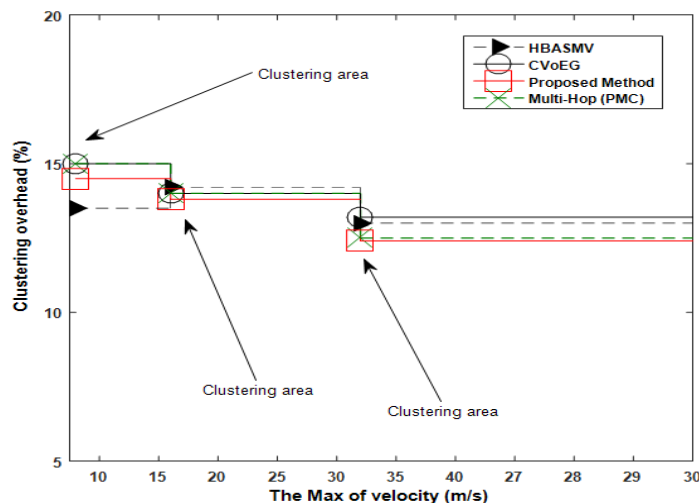


Figure 4.6: Clustering Overhead

The experimental findings reveal that the suggested model's average reliability is about 0.58, the CVoEG [34] is around 0.38, the PMC[4] is around 0.42, and the HBASMV[62] is around 0.33 on a scale of 0 to 1.

As a consequence, we can claim that the proposed method not only improves the QoS requirements but also outperforms the other three examined methodologies in terms of stability.

4.4 Summery

In this chapter, the value of the parameters is determined, and then the software and measurement tools applied in implementing our approach are explained. The NS2 simulator combined with the VanetMobiSim traffic generator is utilized to analyze the NCBR protocol, and our results reveal an improvement in latency, packet delivery ratio, reliability, clustering overhead, and stability. According to the simulation results, NCBR can offer emergency vehicles faster service by minimizing latency and prioritizing. Improved stability can be proven by lowering the number of CH changes and increasing their longevity, while enhanced reliability can be demonstrated by increasing the packet delivery ratio.

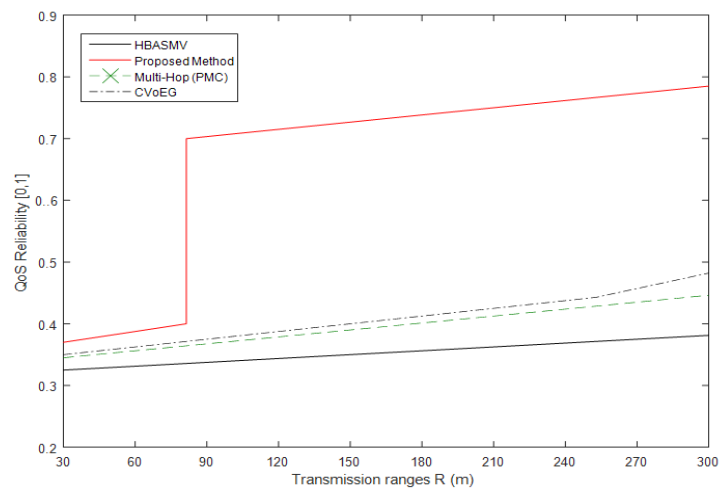


Figure 4.7: Link Reliability

Chapter 5

Conclusion and future work

Emergency vehicles such as ambulances or fire trucks convey vital messages, particularly in emergency and accident situations. Prioritizing their communications in a challenging vehicle network environment can significantly reduce the risk of their information being lost or delayed. However, prioritization, on its own, cannot overcome all of the hurdles in vehicular networks and maintain the network QoS, which keeps users satisfied with the application services at the desired level.

5.1 Conclusion

Due to the high-speed feature of vehicles, mobility restrictions, and driver behavior, which produce dynamic topology and uneven network density in the vehicular environment, we must develop an appropriate routing method to deliver information with high reliability and in real-time through the VANET.

In this study, we developed a novel cluster-based routing protocol (NCBR) intended for emergency vehicles, which alleviates the issues associated with VANET applications. To address problems related to the unequal network density, we used a hybrid IEEE802.11-LTE communication protocol that provides broad dissemination reach and reduced transmission latency. We also delegated some computing responsibilities to the RSUs to provide distributed and near-vehicle compute servers that acquire the most recent information about network changes to alleviate fast-changing topology issues and service delays.

The clustering technique in our proposed method reduces frequent handover between vehicles and BSs and boosts network efficiency and scalability. All vehicles in a BS-

covered region traveling in the same direction can form a cluster. Vehicles in the clusters with the strongest signal-to-noise, the maximum number of neighbors, and the shortest distance from the BS are chosen as cluster heads.

The SNR and distances from the BS of all nearby CHs are compared by the BSs, to discover a reliable route to disseminate data. CH with the highest SNR and shortest distance becomes responsible for delivering its data and the packets of other adjacent CHs to the BS. Messages delivered by emergency vehicles are sent through priority queues. In addition, the epigenomic workflow technique uses the scheduling task to optimize resource management in the limited-resources RSU's computing node, which reduces time and cost requirements for computation.

To analyze the performance of NCBR, we used the NS2 and VANET Mobisim simulators, and our results revealed an improvement in latency, packet delivery ratio, reliability, clustering overhead, and stability compared to the three validated clustering schemes.

5.2 Future Work

Although this research presents an all-inclusive investigation and assessment from many perspectives, there are still some outstanding concerns and numerous research paths that can be explored to maximize the performance of the proposed cluster-based protocol. The following future works we aim to investigate to extend the NCBR are :

- **Using Meta-Heuristic Algorithms:** Clustering method is one of the strategies that considerably enhance the routing protocol in the face of numerous problems in the vehicle environment. However, one of the primary concerns in developing such an algorithm is picking suitable cluster heads. Improper cluster head selection can have an adverse effect on network performance, so we can apply meta-heuristic approaches to optimize CH selection algorithms to improve the performance of the suggested method.
- **Implementing in 5G next generation VANETs:** As new technologies become available for use in 5G networks. Another option is to deploy the NCBR approach in a 5G context. In this plan, we can also employ SDN and fog-based technology to improve data management.
- **Deploying Security Algorithm:** Another challenge in the VANET application is the creation of security in the vehicle network. Aside from the benefits of im-

proved scalability and efficiency provided by clustering, another advantage of this technology is the deployment of security. As a result, including the authentication mechanism in this architecture may be considered to broaden our approach.

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