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Improving the Performance of Emergency Message Dissemination Scheme for VANET using Selective Forwarding Algorithm in Multi Directional Road Scenario

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Approval sheet

This independent research entitled as “Improving the Performance of Emergency Message Dissemination Scheme for VANET using Selective Forwarding Algorithm in Multi Directional Road Scenario” has been read and approved as meeting the preliminary requirements of the Faculty of Computing and Informatics in partial fulfilment for the award of the degree of Master in Computer Networking, Jimma University, Jimma, Ethiopia.

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Acronyms

ASPBT: Adaptive scheduled partitioning and broadcasting technique

BFS: Breadth-First Search

BSP: Broadcast storm problem

BSSA: Broadcast storm-suppressing algorithm

CCH: Control Channel

CPU: Central Processing Unit

CSMA/CA: Carrier Sense Multiple Access with Collision Avoidance

DCF: Distributed Coordination Function

DSRC: Dedicated Short-Range Communication

EM: Emergency Message

ETGPH: Expected transmission gain per hop

FIV: Farthest Infected Vehicle

FN: Forwarding Node

GPS: Global Positioning System

ITS: Intelligent Transportation System

IP: Internet Protocol

IPv6: Internet Protocol version six

LOA: lion optimization algorithm

LLT: Link Lifetime

MAC: Media Access Control

MANET: Mobile Ad Hoc Network

MBM-EMD: Multi-hop broadcast mechanism for emergency message dissemination

MCA-V2I: Multi-hop clustering approach over vehicle to the internet

OBU: On Board Unit

OFDM: Orthogonal Frequency Division Multiplexing

OMNET++: Objective Modular Network Testbed in C++

P_ACK: Passive Acknowledgment

PBB: Partner-Based Broadcasting

RBO-EM: Reduced Broadcast Overhead scheme for Emergency Message

RSU: Road Side unit

SEB: Selective Epidemic Broadcasting

SEIR: suspected, exposed, infected, and removed

SIR: Susceptible, Infected, and Removed

SCH: Service Channel

SUMO: Simulation of Urban Mobility

SNR: Signal Noise Ratio

TCEMD: Trust Cascading-based Emergency Message Dissemination

UMBP: Urban Multi-Hop Broadcasting Protocol

VANET: Vehicular Ad hoc Network

V2V: Vehicle to Vehicle

V2I: Vehicle to Infrastructure

Veins: Vehicle in Network Simulation

WAVE: Wireless Access in Vehicular Environment

WHO: World Health Organization

WSA: WAVE Service Advertisements

WSMP: WAVE Short Message Protocol

Abstract

A kind of mobile ad hoc network called VANET is created for vehicular communication. The performance and efficiency of transportation systems are being greatly enhanced by VANET, which is assisting in reshaping Intelligent Transportation Systems. In a VANET, vehicles can share and exchange information in terms of Vehicle-to-Vehicle or Vehicle-to-Infrastructure communication. V2V is communication among vehicles and V2I is communication between vehicles with roadside infrastructures. Dissemination of safety messages in VANET highly relies on the broadcasting mechanism. Since VANET is characterized by its dynamic nature and high mobility, flooding and simple broadcasting cause the broadcast storm problem. Because of broadcast storm issues, message broadcasting processes are slowed down in ways like higher overhead, broadcast collisions, and delayed dissemination. This thesis aims to provide a VANET emergency message dissemination scheme with a high delivery ratio, little end-to-end delay, and minimal overhead. A selective forwarding scheme based on the SIR epidemic spreading model is designed to solve the broadcast storm and network overhead problems that are caused due to the redundant selection of forwarding nodes in a multi-directional road scenario. An algorithm for selecting stable forwarding nodes and safety message dissemination is proposed. In the proposed approach the forwarding node is selected by considering the passive acknowledgment, distance, direction, and link lifetime as a parameter. We used the SUMO simulator for generating mobility and OMNET++ for simulating our network with the Veins framework. From the simulation, we get 160ms end-to-end delay, 40sec duration of forwarding node, and 83% emergency message delivery ratio in the proposed approach, whereas the existing scheme results in 187ms end-to-end delay, 35sec duration of forwarding node, and 80% Emergency message delivery ratio with 100 node density. The result of this simulation showed that the proposed approach improves the emergency message delivery ratio by minimizing the end-to-end-delay and overhead as compared to the previous approach.

Keywords: ***Emergency Message Dissemination, Multi-directional Road Scenario, and Selective Forwarding Algorithm***

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Vehicular Ad hoc network (VANET) is a recent technology for Intelligent Transportation Systems (ITS) that is used to disseminate an emergency message in advance to minimize traffic accidents and traffic jams between vehicles [1], [2]. The main goal of implementing this new technology is to create an environment that is free of emergencies by delivering emergency or safety messages on time. Based on their criteria, VANET safety messages are categorized as warning and status messages [2]. When vehicles are in an emergency, such as a road accident or road construction, warning messages are transmitted to them. Status messages are non-safety messages broadcast to the vehicle to keep neighbours updated on non-safety information. These emergency safety messages are disseminated across the VANET via Vehicle-to-Vehicle and Vehicle-to-Infrastructure communication. V2V communication is also called the on-board unit to on-board unit communication. It is a method of wireless communication that transfers data over wireless media between vehicles by using dedicated short-range communication (DSRC) frequencies. In the same way, the Vehicle-to-Infrastructure is a communication system that allows vehicle and roadside infrastructure to exchange information via its component [3].

In this thesis, both V2V and V2I communication techniques are considered to transmit data between the vehicles in their transmission range. In the V2V method, the vehicle automatically identifies an emergency using an On-Board Unit (OBU) that is mounted inside the vehicle and allows the driver to be alerted during driving, allowing the vehicle to survive a disastrous circumstance. This method of notifying a driver of a road accident needs to send the information to all nearby vehicles that are at risk. In this case, where hard constraints on delays should be respected, it is common to use broadcasting techniques.

Broadcast is the simultaneous broadcasting of a single message to all vehicles within the transmission range. However, because of their rapid mobility and varied density, message broadcasting in VANET is extremely difficult. Blind flooding or simple broadcasting generates broadcast storm problems due to the high mobility and fluctuating density of vehicles. Broadcasting is a frequent method of exchanging messages via the VANET. Because of the host mobility, this process requires the simultaneous execution of route finding, paging a specific host, and delivering an alert signal. Blind flooding is the most basic means of sending emergency safety messages in this network. Due to the shared wireless medium, flooding is always very expensive and will result in major collisions, contention, and redundancy, which will lead to broadcast storm problems. When numerous vehicles attempt to transmit at the same time a network system is overwhelmed by continuous multicast or broadcast traffic, and a broadcast storm problem is occurred [4], [5]. The broadcast storm had the most catastrophic impact on VANET in terms of safety-related service disruption, which resulted in message loss, collision, a high number of redundant messages, and delays. This issue has had several impacts on the distribution of emergency messages in VANET, as well as causing service disruption in the MAC layer.

The reason for this is that broadcasting communication in a VANET is unreliable due to a lack of acknowledgment in the IEEE 802.11p standards Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol [6]. When several vehicles exit in the same transmission range at the time of a dense network and all these nodes resend the same message, this will occur contention, resulting in MAC layer collisions, duplicated transmission, and significant delay among neighbouring vehicles.

Different researchers have proposed several methods to solve this problem and disseminate emergency messages in VANET. Papers [7], [5], [8], [9], used a cluster-based and epidemic approach to broadcast emergency messages to other vehicles on the transmission range. However, the proposed solutions are incomplete in terms of finding the exact forwarder node by identifying the direction of the vehicle for broadcasting the message and the message is only disseminated in a straight road scenario. Furthermore, the previous solution focuses on selecting the furthest vehicles as rebroadcasting nodes based on the distance, they have from the source node which does not provide any grant about neighbour node availability. They did not consider a link life time for selecting a stable forwarding node. Stability is to say the duration of time that a vehicle remains the forwarding node during the simulation. If the stability of a forwarding node is not considered the redundant selection of the broadcasting node is required, which leads to the overhead in the network. Therefore, VANET requires an effective algorithm for disseminating the emergency message in a multi-directional road scenario by reducing the broadcast storm problem and network overhead. To address the above problem, we proposed to design an RSU decision-based selective forwarding algorithm.

The algorithm improves the performance of emergency message dissemination and solves the broadcast storm problem that occurs due to broadcasting in an intersection. The proposed RSU decision-based selective forwarding algorithm is implemented by applying the SIR (Suspected, Infected, and Removed) epidemic spreading model. The algorithm reduces the number of forwarding vehicles by selecting stable forwarding vehicles as rebroadcasting nodes in the next transmission range. In our proposed work, the process of selecting the forwarding node is based on four criteria. The first one is the direction of the vehicle should be toward the intersection point. The second one is the vehicle should be sent the passive acknowledgment to the source vehicles and the distance (position) of the selective vehicle should be greater than the distance of other vehicles that exist in that transmission range. The fourth one is the link lifetime of a vehicle should be high to ensure the stability of the forwarding node. The vehicle which fulfilled these criteria is only permitted to rebroadcast the emergency messages. Hence the performance of the emergency message is improved by minimizing the broadcast storm and overhead problem in a multi-directional road scenario.

1.2. Statement of the Problems

According to a report by WHO, approximately 1.3 million people die every year due to road traffic accidents [10]. Especially, for children and young adults aged 5 to 29, it is the greatest cause of death. This information indicates that road traffic injuries have become a severe problem, which will only get worse if preventive measures are not adopted now.

When an accident occurs, all emergency vehicles must have immediate information to escape a dangerous situation. This can be accomplished by informing the driver about an accident on the road, this necessitates broadcasting the message to all endangered vehicles in the region. During this time, it is common to use broadcasting techniques in a vehicular network. Message transmission in VANET, on the other hand, is extremely difficult due to the high mobility and fluctuating density of the vehicle. These must share and route safety-critical information in real-time to another intended vehicle. Multi-hop relaying is used in a vehicular ad-hoc network to broadcast information to an area larger than the transmission range of a node. Flooding a packet is the simplest way to perform multi-hop relaying. When a node receives a broadcast message for the first time, it re-broadcasts the message in these circumstances. When all of the vehicles that get the emergency message attempt to rebroadcast by flooding, a significant situation known as broadcast storm problems arises. The consequence of broadcast storm problem is increased the network congestion, data traffic, higher delays, packet collisions, and service disruption in MAC layer. VANET performance is get affected due to broadcast storm problem.

By repeating similar messages several times during rush hour, the difficulties may become worse. As a result, one vehicle may receive a similar message from one or more vehicles several times, resulting in a congested network and the waste of valuable network resources such as bandwidth. This keeps the nodes busy by redundantly processing and sending similar messages to all vehicles in the transmission range, resulting in significant message loss, redundancy, and collision. As a result, the broadcast storm problem increases the time it takes for a message to reach its intended recipient, lowering the emergency message delivery ratio. Because VANET deals with emergency safety communication, a fraction of a second might cause death and cost the group or individual a million dollars. As a result, the rise in traffic accidents has resulted in unanticipated economic losses for people and countries as a whole.

The research conducted in this area is not complete in handling the broadcast storm problem. This is due to most of the recent works addressing the broadcast storm problems only in a highway scenario. As a result, they overlook several potential broadcasting directions and ignore realistic road topologies and traffic distribution. According to the current study of message dissemination in two-directional road scenarios, the broadcast storm problem increases twice compared to single-directional message dissemination and this becomes even more complicated when we take in to account the multi-directional road scenario. The reason behind this is, that in an intersection many vehicles enter the communication range or leave the communication range. The road becomes dense when the number of vehicles entering the communication range increase. When an emergency happens at this time, all the vehicles within this communication range begin to rebroadcast the emergency message they receive, causing congestion and repetitive broadcasting of the same message to their neighbours.

Furthermore, selecting the stable forwarding node and identifying the vehicle's direction of movement is a challenging task at an intersection. This is due to the possibility of one road having numerous lanes in a multidirectional road scenario, allowing a vehicle to go either toward or away from an intersection point. In this situation, selecting a stable forwarding node that can minimize the broadcast storm problem and transmit the message in all directions is similarly difficult because one or more vehicles may have an equal chance of being selected as a forwarder node. In addition to that ensuring neighbour availability in a dynamic network such as VANET is also the main research concern. Due to their rapid mobility, vehicles may dynamically change their position and speed after selecting the next broadcasting node. This requires checking neighbour availability at each point in time by identifying their exact position. Therefore, we proposed the selective forwarding algorithm that can solve the above-stated problem by selecting the stable forwarding node by considering the passive acknowledgment, distance, direction, and link lifetime of a vehicle as a parameter. This approach minimizes the broadcast storm problem and network overhead issues that occurred in an intersection.

1.3. Research Questions

- ✓ How to design an algorithm for selecting stable forwarding node?
- ✓ How to apply SIR epidemic spreading model to reduce the redundant broadcasting of emergency message in multi-directional road scenario?
- ✓ How to minimize the overhead issue which is caused by the redundant selection of forwarding node?

1.4. Objective of the Study

1.4.1. General Objective

The main objective of this thesis is to improve the performance of the emergency message dissemination scheme for VANET using a selective forwarding algorithm in a multi-directional road scenario.

1.4.2. Specific Objectives

- ✓ To design an algorithm for selecting a stable forwarding node.
- ✓ To apply SIR epidemic spreading model to reduce the redundant broadcasting of emergency message in a multi-directional road scenario.
- ✓ To minimize the overhead issue which is caused by the redundant selection of forwarding node.
- ✓ To test and evaluate the developed selective forwarding algorithm in a simulation environment.
- ✓ To compare and contrast the developed scheme with the previous dissemination approach by using different performance metrics.

1.5. Methodology

1.5.1. Literature Review

To fulfil the aforementioned goals, we analysed various publications on general VANET technology to gain a better understanding of the overall technology as well as existing emergency message broadcasting systems. The difficulties in disseminating emergency messages through VANET have also been discussed.

1.5.2. Design and Implementation

The proposed architecture and algorithm for selecting a stable forwarding node, and disseminating emergency messages are designed in this phase. All the proposed work's detailed architecture is designed using *draw.io* software. We constructed the proposed system in a network simulation environment due to the complexity of deploying VANET in a real setting. We use OMNET++, Veins, and SUMO to create a realistic simulation. We used python for the result analysis.

1.5.3. Evaluation of the Proposed Work

We evaluated our work by utilizing network parameters such as end-to-end delay, stability of forwarding node, network overhead, and emergency message delivery ratio in a simulated scenario. After analysing the work, we compare and contrast the proposed method with the existing approach.

1.6. Scope and Limitation

The goal of this thesis is to create an emergency message distribution system in VANET, primarily for multi-directional road scenarios by minimizing the redundant selection of forwarding nodes and broadcast storm problems. This method includes an algorithm for stable forwarding node selection and emergency message dissemination and applying an epidemic spreading model for emergency message broadcasting. The proposed scheme reduces the redundant selection of forwarding nodes by selecting a stable forwarding node and minimizing the broadcast storm problem, hence improving the performance of emergency message dissemination in a multi-directional road scenario.

The thesis will not cover the security issues that might be occurred at the time of the message exchange (due to beaconing).

1.7. Application of the Results

The world's most advanced Intelligent Transportation System technology is the Vehicle Ad hoc Network. The proposed method can be utilized in VANET safety applications to reduce emergency message loss before reaching the target or danger zone, as well as to increase the likelihood of receiving an emergency message. The approach can be implemented in an intelligent transportation system to reduce the amount of time it takes to distribute emergency messages. Because one of ITS’s missions is to provide passenger care, this thesis is critical to this application. Our method is used to make ITS safety applications more user-friendly.

1.8. Thesis Organization

The thesis is organized as follows. In chapter two we discussed the general overview of VANET technology, its characteristics, the standard of VANET, its application, challenges, and the emergency message dissemination mechanism. The existing work which is related to our work is discussed in chapter three. Chapter four presents the details of the proposed model and algorithm. The simulation study and evaluation of the proposed algorithm are described in chapter five. Conclusion, contribution, and future work are also presented in chapter six.

CHAPTER TWO

LITERATURE REVIEW

2.1. VANET

High node mobility and dynamic topology changes are the two characteristics of vehicular ad hoc networks, which are networks of moving vehicles. A form of MANET known as VANET uses a wireless connection to enable communication between vehicles or between vehicles and Road Side Units [11]. VANET enables the sharing of data between vehicles regarding the security and comfort of the driver and passengers. To enable wireless communication between vehicles and to provide drivers with a safety message, VANET uses the DSRC [11], [12]. OBU and RSU are the DSRC devices that are used for communication in a VANET. A roadside Unit (RSU) is a computing device that is mounted alongside a road and used for Vehicle to Infrastructure (V2I) communication. The Intelligent Transportation System (ITS) uses communication between moving vehicles and stationery RSU to enable moving vehicles to update their information on the traffic condition. On broad Unit (OBU) is a GPS-based tracking device that is commonly mounted in each vehicle for the exchange of information between vehicles and/or RSUs. OBU contains different electronic components including reading/write storage for recovering the stored data, user interfaces, and sensor devices. The primary purpose of an OBU is to communicate with RSU and other OBUs over an IEEE 802.11p wireless link [13].

There are three types of VANET communication: V2V, V2I, and hybrid. To enable message exchange in vehicle-to-vehicle communication, vehicles serve as relay nodes. For vehicles that can communicate with each other directly, this method of communication is appropriate. RSUs serve as relay nodes in vehicle-to-infrastructure (V2I) communication, sending data to other adjacent vehicles and RSUs. Vehicles to vehicle (V2V) and Vehicle to Infrastructure (V2I) communication are combined in the hybrid. The vehicle communicates with the roadside device using either a single-hop or multi-hop communication mechanism, depending on the distance. In general, communication is required to deliver both safety-related and non-safety services, such as emergency alerts and information as well as anti-collision messages [11], [14]. Fig. 2.1, shows the general architecture of VANET.

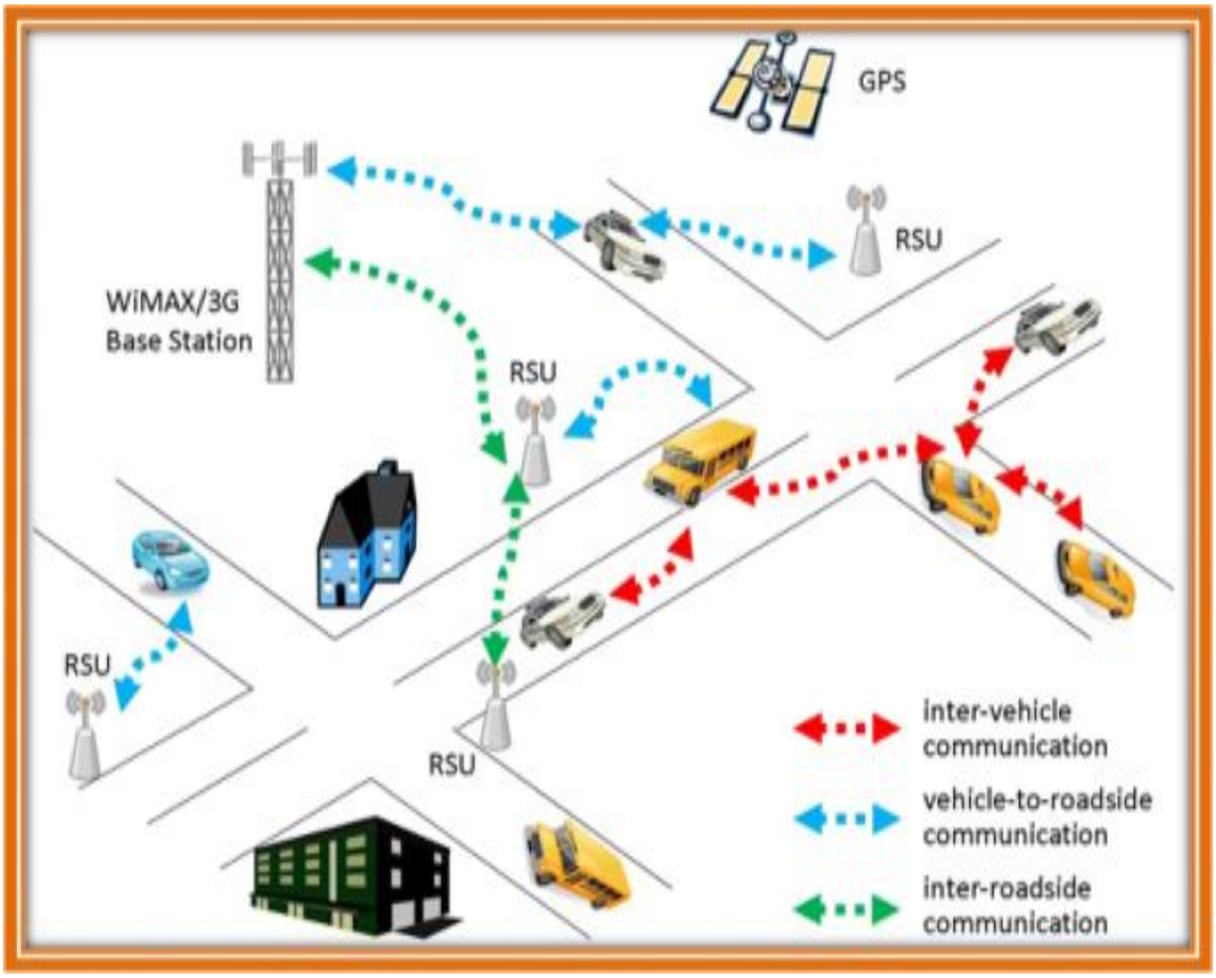

Figure 2.1: General Architecture of a VANET *[15]*

2.2. Characteristics of VANET

In contrast to other kinds of MANETs, VANET has unique characteristics. The unique characteristics of VANETs are explained below [16], [17], and [18].

Dynamic topology: since the vehicular network functions in a highly dynamic environment with an unpredictable topology, VANET topology is always changing. It may work in both an urban setting and a highway environment. The radio communication range and the direction of the vehicle have an impact on the link's lifetime. A longer link lifetime results from extending the radio communication range. The association time or the lifetime of the link is very short-lived, particularly between the vehicles moving in inverse directions compared with a case in which vehicles move in the same direction. The effective network diameter is small because of the frequent changes in link connection, while many paths are disconnected before they can be utilized. Moving vehicles typically travel at fast speeds, especially on the highway, which causes network topology to change very quickly. Additionally, the need to respond to network data influences driver behaviour and changes the topology of the network.

Predictable mobility: unlike other types of mobile ad hoc networks, VANET's nodes are not arbitrarily moved. Vehicles are driving in a variety of directions and at varying speeds during a crucial vehicular communication procedure. Nodes of vehicular networks must adhere to traffic signals, stop signs, and other moving vehicles due to road topology, layout, and constraints, which makes their movement predictable. The complicated topology of the vehicle network is a result of high node mobility. Compared to MANET, VANET has a wide range of mobility.

Frequent Disconnection: because of the dynamic topology, high node mobility, and various environmental factors including the atmosphere, there were frequent vehicle disconnections from the system.

Limited bandwidth: the established DSRC spectrum for VANET can be regarded as being confined; the entire transmission capability range is 75 MHz, but utilization in some countries suggests that this 75 MHz range is not all permitted. The maximum possible throughput is 27 Mbps [19].

Hard Delay constraints: despite having strict delay limits, certain VANET applications do not need high data rates. When a safety application is used, it takes little time to spread the safety message to other vehicles as soon as an emergency event is detected.

Limited transmission power: when using WAVE, the transmission power must continue to run until the data is received. The data reach-ability distance can be up to 1000m. It is permitted to transmit with high power in times of emergency and any situation involving public safety, such as an accident issue or a traffic jam.

High computational ability: the nodes in the VANET can be outfitted with an adequate number of sensors and computing resources, like CPUs, enormous memory capacities, cutting-edge antenna technology, and GPS, because they are vehicles. These resources boost the node's processing power, facilitating accurate information about its present position, speed, and direction as well as reliable wireless communication.

Services of safe driving: improved traveller satisfaction and increased traffic efficiency are the driving forces behind this. VANETs allow direct communication between mobile nodes, enabling a variety of applications that call for direct vehicle-to-vehicle communication via the network. The driver must construct a bigger vision of the road topology ahead because these applications provide warning information to passengers going in the same direction about the necessity for rapid hard braking or accidents. By giving information on stores, gas stations, the weather, and traffic flow, VANETs can also increase traveller satisfaction and increase traffic efficiency.

No power constraints: because vehicles can continuously supply power to the OBU via the long-life battery, energy in VANET is not as much of a challenge as it is in MANETs.

Variable network density: the traffic density of a VANET can be very high, such as in heavy traffic, or very low, such as in suburban traffic. When traveling on a road in an urban setting, there are many different types of vehicles, whereas, on a highway, there are few vehicles. Variable network densities exist in VANET as a result of the wide range of vehicle numbers.

2.3. VANET Communication Standard

To offer the radio access needed for the vehicles to connect via V2V, V2I, or hybrid, every wireless access and communication protocol for VANETs needs standards. This is so that the development of new items is made simpler and that it is easier to compare similar products. These communication protocols are primarily intended to increase traffic efficiency, road safety, and driver and passenger comfort by enabling a variety of comfort applications. Vehicular network communication uses the WAVE and DSRC communication standards.

2.3.1. Wireless Access in Vehicular Environment (WAVE)

The WAVE system is a radio communications technology that offers transportation interoperability services [20]. The whole DSRC protocol stack, which includes the IEEE 802.11p and IEEE 1609 specifications, was combined to create the WAVE standard. The disadvantage of using the traditional IEEE 802.11 in vehicular communication is the overhead which is generated at a significant rate. For instance, fast information sharing is needed to guarantee timely vehicular communication. To overcome all of these issues, the DSRC standard is coupled with the IEEE 802.11 standard to create the new IEEE 802.11p standard, which is then combined with the IEEE 1609.x standard to create the globally recognized standard known as WAVE [21]. One of the IEEE 1609/802.16e standards is IEEE standard 1609. The communication model, security measures, management structure, physical access, and overall architecture for wireless communications for fundamental elements (RSU and OBU) in the vehicle context are all defined in IEEE standard 1609 [22].

The key components of the WAVE applications' architecture are described in detail in IEEE standard 1609.1-2006, which also defines storage message formats and commands [23]. For the management of WAVE, the IEEE standard 1609.2-2006 outlines different security services and provides application messages to avoid attacks including spoofing, eavesdropping, and tampering [24]. The IEEE standard 1609.3-2007 offers routing services and addressing mechanisms for WAVE systems to enable different stacks of upper/lower layers above/below WAVE networking services, secure data exchange, and defines WSMP as a replacement for IP for WAVE applications. The improvements made to the Media Access Control layer of 802.11 to allow WAVE are described in IEEE standard 1609.4-2006. Interoperability between diverse multi-vendor broadband wireless access products is made possible by IEEE standard 802.16e. Both stationary and mobile devices are described by WAVE standards. A stationary device, RSU, or a mobile device, OBU, can both offer and receive services. Applications that sit on the RSU but are intended to grant access to OBU by multiplexing the requests are defined by the WAVE standard. By using Orthogonal Frequency Division Multiplexing (OFDM), which also allows for data payload transfer, it splits the signal into several narrowband channels. The WAVE standard offers communication between vehicles and roadside equipment, vehicle-to-vehicle communication, and device-to-device communication. The general WAVE architecture includes IEEE P1609.

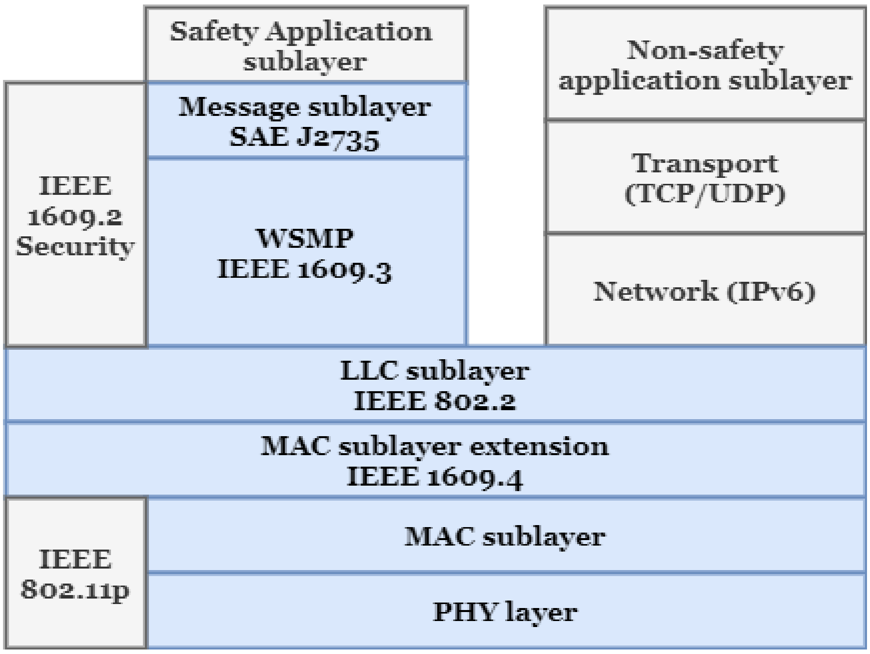

Figure 2.2: WAVE/DSRC communication’s layered architecture *[25]*

IEEE 802.11p, which is specifically designed to support VANET applications, serves as the foundation for the physical layer of the VANET (fig. 2.2). To support ITS applications like data transfers between high-speed vehicles and between vehicles and the roadside infrastructure in the 5.9GHz band, the IEEE 802.11 p WAVE protocol suggests changes to the physical (PHY) and medium access control (MAC) layers of the current IEEE 802.11 wireless standards.

The 802.11e-specific quality of service requirements is supported by the IEEE MAC layer. To reduce unnecessary overhead, IEEE 1609.3 WSMP (WAVE Short Message Protocol) was developed. WAVE Short Message (WSM) and WAVE Service Advertisements (WSA) can be found in 1609.3. The SAE J2735 DSRC message set dictionary, which may support about 15 different types of messages, is the message sublayer as shown in (fig. 2.2). Generally, the WAVE layer can accommodate both fundamental safety messages and non-safety messages. Depending on the Ethertype that was extracted from the SNAP header file, the LLC sub-layer either sends the data to the network or the WSMP layer.

Different channels have been created especially for certain applications. The interchange of management frames, such as WAVE service advertisements and WAVE short messages [26], takes place on the Control Channel (CCH), a single radio channel [27], [28]. Using this channel, the WAVE-enabled devices can communicate safety-related information. The management frame, higher-layer information exchanges, and IPv6 packets all go across the Service Channel (SCH).

2.3.2. Dedicated Short-Range Communication (DSRC)

DSRC primarily supports vehicle-to-vehicle and vehicle-to-infrastructure communications. A short- to medium-range communication service based on IEEE 802.11p, which was derived from IEEE 802.11a [29]. DSRC aims to support low-overhead operations in communication [21]. These communications for VANETs could be things like toll collection, drive-through payment, inter-vehicle safety messaging, traffic and accident information, road conditions, etc. DSRC is mostly utilized in communication to deliver high data transfer with minimal latency or communication delay.

There are seven distinct channels in the DSRC spectrum. Each channel is 10 MHz wide. This channel consists of 1 control channel and 6 service channels. The control channel is in charge of transmitting management information and messages with a high priority. To monitor the control channel and send additional data, service channels are switched.

Different DSRC standards are utilized by numerous nations, including the USA, Europe, and Japan [30]. These standards differ in terms of communication mode, the radio frequency band used, channel number and spacing, data transfer rate, coverage, and modulation.

2.4. VANET Application

A VANET aims to ensure the safe movement of vehicles and passengers by providing early information and timely feedback in response to a situation. The two primary types of VANET applications are safety-related and non-safety-related applications [31], [32].

2.4.1. Safety-related Application

A safety-related application is used to ensure safer travel by issuing early warnings and responding to situations on time. These safety applications are used to prevent the risk of road accidents by broadcasting information about hazards and obstacles. Safety applications can play an important role in avoiding accidents or minimizing the impact of this problem [14]. These application provide information by sharing information such as location, distance and speed between vehicles and RSU, and help drivers to avoid collision with other vehicles. The exchanged information is used to identify dangerous areas [33]. According to [34], more than half of collisions can be prevented if the driver receives a warning half a second before the collision. There are too many things to consider for the vehicle drivers, like the driver's attention to the traffic management lights, other vehicles, and pedestrians, and also following the direction using GPS. Giving full attention to all of these events at once is too difficult for the drives to give timely attention. Some kind of safety warning messages, like when a driver is getting ready to make a turn to the right /left might simply look like a pedestrian crossing the right or left side of the road. This kind of early notification of warning messages helps to reduce traffic accidents.

Other types of warning systems, such as work zone warnings, stopped vehicle alerts, and low bridge warnings for trucks, can also be used to prevent accidents. Some safety applications can also be helpful after an accident such as sending emergency message notifications to nearby emergency responders. These applications also identify alternative routes and manage traffic flows. Along with warning messages, safety applications help drivers with lane changes, navigation, and collision avoidance by automatically applying emergency brakes. Safety applications also inform drivers about posted speed limits to prevent collisions [14]. Strict time delay limits are required for safety applications. In a decision making even a fraction of a second is required. Thus, the requirements of the hard deadline posed by safety applications require special handling at the lower layers. As far as the network layer is concerned, there is not much routing involved in safety application since message target groups are usually in close proximity. Therefore, the messages need not be sent to nodes more than one hop away. Some of the VANET safety applications are:

Post-crash notification: the vehicle that detects an accident in this type of application broadcasts warning messages about its location to the following vehicles so that they may make decisions quickly.

Road hazard control notification: due to road curves, rapid downhills, road slides, etc., vehicles notify other vehicles with information on road feature notifications.

Co-operative message transfer: this application focuses mostly on the exchange of messages between slow or stopped vehicles and works with other vehicles to assist them. Even though latency and reliability are serious issues, this application might automate emergency braking to prevent accidents. Emergency electrical brake lights may be another application that is similar to this one.

Real-time traffic: at the RSU, real-time traffic information can be stored and made accessible to the vehicles whenever and wherever they are required. This has the potential to be very helpful in resolving issues like traffic congestion, preventing it, and providing emergency notifications for things like accidents, etc.

Traffic signal violation warning: designed to send a warning message to a driver when it detects that the vehicle is at risk of running the traffic signal. The condition and timing of the traffic light, the vehicle's speed, and its position are taken into consideration while deciding whether to send a message. To further disseminate the traffic infraction warning message, RSU broadcast it to all other vehicles in the neighbourhood.

Emergency Vehicle: a dynamic emergency vehicle, like a police vehicle or ambulance, can inform other vehicles to stop or move out of the necessary emergency lane. Other vehicles or RSUs are capable of replaying such helpful messages.

2.4.2. Non-safety Application

The primary goal of VANET is to offer safety, but other uses, such as traffic efficiency, control management, and certain entertainment applications, are also being investigated to improve market penetration [35].

2.4.2.1. Comfort and Infotainment Application

In addition to applications for road safety, VANETs are also expected to include applications for comfort and entertainment. These programs are designed to make traveling more enjoyable and comfortable. The three subcategories of these applications are infotainment, mobile e-commerce, and city leisure information. Whereas other more conventional wireless internet connectivity choices like Wi-Fi, Wi-MAX, etc. are not available, passengers in a car can take advantage of the facility of internet connectivity. Even with such alternatives available, a node connected to the internet using one of them can share its connectivity with other vehicles via VANET. Web browsing, gaming, messaging, and other peer-to-peer applications can also find their place in VANETs. The VANET is used by many businesses to advertise or broadcast location-based sales information. For instance, petrol stations may announce updated prices or different restaurants may highlight special offers to draw customers. In addition, several VANET applications make it simple for travellers to find the closest restaurants or service centres, among other things. Routing will be involved since messages sent by these types of apps typically need to be sent over several hops. Peer-to-peer and internet-based applications can be used to categorize infotainment applications in VANET. These applications help offer services like media file sharing, movie streaming, and music streaming among the vehicles in a network. People can connect through the internet constantly, so VANET gives people access to constant internet connectivity. These applications provide comfort for travellers such as advanced traveller information systems and general entertainment [14].

2.4.2.2. Traffic Control and Management Application

Applications for traffic control and management are primarily used to streamline traffic flows, save travel times by avoiding traffic jams, or advise drivers on the best routes based on the most recent road conditions. This may entail the employment of some roadside tools, such as electronic sign boards and intelligent traffic lights. Road capacity can be increased and congestion can be reduced with the help of information about upcoming traffic jams. Intelligent traffic lights can be used to effectively manage traffic jams at road intersections. These traffic signals can adjust themselves in response to the traffic conditions at intersections and can even communicate the status to neighbouring intersections. Neighbouring intersections can thus display this information on the s-sign boards and adjust their traffic signals accordingly. Applications for traffic control make considerable use of the roadside infrastructure. While certain infrastructures may be free to use, others may require a subscription. For instance, to provide its services, eToll infrastructure will need a subscription. For these applications, the infrastructures with relevant information need to be managed and controlled.

2.5. Message Dissemination in VANET

Message dissemination in a key component of Vehicular Ad hoc Networks (VANETs). It gives intelligent transportation systems the potential to support safety and entertainment services for vehicles and passengers. In VANETs, the spreading of information often depends on the intelligent selection of particular vehicles to serve as relay nodes. This critical element helps to prevent broadcast storm problems and other safety application difficulties [36]. Due to the unique characteristics of safety messages, broadcasting may be the only method for message exchange. The transmission of the signal triggers the transfer of a warning message to all vehicles out of the radio transmission range of a single hop [37]. The process of message dissemination determines many different problems because of a unique feature of VANETs. Another factor that has a significant impact on the entire process is the speed of the vehicle, the size of the network, and the connectivity between mobile nodes. According to different researchers, there is a mechanism of information delivery mechanism. In this case, all the necessary information about the status of the vehicles has to be discovered and shared between vehicles. Based on different studies, many of the research distinguished the following data dissemination approaches:

Vehicle-assisted data dissemination approach: all vehicles are assumed to know information along with them and deliver it either to the infrastructure RSU or to other vehicles when they have encountered an emergency event on the road. The mobility of the vehicle is also engaged in the message dissemination process in addition to wireless transmission.

Opportunistic data dissemination approach: according to this method, data is likely or opportunistically gathered from vehicles or infrastructure. Broadcasting strategies are typically used in those dissemination ways for safety applications. According to different kinds of literature the main broadcasting approaches are relay into two categories. Those are one-hop dissemination and multi-hop dissemination.

2.5.1. One-hop Message Dissemination

In a single-hop message dissemination strategy, information is exchanged via a vehicle that is within range of the sending node. The receiving vehicles do not broadcast the information they have received from other vehicles again [38]. To enable safety applications to span a vast area, extra aggregation methods are required because single-hop safety message dissemination approaches only provide local information [39]. These processes increase the computational overhead of the applications, which may delay the detection and notification of dangerous situations, thus making them unsuitable in many scenarios.

2.5.2. Multi-hop Message Dissemination

When a vehicle senses an emergency in this disseminating scheme, it notifies its neighbouring vehicle and the message should be rebroadcast to announce the other vehicle that is not within the source node's transmission range. All vehicles are anticipated to receive the information because VANET is built to enable safety applications.

In VANET, message dissemination is a critical issue to quickly inform vehicles about problems that may have a positive or negative effect on the neighbour nodes. There are various categories of multi-hop message broadcast systems, which are detailed below, to minimize or possibly eliminate any potential harm to nodes that are inside the range of the vehicle network [38].

Flooding: One of the disseminating systems in which nodes can merely broadcast again after receiving a message. When N numbers of nodes in the network they simply rebroadcast for further coverage of messages. When an RSU or vehicle receives a message that needs to be broadcast, they first determine whether the packet is new or not. They transmit it if it's new; else, they discard it. Since every node forwards the message, this leads to redundancy of the message. The redundancy is based on how many vehicles are present in the transmission range.

Counter-based dissemination scheme: is frequently referred to as limited flooding and is a component of the flooding-based strategy. According to this, if a counter is greater than or equal to (threshold) for a received message, rebroadcasting is not allowed for that message.

Beacon: beacons are periodic messages that vehicles send to one another to exchange data on their locations, speeds, and other basic details. Compared to alarm messages, those messages have lower priority. These messages are distributed in a one-hop fashion; neighbouring nodes do not repeat them.

Distance: The distance between the sender and the recipient affects how often the message is broadcast. Rebroadcasting is not recommended in this dissemination scheme when the separation distance is at its shortest to provide extensive coverage.

Store and Forward: When an emergency message is received by a node using this type of dissemination approach, the node caches the message for a while until it may reach another node within transmission range. With this method, the vehicle usually waits for a broadcast message until it finds a new neighbour is located. Typically, sparse network scenarios adopt this method.

Probabilistic: The probabilistic distribution is used in this technique to determine the likelihood of broadcasting a specific message, depending on the circumstances of the transmitting vehicles. To assign a probability to each message or vehicle, the majority of the schemes based on this method use the Gaussian or uniform distribution.

2.6. Challenges in VANET

There are numerous VANET applications in the ITS environment, as previously mentioned. In the last decade, there is remarkable progress in the field of VANETs. Despite its benefits, VANET still suffers from many challenging issues [33], [40], and [41].

High latency: the message sent by the OBU must be received by one or more OBUs within the VANET-acceptable time frame. So that, the driver of the receiving OBU has enough time to take the appropriate action in accordance with the message received. Since VANET lacks a central coordinator for bandwidth control, there may be congestion as a result of bandwidth limitations, especially in locations with a high-density area. Fair bandwidth management minimizes message transmission delays.

High Mobility: VANET has highly mobile nodes. The vehicles follow a predetermined path. Due to fast speed, a node establishes connections to RSUs or neighbouring OBUs for very brief periods. A connection that is now active may be broken up by a high mobility rate, and a new connection may be established. Frequently disconnection and establishment may produce increased delay. This has an impact on communication quality. Furthermore, it is very difficult to verify a fast-moving vehicle. Many researchers recommend using low-overhead IPv6-enabled authentication methods for this.

Information Dissemination: a crucial concern is the distribution of emergency information in VANET. The nature of the safety information in VANET necessitates broadcasting, in contrast to other networks like the internet where data is normally unicasted [20]. Disseminating this information through a broadcasting method is preferable to a routing approach that uses unicasting because safety messages can be distributed to numerous nodes rather than a single node to raise awareness about emergencies [29]. The destination address and the path to a specific location are not necessary for a vehicle in a broadcasting scheme. VANET's multiple challenges, such as the complexity of route discovery, address resolution, and topology management, are made easier to manage by broadcasting. Despite being a solid alternative, this technique creates a blind storm problem in environments with the high network coverage. Therefore, creating a broadcasting plan that can handle those issues is a difficult task.

Heterogeneous networks: one of the major problems is the network because different nations have different security and privacy laws as well as diverse infrastructure that is readily available and how manufacturers integrate it. Different networks may utilize various protocols, which could result in significant latency.

Frequent link disconnection: unlike nodes in a MANET, vehicles are highly mobile and can move at speeds of over 100 km/h. This may lead to frequent network topology changes. Thus, a link failure between the source and the destination is occurred [18].

Protocols standardization: VANETs may contain a variety of vehicles, including trucks, cars, taxis, motorcycles, bicycles, and buses. All of these vehicles must be able to interact with one another using the same protocol in this kind of circumstance. Consequently, setting a standard is the difficult issue at hand.

CHAPTER THREE

RELATED WORK

3.1. Introduction

In the previous chapter, we discussed different ways of data dissemination of vehicular networks depending on different studies. There are different problems in VANETs message dissemination which is a critical part of this network, and it needs better enhancements. The reason why message dissemination is the issue that needs improvement is the characteristics of the VANETs like frequent disconnection of nodes, high mobility, and dynamicity of the topology. These characteristics of the VANET network come with challenges, this is why the enhancement of safety message dissemination is needed because of we need an immediate reaction to the emergency event happening to the network. In this chapter, we are going to discuss many investigations of message dissemination studied by different researchers. Safety information exchange is essential for life-critical VANET applications because it provides features like lane merging and alerting during junction traversal.

3.2. Broadcast-based Message Dissemination Scheme

In vehicular ad-hoc networks, safety-related information always operates based on wireless channel dissemination since emergency messages like accidents and traffic load need to be delivered to all neighbour vehicles. Sometimes VANET nodes that are used to detect emergency events disseminate the emergency message to only their neighbour vehicles within the transmission range. In these cases, the MAC protocol becomes the dominant component that determines the efficiency of message transmission. And the design of this protocol is a very fundamental challenge in the network with unique characteristics like constantly moving nodes in the network. The message may be limited to unexpected delay due to the medium access contention and medium access delay. Along with delay, a major issue with message dissemination at the MAC layer in the vehicular network is channel overhead, which causes just one message to be lost, leading to a very dangerous accident or increased traffic load. In addition to the MAC layer issues, the network layer plays a major role in end-to-end delay performance in VANET [42].

Authors in [43] implemented a protocol called partner-based broadcasting (PBB) for Vehicular Ad-hoc networks safety message dissemination based on multi-hop communication. In the PBB protocol, the forwarding node is selected based on neighbour information by the periodic exchange of hello messages like velocity, direction, location, and SNR. According to the authors when the source node needs to broadcast the emergency message, the partner1 will be selected from its neighbour set as the next forwarding node. The node that has minimum weight will be elected as rebroadcasting node. When the message is received by the partener1 it will broadcast immediately. The source node selects a node that has a second minimum weight as its partener2, to prevent packet loss and for ensuring data reachability. In PBB the beacon messages should periodically exchange among neighbouring vehicles. As the result showed, the developed protocol has a good performance in reducing the end-to-end delay. But, the redundant broadcasting of hello and beacon message leads to signalling overhead, and consume many wireless channel resources. The paper considers a highway scenario i.e. the message is broadcasted in only one direction. Here multi-directional road scenario is not considered (the message should be broadcast in all directions).

Time slotted multi-hop broadcasting mechanism is designed to minimize the number of required transmission nodes. This approach works by selecting some of the nodes to be the potential relay nodes, to avoid the broadcast storm problem. The developed approach focuses on dividing the roads into segments with fixed lengths. Every node can set to which segment it belongs and calculate the distance between its position and its destination which is in the segment [22]. The result of this approach assures the reliability of message dissemination by allocating a timeslot for the emergency message including a short time for acknowledgment. During this, the message collision is reduced. The proposed method can only minimize the overhead. But, since the emergency message is time critical, this approach is not suitable for emergency message dissemination.

The multi-hop broadcast mechanism for emergency message dissemination (MBM-EMD) is proposed by S. Li and C. Huang in [44]. The paper focuses on the dissemination of the emergency message to the network through vehicle-to-vehicle communication. For the selection of the optimal relaying node, the authors integrate vehicle density, channel quality, and relative movement with the expected transmission gain per hop (ETGPH). The proposed MBM-EMD method combines both the advantages of sender-oriented and receiver-oriented protocols. As the result, the proposed method reduces the broadcast delay and guarantees a high packet reception rate. However, the proposed approach has a high overhead in the network due to beaconing, and an extra waiting time caused by distributed operation needs to be reduced to get better performance. And also, the paper is only focused on the highway scenario. The emergency message should be broadcast in all directions. To solve this problem Y. Bi et al. in

[45] proposed an Urban Multi-hop forwarding algorithm (UMBP) to disseminate the emergency message. The authors used iterative partition, mini-slot, and black burst as a parameter for selecting the forwarding node. When the source vehicle detects an emergency event, it automatically disseminates the emergency message according to CSMA/CA MAC mechanism. When the emergency message is received by the neighbour node, the forwarding node selection is established. According to UMBP, the message is broadcasted in a different direction by selecting a single forwarding node in each direction. The proposed algorithm enhanced the message reliability and reduced the message redundancy. But, the problem with the proposed approach is it takes time to select a forwarder node in each direction. Since the neighbouring node from each direction needs to participate in the forwarder node selection procedures.

Multi-hop broadcasting causes high propagation delay, lower packet delivery ratio, and increased communication delay in a dense network [46]. This is because of the characteristics of decentralization, high mobility, and the hidden terminal problem of VANETs. This multi-hop broadcasting approach is not suitable for emergency message dissemination in a multi-directional road scenario.

3.3. Cluster-based Message Dissemination

Several researchers proposed a clustering approach as a solution for VANET emergency message dissemination. The approach which targets a different region of the network is proposed depending on distributed and dynamic data dissemination protocol [47]. According to the authors, the proposed protocol includes two things. The first one is geo-casting initialization which employs the path-sharing key landmark to minimize the total data dissemination time. The second one is to divide each target region into many small regions to decrease the information redundancy. As the result, the proposed approach reduces the probability of data redundancy and packet loses. However, the developed scheme did not consider the delay time of the message in the risk area, i.e., the method is not suitable for safety message dissemination that may cause a big crisis in human life and traffic conditions. A clustering-based strategy for emergency message dissemination in V2V communication is proposed in [48]. The paper used optimization and clustering approaches to achieve the objective. The first stage consists of a data handling mechanism before the dissemination process of the data. At this step, the initial message exchange is optimized to reduce the number of packets. Constructing a clustering to improve the message delivery time and reduce bandwidth consumption is the second part of the proposed method. The developed approach is based on a fitness function and considers the transmission period, relative velocity, and link time validity as a parameter. Adaptive real-time A*[RTAA*] algorithm is used for routing data among clusters. The proposed approach has better stability and performance. The problem with the approach is that end-to-end delay increases due to the post-event detection clustering process, so this method is not effective in case of safety message dissemination.

An emergency message forwarding scheme based on a clustering approach was proposed for VANET in [8]. The proposed architecture is intended for use by VANETs in the propagation of emergency messages and to prevent message collisions during broadcasting. To avoid message collisions, the algorithm provided in this technique is used to carefully place distinct nodes in a cluster formation. A cluster head is chosen based on particular features of a node in the cluster and is responsible for managing intra-cluster communication and preventing interference with other clusters nearby. The messages are disseminated using two trustworthy protocols that work on the MAC layer to ensure that they arrive on time and without undue delay. The proposed approach has a good performance in terms of packet delivery ratio. However, the problem with the proposed system is that it takes time to select a new cluster head, which diminishes the model's effectiveness [49]. A clustering-based approach for VANET in an intersection was proposed by H. Zhao et al. in [50]. In this approach vehicle driving information such as direction, position, and speed are periodically exchanged through a beacon message, which is broadcasted periodically to the neighbour. The author considers both highway and intersection scenarios. In a highway scenario, the algorithm takes relative speed and distance as clustering metrics using Gaussian similarity, and at an intersection, turn direction is used as a parameter for cluster head selection. The proposed algorithm has a high performance in a cluster maintains time and better cluster stability in a highway scenario. But, at an intersection, the approach considers a turn direction only i.e., the distance and link lifetime of the vehicle is not taken into account. This leads to the redundant selection of cluster heads at an intersection. In the paper [51], a multi-hop clustering method for vehicle-to-internet (MCA-V2I) communication is proposed for the improvement of VANET communication. In this method, the Vehicle is connected to the internet through the Roadside unit gateway. A vehicle will acquire and share information concerning its multi-hop neighbours when it is connected to the internet to perform the clustering process. Breadth First Search (BFS) algorithm performs this process and is used for traversing a graph based on a mobility rate that is computed according to the mobility metrics. The proposed approach selects the slave cluster head in addition to the master cluster head for emergency message dissemination. Here, the clustering is done based on Breadth First Search (BFS) algorithm, which is time-consuming, and therefore, it is not suitable for the dense network.

Position-based emergency message dissemination for the Internet of vehicles was proposed in [52]. According to the paper position and clustering-based approaches are used to disseminate the data. The vehicles are dynamically clustered to minimize the broadcast storm issues, and a position-based algorithm is also proposed to reduce the communication delay and ensure message dissemination on time. The proposed work shows the transmission delay, information coverage, and packet delivery ratio are improved. But the problem is that the authors only consider the position as a parameter for message dissemination. The direction and link lifetime of the vehicle is not considered as a parameter. A multi-directional road scenario is also not considered.

Seyhan Ucar et al. [7] proposed multi-hop cluster-based safety message dissemination for VANET using a hybrid approach (IEEE 802.11p and LTE). This technique creates clusters of several nearby vehicles, each with its cluster head. The network is divided into clusters, and each cluster has its routing table, which stores cluster-ID, message type, vehicle location, distance between neighbors, and other information. The authors proposed that instead of sending a message to every node in the cluster, only one message should be sent to one cluster. Each member of the cluster distributes the message to the rest of the cluster. The notifications are sent to all clusters that are a little outside of the risk zone to avoid both network and traffic congestion. The result of the simulation showed that the proposed system provides a high emergency message delivery ratio while minimizing network overhead. However, the vehicle speed is not considered in the study which results in inaccurate time estimation and redundant selection of cluster head.

To reduce the overhead of the message that the cloud clogs the network, a time barrier approach was proposed in [53] as a method for disseminating emergency messages for VANET. In this method, only the vehicle that can travel the longest distance forward the message. The developed approach is based on the concept of a clustering technique to handle the broadcast storm problem. The time-barrier-based approach is used to discourage vehicles from transmitting based on their position. In the proposed method the vehicle can only broadcast a message after a time barrier expires. In the proposed approach, there may be more than one vehicle at the same distance. So, multiple vehicles can forward the message at the same time, which causes communication congestion. Authors in [54] proposed a method to reduce the broadcast overhead of emergency message dissemination in VANET. They used a clustering approach in which the emergency message can be re-broadcasted to adjacent clusters only by the smaller number of vehicles. To support cluster formation, eliminate communication overhead, and ensure message reliability in a high-mobility scenario, the proposed system is based on mobility metrics. According to the simulation results, the proposed approach performs better than earlier methods in terms of packet delivery ratio, end-to-end delay, and network overhead. However, the message is only transmitted in one way under the proposed technique. A multi-directional road scenario is not considered.

An emergency message dissemination model based on Trust Cascading (TCEMD) was proposed in [55]. This work successfully combines entity-oriented trust values with data-oriented trust evaluation in an effective manner. According to the proposed model, when an emergency (such as a roadblock) arises, the emergency messages can be distributed among the nearby vehicles using a trust cascading mechanism, with the entity-oriented trust values (which are adopted as important weights and evaluated and updated by utilizing the trust certificates and are contained in the messages) serving as the key inputs. The authors used a highway (straight road) scenario for conducting the simulation. The proposed model has a better performance than the existing method. But the problem is that the message is broadcast only in one direction, and vehicle from another direction is not notified about the emergency event (i.e., a multi-directional road scenario is not considered. To solve this problem, an adaptive scheduled partitioning and broadcasting technique (ASPBT) was proposed in [56] for reliable and efficient emergency message broadcasting. This protocol dynamically modifies the number of partitions and beacon periodicity to reduce the number of retransmission. In the proposed method, network density is used to define partition sizes, and the lion optimization algorithm (LOA) is used to estimate each partition's transmission schedule. One forwarding node is effectively selected by their asynchronous competition in ASPBT, which also contains a novel broadcasting node selection strategy that uses optimal partition, mini-slot, and black burst to quickly choose distant neighbouring nodes. This decreases message redundancy and minimizes the transmission delay of emergency messages. Both highway and urban scenarios are taken into account in the proposed ASPBT model. As the result showed, the proposed model has better performance in terms of efficiency and delay. At an intersection, there may be a possibility of an empty vehicle, during this time some of the vehicles that cross the intersection will not receive an emergency message, which may lead to the problem. To solve this problem, each vehicle will keep the message in the queue for a certain period and it broadcast the message whenever it reaches the intersection. However, this results in the re-transmission of a similar message and causes a broadcast storm problem.

3.4. Epidemic-Based Broadcasting

M. Chatra and S. Siva Sathya [57] proposed an epidemic-based broadcasting algorithm for VANET. The paper tried to reduce the broadcast storm problem using the SIR (Susceptible, Infected and Removed) model which is inspired by the epidemic spreading technique. According to the authors, the farthest vehicle from the source node is selected as a broadcasting node for the next transmission range. But, the problem with this paper is after selecting the farthest vehicle, the position may change in varying time and speed. So, the neighbour node availability at a specific point in time is not considered. This problem is solved in the selective epidemic broadcast approach [58]. The SEB algorithm seeks to reduce the broadcast storm issue and enhance the performance of the rate at which emergency safety messages are disseminated. In the SEB algorithm, the broadcasting node is selected based on passive acknowledgment (P_ACK) from the neighbour node and distance. When the source vehicle receives an emergency event, it finds the neighbour node by broadcasting the beacon message. The neighbour node that replies to the connection and has the farthest distance from the source node is selected as the forwarding node. As the result showed, the SEB algorithm minimizes the redundant rebroadcast ratio. However, in the approach, the stability of the forwarding node is not considered which leads to the redundant selection of the broadcasting node. If there is a redundant selection of forwarding nodes, the network overhead will increase.

SEIR epidemic model to reduce the broadcast storm problem in VANET was proposed in [2]. The proposed broadcast storm suppressing algorithm (BSSA) is based on the epidemic spreading technique called SEIR (suspected, exposed, infected, and removed) model. The SEIR algorithm aims to select the farthest infected vehicle (FIV) as a forwarding node or rebroadcasting vehicle to disseminate the message. The proposed algorithm minimizes the redundant rebroadcasting ratio of the emergency message. But the algorithm focuses only on finding the farthest vehicle to select it as rebroadcasting node. The direction of the vehicle and link lifetime is not considered as a parameter for the selection of a stable node. This causes the redundant selection of forwarding nodes and results in high overhead in the network.

Table 3.1: Comparisons of the existing related works

Paper	Year	FN selection parameter	Methods	Strong points	Limitation
[44]	2018	-Density -Relative movement -Channel quality	-Multi-hop broadcasting	-High packet delivery ratio	-High overhead due to beaconing
[53]	2019	-Distance	-Time barrier	-Transmission delay is minimized	-High no of re-transmission cause congestion and lower PDR
[54]	2020	Neighbourhood connectivity -Direction -Velocity	-Clustering	-End-to-end delay is minimized	-The message is broadcast in one direction only.
[46]	2021	-Direction -velocity -Distance -Time to leave	-Clustering	-Redundant transmission of the EM is minimized	-High end-to-end delay
[59]	2022	-Mobility -Link quality -Buffer size -No. of neighbour	-Harmony search algorithm	-High packet delivery ratio	-Stability of forwarding node is not considered
[58]	2018	-Distance -Passive acknowledgment	-Selective epidemic broadcast algorithm	-The redundant rebroadcasting ratio is minimized	-Overhead due to the redundant selection of broadcasting node
Proposed Approach		-Passive acknowledgment -Direction -Distance -Link lifetime	-Selective forwarding algorithm	-Overhead issues and BSP is minimized	-Security issue

To generalize the above table, different types of emergency message dissemination scheme is analysed. All of the proposed schemes have their contribution to the area of VANETs and also have their limitations. Most of the scheme uses the concept of reducing the number of rebroadcasting nodes and varying the time to rebroadcast the emergency message. Varying time to forward the emergency message may reduce the occurrences of a broadcast storm problem. This makes the vehicle that requires a short rebroadcasting time wait for a long which brings much delay in delivering the message. The other solutions are based on reducing the number of rebroadcasting vehicles in a given transmission range. But the limitation of such solutions is that they are exposed to broadcast storm problems if the number of rebroadcasting nodes is not correctly handled it. The other problem is that the stability of the forwarding node is not considered in the previous approach. If the stability of the forwarding node is taken into account the redundant selection of the broadcasting node is required, which causes overhead in the network. And also, most of the previous approaches lack multi-directional broadcast support at the intersection (i.e., the message is broadcasted in only a straight road scenario).

Due to the above problem, there is a need to design a new emergency message dissemination scheme for VANET which is capable of solving the existing problems. Our proposed approach is based on an RSU decision-based selective broadcasting algorithm that reduces the broadcast storm and overhead problem which is caused by the redundant selection of forwarding nodes in a multi-directional road scenario. The stable forwarding node is selected based on passive acknowledgment, distance, the direction of vehicle, and the link lifetime of a vehicle. To reduce the broadcast storm issue and distribute the emergency message, we use the SIR epidemic spreading model.

CHAPTER FOUR

DESIGN OF THE PROPOSED SOLUTION

4.1. Introduction

As we have described in the previous chapters, different emergency message dissemination approach was proposed by various researchers. But still improving the emergency message dissemination in multi-directional road scenarios by minimizing the frequent change of forwarder nodes as well as broadcast storm problem needs additional improvement. To solve the existing problem, we proposed an RSU decision-based selective forwarding algorithm which is developed by applying an epidemic spreading model. The developed algorithm minimizes the number of rebroadcasting vehicles in the next transmission. We use packet acknowledgment, distance, direction, and link lifetime as a parameter for selecting the stable forwarding node.

4.2. Architecture of the Proposed Solution

The architecture explains the overall components used for emergency message dissemination by minimizing the broadcast storm problem and the general way of communication in vehicular networks. The architecture is composed of the proposed approach, the modules, and the protocols we used in each layer of WAVE architecture which have their purposes for the exchange of messages by dissemination of messages among the nodes.

For message exchange, vehicles require every layer of the network. When vehicle one detects an emergency, it broadcast to all other vehicles by applying all network layers. IEEE 802.11p and the WAVE standard are used to implement our scheme.

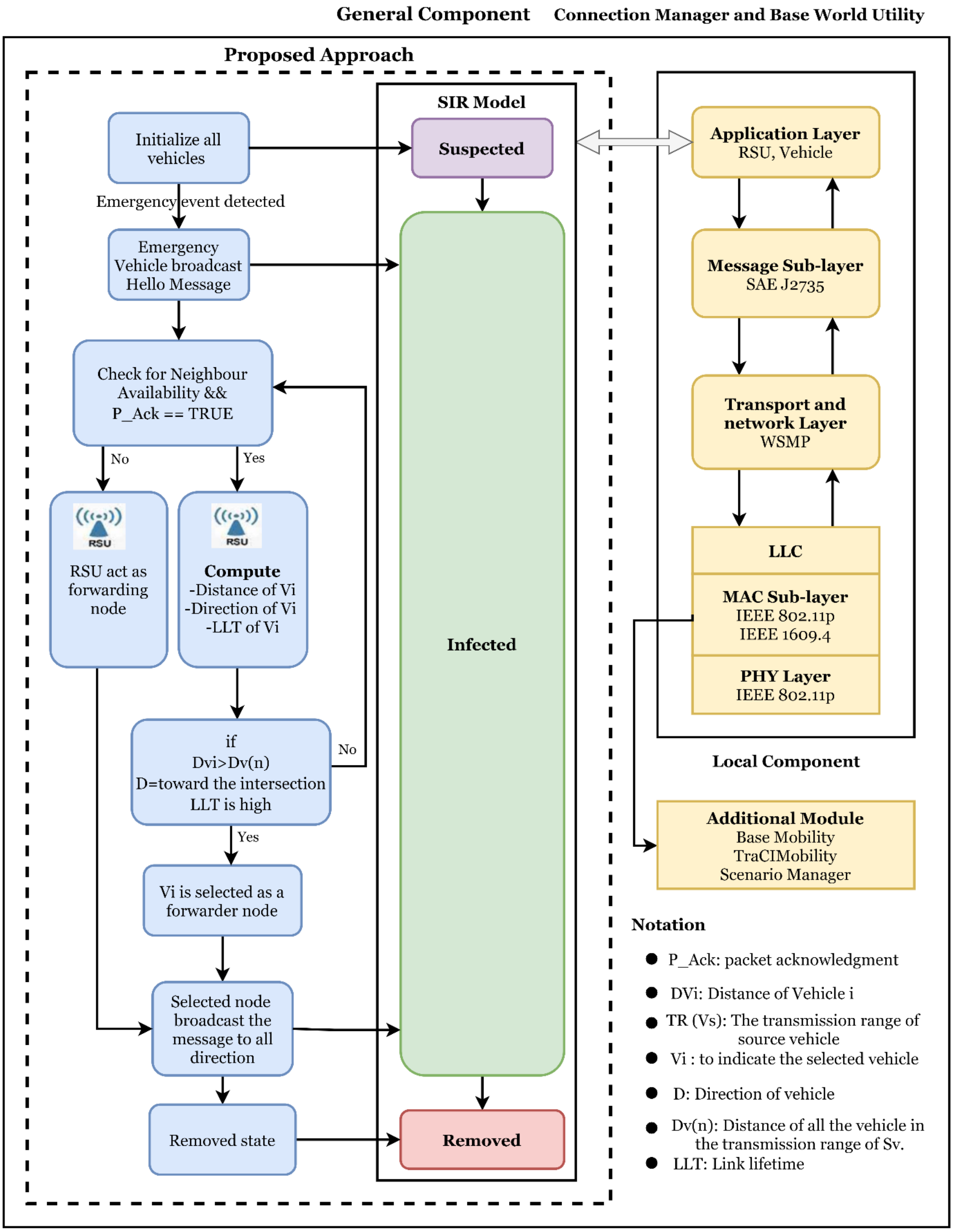

Figure 4.1: Proposed Architecture

The above architecture (fig. 4.1) shows the general architecture of the proposed work for disseminating the emergency message in VANET by applying an epidemic spreading technique called the Suspected, Infected and Removed model. The proposed approach consists of both RSU and Vehicle to design an efficient emergency message dissemination scheme in a multi-directional road scenario. Vehicles and RSU are expected to have GPS to get the neighbour information and they have different modules to forward the emergency message to another vehicle. Two components are there to implement our design: the General component and the local component [38]. The general component shows the public information about the whole network. The general components consist of the Connection manager, Obstacle manager, Radio manager, and Base world utility.

Base World Utility is the fundamental utility module for the entire network and offers the utility methods and data that the entire network needs.

The connection manager is the module that is used to manage all connection-related information. The mobility module and channel access are periodically communicated with by this central module, which also serves as the coordinator of connections between all nodes.

Each vehicle must have an IEEE 802.11p physical layer that is specifically designed for VANETs, as well as an IEEE 802.11p and IEEE 1609.4 MAC layer for MAC-based information dissemination. 802.11p MAC is used for assigning the MAC to the address for each node and IEEE 1609.4 MAC is used for channel allocation. The MAC layer in VANET serves as a relay for safety information [23], [26].

Our dissemination strategy is based on the WAVE application and network layer. The message sub-layer is used to incorporate the emergency message generated by our algorithm. The flow shows how the new scheme obtains its MAC address from the IEEE 802.11p MAC sublayer, which also contains other modules. Then the new scheme's algorithms were deployed as an application type at OBU and RSU.

Additional modules are the modules that should be imported for the design to be successfully compiled. These modules are mostly used to integrate with IEEE 802.11p of the MAC layer.

TraCIScenarioManager: used by SUMO and *sumo.lounchd.py* to access the network simulation tool's realistic mobility model.

TraCIMobility: used in the module which is created by *TraCIScenarioManager*, which can control the mobility of vehicles in the mobility module.

BaseMobility: modules that handle mobility-related information such as the position and movement of the base mobility itself. It also defines a static mobility pattern that only includes position and not movement.

In general, the flow of information exchange from the source node to the destination node can be described from the sender side and receiver sides. The sender vehicle tries to exchange information with another vehicle from the sender's side. On the side of the sender, the message is in the message sub-layer, the WSMP adds its header file, the LLC sublayer checks the SNAP header files, extracts based on the Ethertype, and sends to the IEEE 1609.4 MAC layer extension. To deliver data to the 802.11p MAC layer, the IEEE 1609 sublayer extension adds channel access, adds access categories for priority, and adds its header file. 802.11p MAC adds its header including MAC address and sends to PHY. The sender sends it to the receiver side. From the receiver's perspective, the receiver's 802.11p MAC extracts the MAC header file, removes it, and sends the result to the IEEE 1609.4 sublayer extension. This layer checks the access categories and channel number extracts its header file, and sends the result to the LLC sublayer. The Ethertype that the LLC sublayer sends to WSMP is verified. The WSMP removes its header and sends it to the message sublayer where it is checked against a dictionary before being sent to the destination node with the data. The proposed approach, known as the selective forwarding algorithm based on epidemic spreading (Suspected, Infected, and Removed) technique, is then used to disseminate the message.

4.3. Proposed Selective Forwarding Algorithm

The proposed RSU decision-based selective forwarding algorithm is developed by applying an epidemic spreading model which is the Susceptible, Infected, and Removed algorithm (SIR). The proposed selective forwarding algorithm mainly addresses accidents that occur at intersections, where a message should be broadcast in all directions. During this period, if the source vehicle broadcasts an emergency message to all vehicles and permits all vehicles to re-forward a message, a collision, message redundancy, and channel waste occur, which is referred to as a broadcast storm problem. The proposed RSU decision-based selective forwarding algorithm, which selects a stable forwarding node based on the direction, distance, passive acknowledgment, and link lifetime, is designed to address these types of issues that are seen in present broadcasting algorithms. The main advantage of the proposed selective forwarding algorithm is to minimize the number of forwarding node by selecting a stable node and for preventing another node from broadcasting the emergency message. Due to this only the selected node can forward the message to all direction, and hence the number of forwarded message is reduced in selective forwarding algorithm.

According to the proposed approach, whenever a source vehicle detects or receives an emergency event, it broadcasts a beacon message to every neighbouring node and RSU within its transmission range. To increase receiver availability, it waits for P_Ack before broadcasting these emergency messages. The neighbour is known as Interested Neighbours when they respond to the connection. When the source vehicle received P_Ack from the interested neighbour nodes, the source vehicle starts to broadcast the message to all vehicles in its transmission range. RSU selects the most stable vehicle among these interested neighbours, and these vehicles relay the emergency message to the next transmission range. In this situation, only these selective vehicles are responsible to forward the messages to the required area. If there is no a vehicle in the transmission range of source vehicle, RSU can act as rebroadcasting node and forward the message into its transmission range. Thus, the redundant selection of forwarding nodes as well as the broadcast storm problem is minimized.

4.3.1. Forwarder Node Selection

An emergency message can be forwarded to other vehicles using a forwarder node. Selecting the proper forwarding node is one of the crucial difficulties when disseminating a safety message because the VANET largely relies on broadcasting to distribute emergency messages. The forwarder node is selected using different parameters, including speed, position, direction, distance, and density, in the previous method. The existing mechanisms have their significance in different scenarios. But the existing approach needs improvement to disseminate the emergency message in multi-directional road scenarios by reducing the redundant selection of forwarding nodes and broadcast storm problems. In our scheme, we consider packet acknowledgment (P_ACK), distance, direction, and link lifetime as a parameter to select a stable forwarding node.

4.3.1.1. Passive Acknowledgment

Since VANET has a dynamic topology, the position of a vehicle may change at varying times and speeds. So, checking the availability of neighbours at a specific point in time is needed. To be selected as a rebroadcasting node the vehicle must have sent a passive acknowledgment to the source node. i.e.

$$V(P\_Ack) = TRUE$$

Where *V(P_Ack)* is to indicate the passive acknowledgment of a vehicle.

4.3.1.2. Direction of the Vehicle

Considering the vehicle moving direction is required to find the stable forwarding node. Determining whether a vehicle is approaching or departing from an intersection is made easier by looking at its direction. Based on the information about the distance between the current node and the source node, each node can decide whether to move toward the source node or not. During vehicle selection, the distance between the current vehicle and the source vehicle at the time of sending passive acknowledgment is represented as $Dist(P_{Ackt})$ and the distance between the current vehicle and the source vehicle at the time of initiation through beacon messages is represented by $Dist(Bcnt)$.

$$D = \begin{cases} True, if\ Dist(P_{Ackt}) < Dist(Bcnt) \\ False,\ \ if\ Dist(P_{Ackt}) > Dist(Bcnt) \\ N,\ the\ conditions\ is\ not\ satisfied \end{cases} \text{.......................Eq. 1.}$$

Where D represents the moving direction of a vehicle.

The vehicles are on their way to the intersection point and it can be selected as the forwarding node if the first condition is satisfied or the value become true. However, if the second requirement is met, the vehicles are leaving the intersection point and are therefore unable to serve as rebroadcasting nodes.

In our proposed approach, for a vehicle to be selected as a forwarding node its moving direction should be toward the intersection point. This is because of a vehicle leaving from the intersection already hears any emergencies that arise within the transmission range of the source vehicle. Due to this, the number of rebroadcasting vehicles is minimized this reduces the number of rebroadcast ratio, and also considering the moving direction of a vehicle increase the stability of the forwarding node.

4.3.1.3. Distance of a node

To rebroadcast the message to the next transmission range, the node that is farthest from the source vehicle and is still within its transmission range is selected as the forwarding node. This value is determined based on the position of the source vehicle (x1, x2) and the current vehicle position (y1, y2). If the value of Di is higher, it means that the vehicle is farther from the source vehicle and is more stable than the other. If the forwarder node is selected redundantly, this leads to more overhead in the network. Thus, a higher value of Di increases the stability of the vehicle. We use the Euclidean distance formula to calculate the position of a node [60].

$$Di = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \text{..............................Eq. 2.}$$

4.3.1.4. Link Lifetime

Link lifetime is also called link expiration time, which represents the predicted duration of time that vehicles remain connected. If the value of LLT is larger, the link is more suitable. As a result, the data delivery ratio increases, and the overhead of the network is minimized. Thus, considering LLT is important for increasing the stability of the forwarder node [61]. The LLT is determined by the following equation [62].

$$LLT_{ij} = \frac{|\Delta v_{ij}| \cdot TR - \Delta v_{ij} \cdot \Delta Dij}{(\Delta v_{ij})^2} \text{.......................... Eq. 3.}$$

Where, ΔVij and ΔDij represent the difference in velocity and distance between Vi and Vj, respectively. The transmission range of a vehicle is denoted by TR, and LLT represents the link time of the vehicle.

In our proposed scheme we considered speed or velocity of a vehicle while computing the link lifetime of a node. As stated by M. A. Shahid in [63], the stability of forwarding node is increase if the speed of forwarding node is similar to those of its neighbouring vehicle. Thus, if the difference in the current vehicle speed and the source vehicle speed is small, the vehicle has a high link lifetime and it is suitable to be selected as a forwarding node in our approach.

4.3.2. Dissemination of Emergency Message

The emergency message is disseminated to vehicles to create awareness about the emergency and the vehicle which receive the message can act accordingly. The broadcast message contains information such as Vehicle Id, emergency safety message Id, rebroadcast Id, P_Ack, maximum distance, maximum transmission range, vehicle speed, and position. The proposed algorithm selects the most stable forwarding node during the broadcast of the emergency safety message to reduce the number of rebroadcasting vehicles and network overhead and hence enhance the ESM delivery ratio. The selection procedure is carried out using a model of epidemic spread. In this model initially, all vehicles are considered susceptible. When the emergency event is detected by the source vehicle, the source vehicle searches for its neighbour by using a beacon message. Therefore, from those neighbours, the vehicle that sends a passive acknowledgment, has maximum distance, ingoing to the intersection area, and has a higher link lifetime is selected as the forwarding node.

The goal of our proposed algorithm is to disseminate emergency safety messages within the transmission range of each vehicle by reducing the broadcast storm problem and enhancing the delivery ratio of the message with a short delay. We apply the SIR epidemic spreading model which was discussed by M. Chitra and S. S. Sathya in [57]. The SIR model is effective in minimizing the broadcast storm problem during emergency message dissemination [2]. In our approach, the SIR model suppresses or prevents the broadcast storm problem by reducing the rebroadcasting node in a multi-directional road scenario. According to the SIR epidemic spreading model, the process of disseminating the information from one vehicle to the other takes place based on these two methods.

i. State transition of each node at a particular point in time. This show that when the nodes are changing from suspected to infected and from infected to removed.
ii. Information dissemination between vehicles. This shows the state where the infected node starts to disseminate the emergency message.

A vehicle in the VANET can be in any of the following communication life cycles:

Susceptible (S): a node's state when it is ready to receive any message. The node in this state has never received the information from the source node before, but it accepts the incoming transmission if an opportunity arises. A susceptible node goes into the infected state after a time.

Infected (I): It is the state in which a node has to disseminate the message. The node in the Infected state keeps transmitting the emergency message, i.e., remains infectious, for a certain period, after which the vehicle enters into the Removed state. The message is repeated to the following transmission range by the infected vehicle.

Removed (R): in this state node will disregard the previously sent message. When a node enters this state, it stops sending the information to other nodes and refuses to receive any further transmissions of the same information from other nodes.

In the epidemic spreading model, the states' S and I will take some sort of action when a message is received; by minimizing the number of rebroadcasting nodes, whereas the state R is temporary and the vehicle in this state does not react to a message.

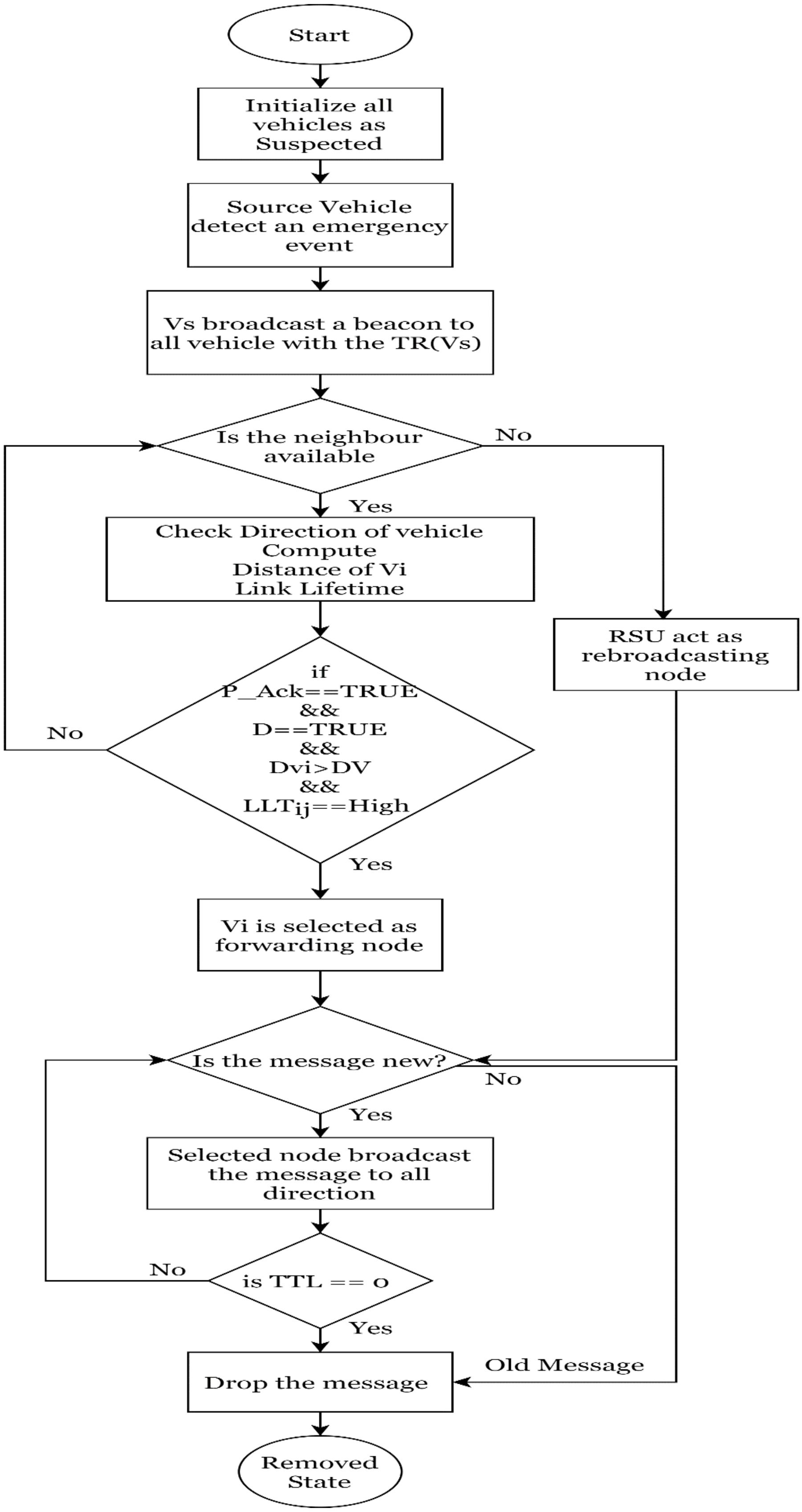

Figure 4.2: Flow chart of the proposed work

4.3.3. Algorithm of the Proposed Approach

Notation

DV_i: *Distance of the farthest vehicle*

D*: Direction*

LLT_{ij}*: Link lifetime of source vehicle (Vs) and current vehicle (Vi)*

P_Ack*: Passive acknowledgment*

(x1, x2) *and* ***(y1, y2)****: the position of the source vehicle and the current vehicle*

TR*: transmission range of a vehicle*

DV*: Distance of all the vehicles in the transmission range of Vs.*

1. *Initialize all vehicles as suspected (v1, v2, ,,,,,Vn)*
2. *Source vehicle (Vs) detects an emergency event*
3. *For all Vi within TR of Vs*
4. *Vs broadcast a beacon message*
5. *If (neighbour node is available)*
6. *Check the Direction of the vehicle*

   Compute

7. *Distance of a node*
8. *Link lifetime of a node*
9. *Else*
10. *RSU act as rebroadcasting node and go to step 15.*
11. *End For*
12. *If (P_Ack == True && D == True && Dv_i > Dv && LL_{ij} == high)*
13. *Vi is selected as the forwarding node*
14. *Else go to step 5.*
15. *If (Emergency Message is new)*
16. *Vi broadcast the message to all direction*

    End If

17. *Else*
18. *Drop the message*
19. *If (TTL==0)*
20. *Drop the message and vi is going to the removed state*

    End if

21. *Else go to step 15.*
22. *End If*

According to fig. 4.2, initially, all vehicles are in a susceptible state where all vehicles are ready to receive the emergency message. The vehicles are moving in a different direction at the intersection. After some time, the source vehicle detects or receives the occurrence of an emergency, and it broadcast the beacon message to all vehicles in its transmission range. The connection is replayed by passive acknowledgment (P_Ack) if the neighbouring vehicles are available within the source vehicle's transmission range. This acknowledgment is being sent so that the precise location and availability of the rebroadcasting vehicles can be determined. When this acknowledgment is received by the source vehicle, RSU checks the distance, direction, and link lifetime of a vehicle to select the stable forwarding node.

The proposed algorithm selects a node as a forwarding node if:

i. P_Ack == True (The neighbour vehicle should have sent passive acknowledgment to the source vehicle)
ii. $D_{vi} > D_V$ (The distance of the farthest vehicle is should be greater than all vehicles in the transmission range of Vs)
iii. D = True (The direction of vehicle movement should be toward the intersection to ensure the stability of a forwarding node)
iv. The LLT of the vehicle is higher than other vehicles in the transmission range.

The selected forwarding node checks whether the message is new or not before broadcasting the message. If the message is new, it rebroadcast the emergency message in all directions. All other vehicles besides the selected forwarding node are unable to broadcast the message again. Therefore, the selected forwarding vehicles are considered as Infected vehicles and continue to infect others in their transmission range until the time to live (TTL) is reached. TTL stands for the average amount of time an emergency message has before it expires. The vehicles are moving into the Removed condition once some time has passed or the emergency safety message has expired. In this state, all vehicles ignore all the messages and cannot communicate with other vehicles.

CHAPTER FIVE

IMPLEMENTATION AND RESULT ANALYSIS

5.1. Overview

Due to the unpredictable changes in topology and the mobility of the vehicles in the network, establishing an emergency message dissemination strategy that can address broadcast storm and overhead issues are a crucial challenge in VANET. Therefore, as we demonstrate in Chapter 4, we develop a dissemination strategy that can disseminate emergency messages by using a stable forwarding node and minimizing the broadcast storm problem. The proposed approach focuses on a multi-directional road scenario (intersection).

It is challenging to simulate VANET in a real environment due to a lack of smart vehicles and technological limitations. So, we used the VANET simulation environment to test our proposed work. A detailed description of the implementation of our proposed work is presented in the following sub-section.

5.2. Development and Simulation Tools

To implement our dissemination strategy, we combine different tools. Network and mobility are the two types of simulation components needed for VANETs simulation.

5.2.1. Mobility Generators

A mobility generator is a type of simulator that generate the necessary realistic vehicular mobility traces for the network simulator as input. In many articles, comparative analyses on VANETs traffic mobility simulators are presented. As stated by N. M. Mittal and S. Choudhary in [64], SUMO is one of the mobility generator tools. SUMO stands for Simulation of Urban Mobility, which is an open-source simulator, highly portable, and designed to support different road networks. The researcher analysed the mobility generator tools based on features like portability, graphical user interface support, XML-based trace support, ease of use, and user-defined map support as an example. SUMO and VanetMobiSim are suggested as the top simulators for mobility generators among other simulator types [64].

According to this evaluation, SUMO is highly portable, useful in different scenarios, and developed for use in traffic strategies and improving route architecture. It can support different operating systems. Large networks can be managed using the free source, extremely portable, and continuous multi-modal traffic modelling application SUMO. It is most popular and widely used in a Vehicular Ad hoc Network. The other mobility generator tool is MOVE

(Mobility model generator for Vehicular Network Environment) it is GNU based mobility generator and generates realistic mobility models for VANETs simulation. The main advantages of using SUMO are that it supports a graphical user interface, is highly portable, open-source, easy to simulate setup, has collision-free movement, and handles a large network. Due to this, we selected SUMO as a traffic mobility generator tool in our proposed work.

5.2.2. Network Simulators

Typically, networks are simulated by network simulators. Those network simulators are used to simulate VANETs by assessing the effectiveness of network protocols for node mobility and other necessary techniques, such as calculating and creating the necessary network components, such as the detailed structure of all nodes (vehicles), roles for sending and receiving packets, data traffic transmission, channels, etc. The Monarch research group at Carnegie Mellon University developed NS-2 to supports the IEEE 802.11 MAC protocol using a realistic physical layer with node mobility, radio propagation model, radio network interfaces, and Distributed Coordination Function (DCF) [65]. GlobMoSim is another network simulator and primarily supports both wireless and wired network modelling environments. GlobMoSim is based on the parallel discrete-event simulation capability [66].

Another network simulator, OMNET++ is an object-oriented modular discrete event network simulator. OMNET++ has a component-based design, and new features and protocols can be supported through modules. Supports network and mobility modules through the independently developed Mobility Framework and INET framework modules [66]. The extensions of OMNET++ are designed to support real-time simulation. It is free for academic use and is already a platform widely used by the world scientific community. Due to this reason, we select OMNET++ for simulating our network.

5.2.3. Data Analysing Tools

Both MATLAB and Python are used for the data processing and analysis platforms, as relevant research has been introduced by C. Ozgur et al. in [67]. The article states that MATLAB is widely recognized as a high-quality environment for all tasks involving matrices, arrays, or linear algebra. And Python language is one of the new languages in this area but is becoming increasingly popular for similar tasks. Both python and MATLAB are interpreted languages. As a result, their code may be modified to work on all popular operating systems and CPU architectures, with only small changes required for different platforms. Python is free and open source. This is one of the advantages of using python. A very popular python distribution, particularly for math, science, engineering, and data science applications, is the Anaconda distribution.

The main reason for the popularity of Anaconda is, that it distributes pre-built packages for Windows, macOS, and Linux, which means that the installation process is really easy and the same for all three major platforms. In addition to that, Anaconda includes all the most popular packages for engineering and data science-type workloads in one single installer. Therefore, we use python and its platform Jupyter Notebook for the analysis of our simulation result.

5.2.4. Selecting Suit of Simulators

To select suitable simulation tools, we use important parameters like user-friendliness, scalability, and the interconnect ability of road traffic and network communication. In our proposed work we use VEINS for the vehicular network simulation. Because VEINS [65] has a feature of online re-configuration and re-routing of vehicles in the reaction of network simulator, fully detailed models of IEEE 802.11p and IEEE 1609.4 DSRC/WAVE network layers, supporting the realistic map and realistic traffic, user friendliness and interconnect ability. Through the use of a TCP socket, VEINS permits the parallel operation of two simulators. VEINS framework was designed using MiXiM. A framework called MiXiM is used for modelling wireless channels, connectivity, mobility, and MAC layer protocol for OMNET++.

5.3. Prototype Implementation

To test our simulation, we use the map of the road in the Ethiopia Addis Ababa intersection scenario. We generate the map from the open street map. The extension of the downloaded map is represented by *.osm*. We use the *.osm* file for generating the network file (*.net*), route file (*.rou*), and polyconvert file (*.poly*), and those files are used to feed SUMO to generate *sumo.cfg* file.

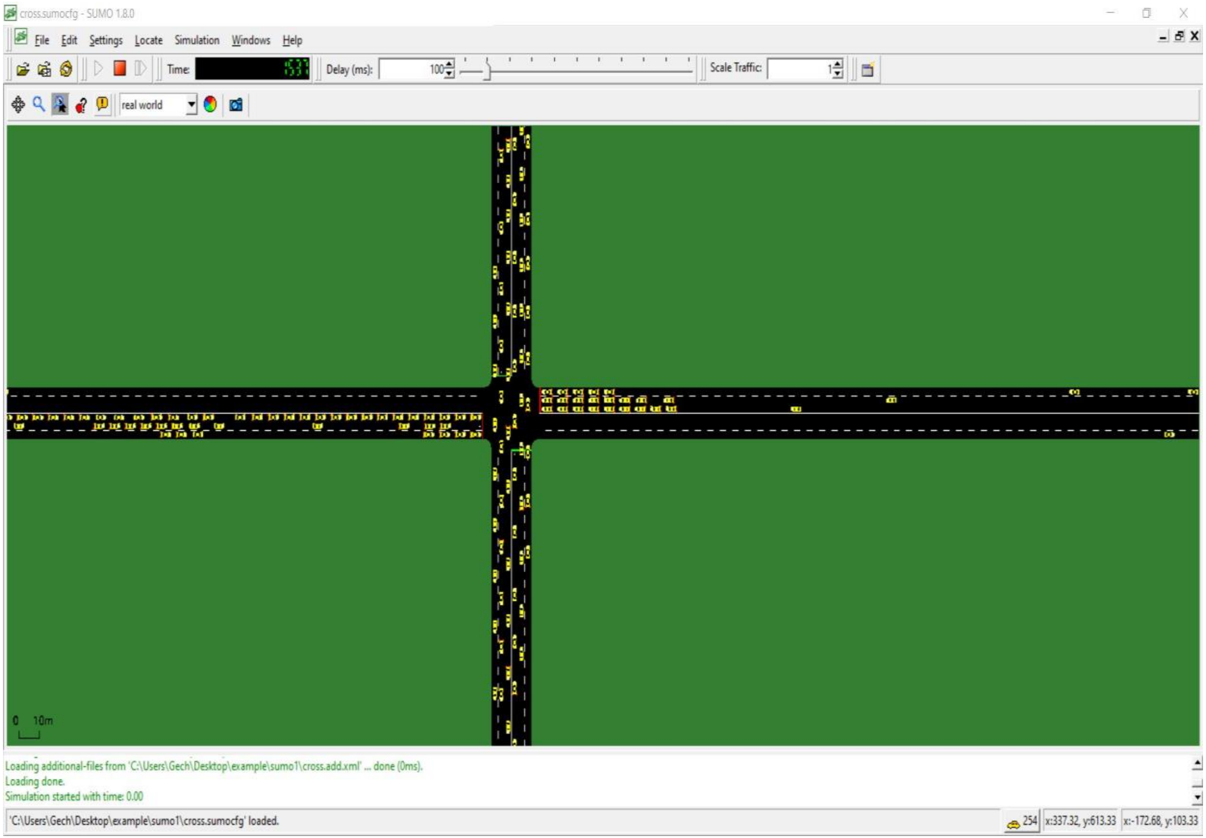

Figure 5.1: Mobility of vehicles in SUMO in an intersection

When the source vehicle detects the emergency event, it broadcast the beacon for finding the neighbour node. If the neighbour node is available in the transmission range the RSU selects the stable forwarding node and the selected forwarding vehicle broadcast the message according to the algorithm stated in chapter 4.

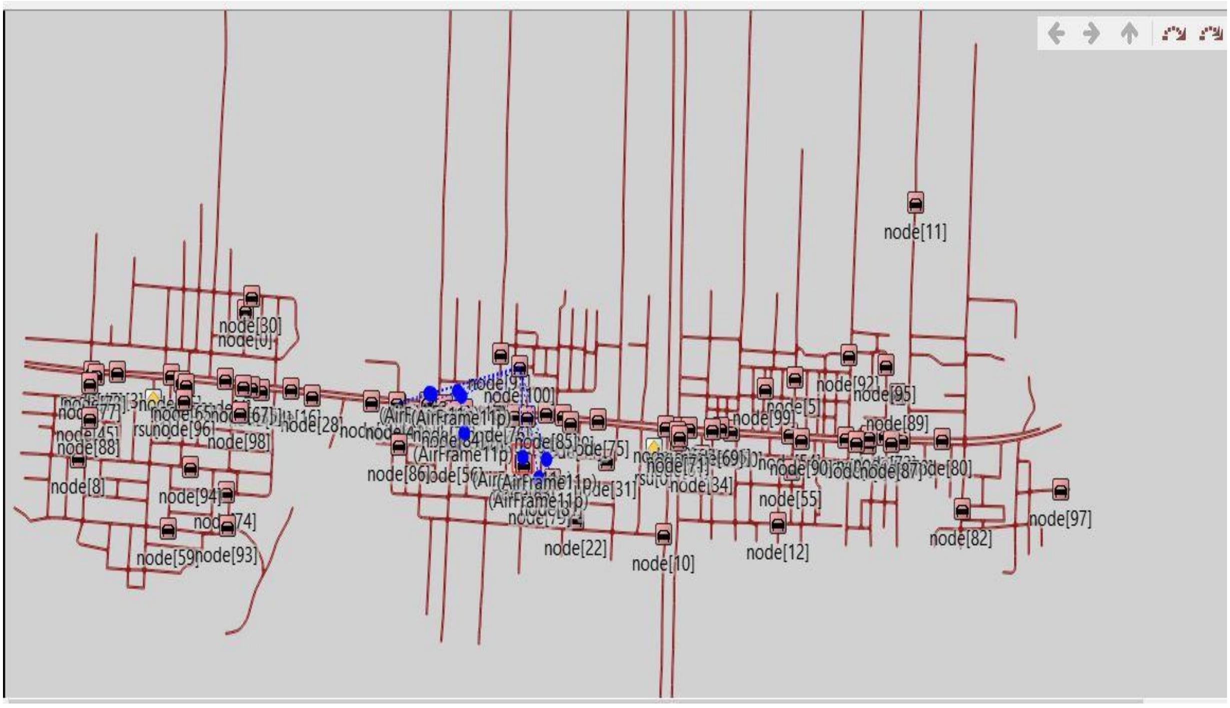

Figure 5.2: Disseminating an emergency message in a multi-directional road scenario using a stable forwarding node

Figure 5.2, show the forwarding of emergency message in an intersection using the selected broadcasting node in its transmission range.

Event#	Time	Relevant Hops	Name	ID	Kind	Length
#13343	81.200174	node[79] --> node[10]		30501	22002	42 bytes
#13343	81.200174	node[79] --> node[17]		30502	22002	42 bytes
#13343	81.200174	node[79] --> node[20]		30503	22002	42 bytes
#13343	81.200174	node[79] --> node[22]		30504	22002	42 bytes
#13343	81.200174	node[79] --> node[34]		30505	22002	42 bytes
#13343	81.200174	node[79] --> node[39]		30506	22002	42 bytes
#13343	81.200174	node[79] --> node[43]		30507	22002	42 bytes
#13343	81.200174	node[79] --> node[46]		30508	22002	42 bytes
#13343	81.200174	node[79] --> node[48]		30509	22002	42 bytes
#13343	81.200174	node[79] --> node[52]		30510	22002	42 bytes
#13343	81.200174	node[79] --> node[56]		30511	22002	42 bytes
#13343	81.200174	node[79] --> node[61]		30512	22002	42 bytes
#13343	81.200174	node[79] --> node[64]		30513	22002	42 bytes
#13343	81.200174	node[79] --> node[70]		30514	22002	42 bytes

Figure 5.3: Sample emergency message dissemination using the selected node

From figure 5.3, we can show that node 79 forward the message to all directions within its transmission range.

5.4. Simulation Experiment and Result Analysis

We perform a simulation experiment with various parameters to evaluate our approach. To implement our scheme initially we made a simulation setup to conduct the simulation. After that, we identify and define the network parameters. Finally, we analyse and compare our scheme with the existing emergency message dissemination scheme.

5.4.1. Simulation Setup

To conduct the simulation experiment, we use OMNET++ 5.6.2, SUMO 1.8.0, and Veins 5.1. To set up our simulation we use various numbers of vehicles traveling on the map we get from SUMO. We use 20, 40, 60, 80, and 100 vehicles. In our simulation two RSUs are used for the selection of a stable forwarding node, and the distance between those two RSUs is 500m. As stated in chapter 4, IEEE 802.11p protocols are used for the physical and MAC layer. In general, the following table shows the simulation parameters of the proposed work.

Table 5.1: Simulation parameters

Parameters	**Values**
Number of Vehicles	20, 40, 60, 80, 100
MAC layer	IEEE 802.11p and IEEE 1609.4
Physical layer	IEEE 802.11p
Simulation time	200sec
Transmission range of a vehicle	275m
Number of RSUs	2
Simulation area	1km
Traffic direction	Multi-directional

5.4.2. Performance Evaluation Metrics and Results

To evaluate our proposed approach and to compare it with the existing scheme we use different metrics. The metrics are end-to-end delay, stability of forwarder node, overhead, and emergency message delivery ratio.

End-to-End delay: average time taken by a data packet to arrive at the destination from the source. The data packets that are successfully delivered to the destination are only counted [58]. To improve the network performance, the delay should be minimized. As described by M. Wazid et al. [68], end-to-end delay is computed as:

$$EED = \sum_{i=0}^{np} (Treci - Tsendi)\ /np \ldots\ldots\ldots\ldots\ldots \text{ Eq. 4.}$$

Where, T_{reci} and T_{sendi} are the receiving and sending time of message i, respectively, and *np is* the total number of received packets.

Stability of the forwarder node: the average duration of time that a vehicle remains the forwarder node during the simulation. If the stability of the forwarder node is higher, the selected node is stable that resulting in less overhead in the network. Because the redundant selection of broadcasting nodes is minimized [69].

Overhead: the average number of packets transmitted at each forwarder node during the simulation. When there is a high number of packets transmitted over a network and a redundant selection of forwarding nodes is there the overhead is high.

Emergency message delivery ratio: the proportion of successfully delivered data packets to the total number of packets transmitted. This demonstrates the amount of data that was delivered to the target location. When the delivery ratio is high, the algorithm successfully increases the reliability of the distribution of emergency messages.

Depending on the evaluation, the performance among the CB-EMD (cluster-based emergency message dissemination), SEB (selective epidemic broadcasting), and the proposed approach are evaluated using the simulation tool. After the simulation, the results are recorded in the result folder of scalar and vector files.

5.4.3. Result Discussion

5.4.3.1. End-to-End Delay

In this metric, we compare the three-emergency message dissemination scheme (SEB, CB-EMD, and our proposed approach) concerning the variation of vehicle density. In figure 5.5, the X-axis represents the vehicle density (the number of vehicles) and Y-axis represents the end-to-end delay of the three schemes.

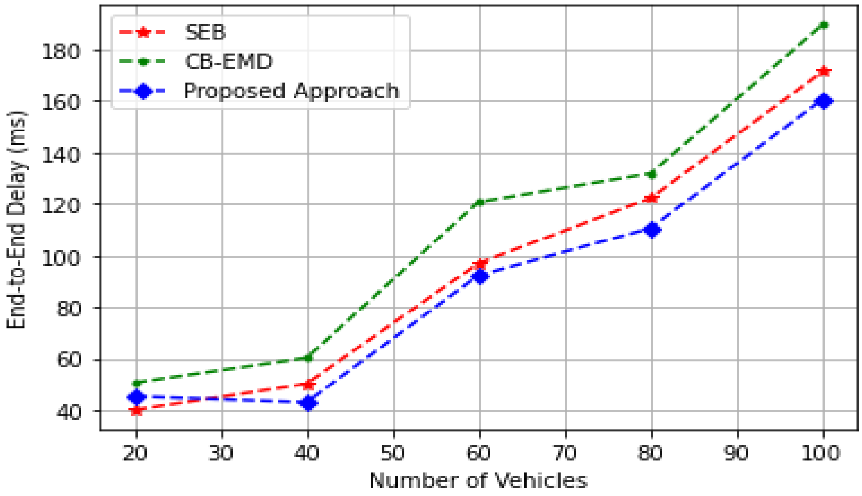

Figure 5.4: End-to-End delay

As shown in figure 5.4, the end-to-end delay of the proposed scheme is reduced as compared to the previous approach. This is because in the new scheme shorter waiting time is assigned to receive an acknowledgment as compared to other algorithm. But, the delay time of a CB-EMD approaches is increased in a higher density of a network. This is because in CB-EMD there is a high beacon rate which results in network congestion in high traffic density, this increase end-to-end delays. When the traffic density become high, the number of broadcast message is also increases this also increases the end-to-end delay.

5.4.3.2. Stability of the Forwarding Node

The following figure 5.5, shows the stability of the forwarding node and the density of a vehicle.

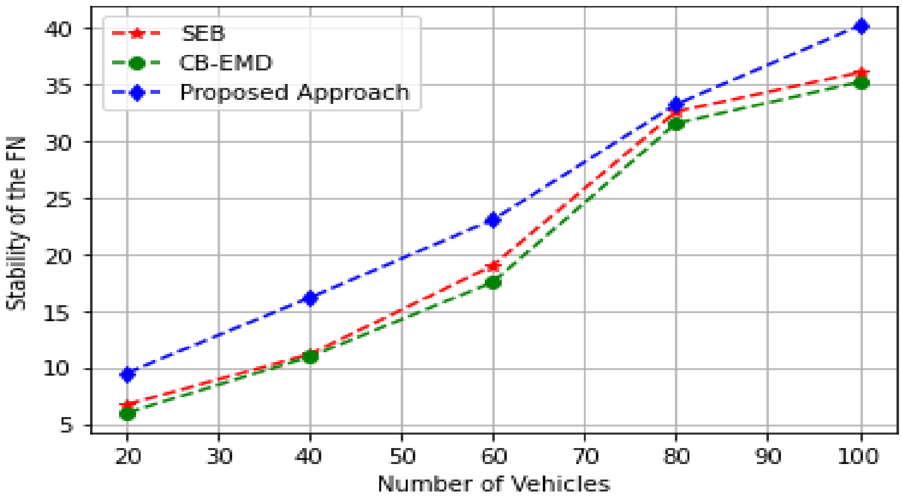

Figure 5.5: Stability of the forwarding node

In the figure above, we can show that SEB and CB-EMD schemes have similar forwarding node duration of time and these two approaches have less duration of time as compared to the proposed scheme. This is because in both SEB and CB-EMD approaches the stability of a forwarding node is not considered as criteria for selecting a broadcasting node. But in the proposed scheme the selected forwarding node has better stability. Since we consider the direction and link lifetime of the vehicle for the selection of the forwarding node, our scheme performs well compared with the two approaches. If the stability of the selected node is high the overhead due to the redundant selection of the forwarding node is also minimized.

5.4.3.3. Emergency Message Delivery Ratio

Figure 5.6 shows the emergency message delivery ratio of all three schemes for varying vehicle densities.

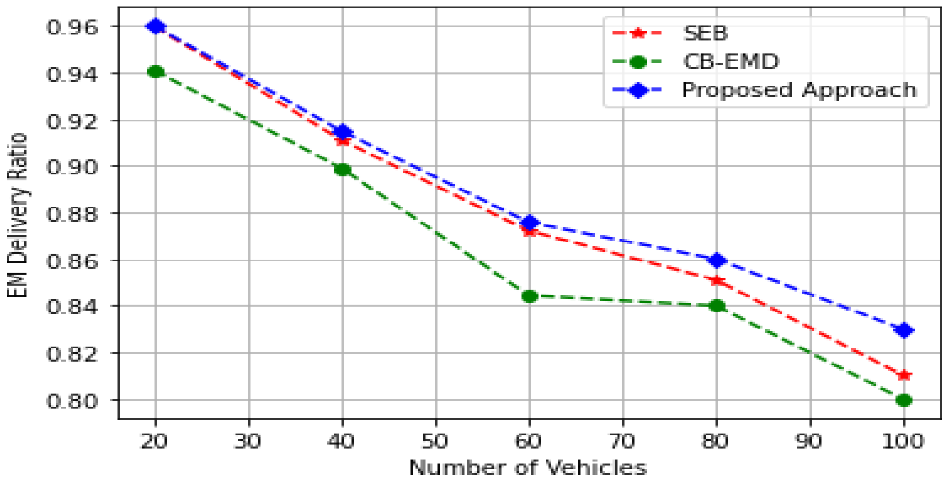

Figure 5.6: Emergency message delivery ratio

In figure 5.6. all three schemes have a better delivery ratio in low density. But, as traffic density increases (congested traffic) the EM delivery ratio is decreased for both CB-EMD and SEB this is because in congested traffic the message gets more flooded which increases the number of rebroadcasting nodes. And also, the redundant selection of forwarding node cause message overhead which interrupts the dissemination of EM. But, in the proposed approach the EM delivery ratio become better in all cases because the proposed approach is based on the SIR epidemic model, which suppresses excessive re-transmission in dense networks and prevents multiple vehicles from broadcasting the same emergency message simultaneously.

5.4.3.4. Overhead

In figure 10, the X-axis represents the vehicle density during the simulation and Y-axis represents the overhead ratio.

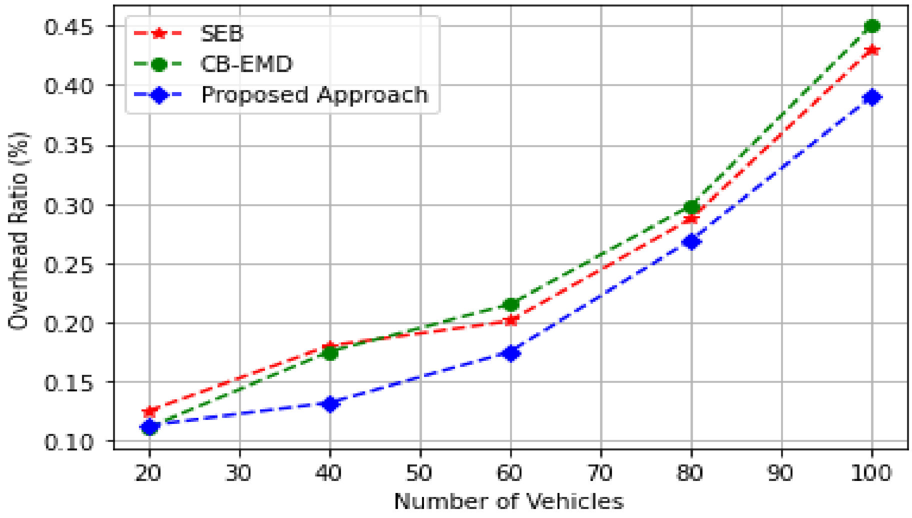

Figure 5.7: Network overhead

From figure 5.7, we can show that in the proposed approach the network overhead is minimized as compared to another scheme. This is because in the SEB approach they consider only the farthest vehicle based on the distance for the selection of the forwarding node without considering the direction of movement and link lifetime as a parameter. This increase the probability of multiple vehicles transmitting emergency message simultaneously. This simultaneous transmission raise congestion and the redundant selection of forwarding node cause high overhead in the network. But, in our approach, the redundant selection of the forwarding node is minimized by selecting a stable forwarding node by considering vehicle direction and link lifetime as a parameter. Due to this, the new scheme is the best option for minimizing the overhead in a multi-directional road scenario by selecting a stable forwarding node.

CHAPTER SIX

CONCLUSION AND FUTURE WORK

6.1. Conclusion

One kind of mobile ad hoc network called VANET was created to address issues with ITS applications. V2V, V2I, and hybrid communication can be used to adapt VANET, which plays a significant role in the ITS environment. Applications for the VANET include those for safety, comfort, and commercial application. Efficient mechanisms are needed for VANET to disseminate those applications. In VANET, broadcasting schemes are mostly used for safety applications. Those broadcasting schemes can be one-hop or multi-hop schemes. Even though many researchers try to design dissemination schemes for VANET, still it is a challenging task. As VANET nodes are moving at high speed, there are problems with network fragmentation in a sparse network environment and highly redundant messages, and packet collision in a dense network environment.

In this thesis work, the RSU decision-based selective forwarding algorithm is developed for a multi-directional road scenario to minimize the broadcast storm problem and to improve the performance of emergency message dissemination for VANET. In our proposed approach, broadcast storm issues are prevented in a dynamic environment by reducing the number of rebroadcasting vehicles. The passive acknowledgment, vehicle direction, distance, and link lifetime are used as a parameter to select the stable forwarding node and only the selected vehicle is responsible for rebroadcasting the emergency message. We used the Epidemic spreading model to show how the vehicles are going to react when it receives new or old messages from its neighbour. By using this approach, the broadcast storm problem is prevented from imposing much delay and packet loss, and the redundant selection of the forwarding node is also minimized by selecting the stable forwarding node.

In this work, we evaluated and compared our work with the dissemination algorithm called SEB which is based on the epidemic broadcasting algorithm, and CB-EMD which uses the clustering algorithm to forward the emergency message. To evaluate those schemes, we used parameters like end-to-end delay, stability of forwarding node, overhead, and packet delivery ratio with a variation of a node. The result shows that the proposed approach performs better than SEB and CB-EMD in terms of minimizing end-to-end delay, and overhead, enhancing the stability of the forwarding node, and the delivery ratio of the emergency message. We evaluate our work by using a realistic simulation environment using the SUMO simulator to generate a mobility file. After generating the mobility file, we use the file in the OMNET++ network simulator. We use the Veins framework to combine SUMO and OMNET++ simulators. Generally, the proposed algorithm is effective in preventing the broadcast storm problem and improving the performance of emergency message broadcasting schemes in multi-directional road scenarios.

6.2. Contribution

We propose a new algorithm to select stable forwarding nodes by combining passive acknowledgment, distance, the direction of the vehicle, and link lifetime as a parameter.

We propose a new emergency message dissemination scheme based on the SIR epidemic spreading model in a multi-directional road scenario that is capable of addressing the broadcast storm problem and overhead issue caused by the redundant selection of forwarding nodes.

6.3. Future Work

The proposed approach improved the performance of the emergency message dissemination scheme in a multi-directional road scenario. This work is effective since it is based on the SIR epidemic spreading model which reduces the broadcast storm problem and overhead issues caused by the redundant selection of the forwarding node. For future work, we recommend as the researchers develop a good-performing scheme for both highway and urban scenarios. And this work will be enhanced if the security is considered, and better if it is developed for any VANET scenario.

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Appendix

Configuration file (omnet.ini)

```
[General]

cmdenv-express-mode = true
cmdenv-autoflush = true
cmdenv-status-frequency = 1s
**.cmdenv-log-level = info
ned-path = .
image-path = ../../images
network = getch
################################################################
#           Simulation parameters                   #
################################################################
debug-on-errors = true
print-undisposed = true
sim-time-limit = 200s
**.scalar-recording = true
**.vector-recording = true
*.playgroundSizeX = 5000m
*.playgroundSizeY = 5000m
*.playgroundSizeZ = 50m
################################################################
# Annotation parameters                              #
################################################################
*.annotations.draw = true
################################################################
# Obstacle parameters                              #
################################################################
#*.obstacles.obstacles = xmldoc("config.xml", "//AnalogueModel[@type='SimplePathlossModel']")
################################################################
#           TraCIScenarioManager parameters           #
```

```
##########################################################
*.manager.updateInterval = 1s
*.manager.host = "localhost"
*.manager.port = 9999
*.manager.autoShutdown = true
*.manager.launchConfig = xmldoc("getch.launchd.xml")
##########################################################
#                    RSU SETTINGS                #
#                                          #
#                                          #
##########################################################
*.rsu[0].mobility.x = 1750
*.rsu[0].mobility.y = 1250
*.rsu[0].mobility.z = 2
*.rsu[1].mobility.x = 400
*.rsu[1].mobility.y = 1150
*.rsu[1].mobility.z = 3
*.rsu[*].applType = "TraCIDemoRSU11p"
*.rsu[*].appl.headerLength = 80 bit
*.rsu[*].appl.sendBeacons = false
*.rsu[*].appl.dataOnSch = false
*.rsu[*].appl.beaconInterval = 1s
*.rsu[*].appl.beaconUserPriority = 7
*.rsu[*].appl.dataUserPriority = 5
*.rsu[*].nic.phy80211p.antennaOffsetZ = 0 m
##########################################################
#          11p specific parameters               #
#                                          #
#                  NIC-Settings              #
##########################################################
*.connectionManager.sendDirect = true
*.connectionManager.maxInterfDist = 300m
*.connectionManager.drawMaxIntfDist = false
*.**.nic.mac1609_4.useServiceChannel = false
```

```
*.**.nic.mac1609_4.txPower = 20mW
*.**.nic.mac1609_4.bitrate = 6Mbps
*.**.nic.phy80211p.minPowerLevel = -110dBm
*.**.nic.phy80211p.useNoiseFloor = true
*.**.nic.phy80211p.noiseFloor = -98dBm
*.**.nic.phy80211p.decider = xmldoc("config2.xml")
*.**.nic.phy80211p.analogueModels = xmldoc("config2.xml")
*.**.nic.phy80211p.usePropagationDelay = true
*.**.nic.phy80211p.antenna = xmldoc("antenna.xml", "/root/Antenna[@id='monopole']")
*.node[*].nic.phy80211p.antennaOffsetY = 0 m
*.node[*].nic.phy80211p.antennaOffsetZ = 1.895 m
##########################################################
#                  App Layer                    #
##########################################################
*.node[*].applType = "MyAlgorithm"
*.node[*].appl.headerLength = 80 bit
*.node[*].appl.sendBeacons = true
*.node[*].appl.dataOnSch = false
*.node[*].appl.beaconInterval = 1s
##########################################################
#                  Mobility                     #
##########################################################
*.node[*].veinsmobility.x = 0
*.node[*].veinsmobility.y = 0
*.node[*].veinsmobility.z = 0
*.node[*].veinsmobility.setHostSpeed = true
*.node[*0].veinsmobility.accidentCount = 5
*.node[*0].veinsmobility.accidentStart = 73s
*.node[*0].veinsmobility.accidentDuration = 20s
[Config Default]
[Config WithBeaconing]
*.rsu[*].appl.sendBeacons = true
*.node[*].appl.sendBeacons = true
```

```
[Config WithChannelSwitching]
*.**.nic.mac1609_4.useServiceChannel = true
*.node[*].appl.dataOnSch = true
*.rsu[*].appl.dataOnSch = true
```

Network Description File (*getch.ned*)

```
import org.car2x.veins.nodes.RSU;
import org.car2x.veins.nodes.Scenario;
network getch extends Scenario
{
    submodules:
        rsu[2]: RSU {
            @display("p=150,140;i=veins/sign/yellowdiamond;is=vs");
        }
}
```

MyParameters.cc file

```
/*
 * Myparameters.cc
 *
 *  Created on: June, 2022
 *      Author: Gech
 */
#include <veins/modules/application/traci/Myparameters.h>
#define TR 275
using namespace veins;
Myparameters::Myparameters(LAddress::L2Type    bmemberId,Coord    bposition,Coord
bvelocity,Coord curPosition,Coord curSpeed)
{
    memberId = bmemberId;
    position = bposition;
    velocity = bvelocity;
```

```
    deltaVelocity = curSpeed.x - bvelocity.x;
    deltaDistance = curPosition.distance(position);
   LLT=(deltaVelocity*deltaDistance+std::abs(deltaVelocity)*TR)/(deltaVelocity*
deltaVelocity);
}
void Myparameters::updateInfo(LAddress::L2Type bmemberId,Coord bposition,Coord
bvelocity,Coord curPosition,Coord curSpeed)
{
    memberId = bmemberId;
    position = bposition;
    velocity = bvelocity;
    deltaVelocity = curSpeed.x - bvelocity.x;
    deltaDistance = curPosition.distance(position);
LLT=(deltaVelocity*deltaDistance+std::abs(deltaVelocity)*TR)/(deltaVelocity*deltaVelocit
y);
}
LAddress::L2Type Myparameters::getMemberId()
{
    return this->memberId;
}
Coord Myparameters::getPosition()
{
    return this->position;
}
Coord Myparameters::getVelocity()
{
    return this->velocity;
}
double Myparameters::getLLT()
{
    return this->LLT;
}
double Myparameters::getDeltaVelocity()
{
```

```
    return this->deltaVelocity;
}
double Myparameters::getDeltaDistance()
{
    return this->deltaDistance;
}
```

TraCIDemo11p.cc

```
#include "veins/modules/application/traci/TraCIDemo11p.h"
#include "veins/modules/application/traci/TraCIDemo11pMessage_m.h"
using namespace veins;
Define_Module(veins::TraCIDemo11p);
void TraCIDemo11p::initialize(int stage)
{
    DemoBaseApplLayer::initialize(stage);
    if (stage == 0) {
        sentMessage = false;
        lastDroveAt = simTime();
        currentSubscribedServiceId = -1;
    }
}
void TraCIDemo11p::onWSA(DemoServiceAdvertisment* wsa)
{
    if (currentSubscribedServiceId == -1) {
        mac->changeServiceChannel(static_cast<Channel>(wsa->getTargetChannel()));
        currentSubscribedServiceId = wsa->getPsid();
        if (currentOfferedServiceId != wsa->getPsid()) {
            stopService();
            startService(static_cast<Channel>(wsa->getTargetChannel()), wsa->getPsid(),
"Mirrored Traffic Service");
        }
    }
}
void TraCIDemo11p::onWSM(BaseFrame1609_4* frame)
```

```
{
   TraCIDemo11pMessage* wsm = check_and_cast<TraCIDemo11pMessage*>(frame);
   findHost()->getDisplayString().setTagArg("i", 1, "green");
   if  (mobility->getRoadId()[0]  !=  ':')  traciVehicle->changeRoute(wsm->getDemoData(), 
9999);
   if (!sentMessage) {
      sentMessage = true;
      // repeat the received traffic update once in 2 seconds plus some random delay
      wsm->setSenderAddress(myId);
      wsm->setSerial(3);
      scheduleAt(simTime() + 2 + uniform(0.01, 0.2), wsm->dup());
   }
}
void TraCIDemo11p::handleSelfMsg(cMessage* msg)
{
   if (TraCIDemo11pMessage* wsm = dynamic_cast<TraCIDemo11pMessage*>(msg)) {
      // send this message on the service channel until the counter is 3 or higher.
      // this code only runs when channel switching is enabled
      sendDown(wsm->dup());
      wsm->setSerial(wsm->getSerial() + 1);
      if (wsm->getSerial() >= 3) {
         // stop service advertisements
         stopService();
         delete (wsm);
      }
      else {
         scheduleAt(simTime() + 1, wsm);
      }
   }
   else {
      DemoBaseApplLayer::handleSelfMsg(msg);
   }
}
void TraCIDemo11p::handlePositionUpdate(cObject* obj)
```

```
{
    DemoBaseApplLayer::handlePositionUpdate(obj);
    // stopped for for at least 10s?
    if (mobility->getSpeed() < 1) {
        if (simTime() - lastDroveAt >= 10 && sentMessage == false) {
            findHost()->getDisplayString().setTagArg("i", 1, "red");
            sentMessage = true;
            TraCIDemo11pMessage* wsm = new TraCIDemo11pMessage();
            populateWSM(wsm);
            wsm->setDemoData(mobility->getRoadId().c_str());
            // host is standing still due to crash
            if (dataOnSch) {
                startService(Channel::sch2, 42, "Traffic Information Service");
                // started service and server advertising, schedule message to self to send later
                scheduleAt(computeAsynchronousSendingTime(1, ChannelType::service), wsm);
            }
            else {
                // send right away on CCH, because channel switching is disabled
                sendDown(wsm);
            }
        }
    }
    else {
        lastDroveAt = simTime();
    }
}
```

Header File (Myparameters.h)

```
/*
 * Myparameters.h
 *
 *  Created on: June, 2022
 *      Author: Gech
 */
```

```
#ifndef SRC_VEINS_MODULES_APPLICATION_TRACI_MYPARAMETERS_H_
#define SRC_VEINS_MODULES_APPLICATION_TRACI_MYPARAMETERS_H_

#include <list>
#include <string>
#include <stdint.h>

#include "veins/veins.h"

#include "veins/modules/application/ieee80211p/DemoBaseApplLayer.h"

using namespace omnetpp;

namespace veins{
class Myparameters
{
protected:
    LAddress::L2Type memberId;
    Coord position;
    Coord velocity;
    double LLT;
    double deltaVelocity;
    double deltaDistance;
    bool P_ack;
public:
    Myparameters(LAddress::L2Type bmemberId,Coord bposition,Coord bvelocity,Coord curPosition,Coord curSpeed);
    ~Myparameters();

    void updateInfo(LAddress::L2Type bmemberId,Coord bposition,Coord bvelocity,Coord curPosition,Coord curSpeed);

    LAddress::L2Type getMemberId();
    Coord getPosition();
```

```
    Coord getVelocity();
    double getLLT();
    double getDeltaVelocity();
    double getDeltaDistance();
    bool getAcknowlegment();
};
}
#endif
```

Sumo Configuration file (*getch100.sumo.cfg*)

```
 <?xml version="1.0" encoding="UTF-8"?>
  <configuration xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
xsi:noNamespaceSchemaLocation="http://sumo.dlr.de/xsd/sumoConfiguration.xsd">
    <input>
        <net-file value="getch100.net.xml"/>
        <route-files value="getch100.rou.xml"/>
       <additional-files value="getch100.poly.xml"/>
    </input>
    <time>
        <begin value="0"/>
        <end value="10000"/>
        <step-length value="0.1"/>
    </time>
</configuration>
```