An effective emergency message broadcasting algorithm to suppress broadcast storm in multi-directional road scenario

By: Fanaye Chala Batu

A thesis submitted to the Department of Computer Science and Engineering

School of Electrical Engineering and Computing

Office of Graduate Studies
Adama Science and Technology University

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Computer Science and Engineering

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September 20, 2019

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Declaration

I hereby declare that this M.Sc. thesis entitled an effective emergency message broadcasting algorithm to suppress broadcast storm in a multi-directional road scenario has been compiled by me under the supervision of Dr. B.M.Thippeswamy at Department of Computer Science and Engineering ASTU, Adama, Ethiopia. This thesis contains no material which has been accepted for the award of any other degree or diploma, except where due reference is made. To the best of my knowledge, this thesis contains no material previously published or written by another person except where due reference is made in the text of the thesis.

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Date of submission: ____

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LIST OF ABBREVIATIONS

AMDIV	At Most Distance Infected Vehicle
DM	Direction of Movement
DV-CAST	The Distributed Vehicular Broadcast (DV-CAST)
G-SAB	Grid-based Speed Adaptive Broadcast
ITS	Intelligent Transport System
MAC	Medium access control
MANET	Mobile Ad Hoc network
NS-2	Network Simulator Version two
NSF	Neighbor Store Forward
NHTSA	National Highway Traffic Safety Administration
SIR	Susceptible Infected and Removed algorithm
TTL	Time To Live
T	Time to broadcast
VANET	Vehicular Ad Hoc network
VSPB	Virtual Slotted p-Persistence Broadcasting
WHO	World Health Organization
ZOI	Zone of Interest

ABSTRACT

Networks of the vehicle (VANET) are a part of a MANET network characterized by having high mobility speed and dynamic topology change. In this network most of the communication interchange in broadcasting mode. Even if, this broadcasting technique assures the optimal delivery of emergency messages all over the required area, it also causes unwanted flooding of an emergency message which brings large contention, redundant rebroadcast and collision that causes for broadcast storm problem (BSP). This BSPs intern affects the overall performance of vehicular ad hoc network (VANET). For this case it, requires some optimal method to suppress broadcast storm in the existing mechanisms by reducing number of rebroadcasting vehicles.

This research proposes a sender decision based location-aware broadcast storm suppressing algorithm for multi-directional road scenario by applying epidemic spreading technique called Susceptible, Infected and Remove on fast broadcast algorithm. The algorithm simulates by using NS2 and SUMO simulator. The result of this simulation show that ,the proposed solution improves the network performance in all cases, especially it reduces RRR, Broadcast Delay, and Broadcast Collision Ratio (BCR) while increase emergency message delivery ratio.

Keywords: *Broadcast storm problem, VANE, Redundant Rebroadcast ratio, Dissemination delay, Multidirectional road scenario, Direction of movement.*

CHAPTER ONE

1. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

A network of vehicles (VANET) is a wireless emerging technology that aims to provide safety and communication services to drivers and passengers, by providing a self-organizing network environment, without requiring centralized management [1]. These Networks are characterized by Intelligent Transportation System to improve road safety by allowing people traveling in the vehicle with updated information on accidents, traffic jams, any commotion, and rainfall. The main target of using this new technology is to create an emergency-free environment through on-time delivery of emergency/ safety messages.

VANET safety messages are classified into aperiodic and periodic messages based on their requirements [2]. Aperiodic messages are broadcasted to the cars when they are in an emergency condition like road accidents, road construction, etc. Periodic messages are a non-safety message that sent to the vehicles to update the neighbors with non-safety related information. These messages are synchronized by the IEEE 802.11p WAVE and ETSI standard by using an intermediate layer called the message sub-layer and facility layer [3, 4]. To disseminate this emergency safety message in VANET, the vehicles are shared information through Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and infrastructure to infrastructure (I2I) communication.

Roadside infrastructure to Roadside infrastructure communication (I2I) is a communication type between infrastructure and infrastructure that required in VANET when a remote roadside unit (RSU) does not have a connection to the backbone network and wants to send its data traffic to central RSU which has backbone connection by the help of vehicle passing. In the same case, the Vehicles to Roadside unit (V2I) is the communication that allows the information exchange between cars and road infrastructure by using its components.

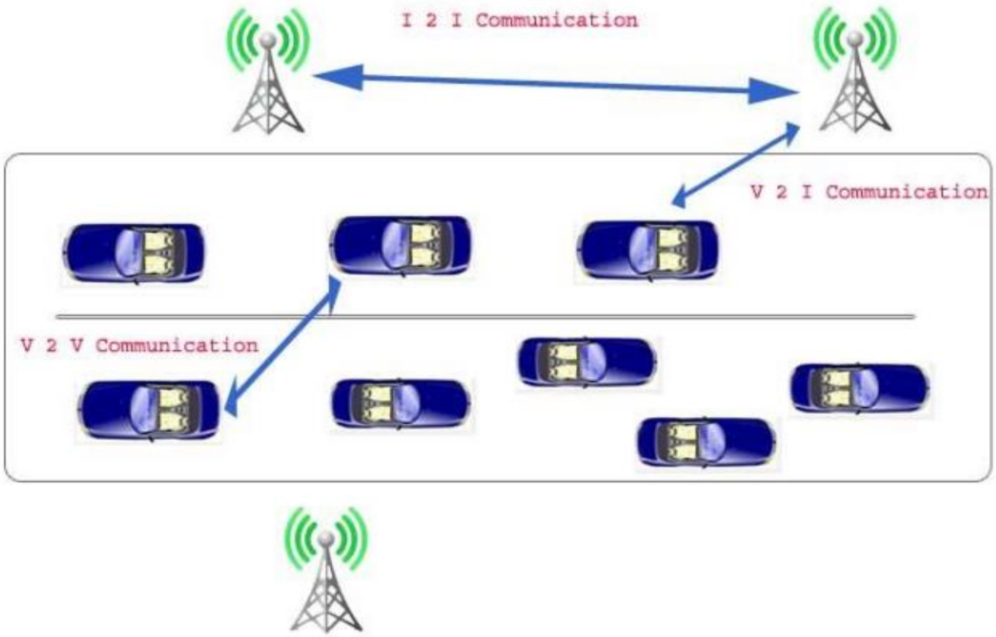

Figure 1.1 Types of Communication in Vehicular Ad Hoc Network **[5]**

These components such cameras, overhead RFID readers, lane markers, traffic lights, signage, streetlights, and parking meters used wirelessly to provide information to the vehicle, and vice versa. In V2I communication a network interface device located in the moving vehicles and connected to both in wireless and infrastructure mode. In this type of communication information from the roadside unit, components can be delivered to the cars over a wireless network and vice versa.

The third type of communication in VANET is called the onboard unit to onboard unit communication (V2V) which is the wireless transmission technology that used dedicated short-range communication (DSRC) frequencies to transfer data wirelessly between motor vehicles. The technology allows preventing the occurrences of emergencies by permitting the cars in transit to send speed and position information to each other over a wireless network. In this onboard unit to onboard unit (V2V) communication every vehicle in the networks is integrated with VANET transceivers or OBU to exchange information with other cars. This forms a subclass of ad hoc networks, called VANETs [6]. This onboard unit (OBU) device in VANET consists of the communication module, processing module, and display unit. With the help of a communication module in OBU, each vehicle node able to exchange information with other nearby vehicles (OBU) and reduce accident that occurs on the road. Unlike vehicles, to RSU communication this technology is not required RSU assistance to communicate with each other and enables a ubiquitous 360-degree awareness of surrounding threats with the help of an OBU device that attached to the vehicles. These three vehicular communication technologies allow transmit and receive the safety and non-safety information that are needed to avoid road accidents or to intimate the drivers about the dangerous situation in the emerging area.

This research uses a V2V communication approach to exchange information between vehicles in their transmission range. In this approach, the vehicle can automatically detect the emergency through On-Board Unit (OBU) which is installed inside the vehicle and allow surviving from a bad situation by alerting the driver during traveling. This alerting driver about an accident on the road requires transmitting the message to all endangered vehicles in the surrounding area. In such situations, where hard constraints on delays have to be respected, it is very common to use broadcasting techniques.

A broadcast is a process of transmitting a single message to all the vehicles within the transmission range simultaneously. But, message broadcasting in VANETs is very difficult due to their high mobility and variable density they have to share and rout emergency safety messages with intended vehicles in real-time. In this high mobility and varying density of the vehicles blind flooding or simple broadcasting cause the broadcast storm problems.

1.1.1 Impact of Broadcast Storm Problems in VANET

Broadcasting is a common operation that used to exchange messages in VANET. This operation contains rout finding, paging a particular host, and sending an alarm signal require simultaneous execution due to their host mobility. The simplest method of broadcasting emergency safety messages in this network is called blind flooding. In such a case due to shared wireless medium, a straight forward by flooding is always very costly and will result in a serious collision, contention, and redundancy which lead the broadcast storm problems.

A broadcast storm occurs whenever multiple vehicles attempt to transmit simultaneously or a network system is overwhelmed by continuous multicast or broadcast traffic [7, 8]. The most serious impact of the broadcast storm in VANET is safety-related service disruption that led, message lose, collision, a high number of redundant messages and delays. This problem has the following common impact on the dissemination of emergency messages in VANET while it makes service disruption at the MAC layer.

- **Redundant rebroadcasts**: When all nodes decide to resend a broadcast message to all the vehicles in its transmission range, but all neighbors already have the message. This consumes a large number of resources due to inefficient use of bandwidth and processor.
- **Contention**: This happens if a node broadcasts a message, and many of its neighbors decide to resend it. These simultaneous transmissions may severely contend with each other.
- **Collision**: This became a serious problem in VANET due to the lack of Red to Send or Clear to Send (RTS/CTS), deficiency of back off mechanism, and the absence of collision detection (CD) cause more damage.

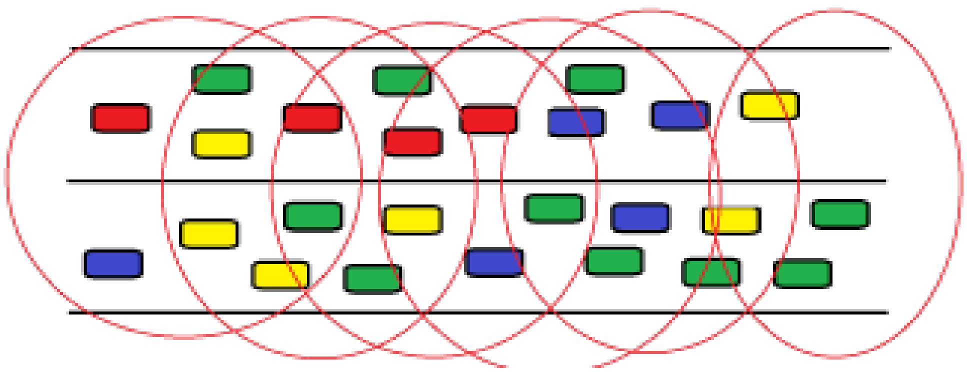

Figure 1.2. Broadcast Storm Problem in VANET **[9]**

The reason behind this is, broadcasting communication in VANET is unreliable due to the lack of acknowledgments in the Carrier Sense Multiple Access with Collison Avoidance (CSMA/CA) mechanism present in the IEEE 802.11p standard [10].In this case, when many vehicles exist in the one transmission range during dense network and all these nodes resend the same message, then, severe contention (contend for the channel) will occur that would lead to collisions in the MAC layer, redundant transmission and large delay among neighbor vehicles [11].

The high mobility of vehicles that bring frequent topology change in VANETs constitutes a nontrivial challenge to broadcast design. The existence of a high density of vehicles on the road brings a great challenge in exchanging emergency safety messages. This is due to the wireless channel is bandwidth-constrained and shared among multiple vehicles that broadcast these messages. The channel computation during high-density vehicles brings a problem called a broadcast storm. Hence it requires to develop an effective algorithm that can handle this problem in multi-directional road scenarios.

It has been observed that although active research such as DRIVE [12], VSPB [7], G-SAB [13], DV_CAST [10] and SIR [14] is being carried out in this area, the proposed solutions are not complete in terms of finding exact rebroadcasting vehicles identifying direction of rebroadcasting node, suppressing broadcast storm in multi-directional road scenarios and ensuring available of the receiver before broadcasting emergency safety message [15]. Furthermore, most of the proposed solution focuses on selecting furthest vehicles as rebroadcasting node based on only the distance they have from the source which does not provide any grant about neighbor availability and identify an exact rebroadcasting node. In addition to this, the existing solution requires pre-established infrastructures (RSU) support to broadcast this emergency message which requires a high cost to implement it. Hence VANET requires an effective algorithm that solves broadcast storm problems to overcome these issues.

This research is conducted to address the above problem that the decrease in the performance of emergency safety messages broadcasting processes like increased overhead, collision and dissemination delay by developing a sender decision based selective broadcasting algorithm called SBA. This algorithm solves the broadcast storm problem that happened due to a multi-directional road scenario where an emergency safety message required to send to all directions. The proposed SBA algorithm handles broadcast storm problem effectively for multi-directional road scenario by reducing the number of vehicles which rebroadcast the message safety messages.

The proposed sender decision based selective broadcast algorithm is developed by applying the epidemic spreading technique on a fast broadcast algorithm. The algorithm reduces the number of rebroadcasting vehicles by selecting furthest vehicles as rebroadcasting vehicles in the next transmission range. This selective vehicle is called at most distance infected vehicles (AMDIV). The process of selecting this vehicle is based on three criteria. The first one is the direction of vehicle movement should be in (towards to intersection point), the vehicle should be sent the passive acknowledgment to the source vehicles and the distance of selective vehicle should be greater than the vehicles that exist in that transmission range. Only the vehicle which fulfilled these criteria permitted to rebroadcast the emergency messages. Hence broadcast storm suppress by selective broadcasting in dynamic networks.

The simulation result that gains from NS2 show that the proposed SBA algorithm enhances the emergency safety delivery ratio in all cases while it reduces redundant rebroadcast, broadcast collision and delay.

1.2 Motivation

The applicability of wireless technology to support driving activities is quickly expanding in the entire world. This is a time when all driving activities face more difficulties and need greater demands to give better care, especially to those most in critical or in an emergency. This rapid evolution of wireless data communication technologies, which emerged in the last years, has led researchers to explore their application in VANET or intelligent transport system. This technology aims to give people traveling in the vehicle with updated information on accidents, any commotion, traffic jams, and rainfall. By using this information, drivers may avoid smash up. Therefore, the applicability of this VANET network is one of my motivators to work on this title.

Road traffic accident causes unexpected economic losses to individuals, their families, and nations as a whole. Every year, due to a road accident many people lose their lives, their wealth and their life. According to the National Highway Traffic Safety Administration (NHTSA) [19,22], and WHO [15] report that supported by World Bank more than 2.7 million people injured by road accidents each year, $230 billion social costs and 70% of those accidents happened in developing countries, with Africa having the highest number. Even if these developing countries have a minimum number (less than half) of the world's vehicles, they contribute to above 90% of the total number of road traffic deaths. This is because of their poorly maintained road network speed of the vehicles, lack of resources to enforce road safety laws and poor medical assistance.

In addition to this according to the latest WHO data published in 2019 [2], Road Traffic Accidents Deaths in Ethiopia reached 27,140 or 4.27% of total deaths that rank Ethiopia #22 in the world. The existing solution to address this problem is also not sufficient because they are not free from the broadcast problem which hinders on-time information delivery during emergencies.

Therefore, the problem in the existing driving system and applicability of vehicular ad hoc networks are the two issues that motivated me to work on this title, which allows solving the major problems in VANET which called broadcast storm problems.

1.3 Statement of the Problem

During an accident, all vehicles in an emergency required to get immediate information to survive from a bad situation. This can be achieved by alerting the driver about an accident on the road which requires transmitting the message to all endangered vehicles in the surrounding area. In such situations, where hard constraints on delays have to be respected, it is very common to use broadcasting techniques in vehicular networks. But, message broadcasting in VANETs is very difficult due to their high mobility and varying density. These have to share and route the safety-critical information to other intended vehicles in real-time.

In a Vehicular ad-hoc network to broadcast information to an area greater than that covered by the transmission range of a node, multi-hop relaying is used. The simplest method to do multi-hop relaying is by flooding a packet. In this situation, when a node receives a broadcast message for the first time, the node then re-transmits (rebroadcast) the message. In this case, when all the vehicles that receive the emergency message try to rebroadcast through simple flooding it causes a serious problem called broadcast storm problems. This causes high network congestion, data traffic, longer delays, packet collisions and service disruption at the medium access control (MAC) layer.

The problems may become worst at rush hour when the vehicle density becomes high by repeating similar messages many times. As a result, one vehicle may receive similar messages from one or more vehicles many times which creates a congested network and consuming scarce network resources like bandwidth. This makes the node busy in processing and forwarding similar messages to all vehicles in that transmission range redundantly which leads, high message loss, redundancy, and collision. By doing so, the broadcast storm problem increases the time taken to reach the target which reduces the emergency message delivery ratio. But since VANET deals with emergency safety messages a fraction of second may bring a million losses to the group or individual. Due to this, the increment of road accidents causes unexpected economic losses to individuals, their families, and nations as a whole.

According to the data provided by the World Health Organization (WHO) [16], Road traffic injuries were the 11th leading cause of death worldwide and contributes 23% of all deaths globally. These death and injuries cost US$ 518 billion globally while middle and low-income countries contribute about US$ 65. From this death and accident, 90% of them happen in middle-income and low-income countries, where 5098 million people or 81% of the world's population live [17]. These countries own about 20% of the world's vehicles but the accident becomes worst. Based upon this road traffic injuries are predicted to rise from tenth place in 2002 to eighth place by 2030 as a contributor to the global burden of diseases. This evidence shows that at present road traffic injuries have become a serious problem and will become worse if preventive action is not taken now.

The research conducted in this area is also not effectively handle these broadcast storm problems. This is because many recent works address broadcast storm problems only for single directional road scenario. Because of this, they miss some possible broadcasting directions and fail to take into account realistic road topologies and traffic distribution. According to the recent research conducted in a bidirectional message, dissemination increases the BSPs twice compared to unidirectional message dissemination where it became more complex when we consider multidirectional high way. The reason behind this is, in the multidirectional road scenario there are N vehicles that inter the communication range or leave communication range. When a number of the vehicles is enter to communication range increases the road becomes dense. In this case, when an emergency occurs all the "N" vehicles in this communication range, start to rebroadcast the emergency message they receive or detect , their neighbors will face the problem called the repetitive transmission of the same message, message collision, and congestion.

In addition to this, identifying the vehicle in which direction of movement from the intersection point is more optimal to send the emergency safety messages a challenging issue. This is because in a multi-directional road scenario one road may have multiple lanes that allow the vehicle moving towards the intersection point or outgoing from the intersection point. In such a case selecting optimal forwarding node that suppresses broadcast storm problem has become a challenge full as one or more vehicles may have an equal chance of forwarding these messages in all directions. Furthermore insuring neighbor availability in dynamic networks such as VANET is the main research concern today. Due to the high moving speed of vehicles after selecting the next forwarding node the vehicle may change their position dynamically. This requires checking neighbor availability at each point of time by identifying their exact position.

The infrastructures based broadcast suppressing technique developed by many researchers are not suitable in many countries especially, for developing countries. The reason behind this is it is impossible to deploy the infrastructure in all areas due to different weather conduction land topology and high cost of implantation. The increment of the traffic congestion impact on socio-economic activities is also the main problem that observed in today's traffic flow. Traffic congestion has a considerable socio-economic impact that, results in increased fuel consumption, increased CO2 transmission and the journey time of road users. Therefore it requires efficient channel utilization to achieve correct and fast on-time message delivery methods to all vehicles in the risk area.

1.3.2 Research Questions

From previous work, different algorithms and methodologies are used to suppress broadcast storms through enhancing the delivery of emergency safety messages to the target area. This suppressing technique was conducted by selecting furthest vehicles or by varying time to rebroadcast. This study is to find out the following research question:

- ❖ The vehicle in which direction of movement is more suitable to suppress broadcast storm in a multi-directional road scenario?
- ❖ How to develop the criteria needed to select the rebroadcasting vehicles?
- ❖ How to create traffic motion in multi_ directional road scenarios?
- ❖ How to check availability of the neighbors before broadcasting emergency safety messages
- ❖ How broadcast storm affect message distribution in VANET?

1.4 Objective

1.4.1 General Objective

- ❖ The main goal of this research is to develop an effective emergency message broadcasting algorithm that suppresses broadcast storm problems in a multidirectional road scenario.

1.4.1 Specific Objective

- ❖ To study literature to understand and examine the effect of the broadcast storm on network emergency safety message delivery.
- ❖ To create real traffic motion for VANET using SUMO.
- ❖ To propose an algorithm by implementing the epidemic spreading technique on a fast broadcast algorithm for vehicular communication.
- ❖ Integrating the proposed NS2 algorithms to the proposed SUMO real traffic model to simulate the proposed algorithm.
- ❖ Compare and evaluate the developed algorithm.

1.5. Methodology

The research adapted to the following research methodology to achieve the above objective. This study started by identifying the research area to reduce the scope of finding the problem. This part mainly concerns with pre-study about VANET technology that used in broadcasting an emergency /safety message. The main concern of this part is identifying VANET technologies and various protocols used, analysis of challenges in implementing VANET and the possible suggested solutions and learning the required tools for modeling and implementation. This allows identifying the main problem in the existing broadcasting method in VANET and finding out the proposed and possible solution for the identified problem.

After identifying the specific research area the next part is concerned with literature review and analysis of related work that conducts on this topic with their limitations presented in this thesis research. This allows identifying the research gap or white spots between the existing solutions and the proposed scheme. This paper investigated and analyzed from best-known libraries such as ACM library, IEE Explore, and science direct.

First, the real traffic model is created for a multi-directional road scenario using SUMO and net edit. This model is similar to the Manhattan grid motion that gets from the open street map and used as a sample to show how vehicles are move on the road by having their line. Then, the proposed broadcast suppressing algorithm is implemented by modifying the existing C++ code of a fast broadcast algorithm. In addition to this, representation of the proposed algorithm, flow chart for the system, the step that shows how the algorithm suppresses broadcast storm and its process are listed under these topics. In this algorithm C++ programming language is used to modify the existing file, the NS2 and SUMO are used as simulator tools, the, E draw Max software are used to draw different pictures and flowchart to explain the algorithm in detail while Microsoft office Excel 2010 is used to visualize simulation result using graph.

After the above activities are conducted to study the effect of the broadcast storm on emergency messages dissemination the modified algorithm integrated with the SUMO file is simulated in using NS2. For this case the research use four performance evaluation criteria which called, redundant rebroadcast ratio (RRR), delay, broadcast collision ratio (BCR) and Emergency safety message delivery ratio (ESM) under various vehicle densities and vehicles moving speed. The proposed SBA algorithm is evaluated with existing solutions [4] and Microsoft Office Excel 2010 is used to plot the comparison result. Lastly, the resulting gain from this simulation discussed clearly and reported.

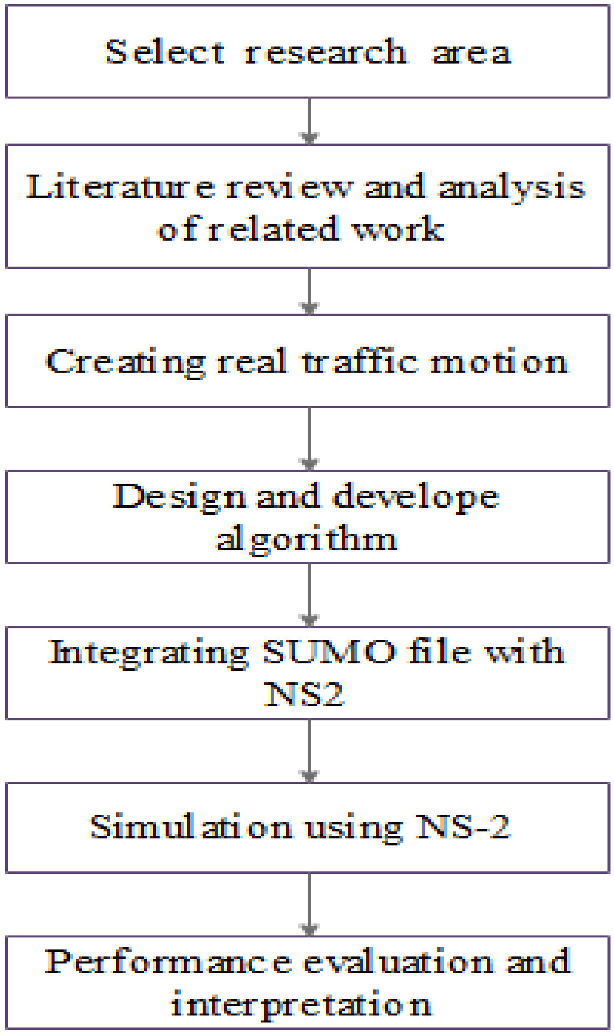

Figure 1.3 The Methodology

1.6 Scope and Limitation of the Study

1.6.1 Scope of the Study

The research will develop an algorithm that solves broadcast storm problem effectively for multi-directional road scenario and allow to create real traffic model for vehicular communication using NS2 and SUMO.

1.6.2 Limitation of the Study

The proposed algorithm suppressing broadcast storm that occurs at the intersection point where message broadcast to four directions. In addition to this, the research mainly concerns aperiodic message exchanges between the vehicles rather than periodic message exchange. Generally, the research limited to analysis of the newly developed framework and review published Journal, and papers which are currently released.

1.7. Significance of the Study

This research will be very important for different applications and organization like

- **Emergency/Active Road Safety Application**

  This category aims to avoid the risk of car accidents and make safer driving by distributing information about hazards and obstacles.

  - ✓ Post-Crash Notification
  - ✓ Road Hazard Control Notification
  - ✓ Cooperative Collision Warning

- **Productive Applications**
  - ✓ Time Utilization
  - ✓ Fuel Saving
  - ✓ Environmental Benefits

- **Traffic efficiency and Management Applications**

This category focus on optimizing the flows of vehicles by reducing travel time and avoiding traffic jam situations.

Generally this algorithm can be applicable in vehicular manufacturing industries to add additional features to V2V communication, public transportation organization and by traffic police to prevent the occurrences road accident. The algorithm is also applicable for the organization that work on environmental pollution, for the purpose of reducing emission of carbon dioxide that released to the environment by reducing the time the vehicles waste during collision. The algorithm also applicable for diver, passengers, public transportation organization and all society.

1.8 Thesis Organization

This thesis contains five chapters including chapter one which explained in the above. The relaxation of the report is prepared as follows. Chapter two discusses the works related to prevention of broadcast storm problem in VANET and the literature review which show the technique that used to suppress broadcast storm problem in previous work. In chapter three, the proposed selective broadcasting algorithm is explained clearly by using flow charts and theory. The design of the broadcast storm suppressing algorithm and its implementation are clarified by using some flow charts. Model for the proposed algorithm, the requirement that used to select the rebroadcasting vehicles, and how the algorithm reacts when it receives the message are additionally explained in detail in this chapter.

The simulation study and its experimental results are discussed in chapter four Here, the simulation scenarios used in this study, the performance metrics, the results of the simulations and the discussions of the results are presented. Chapter five is the last chapter that presents the conclusions and recommendations concerning the idea that should be added address in the feature. Then the reference materials used to develop this thesis work are presented next. Finally, in the appendix, a sample AWK scripts, mobility files, sumo routing file and sample C++ codes of the proposed broadcast storm suppressing algorithm implemented in the NS-2 simulator are presented.

CHAPTER TWO

2. LITERATURE REVIEW AND RELATED WORK

2.1 Literature Review

Vehicular Ad-Hoc Networks are the networks of vehicles which are characterized by high node mobility and dynamic topology change. Most of the communication interchanges in this network take place by using broadcasting which allows disseminating (spread) emergency messages all over the vehicular network. Broadcasting is the simplest way of disseminating emergency/safety message that assures the optimal delivery of emergency messages all over the VANET by using different broadcasting technique. However, in this technique simple broadcast or flooding results in many contention and collisions that leading to Broadcast Storm Problem (BSP) and in turn affects the overall performance of VANETs. The Broadcast Strom Problems happen when multiple cars attempt to transmit the ESM at the same time, thereby causing high data traffic, network congestion, message collisions, service disruption and extra delay in VANET [18].

A Multitude of research work has proposed to suppress this broadcast storm either by reducing the number of rebroadcasting/ relaying nodes or by identifying the best relay node and solve network partition problem by using store carry forward mechanism or by allowing opposite direction vehicles as recovery vehicles. The technique used in VANET to disseminate emergency/safety message are generally classified into the following technique.

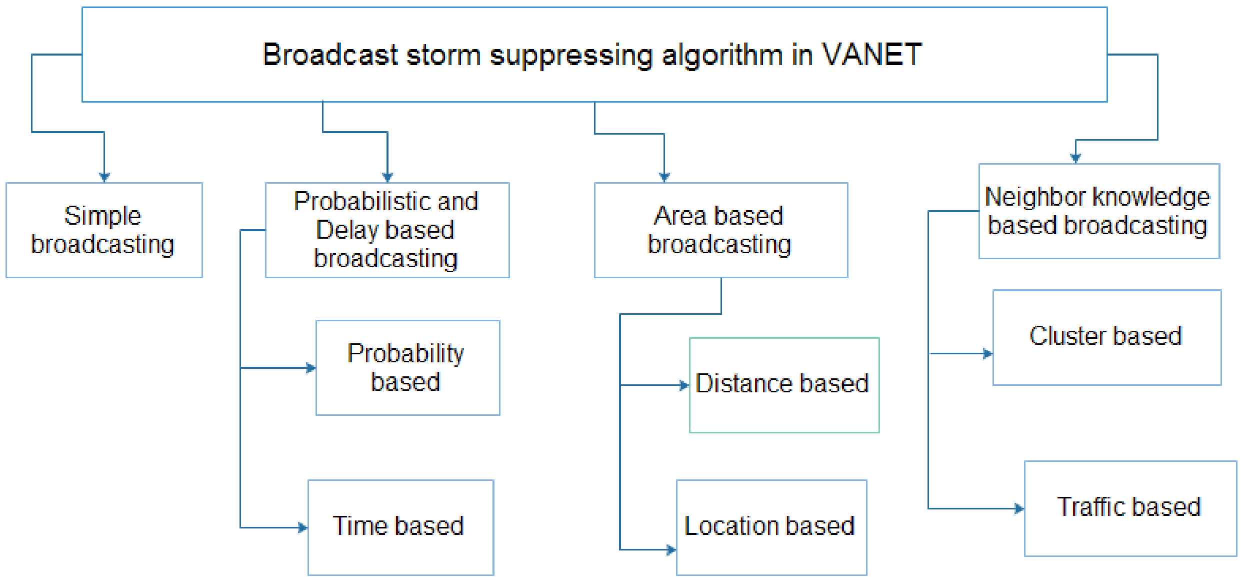

Figure 2.1 A Broadcasting Technique in VANET

1. Simple Broadcasting/flooding: The messages are simply disseminated to all the cars in the network without using any BSSA. According to flooding rule, whenever a node receives an emergency/safety message it will re-broadcast it to all other nodes in the transmission range [19]. This leads to redundant re-broadcasts of emergency/safety messages because the neighbor of the rebroadcasting vehicle may already have received the same message. In addition to this, simple broadcasting doesn't facilitate for CTS/ RTS (Clear To send / Read to send) and Collision Detection strategies. Due to this, the available channel bandwidth is wasted by sending redundant frames that will probably collide [3].

2. **Probabilistic and Delay based Broadcasting**: In this method, probabilistic based broadcasting techniques such as weighted p-Persistence Broadcasting, Slotted 1-Persistence Broadcasting, and p-Persistence Broadcasting are used to broadcast in a probabilistic way based on a certain value of chance. Probabilistic values of these methods are calculated as a ratio between the distance of the sending &receiving vehicle and the average transmission range [18]. This technique reduces the chance of BSP by selecting nodes based on a 'value of probability. This value of probability identifies the broadcasting vehicles based on their availability at border locations and the highest probability is assigned to the vehicles that have the greatest distance from the sender position [18]. Probabilistic based techniques reduce the occurrence of a broadcast storm but, does not completely overcome this problem. Because if two or more vehicles have an equal probability of broadcasting they may cause broadcast storm problem.

3. Area-based Broadcasting: The emergency messages are broadcast based on the location of transmitting and receiving vehicles in a given region. In this technique, if coverage area is less than a threshold value, the vehicles will not rebroadcast the message to the intended receiver and distance information is used to decide which nodes should rebroadcast [20]. However, this technique is completely required GPS information to identify the farthest node. For this reason area based broadcasting is not suitable for the area that GPS is not available and information may be inaccurate many times

.**4. Neighbor Knowledge-based Broadcasting***:* The messages are broadcast based on the knowledge of the neighboring nodes that requires 1-hop or 2 n-hop neighborhood information. In this technique, the cars are exchange periodic hello messages to share 1-hop or 2-hop neighborhood information with other cars. This allows them to decide the next forwarding node. However, this technique is not appropriate for high mobility nodes like vehicular ad hoc networks since messages become outdated frequently [6].

These types of broadcasting techniques help to reduce road accidents and alert the drivers about any emergency event in a particular area, thereby securing safety in road transport. In vehicular ad hoc network when a large number of nodes available in the same transmission range and re-broadcast the same message then, contend for the channel (severe contention) will occur that would lead to collisions in the MAC layer [16]. But the main requirement of this broadcasting techniques is to improve the reliability of message dissemination, through decrease dissemination delay [3]. These requirements are achieved only by the appropriate utilization of the broadcasting channel. Reducing the number of rebroadcasting vehicles in a given area of interest and selecting the best possible rebroadcasting node is the best approach to achieve this goal in VANET. Therefore there is a need for an effective emergency message broadcasting algorithm that can handle broadcast storm problems simultaneous.

2.2 Related Work

In vehicular ad hoc networks broadcasting is the best method to disseminate the Emergency Safety Message. Simple, probabilistic, timer-based, neighbor knowledge and distance-based broadcasting are the basic broadcasting techniques referred to in the literature. The detail of this technique is discussed in [19] which shows the limitation of these techniques based on some QOS metrics. Some research s that conducted on this topic is listed as the following with their drawback.

2.3.1 Distributed Optimized Time (DOT) (42): It is a recent delay-based approach that provides time slot density control to suppress broadcast storm for dense networks. In this paper the outer focus on solving the scalability issue of current research by controlling with a high precision density of vehicles within each time slot. To accomplish this, the outer consider bacon which are messages sent periodically by each vehicle containing information such as the vehicle's position and speed. The algorithm always selecting the farthest cars while reducing transmission redundancy. Despite the advantage of DOT, it uses large size of beacon message to gather neighborhood data which resulting a waste of the available channel bandwidth and the vehicle Density in each slot is not mentioned clearly. Wahabou Abdou, Benoit Darties, and Narder Mbarek propose a density and priority aware data dissemination protocol (ADM) [21]. This protocol allows the delivery of messages by given priority and density levels in VANET. In addition to this ADM allows each vehicle to dynamically adapt its broadcasting with respect not only to the network density but also according to apriority level of the message to send. Even if ADM reduces redundancy and radio interface of data flooding it does not improve the redundancy rate.

2.3.2. An efficient and robust data dissemination protocol for highway and urban vehicular Ad Hoc networks (DRIVE) [12]**:** One of the researches that rely exclusively on local one-hop neighbor information to deliver messages under dense and sparse networks. The algorithm minimizes the broadcast storm problem and increases data dissemination abilities across network partitions with short delays and low overhead by using the sweet spot to disseminate the message. But, DRIVE still suffers from increased message overhead and broadcast delay when no cars exist in the sweet spot. In addition to this, the algorithm is not considered a multi-directional high way.

The Distributed Vehicular Broadcast (DV-CAST) [10] was designed to solve broadcast storm and network partitioning problems based on the slotted-1-persistence broadcast suppression technique. The protocol mainly relies on Local one-hop neighbor information observed by each vehicle via the periodic hello messages. This requires the complete knowledge of the local (1-hop neighborhood) network topology. To know this every neighbor should have to send hello messages periodically. This introduces undesirable side-effects such as an increase of the network load, contention, wasting bandwidth and collisions when not properly coordinated. In dense network number of reception and transmission performed on average is generally increased. This is expected as more vehicles are assigned to individual time slots and thus rebroadcasting. Due to this redundant rebroadcasting ratio and the number of collisions caused by hello messages also increase.

The improved version of DV-cast A Simple and Robust Dissemination Protocol for VANETs (SRD) [4] was proposed by haqfeh Moumena, Lakas Abderrahmane to suppress broadcast storm problems further. The protocol designed with the aim of aims to deliver safety information in both dense and sparse networks. It addresses directional in-formation dissemination solution, in both dense and sparse traffic conditions on a single directional highway scenario. SDR broadcasts a message in a pre-defined Direction of Interest (DoI) after detecting an emergency. The algorithm depends on local one-hop neighbor information and does not require any special infrastructure to forward the broadcast messages or the algorithm conducted base on the V2V communication method. SRD uses broadcast suppression and SCF mechanism to deal with the broadcast storm and intermittently connected networks. It demonstrates improvement over DV-CAST protocol, in terms of high message delivery ratio, low end to end delay and robustness in different scenarios with diverse traffic conditions. SRD protocol is application-centric and unreliable for safety messages. In addition to this SRD apply only for single dimensional road scenario.

2.3.3 Susceptible infected and remove algorithm (SIR) [14]**:** In the SIR algorithm, the Emergency Safety Message is sent to all the vehicles considering the bidirectional dissemination. SIR reduce broadcast storm problem by selecting furthest vehicles as rebroadcasting vehicle. The source vehicle finds the Farthest Vehicle (FV) in its range and forwards messages to these furthers vehicles. This algorithm reduces the scalability issues in simple scenarios and improves message reliability compared to the existing algorithms, but still suffers from transmission overhead in complex scenarios. The main limitation of this algorithm is choosing one vehicle as a forwarding Vehicle is not appropriate in a dynamic network like VANET. This is because the receiver may out of the transmission range or may not receive the message due to channel problems like shadowing. Therefore in this algorithm after finding the FV the position may change in varying time and speed. So the neighbors' availability at the specific point of time is not assured in the SIR algorithm and not address network fragmentation problems. This paper considers only a high way road with directional data dissemination in dense case vehicular network scenarios. Similarly the author who called Chitra, S. Siva Sathya proposed Selective epidemic broadcast algorithm to suppress broadcast storm in vehicular ad hoc network (SEB) [22].SEB suppressed broadcast storm by sending the emergency message to selective vehicles based on passive acknowledgment. This research achieves better emergency message delivery ration by broadcasting messages to a few vehicles only. The main limitation of this algorithm is once the vehicle selected in a given area as a rebroadcasting vehicle they start rebroadcasting emergency safety messages to the required area. But in this research, the vehicle in which direction used as a rebroadcasting vehicle is not specified. If this is not insured both the outgoing and ingoing vehicles retransmit a similar message at a time which increases RRR and messages lose.

Bidirectional Data Dissemination in Vehicular Ad Hoc Networks using Epidemic Spreading Model [11]. In this research, the author proposed the message dissemination technique follows the epidemic spreading model to spread the message all over the network without repetition. This research conducted based on Susceptible, Exposed, Infected, and Removed (SEIR) epidemic spreading model by selecting the farthest neighbor as the relay vehicle to suppress broadcast storm and giving the provision of the farthest relay vehicle to rebroadcast the received message. This algorithm was created to improve the reliability of the Emergency Safety Message (ESM) dissemination thereby achieving the 100% message reachability in the highway scenario, scalability of the emergency safety message dissemination and achieve the minimal rebroadcasting vehicles, thereby reducing the Broadcast Storm Problem during broadcasting emergency safety message. The algorithm relies on the Geographic Positioning System (GPS) information to know the details of its neighboring vehicles. The main limitation of this proposed message dissemination scheme is it considers the propagation range of message transmission only in two directions (East and West) rather than all directions. Therefore the algorithm does not work for a multidimensional road scenario.

2.3.4 Urban Multi-Hop Broadcast Protocol for Inter-Vehicle Communication Systems. This research was conducted by Fusun and Umit [23] to address, hidden node, broadcast storm and reliability problems of multi-hop broadcast in urban areas. This protocol sends and acknowledges the broadcast packet to only one vehicle by dividing the road portion inside the transmission range into segments. In addition to this, the designed protocol allows choosing the vehicle in the utmost non-empty segment without a priori topology information. When there is an intersection in the path of the information broadcasting, the protocol initiates new directional broadcasts by the repeaters which located at the intersections. The main limitation of this protocol is the repeaters retransmit the same message more than once which leads to great overhead and channel wastage.

The author who called Tatsuaki et al proposed a multi-hop flooding protocol [4] to effectively disseminate the active safety information such as velocity and position to prevent potential dangers situations such as intersection collisions or accident ahead call during driving. The researcher used a backfire algorithm to forward packets efficiently by selecting the adequate receiver nodes based on the distance and implement the congestion detection algorithm to suppress unnecessary packets. The main limitation of this work is to cover the required communication range while keeping the delay time within the requirement of safety applications. Therefore, this protocol suffers from scalability issues.

2.3.5. Adaptive Multi-Directional Data Dissemination Protocol (AMD) [23]**:** The author who called (Schwartz, Scholten, & Havinga, 2013) develop infrastructure-less multi-directional data dissemination protocol for both highway and urban scenario. AMD is A Slotted 1-Persistence based algorithm that combines the distributed optimized Time and Simple and Robust Dissemination (SRD) scheme to provide full-scale solutions. This algorithm provides three different features: time-slotted density control, adaptive multi-directional dissemination, and store-carry-forward. Multi-directional dissemination is achieved by using GPS data, attaching directional vector data to warning messages, and customizing road maps. In all cases, the road map has to be pre-loaded to each vehicle and each center point of every intersection must be explicitly marked.

AMD assumed Manhattan Grid topology for urban scenario and one-dimensional topology, this reduces possible dissemination direction to two and four. The number of dissemination directions known by marking a center point of each intersection on the map when it is approaching the location (approximately 15).In this AMD adapted the sender-oriented approach, where a sender designed a group of CF to forward warning messages. Time slot density control originates from DOT, which was designed to reduce the number of vehicles that are assigned to the same time slot to prevent simultaneous rebroadcasts. However, in AMD, it is used to assign vehicles in different directions to the same time slot, therefore, accelerating the dissemination. Store-carry-forward initiates from SRD, which is designed to forward messages in a disconnected network, occurring when traffic density is low. The most distant vehicle in one of dissemination directions is assigned the duty of buffering the message. Once it encounters other vehicles outside the sender's transmission range, it rebroadcasts the message.

In AMD, before a sender broadcasts a warning message, it obtains its one-hop neighbors' coordinates data through beacons and makes a list $\vec{v}$ Then it sorts the list $\vec{v}$ by the neighbors' distance to itself (farther neighbors are put on top of the list, and the arrangement follows a spiral-shaped pattern). Next, the sender attaches list $\vec{v}$ along with the directional vector data $\vec{a}$, b where b show sectors direction and $\vec{a}$ shows the sender's velocity vector rotated by degree, where β = 360/2b. After that, it broadcasts the message. When considering a receiver, it finds its position on the list $\vec{v}$ and applies its position to the above equation. Then it sets up a timer based on the wait time obtained from the equation. Next, it will rebroadcast the message upon the timer's expiration if it does not receive any duplicate. The main drawback of this algorithm is that the vehicle in which direction of movement (in going or outgoing to intersection area) is more important to rebroadcast messages is not specified rather than a concern with several dissemination directions. In addition to this, if two vehicles are equal probability to disseminate messages in one transmission range lower priority, vehicles require to wait for the additional delay which increases waiting time that delays the delivery of ESM.

2.3.6. **How Do You Quickly Choreograph Inter-Vehicular Communications? A Fast Vehicle-to-Vehicle Multi-Hop Broadcast Algorithm, Explained** [24]**:** In this paper, the author proposed a position-aware broadcasting algorithm to reduce the number of forwarding hops based on the transmission range estimation. This timer based broadcasting algorithm flow two phases which called estimation and broadcast phases to conduct vehicle to vehicle communication. The reason behind using the estimation phase was that of making cars aware of their transmission range through hello message exchange while the broadcast phase is used to dissemination the required messages by assigning a priority of forwarding the broadcasted emergency safety message based on its distance from the source vehicle (message sender).In this algorithm the rebroadcasting vehicles are selected based on the distance they have from the sender position and the higher the relative distance, from source vehicle get the higher the priority to rebroadcast these messages. Hence the number of hops and the propagation delay are minimized. In addition to this, the algorithm control broadcast Collison by assigning different waiting time to the vehicles for messages reception and the time at which they try to forward it. Therefore the time needed by, a broadcasted emergency safety message to reach all the cars following the sender within a certain distance. The advantage of this research is not required perfect knowledge of the network topology and eliminating the performance dependency on the difference between the assumed transmission range and the actual one. But the research. The main drawback of this research only reduces the number of rebroadcasting nodes for a single directional road scenario. Furthermore, the algorithm considers the vehicle that moves on a different lane by having the same direction of movement but what happens if the vehicles move in a different direction is not included. Because when the vehicles are moving in the opposite direction or if the vehicles are moving towards to emergency area or outgoing from the emergency area the vehicle in which direction of movement should rebroadcast the emergency safety message should be specified. Unless two or more vehicles that move in the opposite direction may have equal distance from the Seder position and exposed to rebroadcast emergency safety messages in the same transmission range at the same time. This increases Collison and number of rebroadcasting nodes (forwarding hops).In addition to this since the algorithm provides rebroadcasting probability by dividing time into a slot the vehicle in other transmission ranges cannot rebroadcast the messages until the time provided by one range is expired. This makes the vehicle in other transmission range to wait for a long period when the vehicle is not available in transmission range.

In general, most of the broadcast storm suppressing techniques are based on the concept of reducing the number of rebroadcasting vehicles and varying time to rebroadcast. Varying time to rebroadcast emergency safety messages may reduce the occurrences of a broadcast storm. This makes the vehicle which requires short broadcasting time to wait for long which brings much delay to deliver these messages. The other solutions are based on reducing the number of rebroadcasting vehicles in a given transmission range. But the limitation with such solutions is that they exposed to broadcast storm problem if the number of rebroadcasting node is not correctly handled as it mentions in the above.

Generally ,from the above literature review and related work it has been pointed out that the proposed solutions to suppress broadcast storm during broadcasting emergency safety message in VANET are not complete in terms of, checking availability of the receiver before broadcasting messages,
Identifying the position of the vehicles after some movement, estimating the vehicle in which direction of movement should be more appropriate to rebroadcast message in a multi-directional road scenario. Furthermore, most of these solutions are proposed for a single directional road scenario that misses some possible rebroadcasting direction. Therefore further solutions that can handle this problem are required for VANET.

This research is conducted to address problems observed in the existing broadcast suppressing technique by developing a sender decision based selective broadcasting algorithm that suppresses broadcast storm in a multi-directional road scenario. The suppressing technique achieved by allowing a few vehicles to act as rebroadcasting node. In addition to this, the algorithm can check the availability of neighbors before broadcasting emergency messages and thus reduce messages loss. Furthermore, the algorithm estimates the direction of movement to identify the vehicle in which direction of movement form the intersection point is best to rebroadcast messages. This is mainly important for the roads which have more than one lanes in a similar direction.

CHAPTER THREE

3. PROPOSED SELECTIVE BROADCAST ALGORITHM FOR VANET

3.1 Introduction

Vehicular ad hoc networks (VANET) exposed to the BSPs when all the vehicles or a large subset of them rebroadcast information at the same time during the high-density network. When this happens, the medium access competition will increase, which brings a high packet loss, message collisions, high delay in message delivery, and hidden terminals issues. This high packet loss ratio during a broadcast storm may cause other urgent safety messages to get lost. Therefore, to prevent losing important messages, it is necessary to design a broadcasting algorithm that can suppress the broadcast redundancy in VANETs. To solve these problems vehicular ad hoc network uses two approaches. These are, minimizing the number of broadcasting vehicles and varying time to rebroadcast. This algorithm mainly focuses on the reducing number of broadcasting vehicles by providing permission to rebroadcast the emergency safety messages only to selective vehicles. This section discusses the proposed sender decision base selective broadcast algorithm.

3.5 Research Assumptions

In this algorithm the suppressing method are based on the following assumptions: The proposed traffic model are similar to Manhattan grid model on the map and all nodes are equipped with GPS receivers, digital maps, optional sensors and On Board Units (OBU). The vehicles estimate their transmission range and direction of movement dynamically and only the vehicle that ingoing to the intersection point are selected as rebroadcasting node. The node make communication only via the ad-hoc network and there is no other communication infrastructure. Node power is not the limiting factor for the design. Communications are message oriented and the Maximum transmission range for both source and selective vehicles are 300m.

3.6 Descriptions of the Proposed Selective Broadcast Algorithm (SBA)

This section describes the proposed sender decision based Selective broadcast algorithm that develops by applying an epidemic spreading technique called Susceptible, Infected and Removes on a fast broadcast algorithm.

Road traffic injuries cause considerable economic losses to individuals, their families, and nations as a whole. These losses would have been minimized if drivers had been informed of the risk ahead in advance. To do this almost all safety applications will possibly work in a broadcast fashion since EM is useful to all vehicles surrounding the emergency area. In this case flooding data blindly cause a serious problem on information dissemination. Since the sender decision-based broadcasting method in which the sender makes the decision which vehicle will be used as the best relay to rebroadcast the emergency message is required for VANET. This eliminates the long waiting time and broadcast storm problem observed in the existing system.

Naturally, traffic accidents may occur either on a road or at an intersection which triggers the initialization of emergency messages in VANET. The proposed selective broadcasting algorithm mainly concern with an accident which occurs at the intersection point, where message required to be broadcasted to multi-direction (all direction). In this case, if source vehicle broadcast message to all and allow all vehicle to re forward message there is an occurrence, collision, message redundancy and channel wastage which called broadcast storm problem.

The proposed sender decision based selective broadcast algorithm which called selective broadcast algorithm (SBA) is developed to handle these kinds of problem that observed in existing broadcasting algorithms where, source vehicle select a single relaying node based on the direction of movement, distance and passive acknowledgment which send from Interested Neighbors.

Hence, Redundant Rebroadcast Ratio and broadcast storm problems (BSP) are minimized by selective forwarding in a dynamic topology through vehicle passive acknowledgment. In this algorithm when a source vehicle receives or detected any emergency event, it searches the neighbors' list by using the beacon message and waits for P-ACK before broadcasting these emergency safety messages to improve the availability of the receiver. The neighbors who reply for the connection are named as Interested Neighbors (IN) and the message is spread only to the IN to establish an adaptive path. After receiving P-ACK the source vehicle starts broadcast to all vehicles in it's transmission range. Among this interested neighbor (IN) it finds the most distance (furthest) vehicles in all directions which forward the emergency messages to the next transmission range. This selective vehicle is called at most distance infected vehicles (AMDIV) while the rest that available in that transmission range are called exposed vehicles. In this case, only these selective vehicles are responsible to rebroadcast the messages to the required area. Thus, reducing the redundant rebroadcast as well as broadcast Storm Problem.

This selective broadcast algorithm (SBA) flows two phases to achieve the expected goal. The first one, named estimation phase, allows the vehicles to estimate their transmission range as it mentioned in a fast broadcasting algorithm (15) and Estimate (identify) their direction of movement which proposed in this research. While the second one is called broadcast phase which performed when an emergency occurs and emergency safety message has to be broadcasted to all cars in area-of-interest. The broadcast storm suppressing technique is also used in this stage.

1. Estimation Phase

A. Transmission Range Estimation

In this phase, both source vehicle and selective vehicle try to estimate its transmission range employing hello message as it solved in (15).The goal of this estimation is that of having all the cars aware of their transmission range and use (exploit) it in the broadcast phase. The transmission range of source vehicle called frontward while the transmission range of selective Vehicle is called backward transmission range. This is because the direction of the rebroadcasting vehicle should be towards the intersection point to prevent the outgoing vehicle from rebroadcasting the emergency messages. The reason behind this is research mainly concern with an emergency that occurs at the intersection point, so the vehicle that moves out (outgoing) from a zone of interest does not require to rebroadcast the emergency messages because there are moving out of the emergency area. But the vehicle that ingoing to the transmission range should be retransmitted backward to all the vehicles behind it in its transmission.

In this continuous estimation of their transmission range time is split into turns and information gathered during a certain turn are held also for the entire period of the next one. Discarded for the entire period of the next turn. Information for the present turn is represented as Current-turn Maximum Back Range (CMBR) and Current-turn Maximum Front Range (CMFR). The CMFR represents the estimation of the maximum front distance (the maximum distance source vehicle can cover to disseminate emergency safety messages in its area of interest) while CMBR maximum backward distance that the selective vehicle can cover. These two variables are updated until the current turn expires on the received hello texts and the value stored as the latest-turn maximum backward range (LMBR) and the Latest-turn Maximum Front Range (LMFR) respectively.

B. Estimating Direction of Movement

Estimating direction of movement helps the vehicles to know either they are moving towards the intersection point or outgoing from the intersection point (moving towards to source vehicle or opposite direction). This method also makes it easier to identify optimal forwarder. Let V= {v1, v2…..Vn} is a set of vehicles and every node can discover whether they move towards the source node or not based on the information about the distance between the current node and the source code. During vehicle selection the distance of vehicle at the time of sending passive acknowledgment represented by Dist(VP_PACKt) and the distance of vehicles at the time of initiation through beacon messages represented by Dist(VBt). If the first condition is satisfied or the value becomes true the vehicles are in going to the intersection point and they can act as next rebroadcasting vehicles. But if the second condition is satisfied the vehicles are outgoing from this intersection point and they cannot act as rebroadcasting nodes. Otherwise, the issues show ignore indication.

$$MD = \begin{cases} T, \text{IF Dist}(\text{Vp}_{\text{ackt}}) < \text{Dist}(\text{VBt}) \\ F, \text{IF Dist}(\text{Vp}_{\text{ackt}}) < \text{Dist}(\text{VBt}) \\ I, \text{otherwise for all conditions} \end{cases} \quad \text{…………eq (1)}$$

According to this research, the vehicle that moves towards the intersection point is selected as rebroadcasting vehicles. This is because the vehicle which outgoing from the intersection point already hears the occurrences of emergency in the transmission range of the source vehicles. Therefore this rebroadcasting occurrence of emergency is more important for the vehicle that travels towards the intersection point. For this case, the number of rebroadcasting vehicle is also reduced to specific vehicles which reduce Redundant Rebroadcast Ratio.

2. **Broadcast Phase:** This phase is triggered by the running application and produce a broadcast message that has to be propagated over the whole area of interest which later rebroadcast by selective vehicles. This broadcast message contains information such as Vehicle ID, Emergency safety message ID, rebroadcast ID, PA_ACK, maximum distance, maximum transmission range and vehicle position that support application that utilized by the algorithm. During broadcasting emergency safety message, to minimize the number of rebroadcasting vehicles, and to hence the ESM delivery ratio the algorithm allows to find the farthest vehicle which called at the most distant infected vehicle (AMDIV) from neighbors list to perform this

task. This selection method is based on an epidemic spreading technique. In this technique initially, all vehicles are considered as susceptible. As Soon as emergency detected by source vehicle, source vehicle search it's neighbor by using beacon messages. The neighbor who replays to the connection through passive acknowledgment is selected as the next rebroadcasting vehicles. Therefore, the vehicle that sends passive acknowledgment, have higher distance and ingoing to the intersection area are considered as the rebroadcasting vehicles.

More in detail, when a vehicle detects or receives occurrences of emergency it initiates the neighbor through beacon message. Then the neighbor which is free and wants to rebroadcast the emergency safety messages replay to the connection through passive acknowledgment. These neighbors' are called interested neighbors (IN). Among these interesting neighbor source vehicles select the furthest vehicle and check the direction of the movement as it missioned in eq(1) to forward the emergency safety messages to these selective vehicles all direction. This case all the vehicle that exists in the transmission range of source vehicle get priority while the rest are based on the sender decision (source vehicle's decision).

The main target of this proposed algorithm is to conduct emergency safety messages dissemination within the Transmission range of each vehicle which reduces the broadcast storm problem and enhances the delivery of the emergency message with a short delay. To do this the algorithm applies the SIR epidemic spreading technique which was discussed in (18) on a fast broadcasting algorithm. Based on the SIR epidemic spreading technique the process of passing information from one vehicle to the other takes place based on these two methods.

1. State transition of each node at a particular time point. This show state when the nodes are changing form suspected to infected and from infected to remove.
2. Information spreading between the various nodes (vehicles). This shows the state where the infected node starts to disseminate the emergency message/state of communication.

To achieve this transition by analogy to the epidemic spreading in a human network, a vehicle in VANET can be in any of the following three states called the communication life cycle.

Susceptible(S): It is the state in which a node is ready to receive any message. The node in this state has never received the information from the source is in the susceptible state (S), in which the node can accept incoming transmissions if an opportunity arises. A susceptible node goes into the state of Infected state (I) after a time.

Communicable State (Infected (I)): The state in which a node has to spread the message. The node incommunicable state (I) keeps transmitting the emergency message, i.e. remain infectious, for a certain period, after which the vehicle enters into the 'Removed' state. This state is also called Communicable Infected Vehicles since the infected vehicle is responsible for rebroadcasting the message to the next transmission range.

Non-communicable State (Removed): The state in which the node will ignore the message already received. A node in this state stops transmitting the information to other nodes and will ignore all future transmissions of the same information from other nodes. In this life cycle, the information transmission should flow according to the given step which means information flow starts from Susceptible to Infected than to remove state.

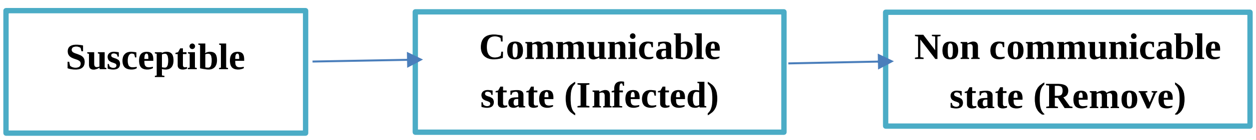

Figure 3.1 Epidemic spreading life cycle [14]

In this epidemic spreading technique the states *R* is temporal and the vehicles in these states do not react to a message, while the state *S and I* will take some action or other when a message is received or when an emergency is perceived. After a certain passage of time, when the message ceases to have any impact on the vehicles, the vehicles in state *R* switch back to the susceptible state. The main reason of using epidemic spreading technique in this algorithm is to show how the emergency/safety messages are disseminated to the neighboring vehicles, how the vehicles react when they receive a new or old message, how to infect (disseminate emergency message to other vehicles in emergency situation) the other vehicles thereby reducing BSP.

Figure 3.2 shows a Multi-directional road scenario in SBA (north, south, east and west) traffic scenarios based on epidemic spreading technique and fast broadcasting algorithm. Each stage of communication represented by a set of colors. The yellow color shows a set of susceptible vehicles when vehicle start communication, the red color represents the source vehicle(SV) which receive or detect the occurrences of emergency and decide which vehicle is responsible for rebroadcast emergency safety messages finally ,the green color shows a set of interesting vehicles which ready to rebroadcast emergency safety messages.

The architecture also contains two transmission ranges which represented as a zone of interest (ZOI) that represented as a Current-turn Maximum front Range in the algorithm and used to show the transmission range of source vehicles can cover. While TRS represents the transmission range of the selective vehicle (Current-turn Maximum back Range).This shows the maximum distance that the selective vehicle can cover to retransmit the emergency safety messages to the next transmission range. Most distant infected vehicle (MDIV) represents a set of furthest selective vehicles selected by source vehicle to rebroadcast emergency safety messages.

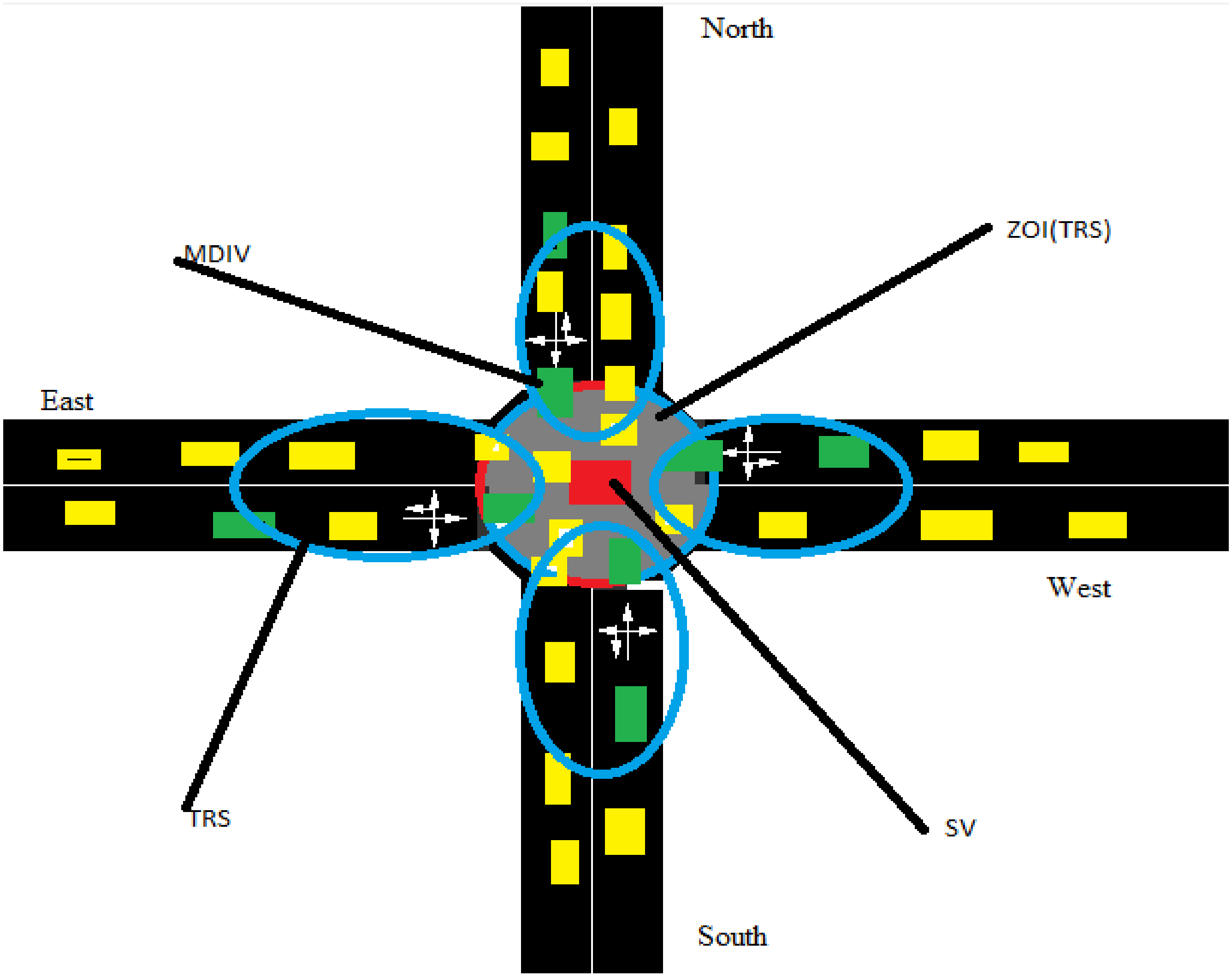

Figure 3.2 Multidirectional Road Scenario in SBA

Initially, all vehicles are in a susceptible state where all vehicles are ready to receive an emergency message. This phase named as estimation phase which is continuously active to provide each car with an up-to-date estimation of its backward and front transmission range as it missioned in a fast broadcast algorithm. The vehicles are moved to the south, east, west, and north by having their line through estimation of their transmission range. After a while where source vehicle (SV) detects or receives the occurrence of an emergency, it initiates the neighbor to check their availability in the transmission range of source vehicle by using beacon messages. The full procedures are shown in the following diagram. In the diagram Time To Live (TTL) represent the total time the emergency safety message take before expired while T represent time to broadcast or the time that taken by vehicle to infect all the vehicles in its transmission range. Furthermore DM represent direction of movement and DI, DV stands for distance of infected vehicle and Distance of all vehicles in that transmission range respectively.

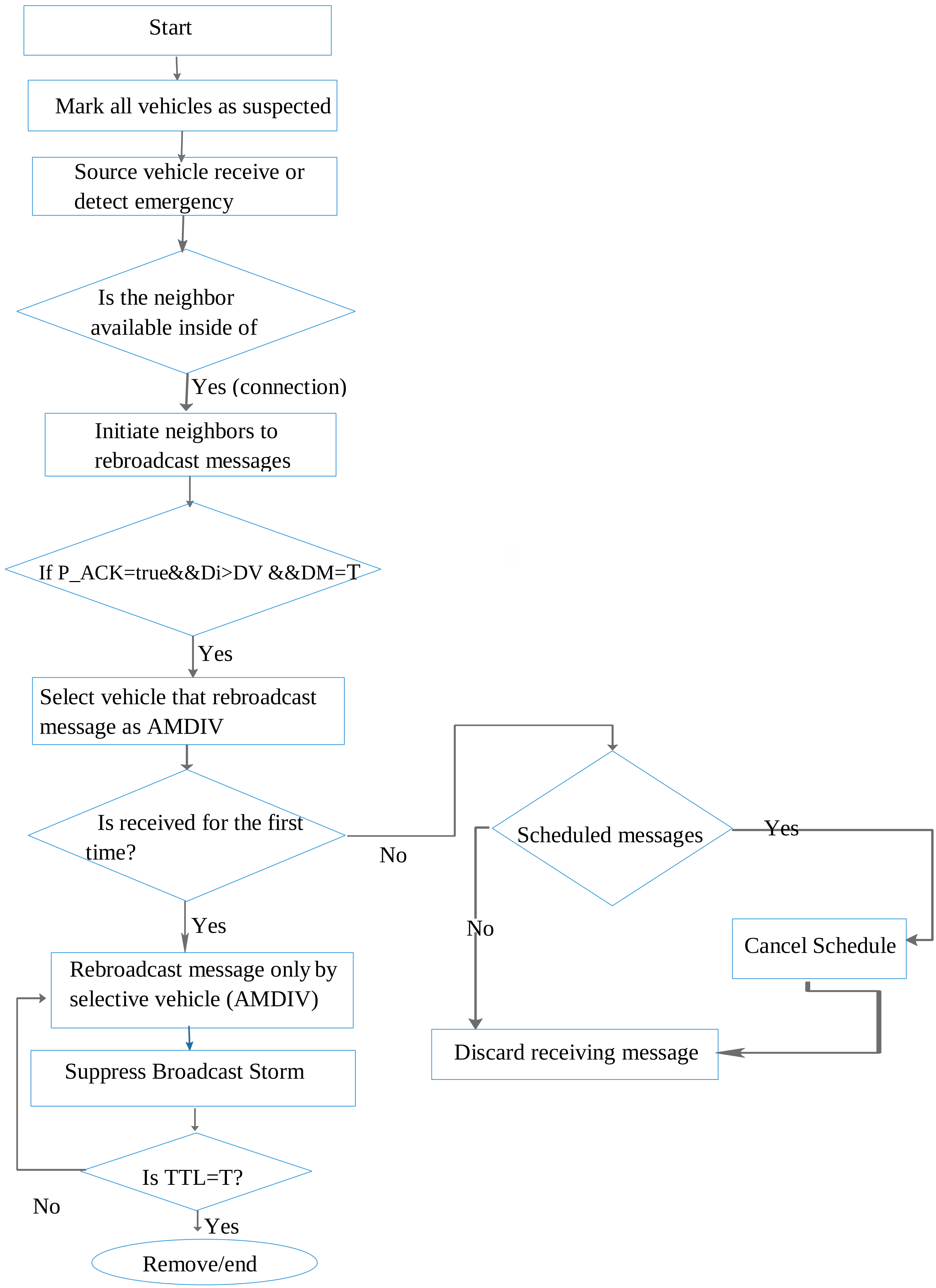

Figure 3.3 Selective Broadcast Algorithm

If vehicles are available in the transmission range of source vehicles they replay to the connection through passive acknowledgment (P_ACK).The purpose of sending this acknowledgment is to identify the exact rebroadcasting vehicle position and its availability. As soon as the source vehicle receives this acknowledgment it checks an additional two parameters to select vehicles as rebroadcasting vehicles. These two parameters are distance and direction of movement. In general to select the vehicle as rebroadcasting algorithm use the following three criteria:

1. **The Direction of Movement (DM)**: As it is shown in the above model the vehicle can move into the intersection point and outgoing from the intersection point. Therefore we should specify for which direction the message is more important to reduce the rebroadcasting vehicles. According to this research, the direction of the rebroadcasting vehicle should be towards the intersection point to prevent the outgoing vehicle from rebroadcasting the emergency messages. The reason behind this is research mainly concern with an emergency that occurs at the intersection point, so the vehicle that moves out (outgoing) from a zone of interest does not require to rebroadcast the emergency messages because there are moving out of the emergency area. But the vehicle that ingoing to the transmission range or emergency area should be retransmitted backward to all the vehicles behind it in its transmission.
2. **Distance from Source Node:** In this case the node that is the furthest from the sender and still in its radio range is used as a relay for the message, to rebroadcast the message to the next transmission range. This node is called the at the most distant infected vehicle (AMDIV). This is reasonable because all the nodes between the source vehicle and this furthest node would be already received the broadcast message the decision for this criterion will depend on the passive acknowledgment that sends from AMDIV to source vehicles in the network and their distance. This criterion is used to minimize the number of rebroadcasting nodes that used to minimize redundant rebroadcast and broadcast storms.
3. **Passive Acknowledgments (P_ACK):** Most of the reputation-based schemes make use of promiscuous listening or passive acknowledgments to observe their neighbor's for packet forwarding activities. In this research, these passive acknowledgments use for channel listing and position identification.

Let DM represent the direction of movement, DV is the distance of all vehicles in one transmission range, DI represents the distance of furthest vehicles and finally, passive acknowledgment represented as P_ACK.

So the algorithm selects the rebroadcasting vehicle if P_ACK=true&&DI>DV&&DM=Front that means

1. P_ACK=true (the vehicles send the passive acknowledgment to source vehicle to show as their channel is free)

2. DI>DV (Distance of furthest vehicle greater than a distance of all vehicles in a given transmission range)

3. DM=Front (direction of vehicle movement is towards the intersection point) then source vehicles select the rebroadcasting vehicles and check if it receives the message for the first time before broadcasting this message to it. The vehicle that selects as to rebroadcast emergency safety messages is called at the most distant infected vehicle (AMDIV) whereas all vehicles in that transmission range called Interesting Neighbors (IN). Except for the AMDIV the remaining vehicles' are considered as ‘‘Exposed “Vehicles. These exposed vehicles cannot rebroadcast the emergency safety message.

Therefore these AMDIV vehicles are considered as infected vehicles and continuous to infect others in it's transmission range until time to live (TTL) is expired. TTL means the general time the emergency message takes before expired. After some time or the emergency safety message expired the vehicles are going to the state of Removal. In this state, the vehicle ignores all the message and this state is known as the non-communicable state.

4.6.2 Creating Traffic motion for Multi-directional road scenario

This section describes the real traffic model that crated for a multidirectional road scenario. This real traffic motion conducted by using simulation of urban mobility (SUMO) and network editor (Net Edit). The main goal of creating this real traffic motion is to generate a network of vehicles for the proposed algorithm and convert it into NS-2 to evaluate the performance of the proposed algorithm. The procedures used for creating this real traffic motion and how it converts to NS-2 code (connected to the proposed algorithm) is presented as the following:

First, we should have to create a real traffic motion for a multi-directional road scenario according to the proposed algorithm by using Net Edit software installed inside SUMO directories. This net edit software allows us to edit the XML configuration of a virtual network, using their preferred editor. In addition to this net edit important for topology projection of different road scenarios.

1. Open Net Edit from < sumo_install directory>/bin and select File-->New Network to create a new sumo network. After opening the environment we should have to enable a chain and two-way button at the top of Net Edit to start the projection. Then select the create edge button and start to create an edges by pressing the blank white area. To connect one edges to another again click the blank white area by selecting the appropriate location. This allows automatic edges connection between new plotted edges and the previous edges.
2. Select "**(c) Connect**" from the drop-down. Select the lanes and ensure connectivity between them. In this case, when all lines are connected the all the points are changed from red color to green color to show the establishment of the connection. When this network establishes correctly create a folder called SBA then save this network files test.net.xml. The reason behind saving the file as net.xml is that the SUMO network file is not meant to be edited by hand. Therefore, to edit this file we should use SUMO XML description files together with net convert which allows loading the simulation file easily.
3. After creating a network file now we should have to create a routing file by using random trips. To do this open command prompt with the current working directory as the folder where you have saved the network file in the previous step? Then generate the routing file for the above network by using the following command.

   Python /C:\Program Files (x86)\DLR\sumo\tools/random trips.py –n test.net.xml -r test.rou.xml -e 50 –l
4. After generating this routing file now create the SUMO configuration file (*.sumocfg) which points to the networks and rout files as the following.

```xml
<?xml version="1.0" encoding="UTF-8"?>

<configuration>

    <input>
        <net-file value="test.net.xml"/>
        <route-files value="test.rou.xml"/>
    </input>

    <processing>
        <time-to-teleport value="-1"/>
    </processing>

    <report>
        <verbose value="true"/>
        <xml-validation value="never"/>
        <no-step-log value="true"/>
    </report>

</configuration>
```

Then save the configuration file as myconfig.sumocfg then run by typing sumo-gui myconfig.sumocfg in Ubuntu terminal and following real traffic simulation is created for multi-directional road scenario.

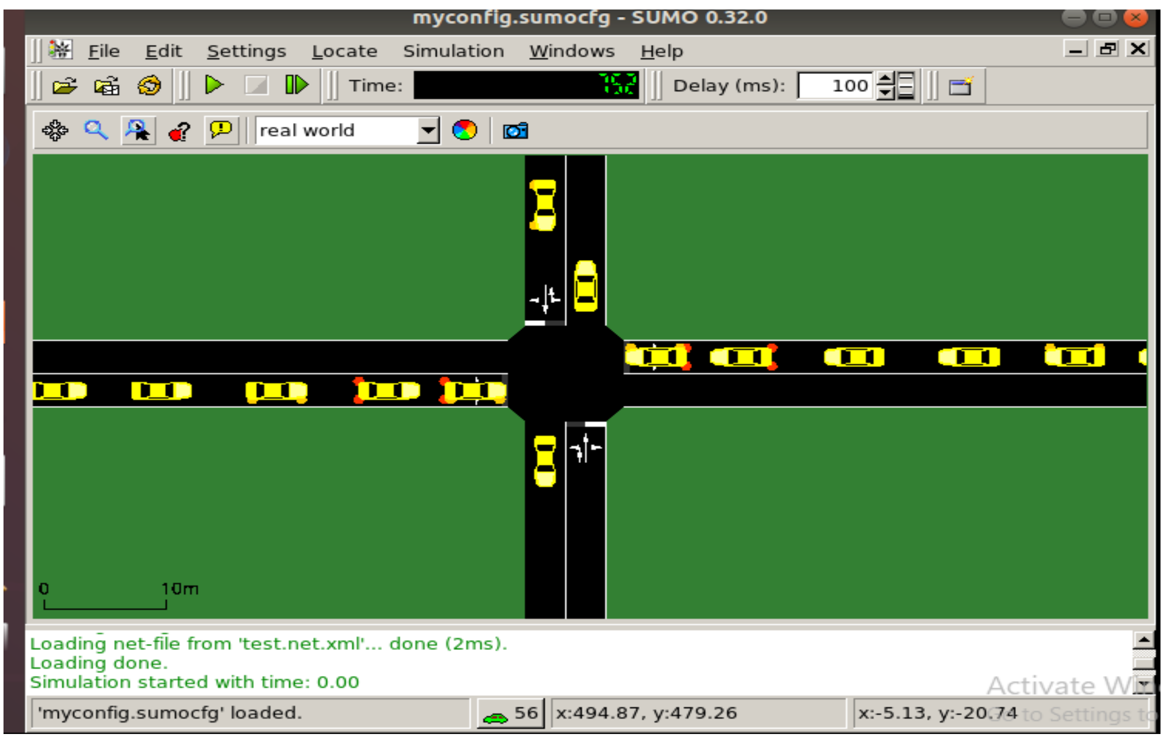

Figure 4.4 Traffic Motion in Multidirectional Road Scenario

5. Then generate the output of this file by using this command SUMO –c myconfig.sumocfg –fcd –output sumoTrace.xml on Ubuntu terminal. Float car data (FCD) represent an output file that contains the location, speed, vehicles angel, position, lane along with other information for every vehicle in the network at every time step. This FCD is like a GPS device for each vehicle. The output can be processed further using the Trace Explorer tool**.** Then the outcome of this file is stored in the folder where we do the simulator which created in above as sumoTrace.xml. Step 1-5 shows how to create a multi-directional road model for the proposed algorithm and how we can create a network of this file to develop a real traffic motion in a multi-directional road scenario. Now after creating this real traffic motion, we should have to connect to the proposed selective broadcasting algorithm for better performance evaluation. This should take place by using the following command.
6. The final step concern with connecting the model that creates in the above sumo file to generate real traffic motion to the developed SBA algorithm for further evaluation. Due to this write following command on Ubuntu terminal which provides an executable tcl file.

Python /C:\Program Files (x86)\DLR\ sumo-0.32.0/tools/traceExporter.py --fcd-input sumoTrace.xml --ns2config-output SBA.tcl --ns2activity-output activity.tcl --ns2mobility-output mobility.tcl

This command generates three output files which called activity.tcl, mobility.tcl and SBA.tcl base on the input file that gets from sumoTrace.xml. In this context the mobility.tcl file is used to know the mobility pattern of moving vehicles in the NS2 network while SBA.tcl (configuration file) used to set parameters that use in this simulation in addition to this ns2 activity.tcl used to generate ns2 activities file contains in each step sumo simulation.

7. After connected the created sumo real traffic motion to the proposed SBA algorithm type the following command on the Ubuntu terminal and a set of susceptible vehicles are start motion in NS2 environment.

   Gedit ns SBA.tcl

   Ns SBA.tcl

   nam SBA.nam

In this case, the command gedit SBA.tcl is used to load the configuration file for further edition if required, ns SBA.tcl to create the trace file and nam file of the configured data while nam SBA.nam used to display the movement of nodes based on configuration files.

4.6.3 The Implementation

First the real traffic motion are created using SUMO and in this stage the net file, rout file, configuration file and trip files are generated as it mentioned in the above section .The net file are used to create a connection between edges and nodes, the rout file are used to create a motion to make a communication between vehicles and finally the configuration file used to display the outcome of this real traffic motion. This real traffic motion are equivalent to the real traffic motion that generated from open street map. The traffic motion that create in this research are used to make clear how the vehicles are move on multi -directional road scenario. The result of this is similar to the Manhattan grid mobility that generate from open street map.

At the end the generated Sumo file connect to NS2 (the proposed algorithm) for network simulation and analysis of the result. Since Sumo file is bulky file it impossible to copy on this paper but, as sample rout file is missioned at appendix C.

To implement this broadcast suppressing algorithms the proposed suppressing mechanism are incorporate to existing fast broadcast algorithm by modifying the C++ code of the fast broadcast algorithm. Some of the modifications (C++ codes) made to implement broadcast suppressing mechanisms are attached in appendix B. In addition to this, sample mobility file, and AWK scripts are shown in appendix A, D, respectively.

Generally, the proposed algorithm broadcast messages during the emergency situation from the source to the selective vehicles in its transmission range. Since the message is not reaching all the transmission range by source vehicle, the selective vehicle rebroadcast these messages to the back to the next transmission range to solve the broadcast storm problems in a multi-directional road scenario. During broadcasting, this emergency messages source vehicle selects the rebroadcasting node based on the direction of movement, distance, and passive acknowledgment. The vehicle that full file this requirement select as rebroadcasting node to next transmission range and apply a similar method as source vehicle while rebroadcasting it. Therefore this research solves the broadcast storm problem observed in the existing system by selective broadcasting in a dynamic network.

CHAPTER FOUR

4.1 SIMULATION AND EXPERIMENTAL SETUP

This section describes the performance comparison of the proposed sender decision based selective broadcast algorithm (SBA). The main aim of this research is to minimize the wide variety of rebroadcasting vehicles that rebroadcasting emergency safety messages in the dynamic network through selective broadcast to reduce the impact of the broadcast storm during broadcasting emergency safety messages. This enhances the emergency safety delivery ratio by reducing delays. The results of the proposed SBA algorithm are analyzed through simulations using NS-2 Simulator version 2.35 and SUMO version 0.32.0 then the proposed algorithm in contrast with a simple flooding and fast broadcast algorithm. The results of this algorithm are obtained under different vehicle density and different vehicle moving speeds during rush hours such as dense network scenarios. To show the impact of broadcast storm in all case the simulation conduct under two different scenarios which contain 20, 40, 60, 80 and 100 number of vehicles per kilometer to analyze the impact of broadcast storm at low, medium and high dense road condition and at various vehicle speed which range from 30, 60, 90 and 120 km/h which will explained in detail next section. Before that, the simulator used in VANET, and integration of SUMO with NS-2 for VANET simulation are introduced.

4.2 Simulator in VANET

Unlike other networks, no single simulator is best for all the use-cases in VANETs. This is because VANET requires the integration of traffic and network simulator to perform both traffic and network simulation simultaneously. This decision depends on what simulation and what parameters you want to simulate with VANET. Therefore VANET adapted to the following simulators to score better results.

4.2.1 OMNET++

OMNeT++ is an object-oriented network simulation framework that used for modeling communication networks, multiprocessors and other distributed or parallel systems. The simulator is completely written in C++ for modeling communication networks and to simulate networks for both wired and wireless. OMNET++ is a general-purpose simulator that can able to simulating any system composed of devices interacting with each other. It provides a hierarchical, component-based and extensible architecture. The component and are written in C++, and assigned into larger components using a high-level language (NED). This simulation can be implemented under various user interfaces which useful for demonstration and debugging batch execution purposes. But this simulation tool does not offer many protocols and very few protocols have been implemented leaving users with significant background work and Poor analysis and management of typical performance. In addition to this, the mobility extension is relatively incomplete. Due to this limitation, the OMNET++ simulator is not suitable to simulate VANET.

4.2.2 NetSim

This simulation is a discrete event simulator covering a large area of wired, wireless, mobile and sensor networks. NetSim comes with a simple and user-friendly GUI used for network lab experimentation and research. The simulator comes with an in-built development environment, which serves as the interface be-tween User's code and NetSim's protocol libraries and simulation kernel [25]. The simulator provides network performance metrics at different abstraction levels such as network, node, sub-network, and a detailed packet trace. NetSim is existed as the standard version and is built on a common design framework of huge level architecture and code. NetSim is versatile and robust that provides features that do not exist in other simulators. The main drawback of this simulator is it is a single process discrete event simulator that does not support multiple processes such as network and traffic simulator which is basic for VANET. In addition to this, the free version of this simulator is not available. Due to this limitation, NetSim is not appropriate for VANET simulation.

4.2.3 Network Simulator 2 (ns2)

Network simulator (NS-2) [26] is one of the most popular event-driven simulator tool that has proved useful in studying the dynamic nature of communication networks. NS2 designed especially for network research and can be used as Simulation for wired moreover as wireless network functions and protocols (e.g., routing algorithms, TCP, UDP). The simulator gains constant popularity in the networking researches community due to its flexibility. This discrete-event simulator mainly associated actions with events rather than time and allow having variable time between a pair of events.

NS2 contains C++ and Object-oriented Tool source language (OTcl). These define the inner mechanism (i.e., a backend) of the simulation objects and setup simulation by aggregation and configuring the objects additionally as designing distinct events (i.e., a frontend) respectively. In NS2 simulator OTcl used to create network configuration while C++ used to run the simulation.

All C++ codes need to be run and linked to provide an executable file. The massive body of NS2 prevents the compilation time from negligible. The NS2 simulator allows users with an executable command ns which takes on an input argument and the name of a Tcl simulation scripting file. To visualize the result a simulation trace file is created and is used to plot graphs and/or to create animation. Users can analyze the specific behavior of the network by extracting a relevant subset of text-based data and transform it into a more conceivable presentation. The NS-2 simulation flow is shown in figure 3.1[12].

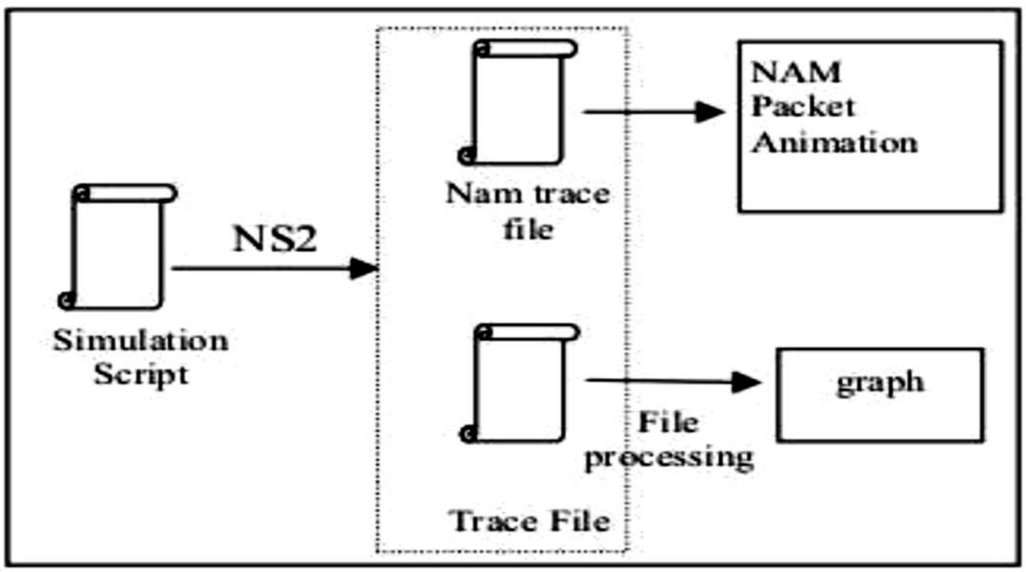

Figure 4.1 NS-2 Simulation Process Flow **[27]**

Unlike other networks, no single simulator is best for all the use-cases in VANETs. This is because VANET requires the integration of traffic and network simulator to perform both traffic and network simulation simultaneously. This decision depends on what simulation and what parameters you want to simulate with VANET. Therefore VANET adapted to pair of simulators to score better results. In this case, many of them are not correctly inter-operate. The most common reason is the mismatch in formats. The mobility models generated by the traffic simulator cannot be processed by the network simulator. When traffic simulators create mobility models, this format is not acceptable by the network simulators. In this case, the closest network candidate is NS-2, discrete event simulators that accept trace files from other simulators are better to simulate VANET. Therefore NS-2 is the popular network simulator that can easily be integrated with traffic simulator (SUMO) to perform traffic and network simulation simultaneously. NS-2 has a large number of available models, realistic mobility models, powerful and flexible scripting, simulation setup, large user community, and ongoing development to modify existing algorithms. Based upon this fact NS2 is better than the above two simulators to simulate VANET.

4.2.4 Simulator of Urban Mobility (SUMO)

SUMO [11] one of the best traffic simulators developed by the Institute of Transportation to reduce the impact of the road accident. It is a highly portable microscopic open-source road traffic simulator that developed to manage large road networks. It includes a multimodal simulator for road traffic and a bunch of applications for preparing simulation input data such as traffic import, routing, network import and modification for working with simulation output. This simulator will introduce some files which can port into NS2 to improve the reality of VANET simulation. In this case, SUMO used to model a multidirectional road scenario with the help of Net Edit and simulate the generated real traffic motion.

4.2.5 SUMO and NS2 integration for VANET simulation

Network Simulator 2 (NS2) is an event-based discrete network scenario simulation software for various protocols in Internet systems and targeted primarily for research and educational use [12]. Since the result of sumo is not directly accessed by other network simulators we should have to implement it using the NS2 simulator. First, the road topology designed based on the proposed algorithm. Then based upon the designed topology we should have to generate network via NETCONVERT which is network importer and generator that reads road networks from different formats and converts them into the SUMO-format, or by creating a set of edges and connecting them on Net Edit, rout files and configuration file which used to store information and settings.in addition to this we should have generated a trace file which is important to create a network scenario for the network simulator which is NS 2 in my case by using SUMO Trace exporter . Finally convert the traffic data file into actual/destination trace file format which is NS2 tcl script that provides three output files called as mobility file, activity file, and configuration file. The sequence of steps in the integration of traffic simulator and network simulator is shown in the following figure.

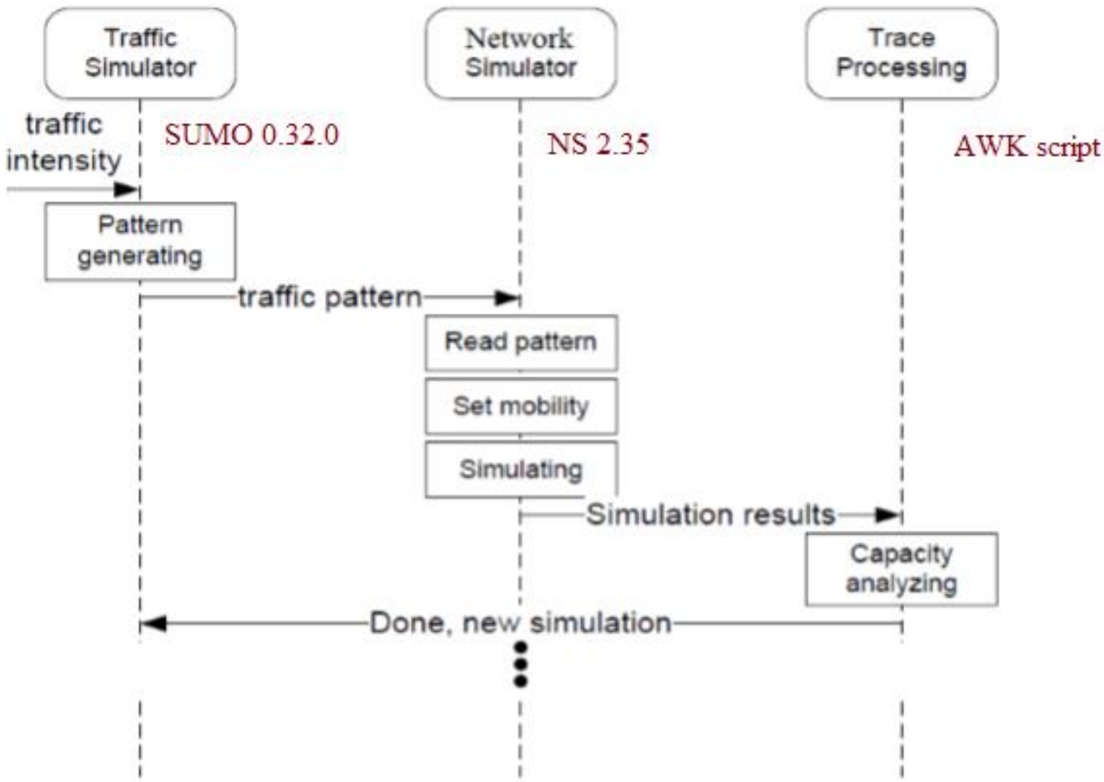

Figure 4.2 Integrating SUMO with NS2 Simulator Process Flow **[18]**

4.3 Simulation Set up and Parameter Description

This simulation conducted under two different scenarios for different vehicles' density and vehicles' speed to show the impact of broadcast storm problems while disseminating an emergency message. The result of this simulation is also analyzed based on these two conditions. First, the simulation conducted to analyze the impact of broadcast storm problem during broadcasting emergency message under different vehicles' density which range from 20, 40, 60, 80 and 100 vehicles per kilometer and average speed (50 km/h) as explained in [28] for low, medium and high dense traffic scenario. The value is taken as assumption because there is no similar standard for how many vehicles can one road hold. In addition to this section important to identify the relationship between vehicle densities and broadcast storm problem.

The second simulation conducts to show the impact of broadcast storm problem on the dissemination of emergency messages in various vehicles speeds that range from 30, 60, 90 to 120 km/h and average density (60/km). This driving speed and average density of the vehicles are used based on the standard that the previous work used to analysis the simulation result which missioned in [41, 42] clearly. The reason behind using this standard is in the entire of the world each country use their speed standard to drive the vehicle base on their road topology and technology facility.

To evaluate this algorithm multi-directional traffic (multi-directional road) scenario is considered. This multi-directional traffic scenario concern with the motion that takes place in four directions south, east, and west. In this simulation, it is assumed that the road length is 1Km in all directions to control the vehicle that move in four direction under radio transmission range. By the same case the two ray ground propagation model is used in this simulation for predicting the received power at large distances from the transmitter and when the transmitter is relatively high above the ground. The speed of transmitting the beacon message is 1 packet per second to update the neighbor information frequently .The reason behind using 1s for beacon sending interval is that due to the high speed of vehicle they change their position, distance and transmission range frequently therefore short waiting time is assigned to update the neighbors.

The maximum transmission area (range) of each car considered 300 m .This restriction is used due to the research is based on V2V communication which use Dedicated Short Range communication frequency to transfer data between vehicles which cover up to 300m . The simulation using 128 bytes total messages, including passive acknowledgment (P_ACK), Emergency, Beacon Message, and Safety Message. The reason behind using a small message is, that the smaller message size reaches the destination quickly. Furthermore the vehicle size in this simulation is 2-6cm to increase the visibility of node on NS2 and the size restricted to this range to include many vehicles on the simulation roads.

The Manhattan mobility model uses as a vehicle mobility model to guide the vehicles' movement on the right path. This quality model permits mobile nodes to maneuver in an exceedingly vertical, straight or horizontal direction by providing completely different likelihood within the choice of vehicles' movements. By victimization this methodology we will forestall the vehicles from keeping taking possession of a similar direction. In this technique, the probability of going straight is greater than turning left and right, which holds 0.5, 0.25, and 0.25 respectively.

In this study, the V2V propagation form is used as the communication model between vehicles while the simulation take 200s which is randomly generated while creating mobility file in SUMO. The Emergency Message interval is set to 10 m/s to avoid channel cognations and the emergency message takes 240 m/s or time to live (TTL) which shows the total time the emergency message take before expired. The proposed algorithm applies 802.11p rule for the physical and mac layer implementation which is standardized in the year 2009 following the European Telecommunications Institute (ETSI) standards [9]. This standard supports ad hoc communication largely for 802 11p without supporting infrastructure. In this simulation unlike MANET random motions are disabled since the vehicle should have to move by having their lines. All the simulation parameters used for analysis purposes are listed in the following scenario.

4.3.1 Scenario 1

The first simulation is analyzed for the different density of the vehicles to analyze the impact of the broadcast storm problem during emergency message dissemination at different vehicle density and constant vehicle moving speed. This research is mainly concern with broadcast storm problems that happen in vehicular ad hoc networks during rush hours such as dense network scenarios. In this case, the simulation conducted under different vehicles' density which ranges from 20, 40, 60, 80 and 100 vehicles per kilometer and constant speed (50 km/h). Manhattan mobility model used as a vehicle mobility model and the simulation require 200s to show the results. The parameters used in this research are mentioned as the following using table.

Objective: To study how to broadcast storm affects the performance of emergency message dissemination in VANET for different vehicle density under average speed.

Table 4.1 Simulation parameter for scenario 1 [22]

Parameters	Value
Network Simulator NS 2.34	NS 2.35
Traffic Simulator	SUMO v0.32.0
Road length	1 KM
Physical propagation model	Wireless
Propagation type	Two ray ground
Vehicle traffic density	20, 40, 60, 80, 100/km
Vehicle size	2–6 cm
Vehicle moving speed	50 km/h
Vehicle mobility model	Manhattan mobility model
Broadcast packet size	128 bytes/20 Messages
Beacon message interval	1 s
Emergency safety message interval	10–240 m/s
Antenna type	Omnidirectional antenna
Communication type	Vehicle to vehicle (V2V)
Traffic direction	Multidirectional/bidirectional
Simulation time	200S

4.3.2 Scenario 2

The simulation for the second scenario conducted by varying vehicle speed to analyze the impact of broadcast storm problems at different vehicles moving speed and constant density. Under this scenario, different vehicle moving speed that ranging from 30, 60, 90 to 120 km/h and average density (60/km) is taken as a simulation parameter. The parameters used for this scenario are similar to the parameter used for scenario 1 except for this section the simulation results are analyzed for various vehicle moving speed under constant density.

Objective

To study the effect of broadcast storm problem on broadcasting an emergency message for different vehicle moving speed under constant density.

Table 4.2 Simulation parameter for scenario 2 [22]

Parameters	Value
Network Simulator NS 2.34	NS 2.35
Traffic Simulator	SUMO v0.32.0
Road length	1 KM
Physical propagation model	Wireless
Propagation type	Two ray ground
Vehicle traffic density	60/km
Vehicle size	2–6 m
Vehicle moving speed	30, 60, 90 to 120 km/h
Vehicle mobility model	Manhattan mobility model
Broadcast packet size	128 bytes/20 Messages
Beacon message interval	1 s
Emergency safety message interval	10–240 m/ s
Antenna type	Omnidirectional antenna
Communication type	Vehicle to vehicle (V2V)
Traffic direction	Multidirectional/bidirectional
Simulation time	200S

4.4 Performance Metrics

In this simulation study, four performance metrics, [38, 39], are used to study the effect of the broadcast storm in vehicular ad hoc networks while broadcasting emergency messages and the efficacy of the reduction mechanism.

Emergency Message Delivery ratio (ESM): It is a ratio of the number of packets the destination receives to the number of packets sent from the original (source) vehicle which illustrates the level of delivered data to the target. In this case, when the delivery ratio of ESM is high the algorithm achieves high reliability of the emergency message dissemination.

$$\text{ESMD} := \frac{Number\ packet\ received\ by\ destination\ node}{number\ of\ the\ packet\ sent\ by\ source\ vehicle}$$

Broadcast Delay: This shows the average amount of time taken to reach the target by the packet. Only data packets that effectively reach the destination are counted. The reduced delay will enhance the general efficiency of the scheme.

Broadcast Collision Ratio (BCR): It is described as the ratio between the amount of transmitted emergency safety messages lost by collision and the complete amount of transmitted emergency safety messages. In this case, the minimized collision ratio solves the broadcast storm ratio that exists during emergency message broadcasting.

$$\text{BCR} := \frac{Number\ of\ \ ESM\ lost\ by\ collision}{Total\ Number\ of\ broadcast\ ESM}$$

Redundant Rebroadcast Ratio (RRR): It is defined as the number of selective vehicles that select to rebroadcast the emergency message to the total number of cars within the transmission range of a source vehicle.

$$\text{RRR} := \frac{Number\ of\ the\ selective\ vehicle(AMDIV)}{Total\ num\ of\ \ vehicles\ in\ TRS\ vehicle}$$

4.5 Simulation Results and Discussions

This section presents the simulation result that analyzed under different vehicle moving speed and density based on the performance metrics considered in the above section. The resulting gain under these two different scenarios are compared with a simple flooding and fast broadcast algorithm for four performance evaluation metrics and their values are plotted together using graph. The simulations are run 5 times for different vehicle densities and four times for different vehicle moving speed and the value is compared with two other algorithms. This is because variable vehicle density and moving speed of vehicles generate different mobility files and the result of this different mobility file becomes different.

The general simulation result shows that when the vehicle density increases, the BSP additionally increases and when the vehicles are moving at high speed, there is no assurance for reliable message conversation.

4.5.1 Simulation Results and Discussions for Scenario 1

The simulations are run by varying parameters according to the scenario presented above. The vehicle moving speed is kept constant (50 km/h) for scenario1 while the result is analyzed for three different traffic flows such as free flow in 20 vehicles/km, medium density in 40-60 vehicles/km and high density in 80-100 vehicles/km vehicles density as it missioned in the above table.

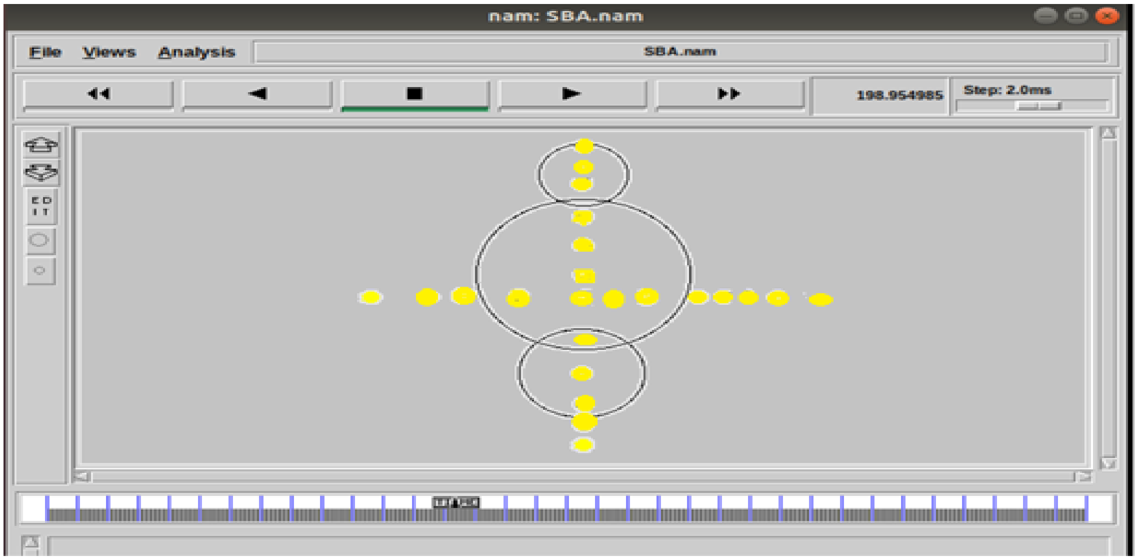

Figure 4.3 NS2 Simulation Result for Average Speed and Various Vehicle Density

The message broadcasting interval is varied from 10-240 m s and bacon message sent interval set to be 1s. The results for scenario 1 are shown below in figures 4.4 to 4.7 for simple flooding, fast broadcast and the proposed SBA algorithm under average vehicle moving speed. This outcome displays that the performance of the proposed SBA algorithm is high in all cases compared to a fast broadcast and simple flooding algorithm.

As you can see from figure 4.4, the ESM delivery ratio for simple flooding is above 90% while the fast broadcast algorithm and proposed SBA algorithm score near 100% Compared to free-flow traffic (20 vehicles/km). But, as traffic density increase (congested traffic) the ESM delivery ratio is decreased for both simple flooding and fast broadcasting algorithm this is because in congested traffic the message gets more flooded which increases the number of rebroadcasting vehicles. Due to this message overhead rises which interrupt the spread of ESM. But in proposed SBA the ESM delivery ratio become moderate in all case because SBA selects fewer vehicles among this varying density, and hence the number of interrupts decreases.

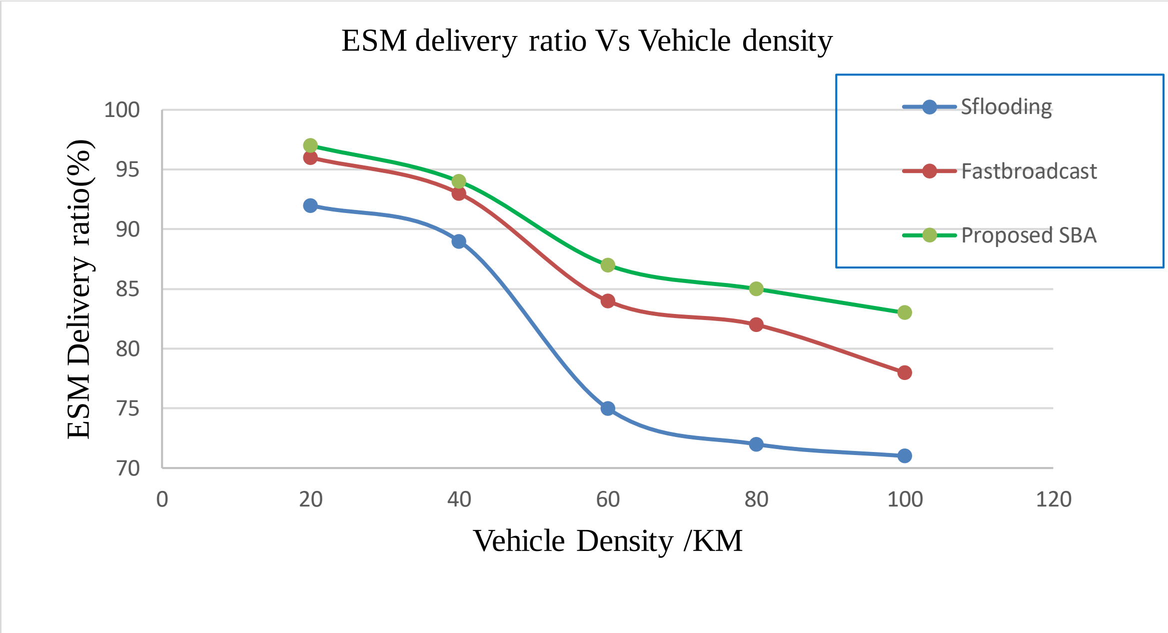

Figure 4. 4 ESM Delivery Ratio VS Vehicle Density

Figure 4.5 shows the result of the Dissemination Delay of these three algorithms for varying vehicle density and average moving speed of vehicles. According to this result broadcast delay sharply rises in all cases with increasing flooding rates in simple flooding and fast broadcast algorithms. But the delay in SBA is low in all cases while it compared with simple flooding. This is because the SBA algorithm assigned shorter waiting times to source vehicles to broadcast the emergency safety message. But as vehicle density rise the number of broadcast increases to cover all vehicles in its transmission range. This increase the communication delay and communication error which result in redundant rebroadcast that bring delay. To solve this the proposed SBA algorithm send the message only to selective (free) vehicles by identifying their direction of movement. This reduces the transmission time of selective vehicles since each selective vehicle broadcast the message in their transmission range.

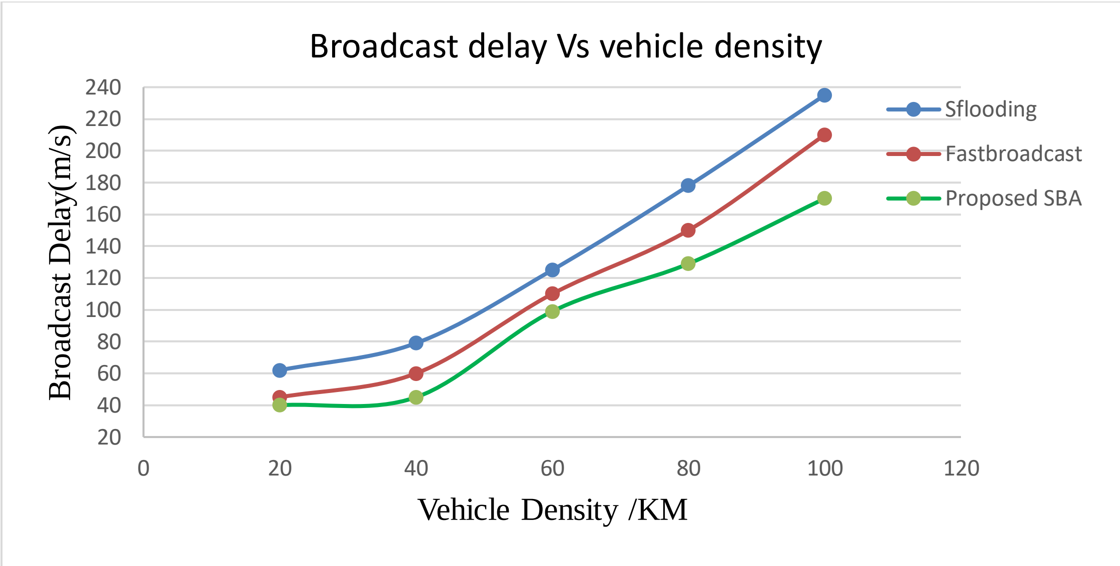

Figure 4.5 Broadcast Delay VS Vehicle Density

Similarly, as it is seen from figure 4.6 the broadcast collision ratio in case of simple flooding sharply rises with increasing flooding rate in different density. In the same case, a fast broadcast algorithm is also scored better result in low and medium density. But as the vehicle density increases all the vehicles in one transmission range have the same distance approximately. Therefore there is a high probability of selecting more vehicles as a rebroadcasting node which increases RRR and collision. In SBA the message loss is minimized by selective broadcast in the dynamic network compared to other algorithms. This message loss is decreased by identifying the direction of vehicle movement and by checking the availability of the neighbor before broadcasting an emergency safety message. In the previous work like SEB, the message is broadcasted by both vehicles that are going to the intersection point and outgoing from the intersection point. This cause many redundancy and collision if the vehicle selected from both direction at the same moment and rebroadcast the messages.

As the vehicle density rise from 20 vehicles /kilometers too high density, the number of broadcast by each vehicle also increases. If the direction of the vehicle which rebroadcasts the emergency message is not identified in the road that has two or more lane this problem becomes worst. Hence in the SBA algorithm, the rebroadcasting permission is provided only to the vehicle that ingoing to the intersection point and the number of communicating vehicles is decided. This reduces the message lose by sending the data to the target node only. For this reason, the message loses in SBA is minimized by 35.2% compared to other algorithms at various vehicle density.

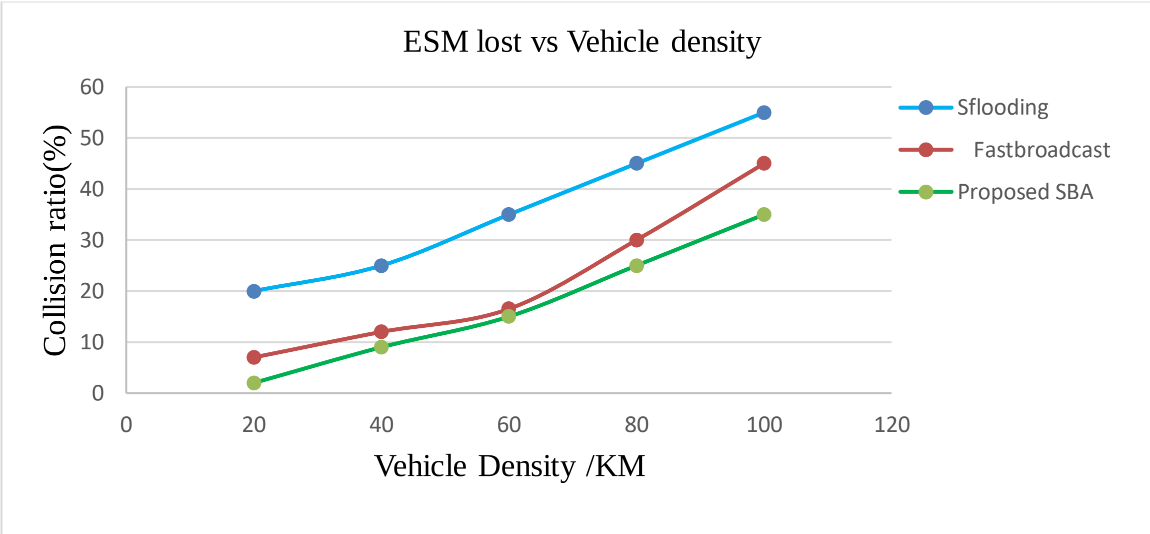

Figure 4.6 Broadcast Collision Ratio VS Vehicle Density

Figure 4.7 shows the result of the Redundant Rebroadcast Ratio, for three algorithms in different vehicle density and constant vehicle moving speed. As the vehicle density reduces, message dissemination for which a retransmission is needed increases. The amount of retransmissions is also dependent on vehicles as all vehicles try to initialize communication, thus increase redundancy. In proposed SBA, as the vehicles are selected based on the direction of movement, distance, and P-ACK. Only a few numbers of vehicles out of the entire vehicles forward the broadcast. For this case number of RRR detected is bellow10% in all cases when compared to simple flooding and fast broadcast algorithms.

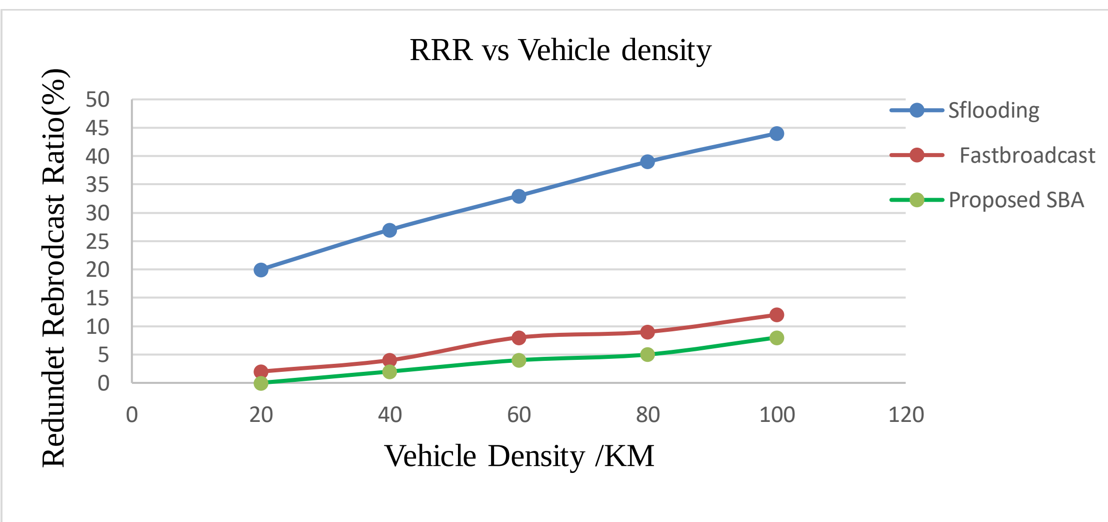

Figure 4.7 Redundant Rebroadcasts VS Vehicle Density

In general, the results of scenario1 analyzed under various vehicle density, different transmission range and the same vehicle moving speed. The result shows that the effect of broadcast storm problem for simple flooding is very severe for higher density vehicles that decrease the performance of ESM broadcasting in VANET. As a prevention mechanism, the sender decisions based selective broadcast is effective for higher density vehicles. Using the new solution the effect of the broadcast storm problem is reduced in all density of vehicles especially if vehicle density is medium (40_60vehicles/km) and high density (80-100 vehicles/km).

4.5.2 Simulation Results and Discussions for Scenario 2

In this scenario, variable vehicle moving speed ranging from 30, 60, 90 to 120 km/h while average density (60/km) is used as evaluation criteria to show the impact of the broadcast storm on disseminating emergency safety messages at various vehicle moving speed. The results of this scenario are shown in figures 4.8 to 4.11 .The result shows that the performance of the proposed SBA algorithm is better in all case when it compared with simple flooding algorithm.

Figure 6.8 shows the ESM delivery ratio, for both algorithms. The results display that the proposed SBA algorithm has a higher ESM delivery ratio than a simple flooding and fast broadcast algorithm with the same density level. According to this result, the proposed SBA algorithm achieves above 94% at a lower speed (30km/h) and this result decreases rapidly for speed ranging from 60, 90 and 120 km/h. This is because the packet delivery ratio is mainly concern with link connectivity. As the vehicle move with high-speed link dis connectivity is also increase which degrades the amount of ESM that reaches the destination. Although with an increase in vehicle speed, the ESM delivery ratio drops considerably in these three algorithms. But as this algorithm evaluated for various transmission ranges when transmission range increases the component merge and included a large number of vehicles. In this case, the ESM delivery ratio rises again when vehicle speed greater than 90 and the transmission rang approach to the maximum point. Due to this dynamic transmission range estimation, the ESM delivery ratio drop is relatively less prominent in this proposed scheme compared with simple flooding and fast broadcast algorithm. This is because the proposed SBA algorithm employs a neighbor availability checking method before broadcasting the message, there for the number packet lose decrease which maximizes the ESM delivery ratio.

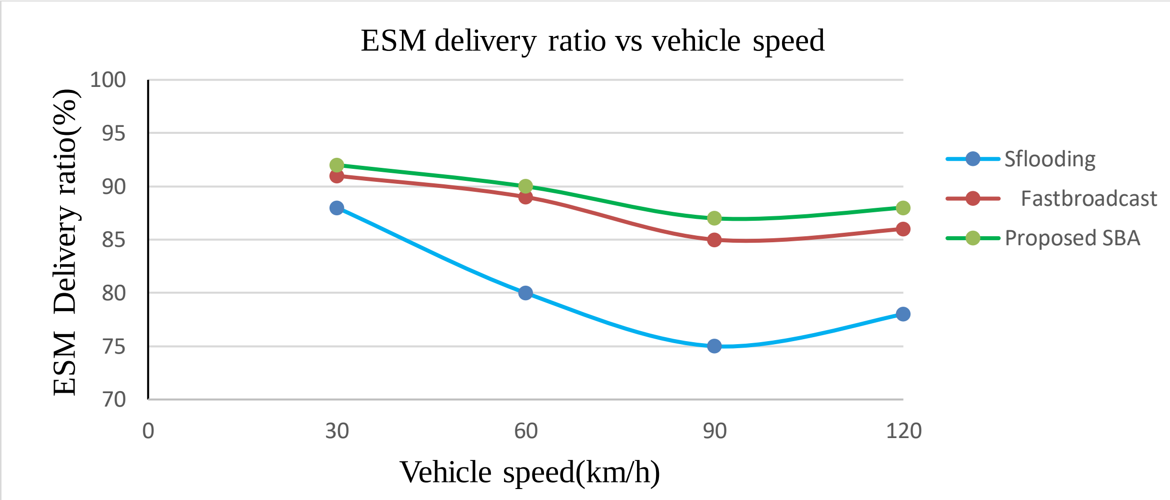

Figure 4.8 ESM Delivery ratio VS Vehicles Speed

Figure 4.9, shows the Dissemination Delay of simple flooding, fast broadcast and the proposed SBA algorithms for varying vehicle moving speed and average density of vehicles. As seen in the figure, with an increase in the node speed, the network delay also increases. This is because when vehicle speed increases, the distance between vehicles also increases and, consequently, it is difficult to maintain the connection between the vehicles. This increasing the broadcast delay since vehicle leaves their transmission range frequently. But, connectivity is efficiently maintained in the proposed SBA algorithm with an increase in vehicle speed due to the selection of an adaptive path based on the passive acknowledgment sent to broadcast the message. For this reason, dissemination delay is minimized in the proposed scheme compared with the others, as shown in Fig. 4.9.

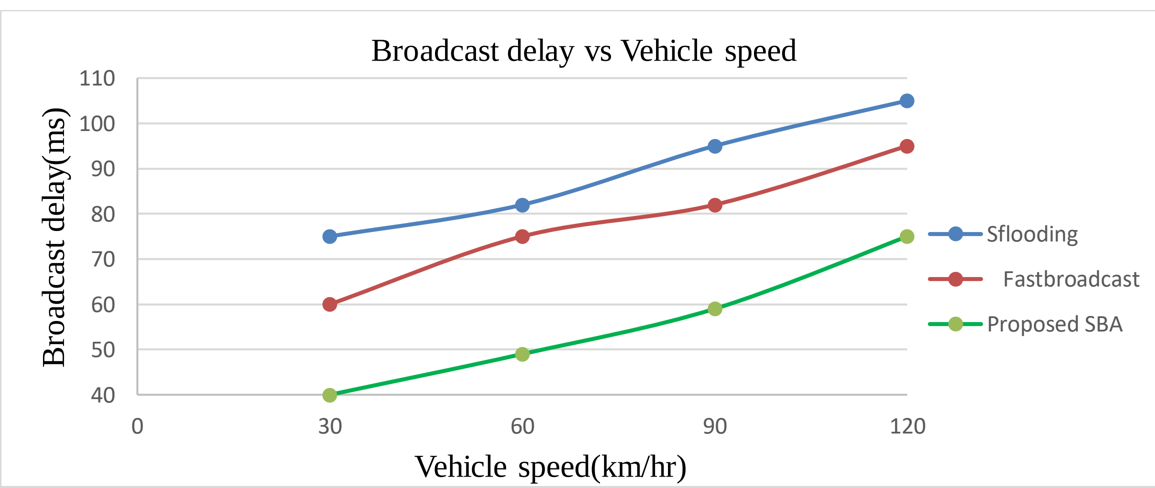

Figure 4.9 Broadcast delay VS Vehicle Speed

As shown in figure 4.10, the broadcast collision ratio (packet loss due to collision) increases sharply in simple flooding as vehicle moving speed varying from 30 to 120 km/h. This is because increased vehicle speed increases the link disconnection probability that leading to loss of packets. In this case, we don't have any guaranty to know whether the packet delivered to the destination correctly. Due to this all nodes that reactive packet is obligate to rebroadcast the message again if they recover from failure. This causes serious redundancy and collision. Due to this broadcast collision increase at a higher moving speed of vehicles which increases packet lose. But in the proposed SBA algorithm the message loss is minimized compared to other algorithms because of three things. The first one is only selective vehicles are permitted to rebroadcast the messages, this reduces the number of rebroadcasting vehicles after linked failures, second neighbor availability is checked before broadcasting the messages and the final one in the direction of the vehicle which broadcast the message are identified. Therefore the messages are not rebroadcast by the vehicle that outgoing from the intersection point. This reduces the number of rebroadcasting vehicles in one transmission range and hence packet loss by collision is decrease.

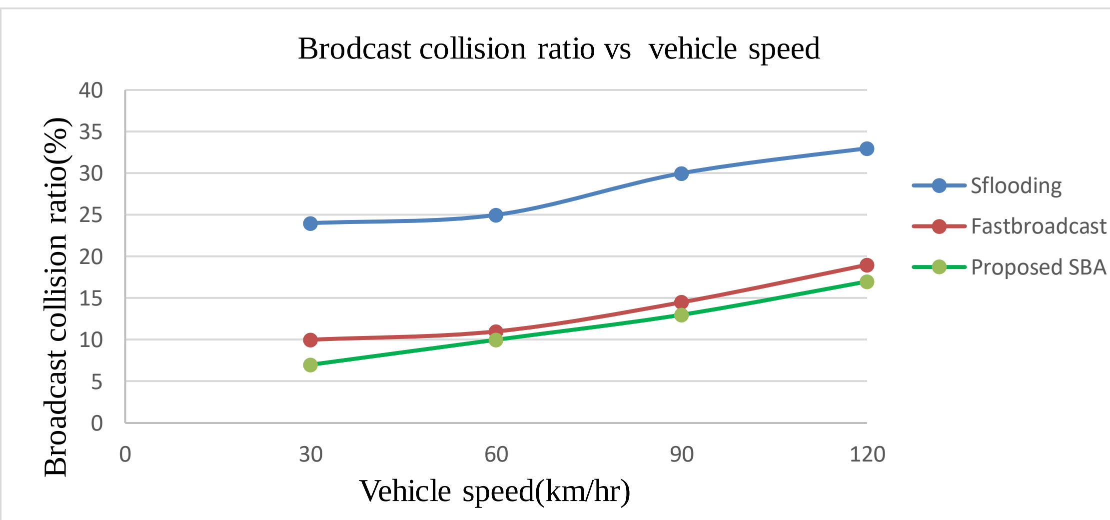

Figure 4. 10 Broadcast Collison ratio VS Vehicle Speed

The impact of the redundant rebroadcast ration on disseminating emergency safety message at various speed are shown in figure 4.11. The result shows that as the vehicle moving speed increases, there is no assurance for message communication. Therefore the number of vehicles involved to enhance message reliability, hence RRR is increased. But the proposed SBA algorithm minimizes the number of redundant rebroadcast in all cases than simple flooding and fast broadcast algorithms. The reason behind this is in the proposed algorithm, only selective vehicles are permitted to rebroadcast the messages and the message is not rebroadcast by the vehicle that outgoing from the intersection point. This reduces the number of rebroadcasting vehicles in one transmission range but moves in the opposite direction.

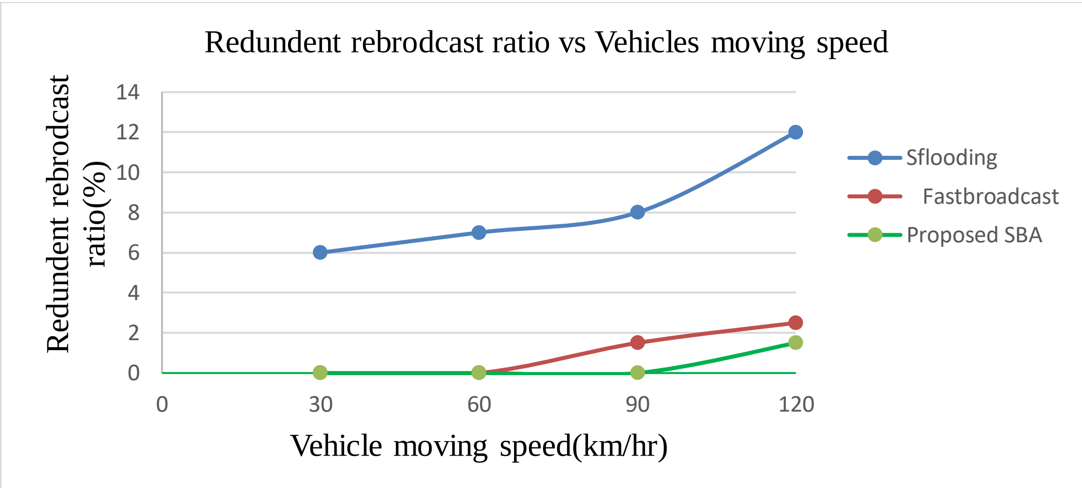

Figure 4.11 Redundant Rebroadcast ratio VS Vehicle Speed

In conclusion, vehicle density and vehicle moving speed has a significant impact on disseminating emergency safety messages in VANET. The Simple flooding based broadcasting algorithm is not suitable in vehicular communication. The reason for this is that the simple flooding method floods the data to the required area without any restriction. This increase broadcast storm, redundant rebroadcast, collision, and message loss, So, to prevent the vehicles from flooding emergency safety messages in the high-density network and high vehicle moving speed, other methods rather than simple flooding should be used. Therefore the proposed sender decision-based broadcast suppressing technique is better in a dynamic network such as in VANET. It can be shown from the results that the proposed SBA algorithm score better result interims increasing the ESM broadcasting ratio and reducing delay, broadcast collision, redundant rebroadcast ratio and broadcast storm ratio in both scenarios.

But unlike the MANET broadcasting in VANET is very challenge full due to variable density and vehicle moving speed of the vehicles that bring dynamic network topology, especially in increasing the vehicle moving speed which leads several link break. Moreover, in a very high vehicle moving speed, there is no assurance for message communication. Therefore in all the scenarios, the improvement of the performance of the proposed broadcast suppressing mechanism is significant especially when the vehicle speed is high.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this thesis work, the sender decision based selective broadcasting algorithm is developed for a multi-directional road scenario to suppress broadcast storm. In this research broadcast storm problems are prevented by reducing the number of rebroadcasting vehicles in a dynamic network. The Vehicle moving direction, Distance and passive acknowledgment are used as a key parameter to select the furthest infected vehicle or (AMDIV) then only these selective vehicles are responsible to rebroadcast the emergency message. Epidemic spreading techniques are used to show how the vehicles are going to react when it receives new or old messages from its neighbors. Therefore using this selection mechanism, broadcast storm problems are prevented from imposing much delay and packet loss. Since all cars don't take part in broadcasting emergency safety message the rebroadcasting vehicles are identified in their transmission range. Hence the problem that occurs due to simple flooding and fast broadcast algorithm are effectively handled in this work.

The broadcast storm problems and the suppressing mechanism are implemented by modifying the C++ code of the Fast broadcast algorithm and the system is simulated using the NS-2 simulator and SUMO simulator. To study the effect of the broadcast storm problem and the effectiveness of the prevention mechanism, two simulation scenarios are used by varying the number of vehicles and vehicle moving speed. For the first scenarios, variable vehicle density that ranges from 20, 40, 60, 80 and 100 vehicles per kilometer and average speed (50 km/h) are used.

In the first scenario, the results show that at lower vehicle density fast broadcast algorithm, simple flooding, and the new solution perform well in preventing the broadcast storm problem, but if the car density is an increase (>= 40), the new solution is better than the simple flooding and fast broadcast algorithm in all instances. The second scenario conducted by varying vehicle moving speed to 30, 60, 90 and 120 km/h under average density (60km/h). The results show the proposed SBA algorithm performs better than a simple flooding and fast broadcast algorithm in terms of increasing ESM delivery ratio and reducing RRR, BCR, and delay.

Generally, in all scenarios, the proposed SBA algorithm is effective in preventing broadcast storm problem especially during high-density vehicles available on the road.

5.2 Summary of Contribution

- The algorithm estimates the direction of vehicles movement to identify the vehicle in which direction from the intersection point acts as rebroadcasting vehicles. This important to reduce redundant rebroadcast ratio by identifying exact rebroadcasting vehicles.
- Unlike the previous work the algorithm check availability of the neighbor or the receiver before broadcasting emergency safety message to improve the link reliability.
- The research suppresses the broadcast storm problem for a multi-directional road scenario which has a common intersection point. In this case emergency safety messages required to broadcast to all possible directions.
- The redundant rebroadcasting of the emergency message is deferred by finding the exact rebroadcast vehicle in the transmission range of source vehicle (ZOI) based on passive acknowledgment. This allows preventing selfish vehicle (unresponsive vehicle) which does not want to retransmit the message to its neighbors.
- Since the exact rebroadcasting node is identified the research is also can solve hidden terminal problems.

5.3 Recommendations

In developing countries such as Africa, the road facility is not a full field like developed countries that is why they contribute 90% of the world's vehicle accidents. In such countries due to different land topologies, high budget requirements and, different weather conditions it is impossible to deployed infrastructure in all areas to reduce this accident. But V2V communication is an infrastructure-less communication that allows the vehicle to change information easily through OBU that attached to them. Therefore we recommended that in developing counties such as Africa using the vehicle to vehicle communication is the best solution to reduce this accident.

5.4 Future Work

For future work we recommended that the researcher focus on optimizing the performance of the Proposed SBA algorithm in both connected and disconnected networks. Currently, the SBA algorithm only allows suppressing broadcast storms in a connected network. By utilizing a store-and-carry mechanism, it is possible to rebroadcast in a connected and fragmented network simultaneously without causing any broadcast storm issues. Another possible direction will be to focus on enhancing the message broadcasting method for a road with several directions and lanes.

It is proposed to extend the algorithm with location privacy and message security for future works.

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APINDEX

A. Sample mobility file

Nodes: 30 max x=502.0, max y: 502.0

$node_(0) set X_ 501.65

#

$node_(0) set Y_ 5.1

$node_(0) set Z_ 0

$ns_ at 0.0 "$node_(0) setdest 501.65 5.1 30.00"

$node_(1) set X_ 5.1

$node_(1) set Y_ 498.35

$node_(1) set Z_ 0

$ns_ at 0.0 "$node_(1) setdest 5.1 498.35 30.00"

$node_(2) set X_ 994.9

$node_(2) set Y_ 501.65

$node_(2) set Z_ 0

$ns_ at 0.0 "$node_(2) setdest 994.9 501.65 30.00"

$ns_ at 1.0 "$node_(0) setdest 501.65 5.9 30.0"

$ns_ at 1.0 "$node_(1) setdest 5.9 498.35 30.0"

$ns_ at 1.0 "$node_(2) setdest 994.1 501.65 30.0"

$ns_ at 2.0 "$node_(0) setdest 501.65 7.5   30.0"

$ns_ at 2.0 "$node_(1) setdest 7.5 498.35 30.0"

$ns_ at 2.0 "$node_(2) setdest 992.5 501.65 30.0"

$ns_ at 3.0 "$node_(0) setdest 501.65 9.9 30.0"

$ns_ at 3.0 "$node_(1) setdest 9.9 498.35 30.0"

$ns_ at 3.0 "$node_(2) setdest 990.1 501.65 30.0"……………

B. Modified BroadcastbaseApp.cc

```
void BroadcastbaseApp::process_data_BroadcastESM(char *pkt, hdr_ip* ih)

    /* control and estimating direction of movement (message propagation direction */

    if(Dist(Vp_ackt)<Dist(VBt)==true){ // going to into intersestion point and can be selected as rebroadcast node

                Dm='in';//

  set_parameters_in(data, d,bmd,Rb_id,Vp);

        else

        {

    if ((Dist(Vp_ackt)>Dist(VBt)==flase)

        Dm='out';//going out from transmission range SV cannot rebroadcast message

     set_parameters_out(data, d,Vp);

    }

    else

    i;//ignore ,the vehicle cannot communicate with other vehicle

    }

    for i=1 to n

 {

 if(SV=center &&DM=4) // identify if the road has four direction

  {S}<-{V}  //mark all vehicles as suspect able

    }

 if (heard_collision&&neighbour_avaliblity=True )
```

```
SV.recivep_ACK=true;

dmax= sqrt(pow((mpx - spx), 2) + pow((mpy - spy), 2)); //comput maximum distance for all vehicles ;

dmax<-AMDIV// select the vehicle with max distance as rebroadcasting vehicles

}

}
```

C. Sample SUMO Rout File

Since sumo file is a bulky file only few lines are present here as a sample.

```
<routes>

    <vType id="SUMO_DEFAULT_TYPE" accel="0.8" decel="4.5" sigma="0" length="5" minGap="2" maxSpeed="60"/>
    <route id="always_right" edges="1i 4o 4i 2o 2i 3o 3i 1o 1i"/>
    <flow id="always_right" type="SUMO_DEFAULT_TYPE" route="always_right" begin="0" end="900" period="30"/>
    <route id="always_left" edges="3i 2o 2i 4o 4i 1o 1i 3o 3i"/>
    <flow id="always_left" type="SUMO_DEFAULT_TYPE" route="always_left" begin="0" end="900" period="30"/>
    <route id="horizontal" edges="2i 1o 1i 2o 2i"/>
    <flow id="horizontal" type="SUMO_DEFAULT_TYPE" route="horizontal" begin="0" end="900" period="30"/>
    <route id="vertical" edges="3i 4o 4i 3o 3i"/>
    <flow id="vertical" type="SUMO_DEFAULT_TYPE" route="vertical" begin="0" end="900" period="30"/>

</routes>
```

D. AWK Scripts

In this section sample code for how to get the result to plot graph are listed

 # delay.awk

```
BEGIN {
For (i in send) {
        Send[i] = 0
      }
For (i in recv) {
       recv[i] = 0
   }
delay = avg_delay = 0
}
{
# Trace line format: normal
   if ($2 != "-t") {
            event = $1
              time = $2
               if (event == "+" || event == "-") node_id = $3
                  if (event == "r" || event == "d") node_id = $4
               flow_id = $8
                pkt_id = $12
 }
# Trace line format: new
  if ($2 == "-t") {
                event = $1
```

```
              time = $3
             node_id = $5
            trace_level=$19;
             pkt_type=$35;
            flow_id = $39
            pkt_id = $41
   }
# Store packets send time
  if (flow_id == 0 &&   send[pkt_id] == 0 && trace_level == "AGT" && pkt_type=="cbr" &&
(event == "+" || event == "s")) {
    send[pkt_id] = time
        }
# Store packets arrival time
    if (flow_id == 0 && trace_level == "AGT" && pkt_type=="cbr" && event == "r") {
           recv[pkt_id] = time
 }
 }
END {
# Compute average delay
 for (i in recv) {
 if (send[i] == 0) {
  # printf("\nError %g\n",i)
   }
    delay += recv[i] - send[i]
  num ++
```

```
    }
  if (num != 0) {
avg_delay = delay / num
   } else
{
  avg_delay = 0
  }
  print avg_delay*1000;
}
```

ESM delivery ratio/PDR

```
BEGIN {
 sent = 0;
  rcvd = 0;
  #fwd = 0
{
}
# Trace line format: normal
  if ($2 != "-t") {
 event = $1;
  time = $2;
  if (event == "+" || event == "-") node_id = $3;
     if (event == "r" || event == "d") node_id = $4;
     flow_id = $8;
     pkt_id = $12;
    pkt_size = $6;
```

```
  }
# Trace line format: new
  if ($2 == "-t") {
    event = $1;
   time = $3;
 node_id = $5;
  trace_level=$19;
source= $31;
  destination= $33;
  pkt_type=$35;
    seq_num=$47;
 flow_id = $39;
 pkt_id = $41;
 pkt_size = $37;
  }
#received
if (( event == "r") && ( pkt_type == "cbr" || pkt_type =="tcp" ) && ( trace_level=="AGT" ))
 rcvd++;
 #sent
if ((event == "s" ) && ( pkt_type == "cbr" || pkt_type =="tcp" ) && ( trace_level=="AGT" ))
sent++;
 }
  END {
 print  rcvd/sent;
  }
```

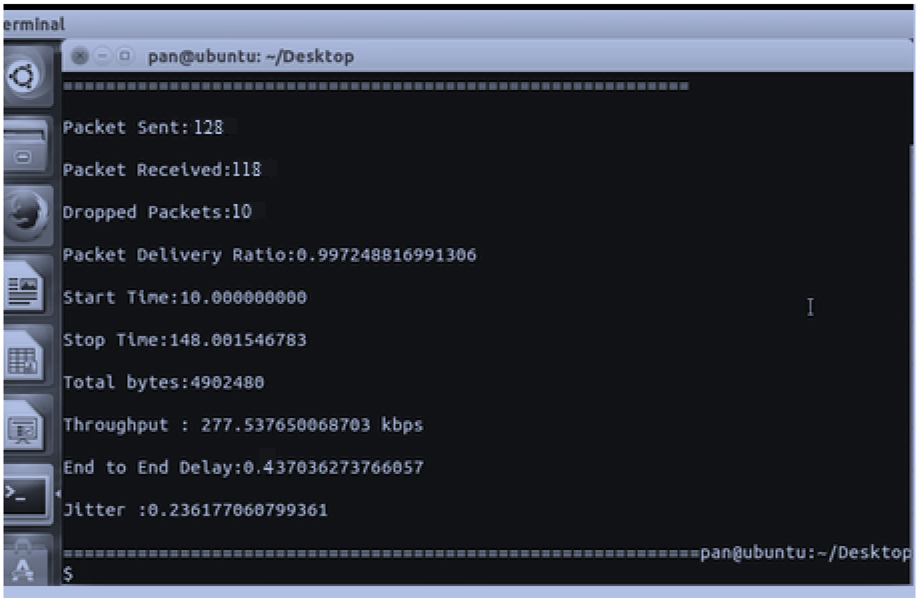

Figure 4.12 Sample Result for Fast Broadcast Algorithm