Traffic Management using Intelligent Transportation System based on Vehicular Ad hoc Networks

Kiros Fisseha Gebru

A Thesis Submitted to

The Department of Electronics and Communication Engineering

School of Electrical Engineering and Computing

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in

Electronics and Communication Engineering

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

June, 2022

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Co-Advisor: Dr. Javed Sheikh (PhD)

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APPROVAL PAGE OF M.SC. THESIS

We, the advisors of the thesis entitled **"Traffic Management using Intelligent Transportation System based on Vehicle Ad hoc Networks"** and developed by **Kiros Fisseha Gebru**, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

_________________________ _____________________ _______________

Major Advisor Signature Date

_________________________ _____________________ _______________

Co-advisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by **Kiros Fisseha Gebru** have read and evaluated the thesis entitled **"Traffic Management using Intelligent Transportation System based on Vehicle Ad hoc Networks"** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science **in Electronics and Communication Engineering.**

_____________________________ ____________________ __________________

Chairperson Signature Date

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Internal Examiner Signature Date

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External Examiner Signature Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

_____________________________ ____________________ __________________

Department Head Signature Date

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School Dean Signature Date

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Office of Postgraduate Studies, Dean Signature Date

DECLARATION

I hereby declare that this Master Thesis entitled **"Traffic Management using Intelligent Transportation System based on Vehicle Ad hoc Networks"** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Kiros Fisseha Gebru ________________________ ________________

Name of the student Signature Date

RECOMMENDATION

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled **“Traffic Management using Intelligent Transportation System based on Vehicle Ad hoc Networks”** prepared under our guidance by **Kiros Fisseha Gebru** submitted in partial fulfillment of the requirements for the degree of Mater’s of Science **in Electronics and Communication Engineering**. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dr. Demissie Jobir (Asst.Professor)	______________________	_______________
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Co-advisor	Signature	Date

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LIST OF ABBREVIATIONS

OBU	Onboard Unit
RSU	Road Side Unit
MANETs	Mobile Ad-hoc Networks
VANETs	Vehicle Ad-hoc Networks
DSRC	Dedicated Short Range Communications
RTA	Road Traffic Accident
TMC	Traffic Message Channel
WHO	World Health Organization
IVC	Inter-Vehicle Communication
ITS	Intelligent Transportation System
IoT	Internet of Things
ORPA	Optimal Route Planning Algorithm
RTA	Road Traffic Accident
S. GPS	Satellite Global Positioning System
V2V	Vehicle to Vehicle
V2I	Vehicle to Infrastructure
I2V	Infrastructure to Vehicle
V2X	Vehicle to Anything
WAVE	Wireless Access Vehicular Environment
WLAN	Wireless Local Area Network

V2P	Vehicle to Pedestrian
TA	Trusted Authority
C-ITS	Cooperative Intelligent Transport Systems
SDO	Standards Development Organization
BSMD	Bachelor of Science and Doctor of Medicine
APs	Access Points
DGPS	Differential Global Positioning System
PDA	Personal Digital Assistant
RCP	Resource Command Processor
EDR	Event Data Recorder
FCC	Federal Communications Commission
OSI	Open System Interconnection
SCH	Service Channel
TPM	Trusted Platform Module
TTP	Trusted Third Party
CCH	Control Channel
DoS	Denial of Service
ECDSA	Elliptic Curve Digital Signature Algorithm

ABSTRACT

As the world's cities grow in number, the total number of mobility of human population from and to in the cities also increases, In addition there has also been an increase in the number of driving vehicles on the public roads. The outcome is, traffic congestion, vehicular accidents, and environmental pollution are on the rise. Car accidents are still a major concern, despite the fact that various systems have been developed using sophisticated technology. However, behind this problem there has been created a promising VANET technology that could solve the vehicular accident in the transportation sector. The principles of mobile ad hoc networks (MANETs) the spontaneous establishment of a wireless network of mobile devices are applied to the domain of automobiles to produce vehicular ad hoc networks (VANETs). Therefore, VANETs were created from MANETs by driving their principles. VANETs (vehicular ad hoc networks) are a type of wireless network that are used to communicate between automobiles and roadside equipment using an open source wireless protocol Wireless Access Vehicular in Environments (WAVE) IEE802.11p based designed by FCC for the purpose of short to medium range communication technology that operates in the 5.9 GHz band of frequency with bandwidth of 75MHz for the use of public transportation system. VANETs are primarily used to provide safety and comfort to drivers and passengers in vehicle situations. Therefore, it is important to develop common improved system for traffic management system. Starting decades ago there has also been tried to design globally traffic management system, however designing of an algorithm for an effective vehicular management system remains still a major challenge that must be overcome and delays and speed controlling are the gaps that are identified to be solved in our thesis. The aim of this thesis is to design communication of traffic transportation intelligent system using VANETs to decrease Vehicular accident to save human life in public transport by solving the delays and controlling speed of vehicles. This thesis solved the gap using Euclidean distance algorithm by creating communications among vehicles and infrastructures on the road. Simulation results demonstrate that the suggested traffic control system is feasible and increased the Waiting time in communication coverage area by 100% which is solved the time delay and the collision of the vehicles also being managed by controlling the speed of each vehicle.

Key words: *Vehicular Ad hoc Networks, Road Side Unit, On Board Unit, Dedicated Short Range Communication, Wireless Access in Vehicular Environment*

CHAPTER ONE

1 INTRODUCTION

1.1 Background of the study

Vehicular ad hoc networks (VANETs) had been found and named in 2001 in the division of truck to truck communication of mobile ad hoc networking in which the information or the data of the network relayed on car to car communication. So as to prepare the safety of the public road, navigating and other services on the roadside part this already endorsed as well known car to car and car to roadside unit communicating engineering going to be exist side by side within VANETs. VANETs have one more name which is the so called as intelligent transportation network (ITN).In accordance to different experts they have morphed the concepts a broadly to a larger idea known as Internet of Vehicles. This is projected to change into an Internet of autonomous vehicles in the coming eras. Even though the target waits on the behavior of network in spontaneously mode, much less on the utilization of infrastructure like Road Side Units (RSUs) or cellular networks, the name VANET largely has became similar with a larger most generic meaning inter vehicular communication (IVC) in 2015 [1]. Accidents on the public roads traffic accidents in any country is the recent on the public health that outcome of greater than 1.24 million deaths and 50 million injuries per year over the world. Ethiopia becomes a country with the higher traffic accident with rapidly increasing from time to time [2]. Different researchers report shows deaths due to injury are a significant influence on the countries which are found in developing status. Here our country Ethiopia has become one of the countries with high rate of mortality due to vehicular injuries. In each and every day, huge numbers of people get in to die in vehicular accidents in the whole world, and a lot of them are injured. VANETs are the best future technology for creating vehicle to vehicle communication on the side of public roads. Vehicles can connecting to Road Side Units which installs at roadside, in Vehicle to Infrastructure, and Infrastructure to Vehicle concept [3]. Each vehicle are assumed to be installed with wireless device of communication in every system which permits to ad hoc networking connection. VANETs are always devoid with infrastructure, with each vehicle in the network being able to transmitting and receiving data's from others within the network. VANETs allow vehicles to communicating with each other as well as fixed infrastructure [4].

The use of sensing, analysis, control, and communications technology to ground transportation in order to increase safety, mobility, and efficiency is known as an intelligent transportation system. The intelligent transportation system is composed of so many different types of applications that processing the data and sharing the data so as to minimizing the overall traffic congestion, modify traffic in management system, keeping environmental safety, and modify the advantages of transportation to commercial users and generally public service [5]. The intelligent transportation system (ITS) is a complex system of an application that tries to create a novel service in related to different modes of transportation system and the management traffic, allowing for customers to have better informed and create safer, very coordinated, and smarter use of transportation networks [6]. Each vehicle should have own wireless device for communication services for allowing to ad hoc network connectivity, or Infrastructure to Vehicle form. VANETs are often devoid of infrastructure, with any vehicle in the network capacity of transmitting and receiving messages from other devices of vehicles. Vehicle-to-vehicle networks permitting automobiles communicate with each and every one as well as fixed infrastructure [7].

1.2 Significant of the study

This thesis improved traffic safety and mobility and reduce car accidents by merging sophisticated communication of technologies with transportation infrastructure and vehicular ad hocs. This thesis works to develop and exchange information to prevent potential accidents, maintain traffic flow, and minimize the negative impact of the transport sector on Ethiopian society. Therefore, this work is very important to prevent car accidents and to protect the ultimate benefits of a fully connected modified transportation system, rich in information, and it can better life for our community and our daily lives.

1.3 Statement of the Problem

The safety of road traffic networks in vehicle ad hoc networks is dependent on real-time wireless communication between fixed nodes infrastructure on the road side's Road Side Units and vehicular mobile infrastructure like On board units that is a device installed inside vehicles so as to make detection and protection of vehicular hazards. The ability of this road safety communication system, however, is contingent on the capacity to ensure the usefulness and trustworthiness of the information or data's sent between the fixed and vehicular mobile infrastructure communications is getting into time delay of information. In addition to that collision of vehicles is another problem according to different papers studied. The loss or delay of information of the data packet could lead to a road accident and being a cause for loss of human life or property. Ensuring the reliability of each of the transmitted data must reach to the destination in time is our prior to work on this thesis. Therefore, to improve the delay of information during transmission and reception time in the vehicular ad hoc networks, and to minimize car accidents, it must be reduced the delay and improved vehicle's speed controller need to be designed and implemented in the vehicular networks. The total system uses inter-communication between cars and support infrastructures, also known as Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications, to minimize traffic levels within the city. The goal of this thesis is to solve time delay and allow the sender to receive the information in proper time and by controlling the speed of vehicles, reduce in to minimum car accident using Euclidean distance algorithm in VANETs.

1.4 Objectives

1.4.1 General objectives:

The general objective of this thesis is to design traffic transportation system using VANETs to make comfort and safety for both the drivers as well as passengers and to decrease Vehicular accident to save human life in public transport.

1.4.2 Specific objective:

The specific objectives of this thesis are listed below:

- To calculate the distance between the fixed and mobile infrastructures using Euclidean distance algorithms.
- To compare the Euclidean distance algorithms with Manhattan and Minkowski distance algorithms
- To calculate the VANET parameters using Euclidean distance algorithms
- To explain the communication between vehicle to vehicle, Vehicle to infrastructure and infrastructure to infrastructure.
- To control collision of vehicles by controlling the speed of driving vehicles

1.5 Thesis Contributions

- Based on the result found from the simulation and theoretical aspects of the study, by managing the vehicles speed we develop speed controlled vehicles to manage the traffic flow throughout the lanes which protects vehicles from crashing each other.
- Based on theoretical and mathematical aspects of the study, the time delay could be solved by adding another infrastructure on the road sides, the waiting time doubles during communication in the given range and the probability of being received the information is increased by 100%.

1.6 Limitation of the Study

The work in this thesis is limited to simulation-based research that is based on theoretical analysis. This thesis is limited to vehicle to vehicle and vehicle to road side unit communication it does not work vehicle to everything like pads, cellophane and other electronic devices communication.

1.7 Thesis Outline

The following is a summary of the thesis's outline:

Chapter one briefly discussed the background, problem statement, objectives, the significance of the study, and limitations and contributions of the study. Chapter two presented a thorough literature analysis on the literature review and background overview, as well as related works on vehicle-to-vehicle communication, vehicle-to-infrastructure communication, general characteristics of wireless access vehicular contexts, and other variables. Chapter three presented the methodology of the study in our thesis, which uses the Euclidean distance technique in MATLAB software to model and simulate vehicle to vehicle and vehicle to infrastructure interactions. Chapter four presented the simulation results and the thesis analysis by simulation parameters. Chapter five discussed the thesis' conclusion, future work, and recommendations.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Background of Vehicular Networks

VANET is found for the first time as an application of MANETs in the early 2000s and later evolved into very sophisticated technologies into the intelligent transportation systems it was designed for the purpose of short distance and for the purpose of medium range of communication between vehicles and fixed infrastructures. The vehicles exchange information between them using the device equipped within the vehicle itself named as OBUs, and the fixed infrastructures are communicating with vehicles and other infrastructure by the device which is called as RUS using IEEE802.11p open source wireless protocol [8]. The communication among vehicles with other things is called vehicle to everything communication. The various possibilities to be real and difficulties to be implement makes challenge especially for the countries in under developing in the IoT transportation technology [9]. Dedicated Short Range Communications (DSRC) is a short-to-medium-range communications system designed to support vehicle to vehicle and vehicle to roadside communications. All the V2V, V2I, and I2I communications, the information of traffic flow and different types of another application going to be covered in the same communication technologies. In a small and narrow area of communication zones, DSRC is designed for providing in higher data transferring and lower communication of time latency. VANETs importance increases in its traffic safety with during the moment of driving vehicles. The protocol of Wireless Access Vehicular Environment in VANETs which is IEEE 802.11p based MAC protocol attracts much attention by different scholars [10]. By the means of wireless access vehicular enviroments (WAVE) as the architecture of a VANET automobiles and RSUs making communication via the wireless technology, which is the so called to WAVE. WAVE architecture is an open source wireless protocol which operates in 5.9 GHz band of frequency [11], and WAVE communication creates safety and comfort of both drivers and passengers by making update vehicular data and making smooth traffic flow through the public road. Via the wireless communication network the data sent to the other vehicles. The roadside units are connected by wired connection in the given networks [12].

The Dedicated Short Range Communication is a short as well as a medium range of communication that is used to vehicular networks to make a connection in a wireless remote area communication which creates amazing technologies even for the next generation created safety and comfort of the public roads. Generally, VANETs are the sum total of different types of electronic devices with radio technology equipment used to create smart vehicular communications such as OBUs, RSUs and other different types of wireless sensor devices. Here in the figure bellow in Fig. 2.1 is placed as a VANET architecture, which has included some of the basic elements like Locating of Positioning System awareness, Communication capacity of OBUs, Vehicular kinetic data's awareness, Inter vehicle communication, Vehicular crash avoidance, Vehicle to electronic devices communication, Road Side Units to other infrastructure (I2I) communication, and OBU to RSU (V2I) communication. The followings are listed bellow as it discussed below [13]:

i. **Location of Positioning System awareness**: The current location of each vehicle gets from Global Positioning System (GPS) via the embedded electronic device the so called OBUs.

ii. **Communication capacity of OBUs:** Vehicles equipped with OBUs can communicate and exchange of an information with another neighbor vehicles which creates a real time communication and gets the location of the vehicles from GPS satellites.

iii. **Vehicular kinetic data's awareness**: each vehicle gets an access of kinematic information by the means of embedded OBUs.

iv. **Vehicular crash avoidance:** The vehicles speed is possible to control by using an algorithm of mathematical analysis by the means of OBUs, so protecting vehicles from collision between them is possible in the real world.

v. **Inter vehicle communication**: The communication among the vehicles is possible without use of any fixed infrastructure, OBUs to another OBUs is the way to exchange information between vehicles.

vi. **OBU to RSU (V2I) communication**: The communication between vehicles and the roadside units or the wireless communication among fixed and mobile infrastructure. Here is a direct exchange of messages between individual vehicles in the given network [14].

vii. **Vehicle to electronic devices communication**: This is the direct communication between the automobiles and humans who have electronic devices like cell phone, pads and others.

viii. **Road Side Units to other infrastructure (I2I) communication:** The exchanging of information or data among fixed RSUs and mobile infrastructure OBUs and so on.

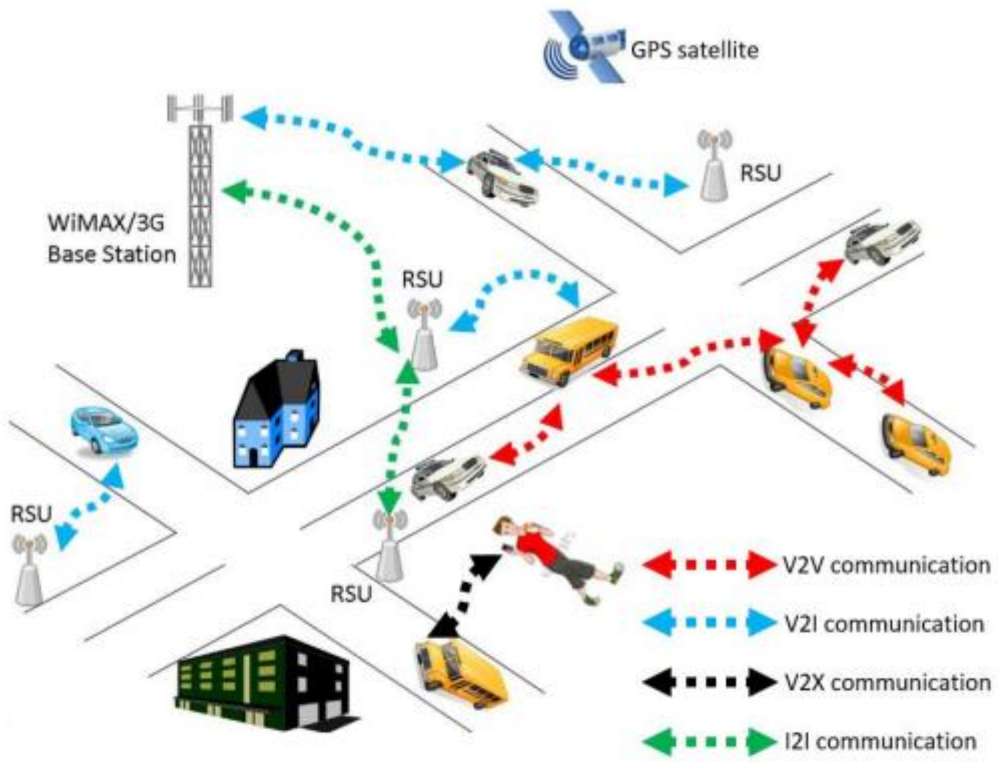


Figure 2.1: The various types of wireless communications in vehicular VANETnetworks [13].

In the vehicular communication networks could have been thought as an element of Mobile Ad-hoc Networks which are the primitive part of VANETs. However, due to the unique characteristics of VANET Technologies comes from existing MANET technologies by taking of their techniques, their protocols, and in some extent they are unsuitable for utilization in VANET technologies. As we can see in the following listed subtitles shows The following are among some of the unfamiliar properties of VANETs they are discussed in [13] and [15]:

i. **Higher nobilities of public vehicles:** when we are going to see the speeds of VANET in relative to MANET VANETs have extremely higher speeds in comparison to the MANETs that own medium speeds. For instances, driving vehicles in cities, the specific speed of each vehicles are limited between the speeds of the 40 km/hr and 60 km/hr, the typical limited speed of vehicles in highway is in between 80 km/hr and 110 km/hr in the given range of communication.

ii. **Active Higher earth science**: Because of the higher mobility of cars and the presence of so many different road lanes in opposite directions for the traffic flowing in vehicles, the behavior of the geographical topologies of the vehicular network that changes in a regular basis of natural phenomenon.

iii. **Systematized of vehicular mobility:** Vehicles are restricted their mobility in accordance with the design of the urban road and rules and regulations of traffic laws with the habits of drivers etc.

iv. **The densities different networks:** when the Network becomes busy, the densities of vehicles get in to very high level of injuries, specifically in the cities lane and urban highways, when we see in the rural areas they are very low and lower in cities during the night time.

v. **Difficult environmental function:** The speedy mobility of cars in the cities, as well as the presence of so many highest buildings and trees longer in height can get different results in unique harsh fading blockage of transmitting and receiving data's and shadowing effects on vehicular communication of channels among mobile vehicles. This can result for unqualified of wireless communication channels in the context of inter vehicle communications.

vi. **Unrestrained energy of capacity:** The capacity power of the node's battery is used by equipped embedded OBUs in vehicles, a lot of electrical sensor devices and other different types of communication of electrical sensor devices which are found in all smart embedded vehicles. As a result, unlike MANETs, energy or power limits in VANET networks do not constitute as a design gap in the vehicular automotive networks.

2.2 Overview of VANETs

The Participant vehicles that connected in VANET networks are outfitted with a number of wireless sensors and OBUs that enable a real time connection in the wireless communication among vehicles and other devices with their neighboring. Those wireless sensor devices and the vehicular electronic devices they all allowing to each other as sending and receiving information's or data's through the wireless medium to other vehicles or OBUs and other electronic devices like RSUs by keeping their communication range. The devices are considered as packet sender and packet receiver possibly considered also as routers. The driving vehicles can create short coverage range wireless communication networks which are ad hoc networks that could broadcasting the kinematic data to vehicular networks or transportation in the transportation sector or agencies who are processing the data to modify traffic flow and traffic safety in the public and private highways. Vehicles connected with VANET networks are equipped with global positioning system (GPS) or DGPS (differential global positioning system) receiver for getting of the vehicles position and location [15].

The fixed infrastructure RSUs are directly connected to the backbone networking device and get positioned in a strategic positions in the highways for helping effectively, and timely arriving vehicular communications. The network electronic devices utilizing using IEEE 802.11p radio technology installed in RSUs to provide the best with shorter range of wireless communication. For both safety and non safety communications VANETs are basic foundation for which cars or vehicles can collecting an information, processing the given data's, and transferring of data are the main some of the VANET functions. So many different researchers and scientists have been examined the capacity of VANET technologies and identified in different ways categorized under safety and non safety communications [15].

Those different algorithms which are already applied in VANET technologies are expressed depend on their natural circumstances like their electrical, physics and in different characteristics of their behaviors. So many different researchers have been conducted their studies on VANET they used different systematically techniques. As we have seen from the different researches so many papers of VANET studies are still they are only conducted in simulation ways rather than practical implemented without very few studies are already implemented. From those many researchers who have made studies on VANET technologies some of them tried to how to analyzing, demonstrating and creating of the system of communication models some of them have put their future recommendations [15, 16].

2.3 Vehicle to everything Communication

Vehicle to everything communication holds a vast or abroad meaning that encompasses all conceivable modes of communication among the vehicles and vehicles among other fixed and mobile infrastructure with its neighbor electronic devices. Here vehicle to everything communication which are the natural extension of conceptual VANET technology, in which the vehicles are no more longer the only communication of node to node included, however it is part of the greater technological system involving so many different parts of elements. VANET is a key part of an Intelligent Transportation Systems which is also called Intelligent Transportation Network that categorized under communication technologies family. Automotive researchers have been built a number of different application systems and services that have been evaluated and defined based on this notion and are closely tied to VANET technology. Although different types of papers are published, but the real time communication of vehicle to vehicle are become difficult when put in to practice despite some VANET technologies are successfully implemented [17]. As a result, there has been discovered rapidly that Vehicle to Vehicle communication technology by itself was not enough to and forced the policymakers to enabling the quickly and successfully employment of the various broadly application scenarios offered by those who are ITS communities. As an outcome, the ability of the communication of mobile vehicles with other electronic devices nodes that can be implemented or used in the fixed infrastructure which are on the side of public roads, remote area service in the central part passengers, the bikers, smart electronics devices, and etc was assumed by realizing that the vehicle's capacity should have not be limited for communicating with other vehicles only. As a result, the V2I and V2V concepts has already evolved into the vehicle-to-anything (V2X) concept [18]. So it is possible now to have the norm in the ITS communities as well. This days, there is considered in the ITS community that future vehicles' networks are going to be fully smarts. these current networks will have enable them to became one of the different cooperative communication nodes of a distributed ITS ecosystem supporting an ever-increasing range of services of applications by utilizing the most correct media of communications [19].

What the point here is this plan of communication is not only in the vehicular communication in the transportation sector but also which includes other modes of transportation that could be more benefit of ICT for making people and their movement going to be safer, more communication efficient, environmentally kept pollution and commercial economics will be viable. The alpha and omega way of creating such as large enough scale of integrated electronic device communication environment is to have a defined communication and to implement a standard strategically communication systems. Intelligent Transportation System is a larger with internationally market with so many different stakeholders and public player communities. From the regulatory authorities and policy makers standpoint, different specifically geographic limits has been applied [20]. The essential instrument required to translate these conceptual restrictions into technically feasible constraints is a global standardization procedure. When trying for integrating the various different standards into a international ITS scenario, fewer inconsistencies and problems emerged, which today's is underway, to emphasize the invention, creation and escalating participants various different SDOs and vehicular ad hoc functional forces in an intersectional harmonization phenomenal process which is this time achieving an international footprint [21]. Would you imagine what the art of mobile communications what today has already reaches? Could you have ever thought what mobile communication will be reached after 10 years? May be experts should focus their hard working efforts on what maximum they can do in real time. In the coming close future, With a small population in the public service, instead of struggling the most hard longer in terms of challenges, such an application systems are more Mindy and technically more interesting, and attractive with those which are found under higher in profile services. Those who are developing an application systems, they must be have to take carefully when they wants to use them. It is the most clear that the given time is obviously in the essence of most safety specifically systems of applications. By using the collision for avoidance technique, the time and the location are became the most important applications. In the fields of intelligent transportation system currently advancing in the right time at the right place with the values of IPv4/IPv6 interoperability in appreciate way of adopting IP values in the fields of wireless Communications in the ITS system. However, the requirement to various speedy wireless communications for those which are already safety based critical communication systems are in nice understood mode, especially with current's radio communication technology. May be the best way in a simple solution we introduced would to limit the 5.9 GHz band of frequency for those safety applications of all other different systems. To create a well established and feasible, hardworking for making workable easily, and when fault happened solving easily for maintenance technology system developers and the ITS regulators should advice together, in the institutions of this EU/US HTGs [21, 22]. There are three modes of communication exist between vehicles, the RSU, and the fixed and mobile infrastructures. Here in this [21-25] clearly being discussed:-

2.4 Ad hoc Domain

In the ad hoc domain of Vehicular Ad hoc Network it can be categorized from driving vehicles prepared with an electronic device On Board Units and a fixed base station infrastructure along the road side the so called RSU. There are two types of available communications within the concept of ad hoc domain as it is discussed before:

- In the ITS industry from time to time it became rapidly attracts the ITS scientists and researchers all including the academicians in united states (US) and Europeans (EU) specially shows more interest in the transportation sector. Because of its ability to improve safety of the road traffic, with efficiency of driving vehicular systems and extending onboard electronic devices of the vehicles communicating with other vehicles by the means of OUBs forming the VANET, that make allowing the communications among the driving and stationary vehicles within enough distributed conditions with the decentralized in coordination form. If there are straight forward communication among the vehicles of the wireless connection is available among the vehicles, forming a single node vehicle to vehicle communication, If there is no direct connection among them a committed routing protocol is used to forward data from one vehicle to another until it reaches the destination point, forming so many nodes of communication in vehicle with vehicle.
- The vehicle make communication with another RSU in the roadside unit so as to increase the distance or range of communication by making send and receive and the data’s forwarding from one point of position to another point of position a special application forming vehicle to another fixed or mobile infrastructure communication (V2I). Although there are no direct communication links between vehicles to

infrastructure, a dedicated routing protocol is used to passing the information or data from the one vehicle to another until it reaches its destination, forming multi node vehicle to vehicle communication. Vehicles communicate with a RSU to extend their communication range by sending, receiving, and forwarding data from one node to another.

2.5 Infrastructural Domain

The RSU get a link access to those different infrastructural networks, and it helps to allow the OBU device to get an access infrastructural device networks. Within this phenomenon, if the AU is getting registered with the device the so called OBU, it is possible to interconnect for any of interne based nodes.

2.6 VANET Components

These three components OBUs, RSUs, and AUs are the basics that are used to create the VANET Technology; these parameters are addressed in detail below [26-28].

i. **Application Unit:** an application unit is an electronic device which is found inside the vehicles that installed in accordance with the procedures of the manual system application. It is designed for different purpose for the safety of applications and a permanent device which is going to provide as an internet access via onboard units such like personal of digital assistant (PDA). An application unit makes a communication with an authorized VANET networks only by the means of OBUs. An AU is being connected via wired connection or wireless connection with OBUs. Most probably the AU could install in the same unit physically as OBU.

ii. **On Board Unit:** An OBU is a wave electronic device which is found in the same condition of AU installed inside the vehicles and it is used to communicate by exchanging an information or data with another electronic devices OBUs and with the fixed infrastructure roadside unit. Here in this point, the Resource Command Processor (RCP) make controlling and managing the resources, this includes the memory that could a read/write for the purpose of storage and for retrieving the information has already stored data, user interface to creating an understanding of the device for humans, the special interface for making connection to another vehicles or OBUs, and a network device for short to medium range of the wireless communication using an open source IEEE 802.11p radio technology based. The radio frequency IEEE 802.11p wireless communication link channel is used to communicating OBUs to OBUs and OBUs to RSUs and providing a service of communication to the application unit. Wireless communication radio technology access, ad hoc and geographical routing, to control networking crowded, message reliability transfer, security of data, and the mobility of IP services are the most beneficial functions OBUs.

iii. **Road Side Unit:** RSU is an electronic wave device which installed on the strategic position of the road side in a specific place like in parking area and intersection place and on other specific strategic positions. It became provide in equipped with the device of an authorized network for the purpose of in a short range of communication by using an open source wireless protocol the so called IEEE 802.11p radio technologies and a possible installed with extra network equipments.

2.7 The Dedicated Short Range of Communication IEEE 802.11p WAVE

A wireless communication of an open source wireless protocol which are DSRCs/WAVEs are IEEE 802.11p FCC standard based on previously Wireless local area networks procedures for specifications. The DSRC (Dedicated Short-Range Communication) system, which is special to VANETs, is a short to medium range communication technology that works in the 5.9 GHz band of frequency for the purpose of public transportation safety and private sector purposes. As a result, a United States institution Federal Communications Commission (FCC) had been assigned as a standard of 75 MHz bandwidth in range 5.850–5.925 GHz band of frequency to the dedicated short range communication. In accordance with the DSRC system it has an ability of handling the vehicles speed up to 200 km/h in the short range of 300 meters up to the medium range of 1000 meters long, and when we are going to see the data rate it handles 6 Mbps up to 27 Mbps which has already covering the operations of the environment changing dynamically. As the following figure illustrates the layer in the media access control controls the process and interfacing the functions has been defined by the IEEE 802.11p. As the result we expected, it is constrained by the IEEE 802.11 standard's scope, which stipulates that the physical and MAC layers must operate within a single channel. As we can see from the figure below in accordance with IEEE 1609 standard, the layer at the top holds the extra difficulties associated with the DSRC channel, as seen in Figure 2.2 [28-31].

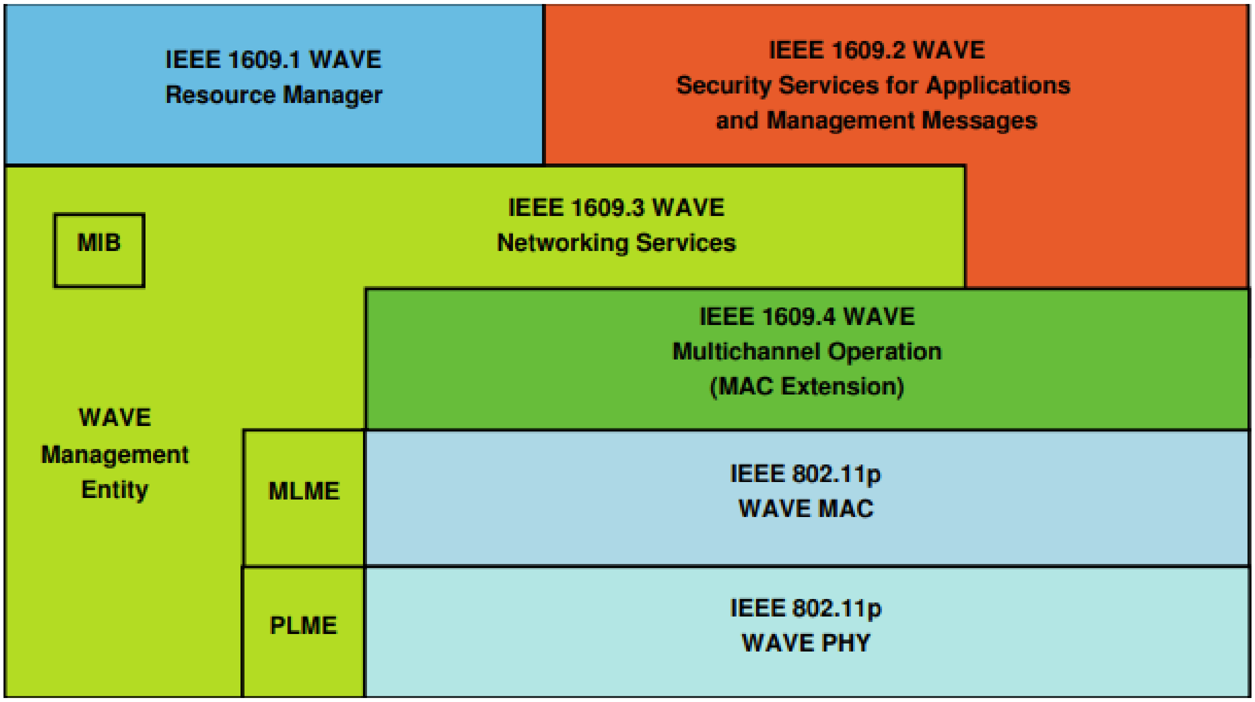


Figure 2.2: The link of Standard architecture of IEEE 802.11p WAVE MAC and IEEE 802.11p in physical layers [29].

2.8 Operational vehicular networks in multichannel frequencies

In each and every frequency assignment of channel frequency in the form of an application system type is must, so as the ETSI Institute made standards: from 5.855 MHz up to 5.875 MHz band of frequencies are assigned to ITS of non-safety applications according to FCC: from 5.875 MHz up to 5.905 MHz band of frequencies are assigned for safety with traffic efficiency application systems, and from 5.905 MHz up to 5.925 MHz band of frequencies are assigned for the future of ITS transportation systems. The overall frequency spectrum is under categorized in 50 ms time in slot in the DSRC, and the data's have two different priorities in separately mode: lower data dissemination information sent in to the SCH frequency channels, and higher safety or control signals frequency channels sent into the CCH. These automated filtered messages are monitored through all the driving vehicles. The DSRC protocol is designed for the purpose of helping automobiles and fixed infrastructure roadside equipment to make communication between them [32].

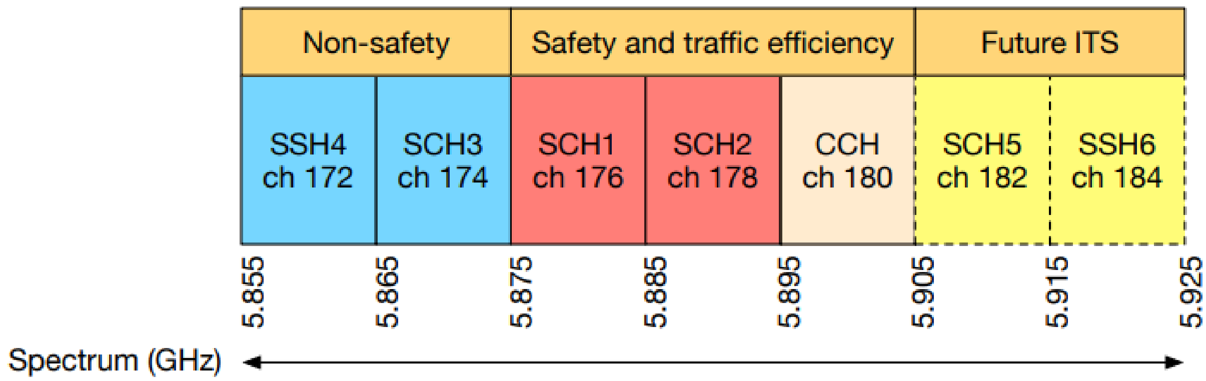


Figure 2.3: According to the IEEE 802.11p European standard, multichannel operation in automotive networks is possible [29].

The IEEE 802.11p WAVE protocol, developed by the IEEE 802.11 technical committee, proposes changes to the existing IEEE 802.11 wireless standards' physical (PHY) and medium access control (MAC) layers to accommodate ITS applications. In the 5.9 GHz range, this comprises data transfers between high-speed cars and between vehicles and roadside infrastructure. The ultimate goal is for WAVE to become a universal standard that may be used anywhere in the world [33].

2.9 The standard communication protocols of IEEE 802.11p based

The communication between vehicle to vehicle and vehicle to fixed infrastructure IEEE 802.11p has been specified a new group the so called physical layer and medium access control layer. The table below shows the difference among the following three IEEE standards that are IEEE 802.11a, IEEE 802.11b, and IEEE 802.11p. In United States the federal communication commission has been developed a standard services and standard license requirements for DSRC, which uses the lower frequency 5.850 GHz up to the higher frequency 5.925 GHz band width of 75 MHz for the use of public application safety and the private sector applications in 2003. With the absence of a central access point, the driving vehicles across a road and the fixed infrastructure that is equipped on the roadside base stations is connected with each other using the assigned standard frequency and a licensed service. The parameters that are called as Quality of service is one of the most difficult tasks in the VANET [34].

Table 2.1: Comparison of IEEE 802.11p with 802.11a, 802.11b [34]

Standard	IEEE 802.11a	IEEE 802.11b	IEEE 802.11p (DSRC)
Modulation	OFDM	DSSS	OFDM
Frequency [GHz]	5.725-5.850	2.400-2.485	5.850-5.925
Bandwidth [MHz]	20	22	10/20
No. of Channels/non-overlapping	12/8	14/3	7/7
Maximum Rate [M Bit/s]	54	11	27/54

2.10 Related Works

In current's technology phenomenon, intelligent transportation sector play a vital role in improving commuter lives made safer daily. The data systems of traffic management in this time centralized vehicular applications victimization technology like Traffic Message Channel (TMC), in the data which offering in the road traffic conditions [35]. Unconditionally, because of the centralized method, an absence of short latency's times, and it doesn't have the opportunity to inventory services to time critical applications. Finally, VANET based technologies are low delays with the capability of utilize extra efficient. Time delays must be modified by making compare and contrast various types of different algorithms [36].

In [37] expresses the distributed approaching to rush hour amount. A vehicle shows only the connectivity between them. The consequences, the algorithm found for the purpose of detecting and quantifying congestion in the distributed condition which is independent of any form of external systems, and to have assurance of data exchanging efficiently. The main aim of this thesis is to have driver's information about the traffic and the road conditions which going above they can’t see physically. In [14, 38, 39] many of those systems give out by ITS experts and forced by policymakers needed beyond the V2V technology of the communication system for being applied rapidly and in effective way. The consequence, the vehicles potential to interconnect the fixed infrastructure with so many different communications node that could be employed within the roadside fixed infrastructure has been investigated by making realize the vehicle's ability for communicating with another vehicle should be unlimited to other cars lonely. As a result, the V2I with V2V ideas evolved into more various extensions of the vehicles to others concepts (V2X). In the current’s ITS societies, it is considered that the vehicular communication capacities would possible future automobiles to become one of many collaborative technologies By making utilize the most applicable communication systems of channels, communication hops of the distributed ITS part can help an expanding multiplicity of the services and systems. VANET depend technologies, in the other ways, going to have shorter time latency and the potential will be recycled beyond rapidly. In [40] has been written in a logical and brief condition to have provided an concepts of the vehicular communication in the ad hoc for networks and to instant the different aspects of this area so as to help investigators and innovators in figure out the basic characteristics of VANET systems of technology, the progressed data routing systems, communications technologies, and protocols pre-owned within those technologies. We innovated that localization systems implementations modified the efficiency, and overall routing protocol capacity using position-based protocols. The node to node communication not holds not only the origin and end nodes, but also most of the nodes in the immediate district. However, the data on those vehicles and the vehicles owners has to be sent with high security and, more importantly, in timely phenomenon, like a delay in message interchange could recorded result in a very catastrophic results, like that vehicle crashes. Additionally, the nature of vehicular network is highly dynamic, with repeatedly and directly vehicle arrivals and departures, as well as clear interconnection in vehicular times. By modifying fixed infrastructures on the road side using the so called RSU, this thesis will be able to solve the time short connection durations delay.

CHAPTER THREE

3 METHODOLOGY

3.1 Software Used

MATLAB is our best chosen software due to its faster computing capacity at doing mathematical computation because it is composed of with a lot of built in and optimized functions within. So we have used MATLAB/R2015b for computing, analyzing and developing algorithms.

3.2 Methods

The following methods were used to perform this thesis research:

- Literature Survey and study the theories ,architectures and related titles
- Reviewing different types of existing works
- System Modeling and Problem Formulation
- identify the basic parameters which are essential during our system's simulation
- Selecting Models and designing
- Simulation of the model and designed system using MATLAB
- Observing the system behavior through software
- Result and discussion

3.3 General VANET architecture diagram

The general architecture of the VANET diagram is shown in the figure below. Both the On Board Unit and Application units are equipped inside the vehicles where as Road Side Unit is installed in the strategic position of the roadside. The function of Onboard Unit is transmitting of an information or data to another Onboard Unit equipped vehicle and it connected to the roadside unit to get an internet access and GPS location from GPS satellite. The Onboard unit equipped vehicles must keep connected to Road Side Unit so as to get some stored data’s from the server and to get an internet and GPS access.

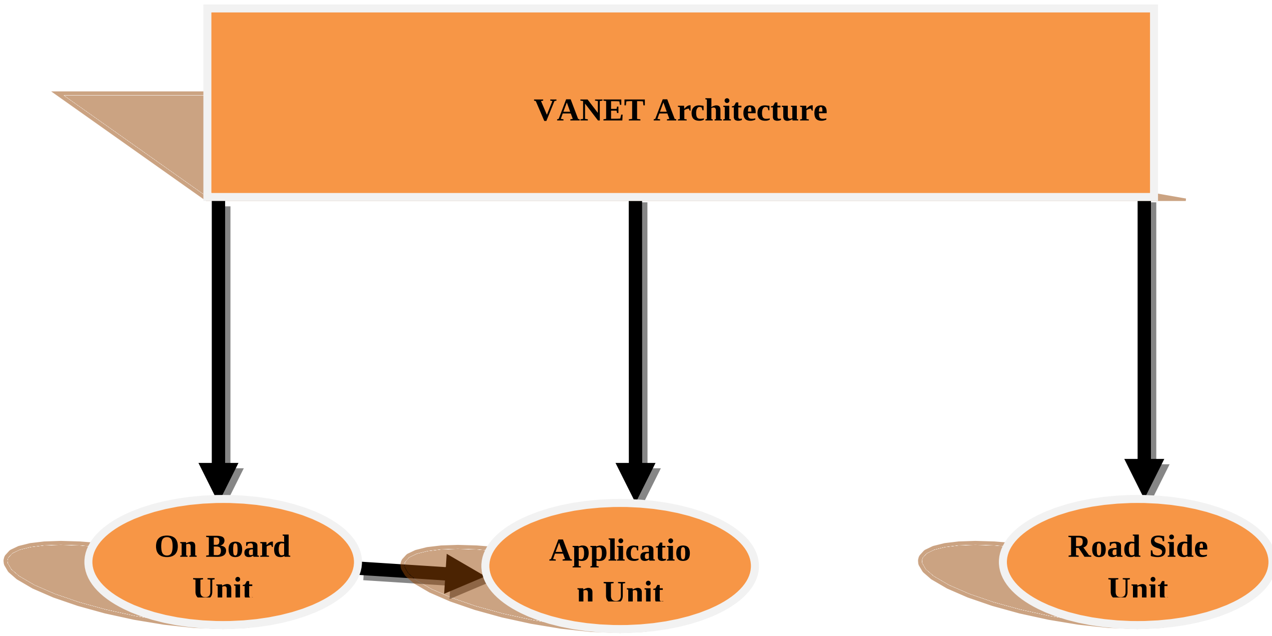


Figure 3.1: General VANET architecture

3.4 Proposed System model VANET communication architecture

i. **V2V:** V2V is an abbreviation word that represents for vehicle to vehicle communication via the Onboard Unit electronic device. The transmission communication medium in V2V communication has a quick rate of transmission and minimum time latency. A car can make important communication for exchanging relevant information such as accident, data analysis, speed control detection, and traffic flow to other OBU equipped vehicles in a vehicle to vehicle (V2V) communication.

ii. **V2RSU:** V2RSU is an abbreviation word that represents the communication between the mobile vehicle and the fixed infrastructure Roadside Unit. It is an ITS communication technology that allows exchanging of relevant information or data between Vehicle to Roadside Unit. The car creates a communication connection with RSUs for exchange data with other given networks such as the Internet. Furthermore, because of the infrastructure communication, V2 RSU consumes larger bandwidth than V2V but is lower exposed to attacks.

iii. **RSU2RSU:** RSU is a fixed infrastructure that placed along the road side. The RSU gets its connection link access from those different fixed and mobile infrastructural networks, and it helps to allow the OBU device to get an access infrastructural device networks. Within this phenomenon, if the AU is getting registered with the device the so called OBU, it is possible to interconnect for any of internet based nodes.

iv. **RSU2SAT:** RSU2SAT describes the connection between the fixed infrastructures Road Side Units (RSU) with GPS satellite which is used to get access of GPS location of the driving vehicles across the roads. The location of any vehicle can be access from GPS satellite through or by the means of RSU internet will be accessed then on the Onboard Unit which has already installed inside the vehicle in the graphic interface the location will seen.

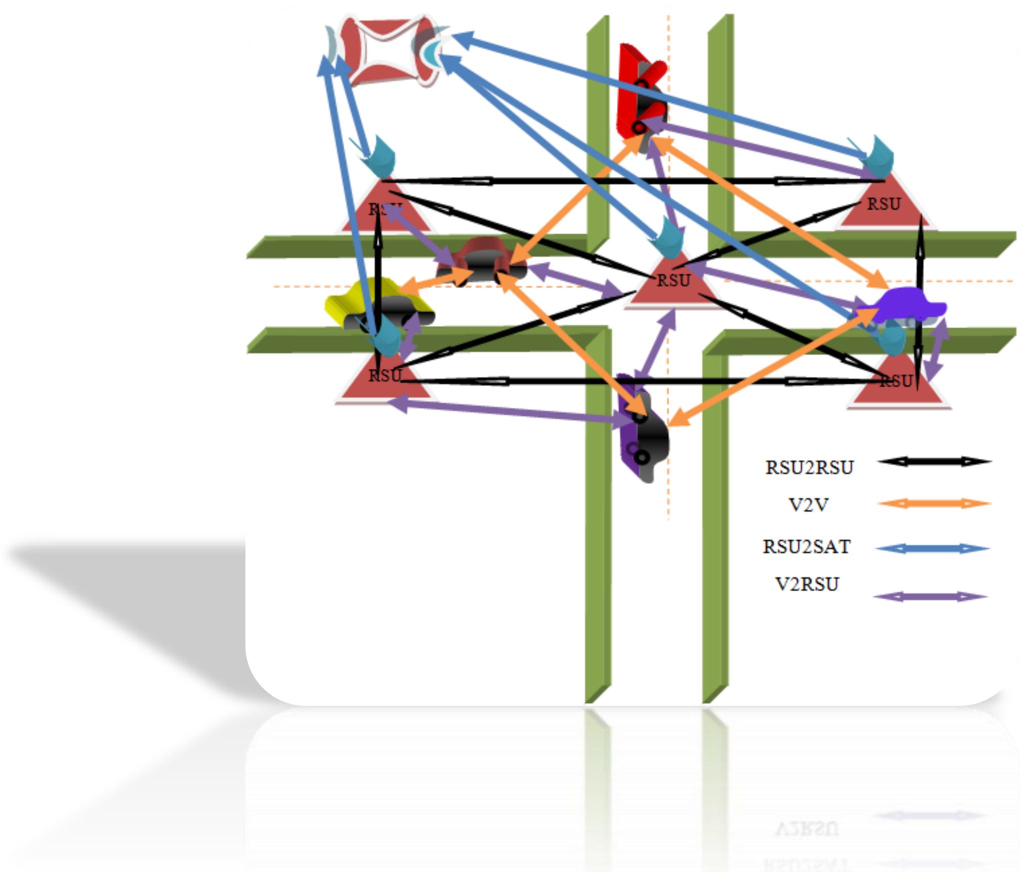


Figure 3.2: Proposed architecture of VANET Communication

3.4.1 Roadside Unit

A road side unit is computing electronic device that is installed alongside strategic position of fixed area, such as a parking area or an intersection crossroads, to create a local connection to vehicular communication traffic flow. RSU is made from network communication devices that use IEEE 802.11p open source wireless radio technology for preparing dedicated short range communication (DSRC). Roadside Units (RSUs) are used to create a connection with other different a devices that are network based devices within different fixed and mobile infrastructure networks. Lets to see some examples

RSU's key functions are listed as follows:

- Ad hoc networks specifically have a finite transmission communication distance, However, RSUs can assist by transmitting the data or information to other devices of RSUs or allow information to other OBU [41].
- RSU is used to connect the onboard unit (OBU) to the Internet.

3.4.2 Onboard Unit

Every vehicle normally has an OBU, a GPS-based tracking device that is used to share vehicle data with RSUs as well as other OBUs. The OBU consists of the resource command processor (RCP), sensor devices, user interface, and read/write storage for retrieving stored data. An OBU's primary purpose is to connect to an RSU or other OBUs over an IEEE 802.11p wireless link, and it is permitted to send messages to some RSUs or any other OBUs. Additionally, each vehicle contains a sensor-type GPS, an event data recorder (EDR), forward again and rearward detectors, and then an OBU that has been supplied more by vehicle's battery. These detectors provide inputs to the OBU Figure 1 demonstrates how to link one OBU with another OBU or RSU in accordance with the IEEE 802.11p (radio frequency channel) specification. Amongst certain an OBU's primary duties are data protection, IP portability, wireless transmission access, congestion control, ad hoc and geographical routing, and other services. A DSRCS transceiver known as an "On-Board Unit" is typically fixed in or on a vehicle, though it may sometimes occasionally be a portable unit. Whether a car or a passenger is moving or stopped, an OBU can still operate. The OBUs fight for time to transmit on one or more radio frequency (RF) channels while receiving data [41].

3.4.3 Application Unit

Application Unit (AU) is an electronic device that is directly connected to the On Board Unit. In order to connect both the electronic devices AU and OBU it need to have some medium which makes them stay connected. So, the medium could have two different way of connection that is through wired connection or by wireless connection one of them is possible to have a common link. The main function of OBU is providing a common link of communication service to another device Application Unit (AU). The AU is a device installed inside the vehicle which employs the supplier's applications in conjunction with the OBU's connectivity.

3.4.4 Dedicated Short Range Communications

An open-source wireless communication technology called Dedicated Short Range Communications (DSRC) is comparable to Wi-Fi in several ways. While Wi-Fi is mostly utilized for wireless Local Area Networks, DSRC is designed for highly secure, high-speed wireless communication between cars and infrastructure. Consistent with previous Wireless LAN specifications, DSRC (Wireless Access in Vehicular Environments) is an IEEE 802.11p WAVE (Wireless Access in Vehicular Environments) protocol. The DSRC (Dedicated Short-Range Communication) system is a short- to medium-range communication technology that operates in the 5.9 GHz band for both private and public uses. It is unique to VANETs. The 5.850–5.925 GHz band of frequencies was subsequently assigned to DSRC by the Federal Communications Commission (FCC) in the United States. The 5.850–5.925 GHz band of frequencies was subsequently assigned to DSRC by the Federal Communications Commission (FCC) in the United States. The DSRC system has a standard transmission range of 300 meters and can handle speeds of up to 200 km/h (up to 1000 meters).

The following are the essential functional characteristics of DSRC:

- Minimum delay: The time taken of opening and closing a communication connection is extremely clear on the scale of 0.02 seconds or 20ms.
- Lower interference: DSRC is highly resistant to other unauthorized radio interference in the communication time. It is limited range which covers maximum communication coverage only 1000 m it is also reduces the possibilities of radio interference from

distant other sources. The Federal Communications Commission (FCC) also protects DSRC for transportation uses.

Bandwidth=highest frequency-lowest frequency = f_h-f_l

Where, f_h = 5.925 GHz, f_l =5.850 GHz

BW = f_h-f_l = 5.925 GHz - 5.850 GHz = 75MHz

3.4.5 Satellite Global Positioning System

A Satellite Global Positioning System SGPS system is composed of a communication network of GPS satellites that are always sending a continuously data coded information, and it will allow the vehicles for their identification of locations on the Earth by measuring or calculating distances between vehicles and the satellites. The receiver of the authorized device can also get its relevant information of its speed, velocity and the direction in the same time.

3.4.6 Euclidean distance

The distance between vehicle to vehicle (V2V), vehicles to roadside unit (V2RSU), roadside unit to roadside unit (RSU to RSU), and in addition to that the distance of the roads all this distances are calculated using Euclidean distances. Euclidean distance is the measurement of distance in between two end points or positions. The other name for Euclidean distance is called Pythagorean distance due to the points can be calculated from Cartesian coordinate. These names are drawn from the ancient Greek mathematicians Euclid and Pythagoras, even though Euclid did not characterize distances as numbers and the connection between the Pythagorean Theorem and distance calculation was not understood until the 18th century. The distance between two items without points is frequently referred to as the shortest distance between pairs of points from two objects. Formulas can be used to determine distances between different types of objects, such as the distance between two points. Higher mathematics has broadened length to include abstract metric spaces, and additional distances outside Euclidean distances have been studied. Several statistical and optimization strategies substitute the square of the Euclidean distance for the distance alone. Numerous analytical and optimization strategies substitute the square of the Euclidean distance for the distance itself.

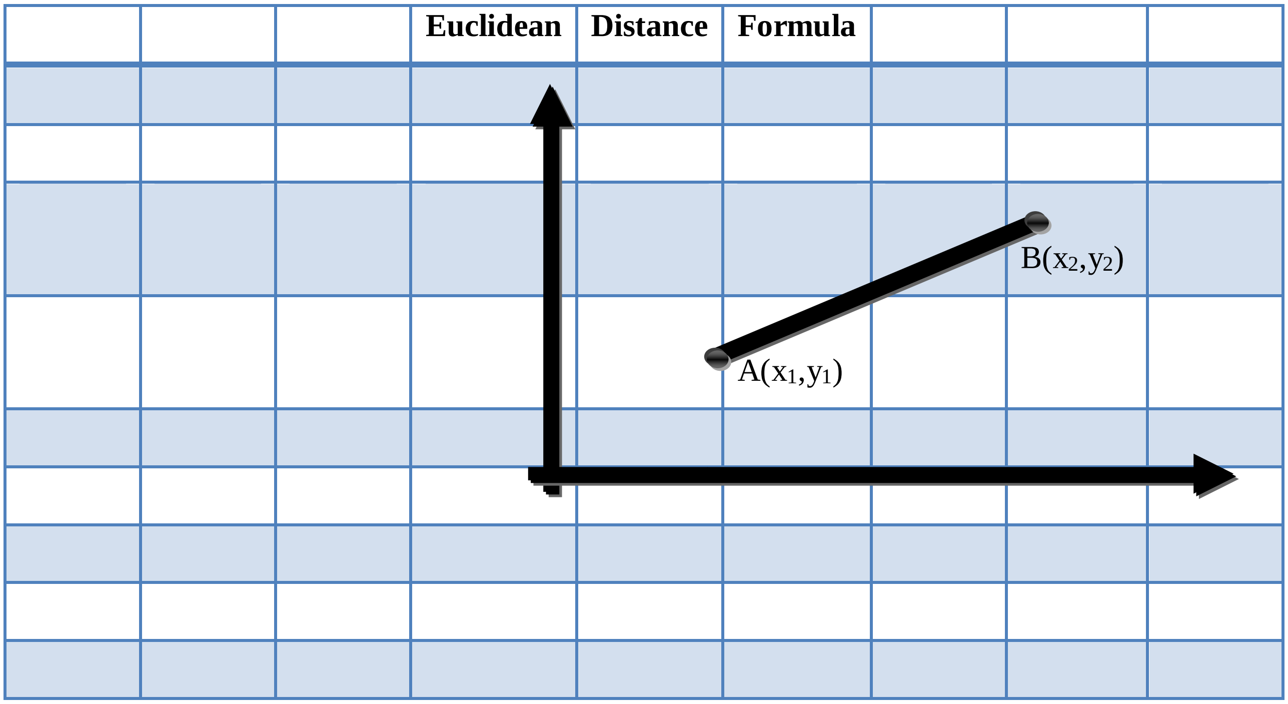


Figure 3.3: Euclidean distance

According to the Euclidean distance formula:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \qquad (3.1)$$

Where, $A(x_1, y_1)$, $B(x_2, y_2)$ are the coordinates of two points and d is the distance between $A(x_1, y_1)$ and $B(x_2, y_2)$.

3.4.7 Manhattan distance

The Manhattan distance is a quantity measurement for measuring the distance between two end points in a given N-dimensional vector of spaces. It is the sum total of the lengths of each line segment of projections onto the Cartesian coordinates between the end points. It is the total of the absolute differences between the measured locations of two points in all dimensional points of the basic two basic end points. Both are known as L_1 norm the first and L_1 metric the second one. It is used extensively in a vast area of field from regression analysis to frequency distribution. It was firstly introduced by Hermann Minkowski. The main concept of the Manhattan distance can be seen in the figure below.

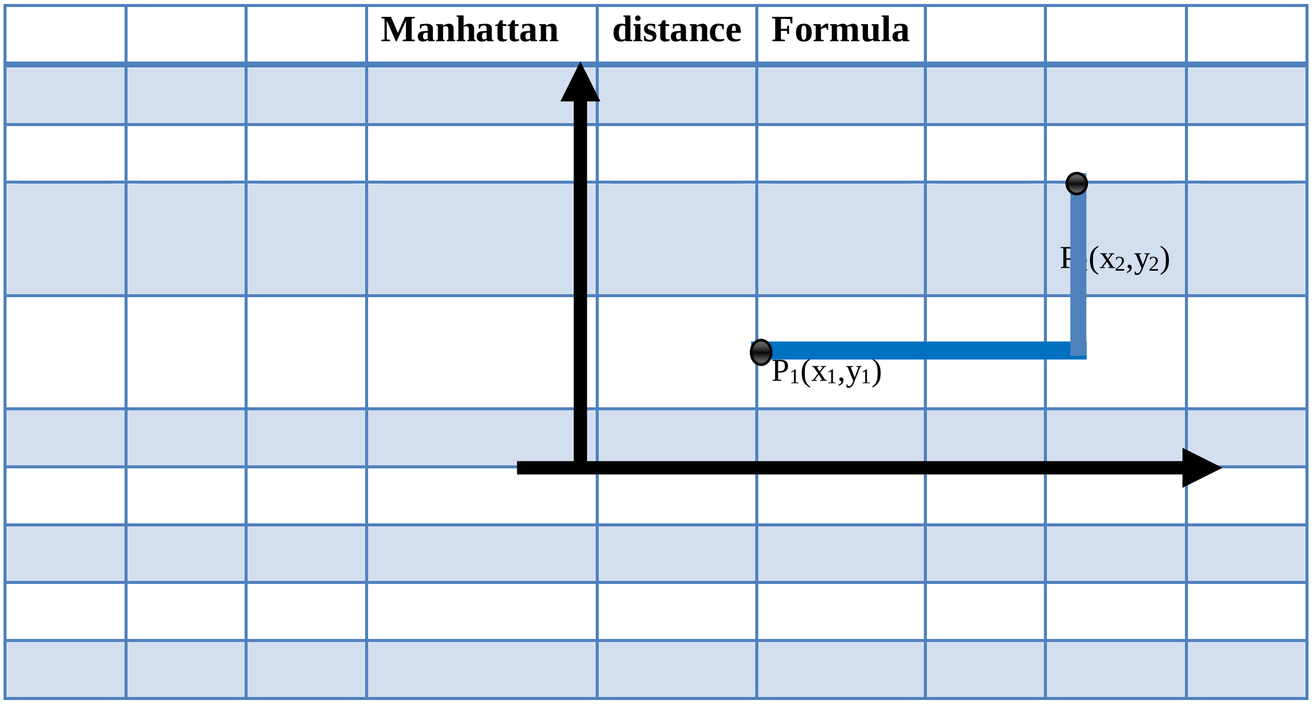


Figure 3.4: Manhattan distance

Manhattan distance two dimension space: Lets to see under consideration of the two points point one P_1 and point two P_2: p_1 (x_1, y_1) and $p_2(x_2, y_2)$,Then, the Manhattan distance formula for the two given points p_1 and p_2 is given as:

$$d = |x_2 - x_1| + |y_2 - y_1| \qquad (3.2)$$

The Manhattan distance formula says: where, $p_1(x_1, y_1)$, $p_2(x_2, y_2)$ are the coordinates of the two points and d is the distance between $p_1(x_1, y_1)$ and p_2 (x_2, y_2).

3.4.8 Minkowski distance

Minkowski distance is the sum total of both Manhattan and Euclidean distance is Minkowski distance.

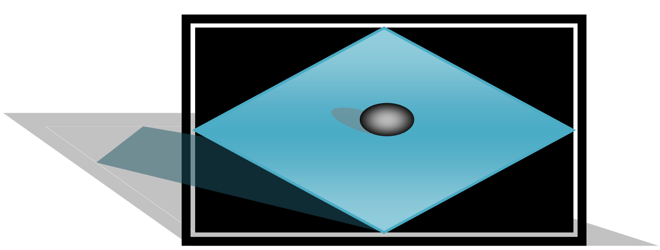
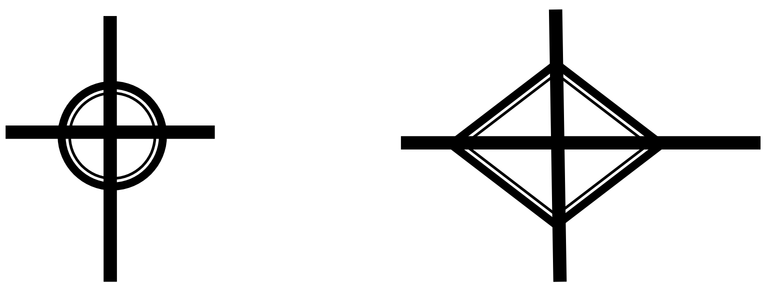


Figure 3.5: Minkowski distance

The following formula is used to get the Manhattan distances p1 and p2. A distance in N-dimensional space called the Minkowski distance is the separation between two points. It effectively combines the Euclidean and Manhattan distances. It is frequently used in machine learning, particularly in the idea of discovering the best correlation or classification of data. Several algorithms use the Minkowski distance, including K-Nearest Neighbors, Learning Vector Quantization (LVQ), Self-Organizing Map (SOM), and K-Means Clustering. Consider a two different dimensional space which has three points that are $p_1(x_1, x_1)$, $p_2(x_2,y_2)$, and $p_3(x_3,y_3)$, the Minkowski distance is given by $(|x_1 - y_1|^p + |x_2 - y_2|^p + |x_3 - y_3|^p)^{1/p}$. In r, Minkowski distance is calculated with respect to vectors.

Unit circles for different values of p



p=2 p=1

Figure 3.6: Minkowski distance Unit circles for different values

For example, we are given two vectors, vector1 as (4, 2, 6, 8) and vector2 as (5, 1, 7, 9). Their Minkowski distance for p=2 is given by, $(|4-5|^2 + |2-1|^2 + |6-7|^2)^{1/2}$, which is equal to 2. This article focuses upon how we can calculate Minkowski distance in distance R. We can calculate Minkowski distance between a pair of vectors by apply the formula,

$$d = (\sum_{1}^{n} |x_i - y_i|^p)^{1/p} \qquad \textbf{(3.3)}$$

Here, x_i is the first vector and y_i is the second vector.

Here, x_i is the first vector and y_i is the second vector.

3.4.9 Comparison of Euclidean, Minkowski and Manhattan distance

If we look at developed countries like United States and Europe, the whole city the buildings and the roads are laid out in blocks. The diagram below shows that buildings and lanes are laid out in block wise. Imagine we wants to travel by vehicles from point A to point B at that time imagine how the distance will get calculated it will not be calculated in a straight line, because there is no direct path because of the buildings rather it is better to calculate following the black horizontal and vertical lines. If the city road is designed in block wise in a system like in developed countries it is better to use Manhattan distance to calculate the distance between the vehicles and road side units following the road pattern of the black horizontal and vertical lines shown in the figure below. If there is no such a modern technology like in our country it is better to calculate using Euclidean distance by making line of sight the vehicles and the road side units it is possible to make straight line the distance between them. That is why we have chosen the Euclidean distance. Manhattan distance is a specific case of Minkowski distance when p=1 for Minkowski distance.

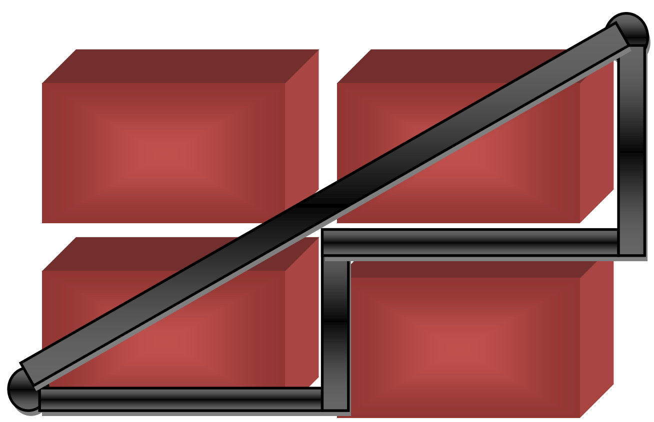


Figure 3.7: Euclidean and Manhattan distance

3.4.10 Mathematical calculation time, distance and speed of the vehicles

The time of the vehicle is calculated as: the time taken of the vehicle is equals to the total distance traveled by the vehicle divided to the speed of the vehicle.

$$T_{vehicle} = \frac{d}{V_{vehicle}} \qquad (3.5)$$

Where, $T_{vehicle}$ is the time taken by the vehicle, d is the distance traveled by the vehicle and $V_{vehicle}$ is the speed of the vehicle. According the FCC standard the maximum speed limit in

Dedicated Short Range Communication (DSRC) is 200km/hr. so we can calculate maximum time in 1km. Time = distance/speed = $T_{\max} = \dfrac{1km}{200km/hr} = 0.005hr = 0.3mim = 18\sec$

3.4.11 Algorithm for vehicle to vehicle communication

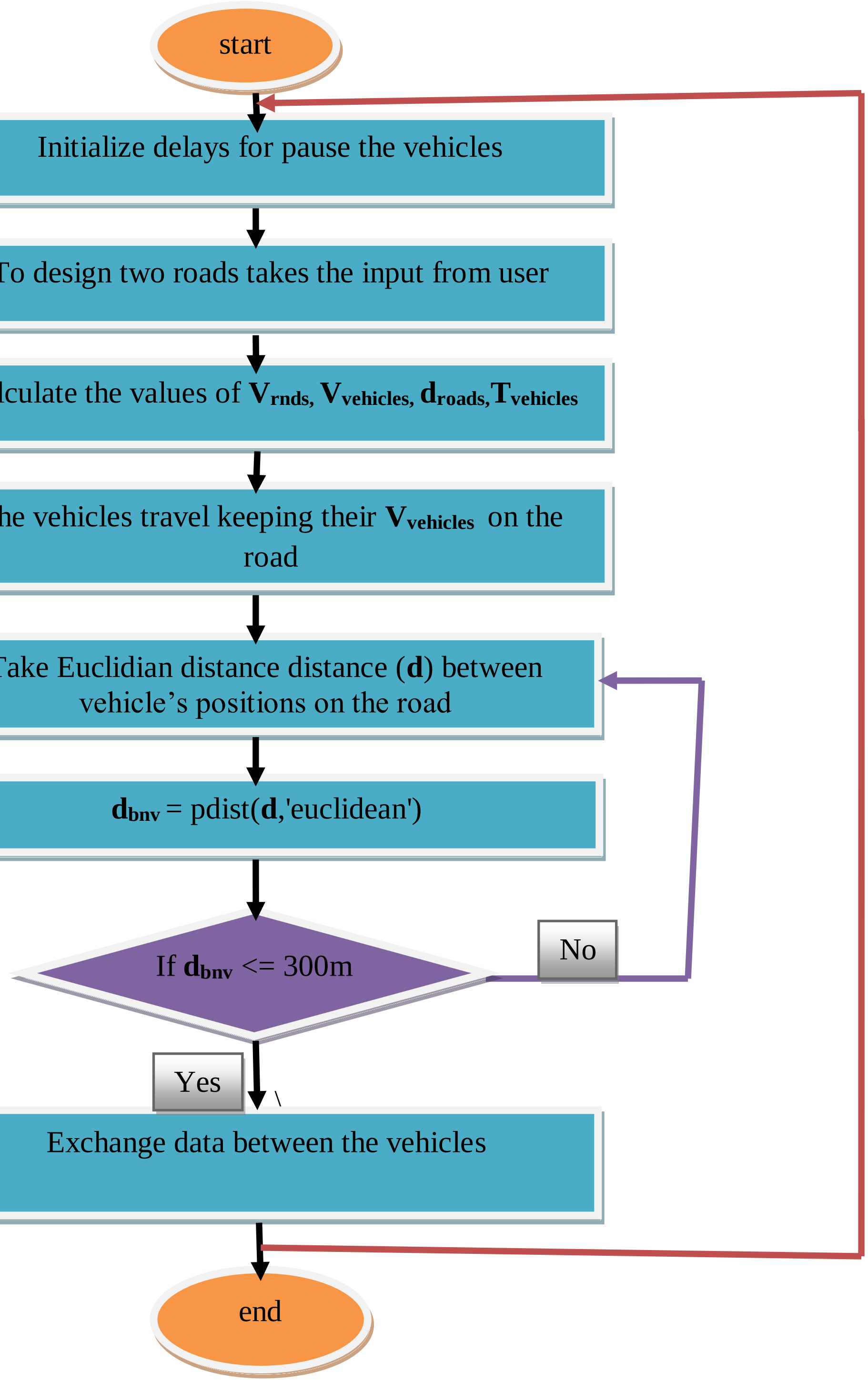


Figure 3.8: Basic Algorithm for vehicle to vehicle communication

3.4.12 Algorithm for vehicle to road side unit communication

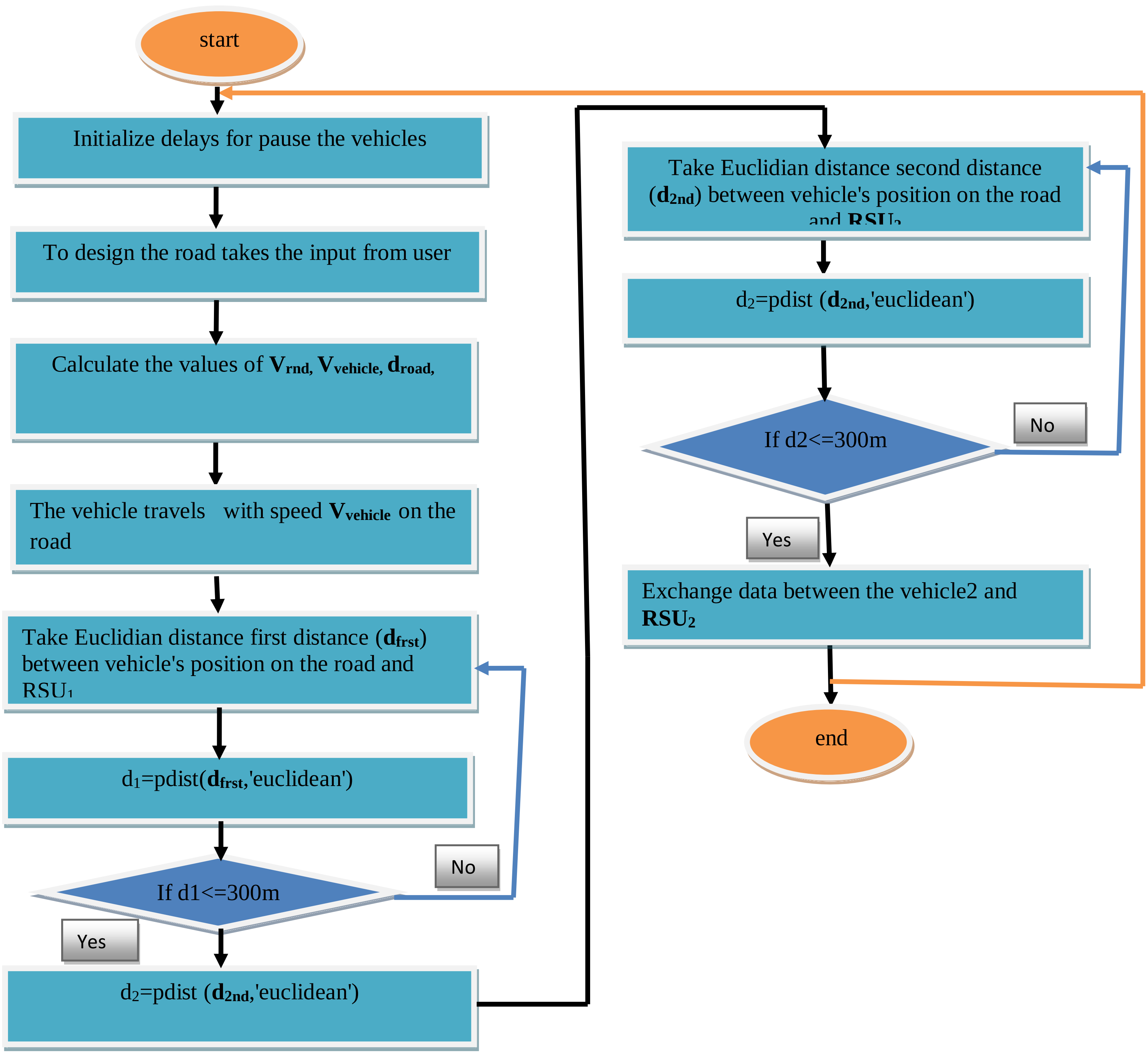


Figure 3.9: Basic Algorithm for Vehicle to Roadside Unit Communication

3.4.13 Algorithm for general VANET communication

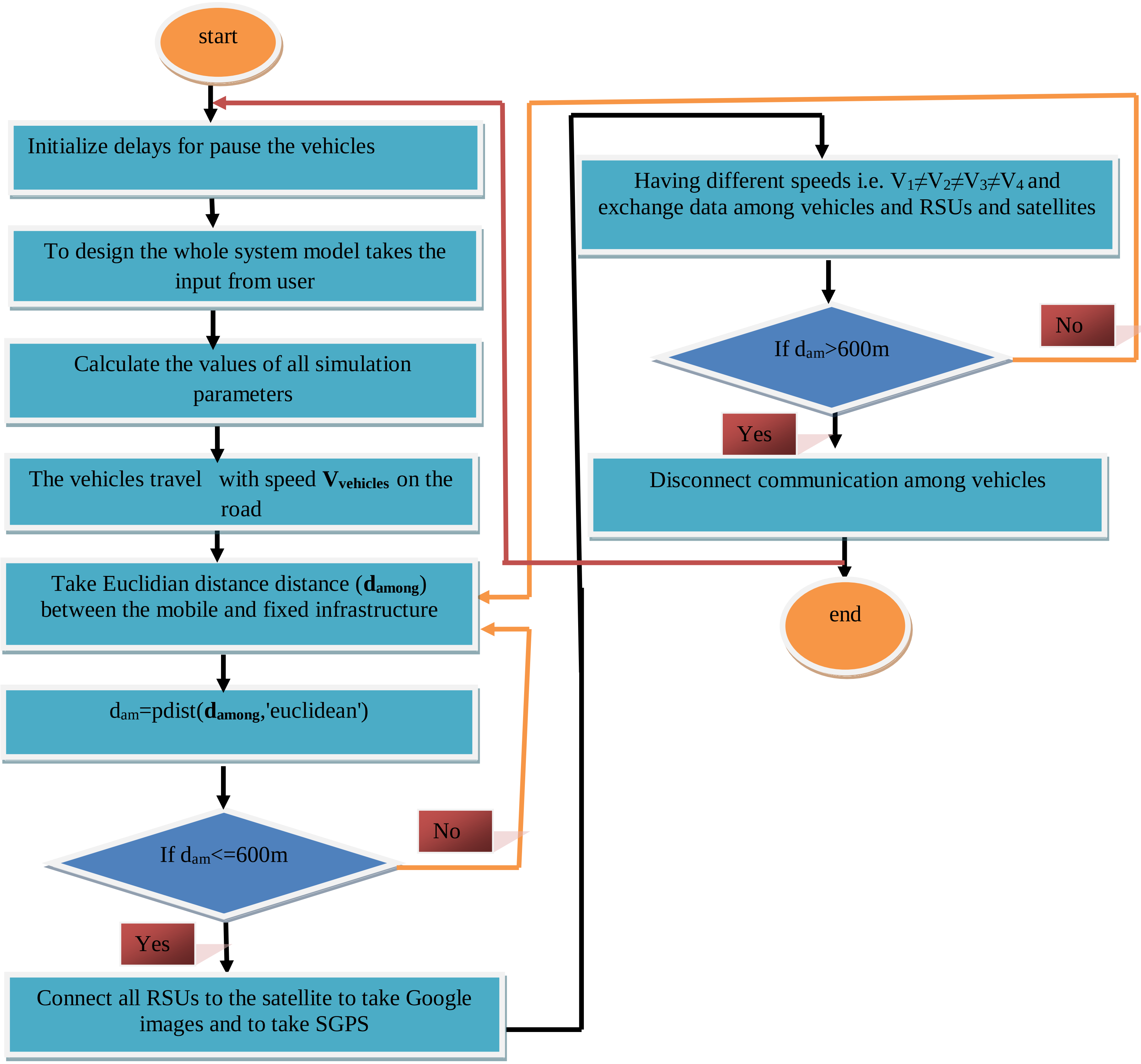


Figure 3.10: Basic algorithm for algorithm for general VANET communication

CHAPTER FOUR

4 SIMULATION RESULTS AND DISCUSSION

4.1 Simulation parameters

Table 4.1: Simulation parameters

No.	Parameters	Values	Remark
1	Band Width	75 MHz	Based o FCC
2	transmission range(DSRC)	300 m (up to 1000 m)	Based on IEEE 802.11p
3	vehicle speed	up to 200 km/h	Based on IEEE 802.11p
4	Range of Onboard unit distance b/n V2V	Up to 300m	Based on IEEE 802.11p
5	Range of Road Side Unit distance b/n V2I & I2I	Up to 300m	Based on IEEE 802.11p
6	W_{time}(in d$\leq$300m RSU) @V_{max}(in second)	5.4	Mathematical computation
7	Theoretical distance b/n V2I & I2I	Any where	Assumption
8	Time taken by vehicles	Depends on V & d	assumption

4.2 Fixed Infrastructure Road Side Unit

The fixed infrastructure RSU's will be placed at an area in equal radius of the curved road. We can install them anywhere but the communication range depends on how located the distance of RSU from the road and another RSU. If the road side unit is installed too far from the road, the connection between the road side unit and the vehicle will be disconnected. The capacity of the RSU's to transmit and receive information the maximum communication range is 200m-300m.The RSU should located at the center of intersection and at the center of parking area to cover large area of communication range. The RSU can be installed anywhere from 200-300m away, but the RSU is going too far from the vehicle and the coverage area will be small. The fixed infrastructure RSU can communicate in range with another RSU and can communicate with satellite. The distance of the road from source to destination and the distance between the road and the infrastructure RSU are measured or computed using Euclidian distance.

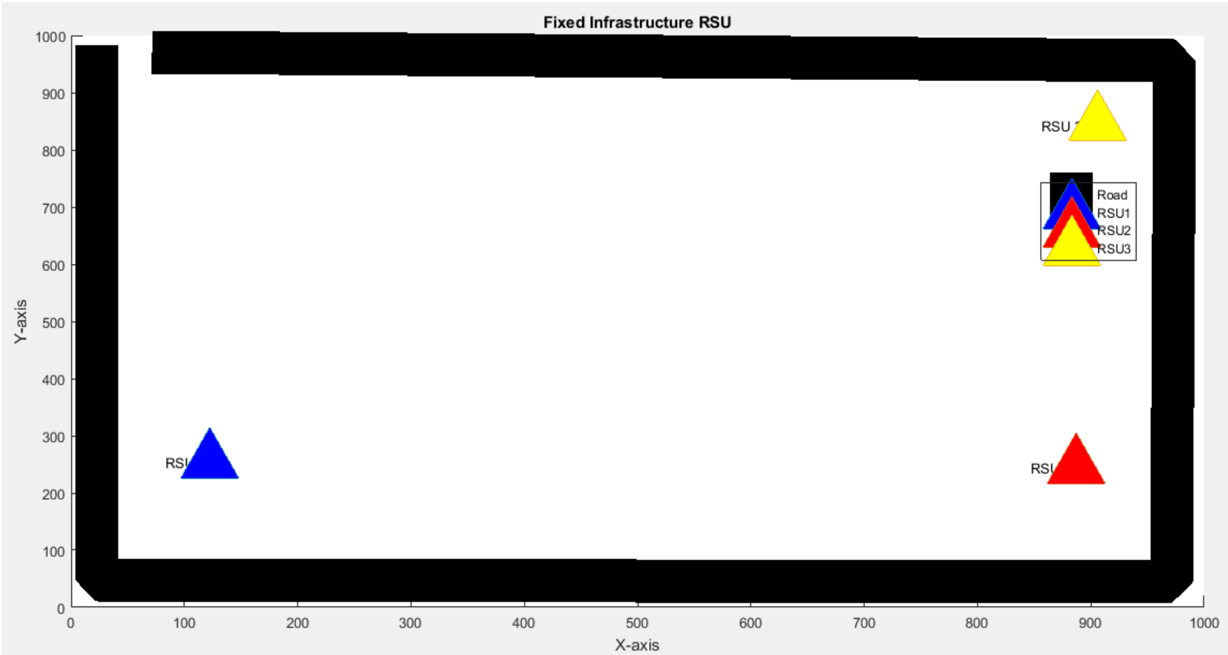


Figure 4.1: Road side unit

4.3 Moving Vehicle on The road

This is the moving vehicle on the road, as the picture below shows. In this part the vehicle is not fixed that is why we said the moving vehicle on the road. There is another device which is called Onboard Unit installed inside the vehicle used to communicate with another vehicle which has the same device equipped and can communicate with the fixed infrastructure RSU. When we are talking about the moving vehicle we are talking about the onboard unit installed inside the vehicle. The communication range of the onboard unit covers equal range of RSU 200-300m.

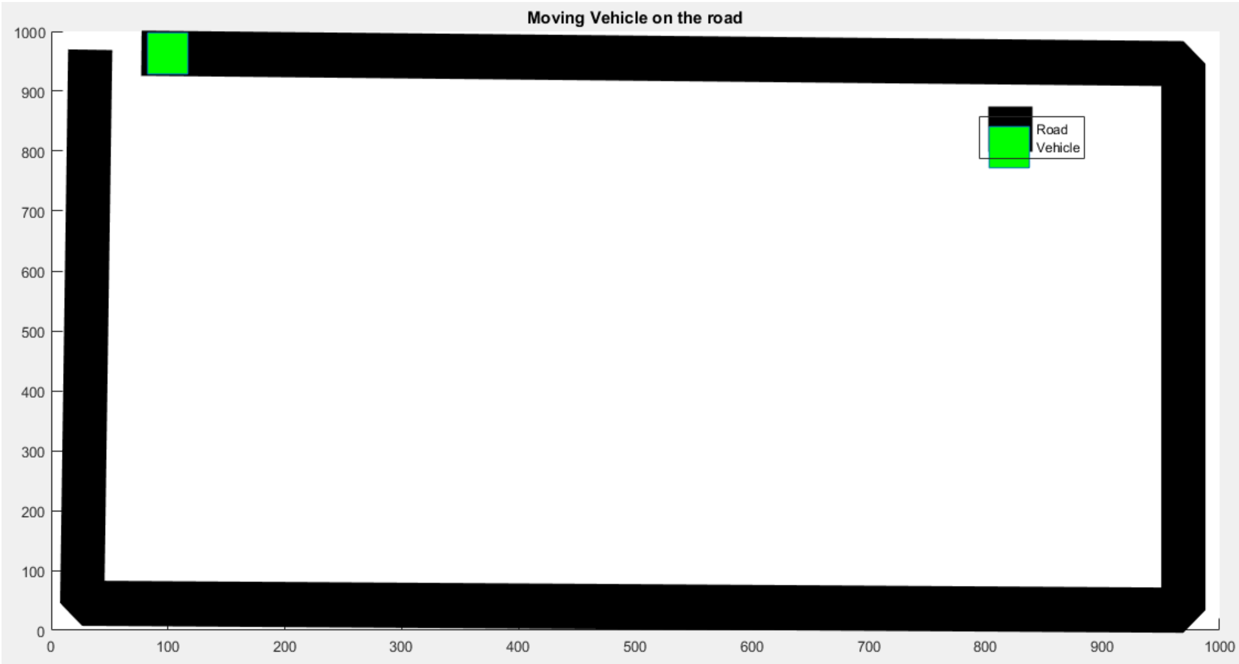


Figure 4.2: Moving vehicle on the road

Table 4.2: Parameters of moving vehicle on the road

Random time & Speeds		Distances of road(m)	Time of vehicle(hr)
Random time	Vehicle speed(km/hr)	d_{road}	$T_{vehicle}$
30	50	1.3876e+03	0.0278

4.4 Theoretical Vehicle to Vehicle Communication whole range

As we have seen on the above figure the following figure shows the theoretical communication range coverage area possible at anywhere no matter the distance between the vehicles is, the figure bellow shows communication range in distance between vehicles anywhere, with the same speed $V_1 = V_2 = 50$ km/hr and $T_1 = T_2 = 100$ seconds, and $w_{t1} = w_{t2} = 100$ seconds. Here two things are going to wrong when we are going to see practical implementation and the capacity to exchange of information or data between the vehicles is possible only in a range of distance d less than or equal to 300m.

In addition to that the speed of the vehicles must be unique or different so as to reduce or minimize collision between vehicles.

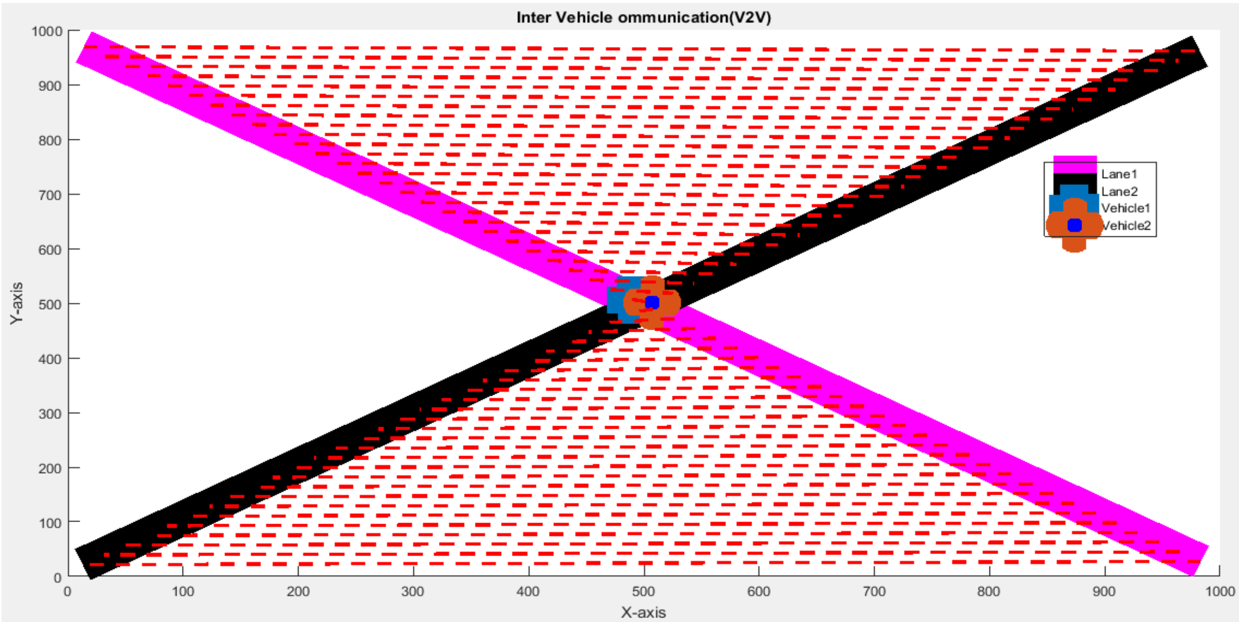


Figure 4.3: Theoretical V2V communication (same speed)

Table 4.3: parameters of theoretical V2V communication

Distance points of vehicles		Distance between vehicles(m)	Random times	Vehicles Speed(km/hr)	Length of roads(m)	Time taken of vehicles(hr)
X_i(i=1-4)	Y_i(i=1-4)		R_{vi}(i=1,2)	V_{veh}	L_{roadi}(i=1,2)	T_{veh}(1,2)
3.3081	986.6226		30	50	1.3876e+03	0.0278
996.6919	996.6919	d_1=993.3999	30	50	1.3975e+03	0.0278
33.8156	959.5501					
956.1070	954.9288	d_2=922.3030				
64.3231	929.4775					
915.5222	914.5745	d_3=851.3295				
140.5918	854.2961					

814.0600	813.6889	d_4=674.6913				
354.1442	643.7881					
529.9661	531.2091	d_5=208.7758				
415.1592	583.6430					
448.7963	450.5006	d_6=137.3257				

4.5 Theoretical Vehicle to Vehicle Communication full of range in different speed

The theoretical or ideal coverage area of the communication range could be making enough to cover larger area. For instance the following figure shows coverage distance less than or equal to 1000m, and with different speed of the vehicles traveling on the road. But in practice it is impossible to cover more than 300m distance because the capacity of the onboard unit device which is installed inside the vehicle can't transmit and receive or exchange information or data out of the device capacity. $d_{b/nveh}$ = 1000 m, V_1 = 50 km/hr, V_2 = 47 km/hr, $L_{road1=}$1.3876e+03 m, $L_{road2=}$1.3876e+03 m ,$T_{veicle1}$=0.0278 hr = 1.668 min = 100 sec ,$T_{veicle2}$ = 0.0297 hr = 1.78 min = 107 sec, , and W_{t1} = 100 seconds and W_{t2} = 107 seconds and Bw = 75 MHz.

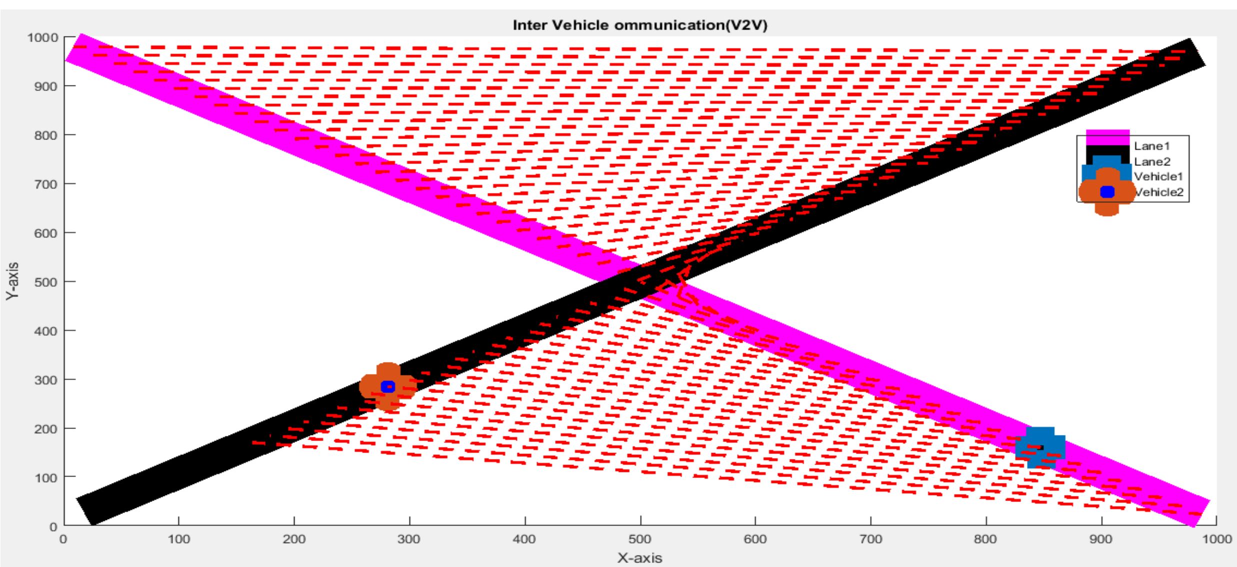


Figure 4.4: Theoretical V2V Communication different speed

Table 4.4: Parameters of theoretical V2V Communication different speed

Distance points of vehicles		Distance between vehicles (m)	Random times	Vehicles Speed(km/hr)	Length of roads(m)	Time taken of vehicles(hr)
X_i(i=1-4)	Y_i(i=1-4)		R_{ti}(i=1,2)	V_{veh}(i=1,2)	L_{roadi}(i=1,2)	T_{veh}(1,2)
3.3081	986.6226		28	50	1.39e+03	0.0278
996.6919	996.6919	d1=993.40	30	47	1.40e+03	0.0297
33.8156	959.5501					
956.1070	954.9288	d2=922.30				
64.3231	929.4775					
915.5222	914.5745	d3=851.33				
140.5918	854.2961					
814.0600	813.6889	d4=674.70				
354.1442	643.7881					
529.9661	531.2091	d5=208.78				
415.1592	583.6430					
448.7963	450.5006	d6=137.3				

4.6 Vehicle to Vehicle Communication Very High different speed

As we have seen on the above figure the communication between vehicles is possible by the Onboard Unit device installed inside the vehicles. Inter vehicle communication makes real using different types of parameters. Speed is one of the parameters that could directly influence the communication range. When the numbers of vehicles on the lane are very small we can save the communication power by giving high speed to those vehicles. Here in this figure below there are two vehicles out of communication range due to higher speed V_1 than V_2. V1 = 191 km/hr and

V_2 = 51 km/hr, wt1 = No , Wt2 = No, i.e. V_1>>V_2. The higher speed difference shows the traffic flow is low or the traffic is not busy there are small number of vehicles on the road. Traveling through this road is safer than other roads with lower speed.

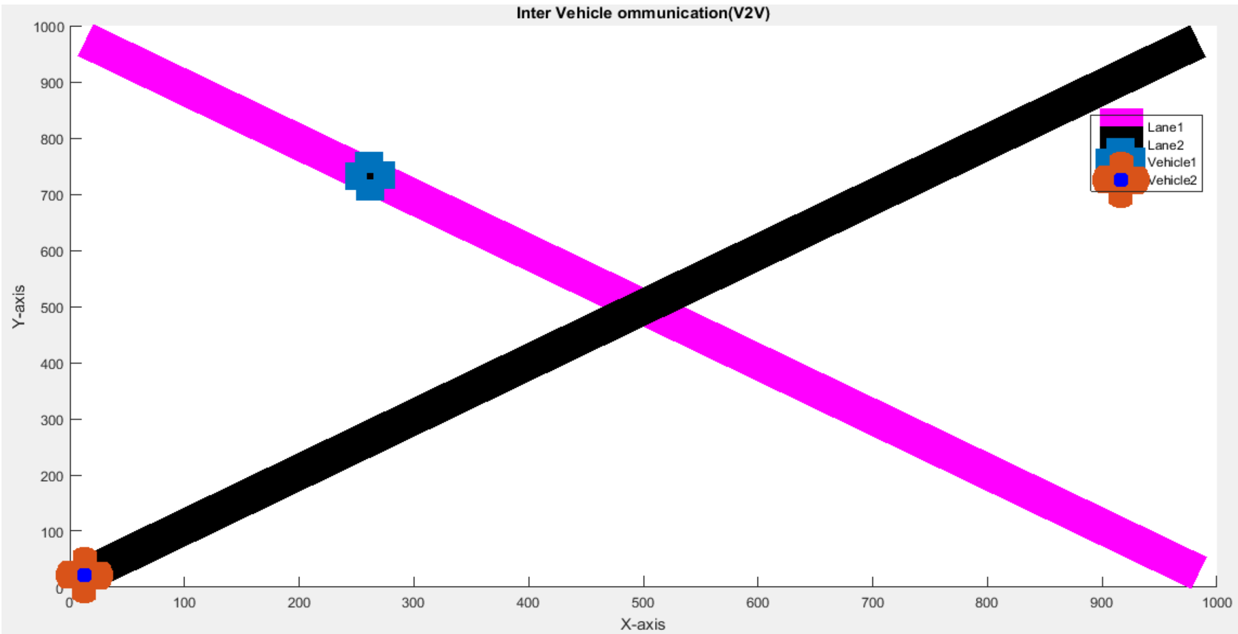


Figure 4.5: V2V Communication Very High different speed

Table 4.5: Parameters of V2V Communication in higher speed difference

Distance points of vehicles		Distance between vehicles(m)	Random times	Vehicles speed(km/hr)	Distances of roads(m)	Time taken of vehicles (hr)
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)		R_{ti}(i=1,2)	V_{veh}(i=1,2)	d_{roadsi}(i=1,2)	T_{veh}(1,2)
3.3081	986.6226		22	192	1.3922e+03	0.0073
996.6919	996.6919	d_1=993.3999	28	51	1.4022e+03	0.0275
33.8156	959.5501					
956.1070	954.9288	d_2=922.3030				
64.3231	929.4775					
915.5222	914.5745	d_3=851.3295				

140.5918	854.2961					
814.0600	813.6889	d_4=674.6913				
354.1442	643.7881					
529.9661	531.2091	208.7758				
415.1592	583.6430					
448.7963	450.5006	137.3257				

4.7 Vehicle to Vehicle Communication Same speed

The vehicles start communicate to each other when the distance between them becomes less than or equal to 300m. If the distance between the vehicles is greater than 300m, the connection will be disconnected. The figure bellow shows the occurrence of collision or car accident because the vehicles have the same speed when they get connected in the communication range i.e.$V_1 = V_2 =$ 66 km/hr, $T_1 = T_2 =$ 75.6 seconds, $W_{t1} = W_{t2} =$ 16.4 seconds. We can manage the accident by giving the cars different speeds to minimize or eliminate the risk. We need to control the speed in different ways to minimize or reduce the risk.

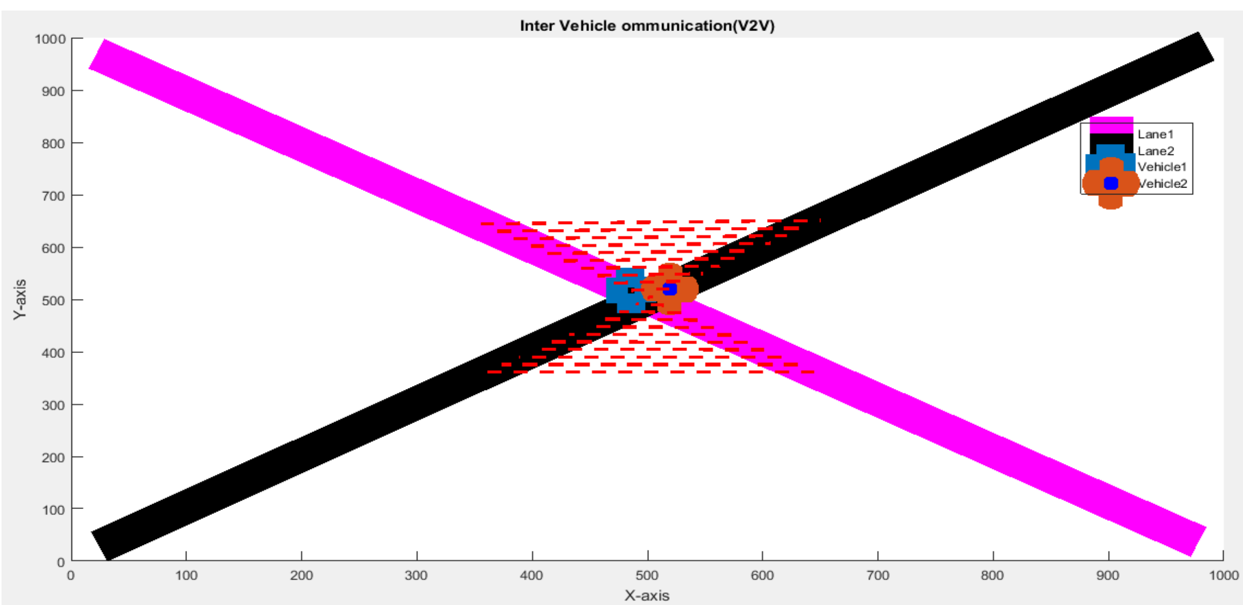


Figure 4.6: V2V Communication (Same speed)

Table 4.6: Parameters of V2V Communication in same vehicular speed

Distance points of vehicles		Distance between vehicles(m)	Random times	Vehicles Speed(km/hr)	Distances of roads(m)	Time taken of vehicles
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)		R_{ti}(i=1,2)	V_{veh}	L_{ri}(i=1,2)	T_{veh}(1,2)
3.3081	986.6226		21	66	1.40e+03	0.0211
996.6919	996.6919	d1=993.40	21	66	1.40e+03	0.0212
33.8156	959.5501					
956.1070	954.9288	d2=922.30				
64.3231	929.4775					
915.5222	914.5745	d3=851.33				
140.5918	854.2961					
814.0600	813.6889	d4=674.70				
354.1442	643.7881					
529.9661	531.2091	208.7758				
415.1592	583.6430					
448.7963	450.5006	137.3257				

4.8 Vehicle to Vehicle Communication different speed

When vehicles on the road are crowded, we can save lives from a car accident or collision by giving different speeds to each vehicle. When the vehicles reach the range of communication area in distance $d \geq 300$m information (data) will be exchanged between the vehicles. Since they are traveling with different speed car accident or collision will not be occurred. Here on the figure bellow shows the safe traveling across the road without any accident with the two vehicles V1=66 km/hr, V2=50 km/hr, T1 = 75.6 seconds, T2 = 101 seconds, and Wt1 = 16.4 seconds, Wt2 =21.6 seconds. The red dash line shows the vehicle to vehicle communication range i.e. $d \leq$ 300m between the Vehicles.

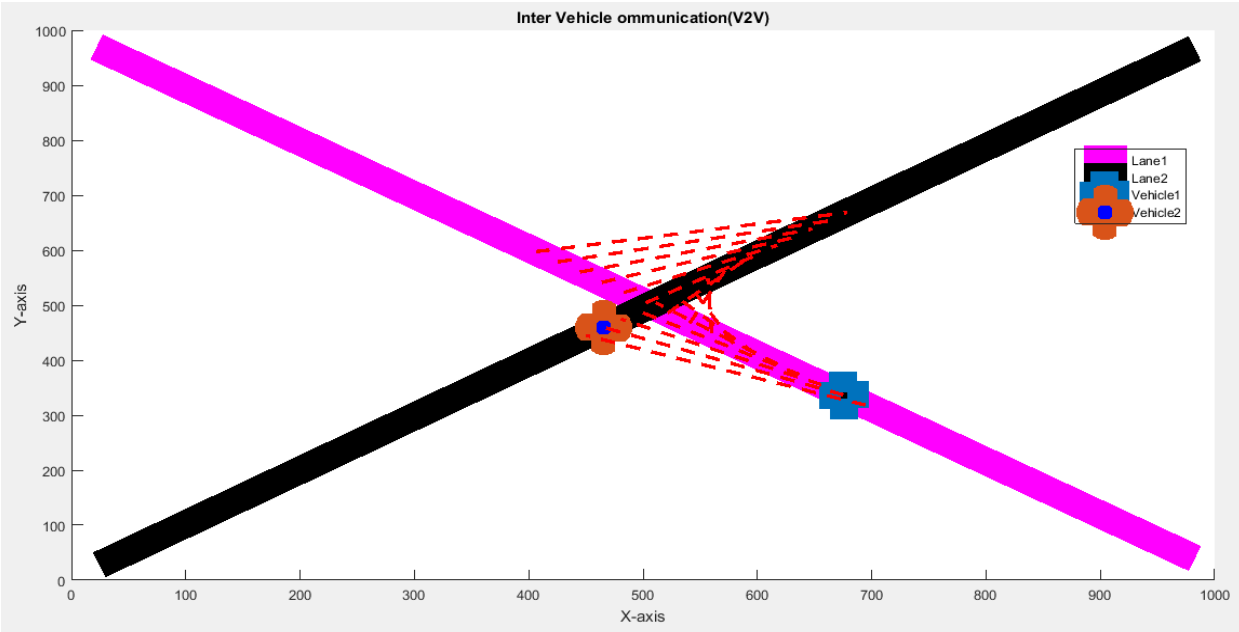


Figure 4.7: V2V Communication (different speed)

Table 4.7: Different parameters of V2V in different speed

Distance points of vehicles		Distance between vehicles(m)	Random times	Vehicles Speed(km/hr)	Distances of roads(m)	Time taken of vehicles
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)		R_{ti}(i=1,2)	V_{veh}	L_{ri}(i=1,2)	T_{veh}(1,2)
3.3081	986.6226		21	66	1.40e+03	0.0211
996.6919	996.6919	d_1=993.40	28	50	1.40e+03	0.02804
33.8156	959.5501					
956.1070	954.9288	d_2=922.30				
64.3231	929.4775					
915.5222	914.5745	d_3=851.33				
140.5918	854.2961					
814.0600	813.6889	d_4=674.70				
354.1442	643.7881					

529.9661	531.2091	d_5 =208.78				
415.1592	583.6430					

4.9 V2V Communication Vertical and Horizontal Alignment

In addition to diagonal alignment of the road lines representing the path or lane can be drawn along vertically or horizontally. The figure below solves the two problems mentioned on the above figure. The first is that the vehicles will be able to communicate within the 300m range according to the exact onboard unit standard distance. Second, it shows that you can avoid collisions by keeping the vehicles at their own speed. d = 300 m, V_1 = 50 km/hr and V_2 = 47 km/hr.

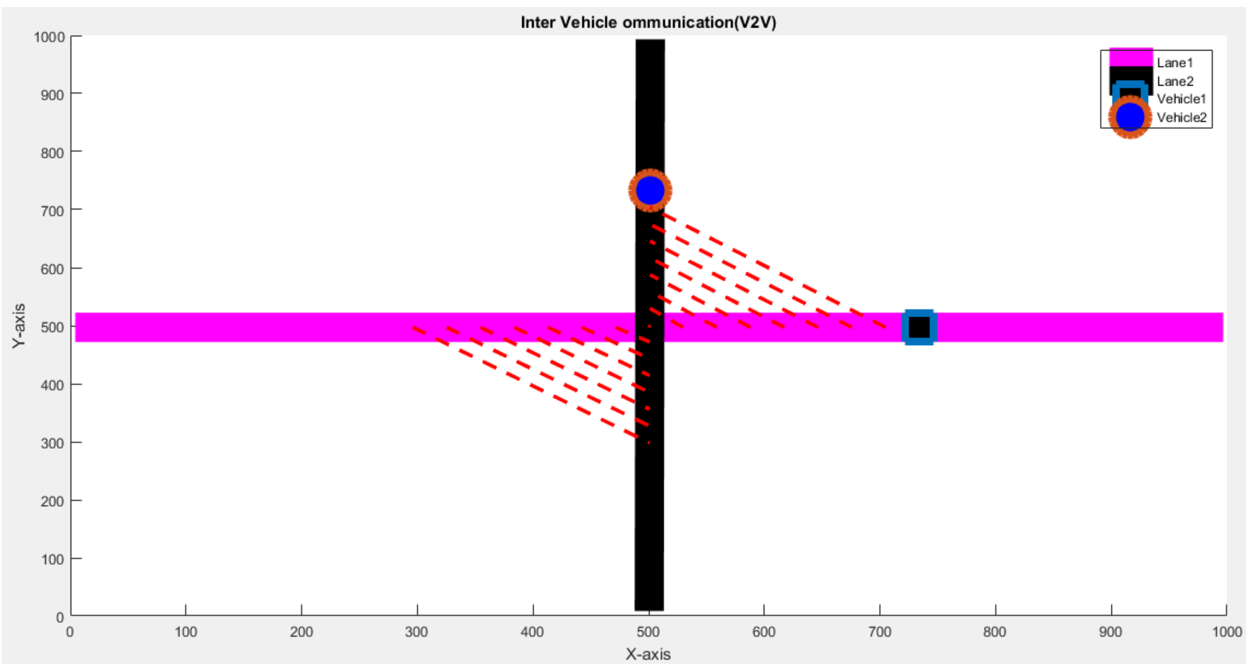


Figure 4.8: V2V Communication Vertical and Horizontal Alignment

Table 4.8: Parameters for V2V Communication an optional Alignment

Distance points of vehicles		Distance between vehicles(m)	Random times	Vehicles Speed(km/hr)	Distances of roads(m)	Time taken of vehicles
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)		R_{ti}(i=1,2)	V_{veh}	L_{ri}(i=1,2)	T_{veh}(1,2)
3.3081	986.6226		21	66	1.40e+03	0.0211
996.6919	996.6919	d_1=993.40	28	50	1.40e+03	0.02804
33.8156	959.5501					
956.1070	954.9288	d_2=922.30				
64.3231	929.4775					
915.5222	914.5745	d_3=851.33				
140.5918	854.2961					
814.0600	813.6889	d_4=674.70				
354.1442	643.7881					
529.9661	531.2091	d_5 =208.78				
415.1592	583.6430					
448.7963	450.5006	$d_{6=}$137.33				

4.10 Theoretical Vehicle to Road Side Unit communication Whole range

This is theoretical communication between vehicle and the infrastructure RSU which covers the whole range from source to destination. It doesn't matter the distance between the vehicle and the infrastructure how far they are. In the figure bellow there are 2 RSU's and 1 vehicle. Theoretically we can install the RSU at anywhere as far as the road to vehicle, but practically it is impossible to do that. The vehicles and the infrastructure have their own capacity to cover the range of communication. V=32km/hr, L (road) = 883m, d (b/n vehicle & RSU) $\leq$ 883m, T_{veh}=0.030hr=1.7944 minute = 107.7 second and Bw = 75 MHz.

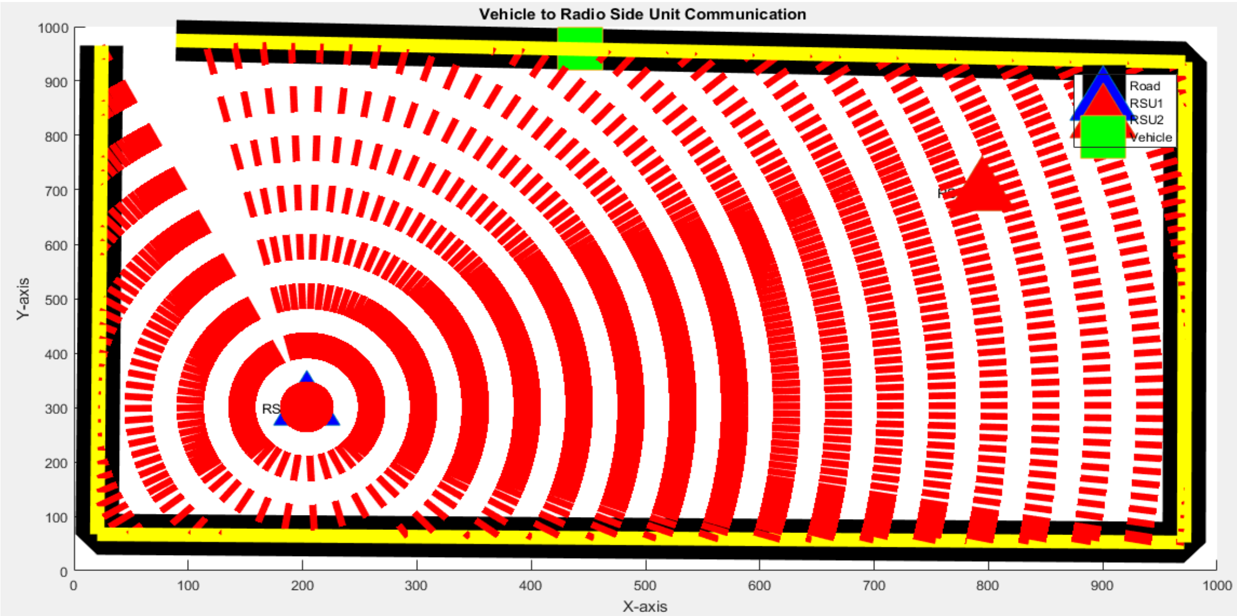


Figure 4.9: Theoretical V2I communication Whole range

Table 4.9: Parameters of theoretical V2I communication

Distance points of Road(m)		Distance between vehicle and RSU(m)	Random times	Vehicles Speed(km/hr)	Distances of roads(m)	Time taken of vehicles (hr)
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)	d_1=b/n V & RSU_1 d_2=b/n V& RSU_2	R_{t1}	V_{veh}	Distance whole (L_{road})	T_{veh}
117.6749	229.2453		28	32	883.0194	0.030
314.4612	26.6457	d_1=282.4384				
876.6541	776.4151					
314.4612	26.6457	d_2=937.1312				
117.6749	229.2453					
774.7847	975.5765	d_1=994.3861				

876.6541	776.4151					
774.7847	975.5765	d_2=223.7021				
117.6749	229.2453					
12.7599	918.3019	d_1=696.9980				
876.6541	776.4151					
12.7599	918.3019	d_2=875.4684				

4.11 Vehicle to Road Side Unit Communication out of range

As we have seen in the figure above to properly communicating between the vehicles and the infrastructures the distance between them should be less than or equal to 300m. If the distance between the vehicles and the infrastructures is greater than the range of the capacity of on board unit and RSU communication is going to disconnect. The figure bellow shows the infrastructures are installed in a distance greater than the standard of the devices there is no communication in between. Simulation parameters $d_1 = d_2 \geq 509.9978$ m, V=32 km/hr, d_{road} = 990m, T_{veh}=0.030hr=1.7944 minute = 107.7 second.

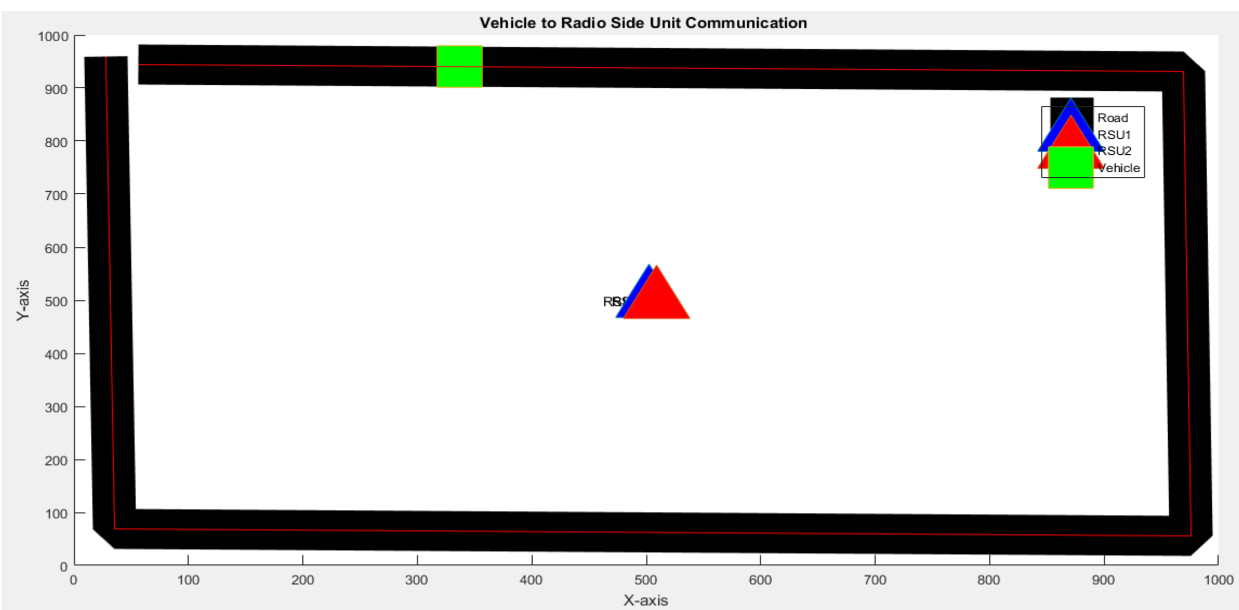


Figure 4.10: V2I Communication out of range

Table 4.10: Parameters for the disconnected V2I Communication

Distance points of Road(m)		Distance between vehicle and RSU(m)	Random times	Vehicles Speed(km/hr)	Distances of roads(m)	Time taken of vehicles (hr)
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)	d_1=b/n V & RSU_1 d_2=b/n V& RSU_2	R_t	V_{veh}	Distance whole	T_{veh}
540.1701	510.3774		26	32	990.0524	0.030
975.7929	245.1782	d_1=509.9978				
540.1701	66.1426					
973.4037	26.6457	d_2=620.5126				
523.1569	229.2453					
787.8072	512.2642	d_1=539.5893				
876.6541	510.3774					
540.1701	42.0335	d_2=529.7830				
787.8072	229.2453					
523.1569	512.2642	d_1=633.7217				
946.5974	40.7757					
540.1701	510.3774	d_2=621.0546				
946.5974	40.7757					

4.12 Vehicle to Road Side Unit the installation position of RSU matters range of communication

There are some parameters that vehicles and infrastructure need to connect. They are: the distance between the vehicles and the infrastructure where they are located. As you can see in the figure bellow, the first blue RSU due to its location where the basis are located which covers a small range of communication, and the second red RSU that covers enough wide range of communication due to its good position where the basis are located. $d_1 = d_2 \leq 300$m, dRSU1 (range covered) =14.68m, dRSU2 (range covered) = 569.57m, Speed Vehicle = 32 km/hr, T_{veh}=0.030hr=1.7944minute=107.7second, W_{t1} = 1.65 seconds, W_{t2} = 64 seconds, and Bw = 75 MHz.

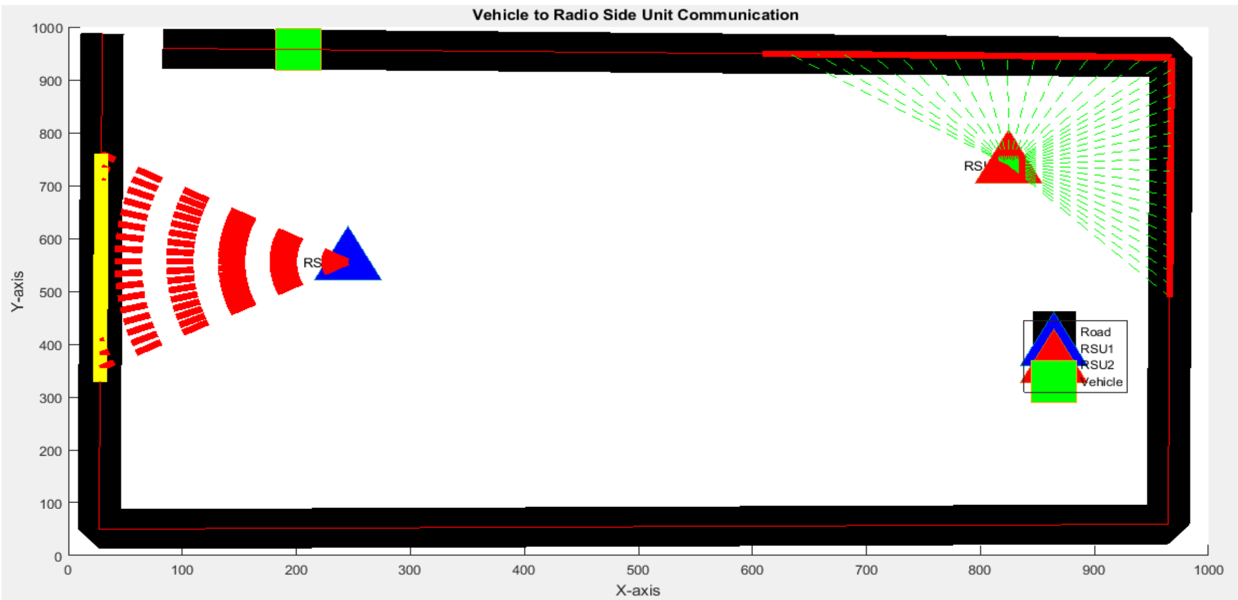


Figure 4.11: V2I the position of RSU matters range of communication

Table 4.11: V2I the position of RSU matters range of communication

Distance covered points of Road		Communication Range covered Distance between vehicle and RSU(m)	Random times	Vehicles Speed (km/hr)	Distances of roads(m)	Time taken of vehicles (hr)
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)	d_1= b/n V & RSU_1 d_2=b/n V& RSU_2	R_{t1}	V_{veh}	Distance whole	T_{veh}
24.08	618.1		26	32	989.0897	0.030
25.18	403.9	L_{RSU1}=14.68				
967.1	538					

25.18	949.3	L_{RSU2}=569.57				
117.6749	229.2453					

4.13 The right way of installing Vehicle to Infrastructure communication

This figure bellow solves problems that are all mentioned on the above three figures. The infrastructures are installed on the basis of exact location that covers wide enough range of communication in equal radius to the curved roads in range of d1 and $d_2 \leq 300$m. Looking for the thick red and yellow lines covered larger area of communication in compare to the figures that are explained above. d_1 (RSU1 to Vehicle) = 500m, d_2 (RSU2 to Vehicle) = 502m, T_{veh}=0.030hr=1.7944 minute = 107.7 second, W_{t1} = 6.15 seconds, W_{t2} = 33.75 seconds and Bw = 75 MHz.

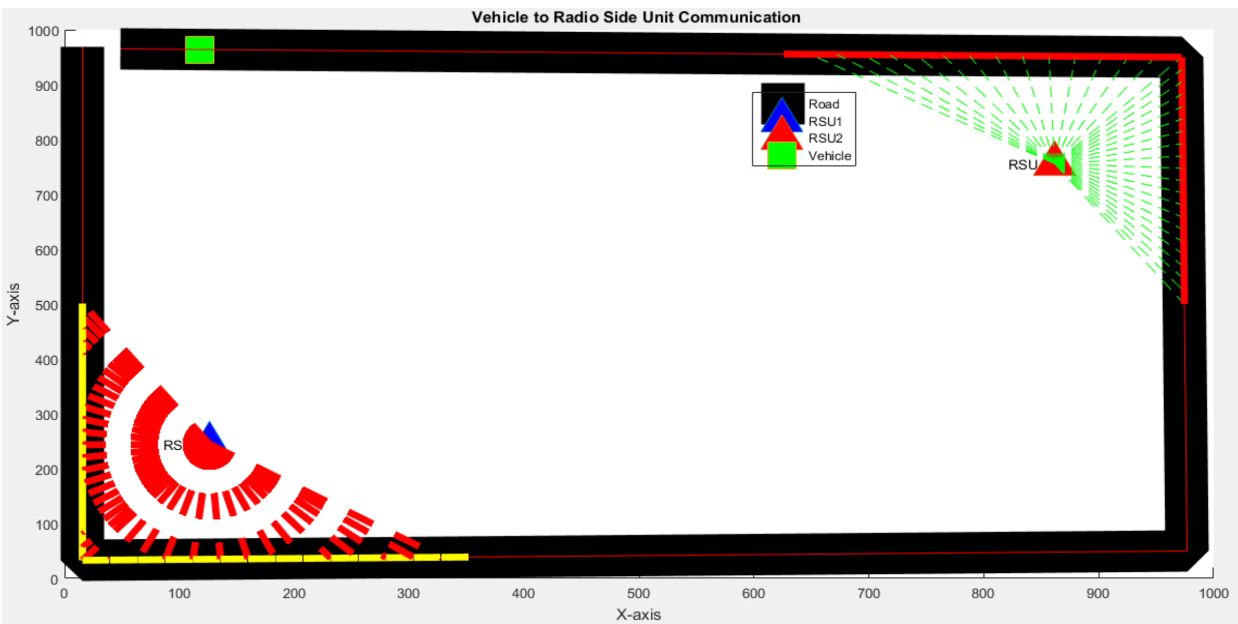


Figure 4.12: V2I communication in standard range

Table4.12: Sample parameters of the best V2I communication in a good placement

Distance points of Road(m)		Distance between vehicle and RSU(m)	Random times	Vehicles speed(km/hr)	Distances of roads(m)	Time taken of vehicles (hr)
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)	d_1=b/n V & RSU_1 d_2=b/n V& RSU_2	R_{t1}	V_{veh}	Distance whole	T_{veh}
117.6749	229.2453		21	32	956.6038	0.030
314.4612	26.6457	d_1=282.4384				
876.6541	776.4151					
314.4612	26.6457	d_2=937.1312				
117.6749	229.2453					
774.7847	975.5765	d_1=994.3861				
876.6541	776.4151					
774.7847	975.5765	d_2=223.7021				
117.6749	229.2453					
12.7599	918.3019	d_1=696.9980				
876.6541	776.4151					
12.7599	918.3019	d_2=875.4684				

4.14 Theoretical Communication of Vehicle to Vehicle with Road Side Unit

The picture below shows full range of theoretical communication in an area larger in range among the vehicles and the communication between the vehicles and the single fixed infrastructure radio side unit (RSU). There are four vehicles traveling across the four lanes and one fixed infrastructure installed in side square for the purpose of data exchange among them. One vehicle can exchange data anywhere and anytime, regardless of distance from the other three vehicles and RSU. Figure 4.13 shows the coverage area of range of communication among the vehicles and the infrastructure RSU. Figure 13 and figure 14 are the same. T_{veh1} = W_{t1} = 0.0157 hr = 0.942 minute =56.52 second, T_{veh2} = W_{t2} = 0.0135 hr = 0.81 minute = 48.6 second, T_{veh3} = W_{t3} = 0.0083 hr = 0.498 minute =30 second, T_{veh4} = W_{t4} = 0.0077 hr = 0.462 minute =27.72 second, and Bw = 75 MHz. , = 6.15 seconds, = 33.75 seconds

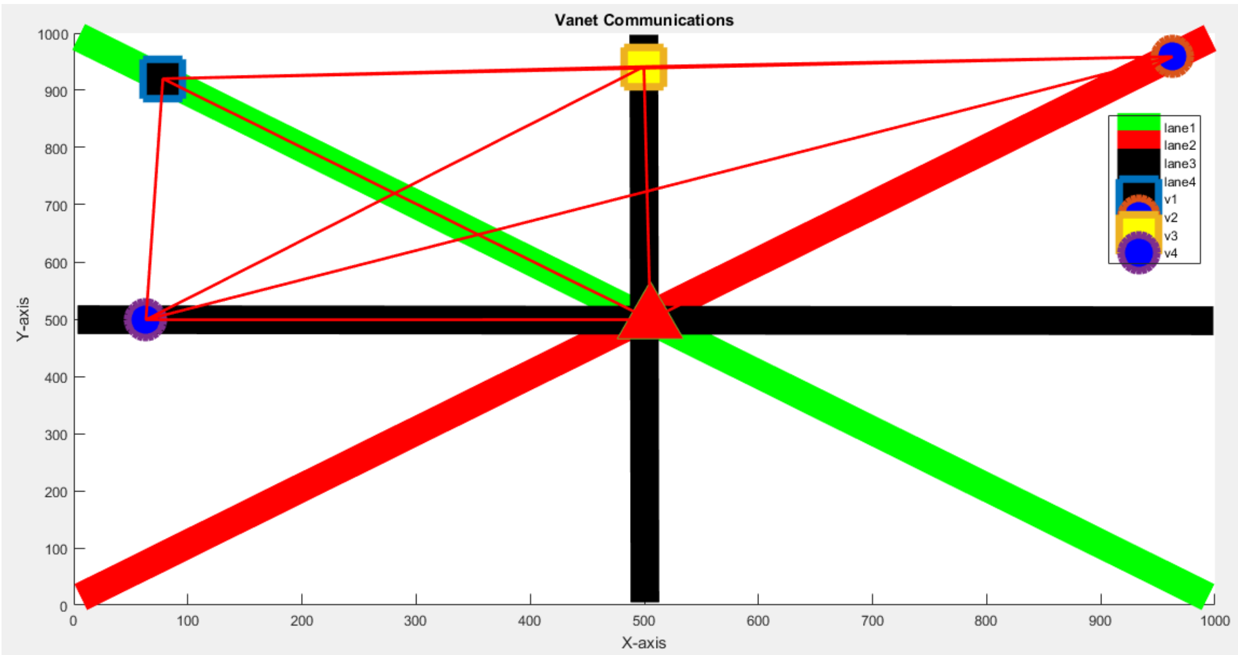


Figure 4.13: Theoretical full range communication

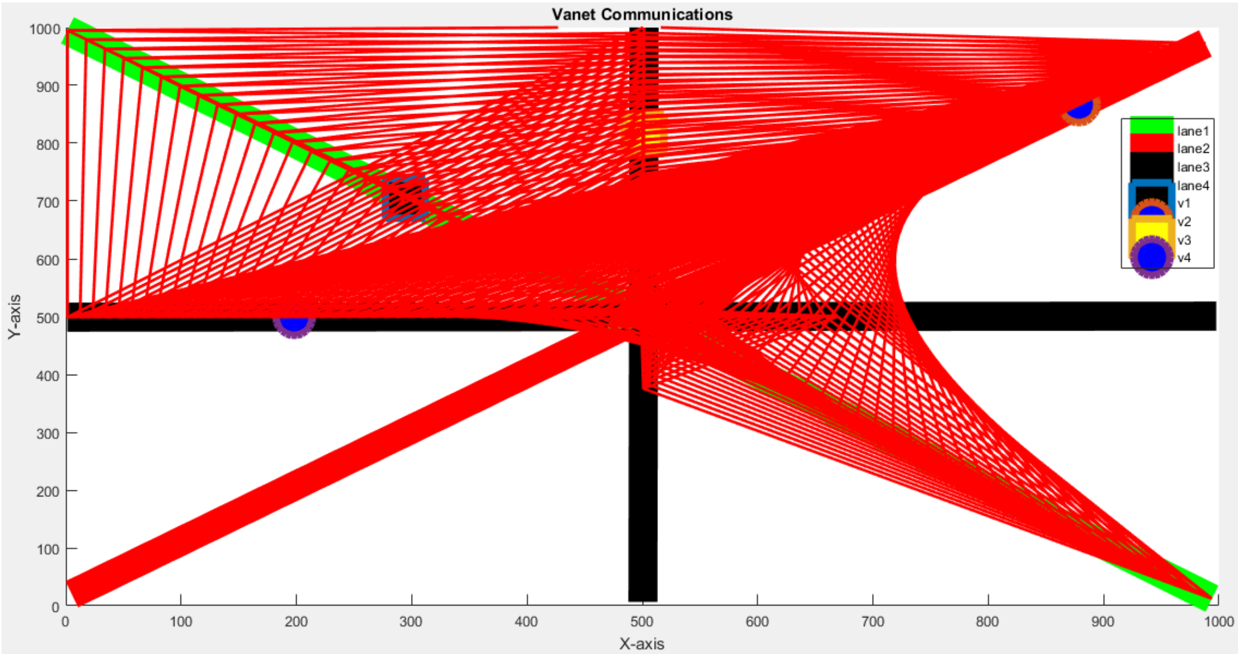


Figure 4.14: Range of theoretical Full range communication

Table 4.13: Sample parameters of theoretical full range communication 4V1RSU

Distance points of Road(m)		Distance between vehicle and RSU(m)	Random times	Vehicles Speed(km/hr)	Distances of roads(m)	Time taken of vehicles (hr)
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)	d_1=b/n V & RSU_1 d_2=b/n V&RSU_2	R_t(1,2,3,4)	V_{veh}(1,2,3,4)	Distance Lane1-4	T_{veh}(1,2,3,4)
117.6749	229.2453		$R_{t1=}18$	V_1=89	1.40e+03	0.015659
314.4612	26.6457	d_1=282.4	$R_{t2=}19$	V_2=102	1.38e+03	0.0135
876.6541	776.4151		$R_{t3=}20$	V_3=117	976.6791	0.0083
314.4612	26.6457	d_2=937.1	$R_{t4=}30$	V_4=127	981.5712	0.0077
117.6749	229.2453					
774.7847	975.5765	d_1=994.3				

876.6541	776.4151					
774.7847	975.5765	d_2=223.7				
117.6749	229.2453					
12.7599	918.3019	d_1=696.				
876.6541	776.4151					
12.7599	918.3019	d_2=875.				

4.15 Practical Communication of Vehicle to Vehicle with Road Side Unit

On the ground, the effective communication between vehicles and the road side unit is 300meters and below. As you can see in the figure below, the actual vehicle and the road side unit are positioned according to the FCC standard for communication distance coverage area of the onboard unit and road side unit. Here, Figure 4.16 is the similar with figure 4.15 figure 4.16 shows coverage area of the range of communication between vehicles and the road side unit. Here, since the road side unit installed somewhere is a single device the waiting time during the communicating coverage area mathematically could be calculated the coverage communication distance divided by standard speed of the vehicle Based on IEEE 802.11p standard as: $W_{timemax}$= $d_{com}/V_{maxstandard}$ = 300m/200km/hr = 5.399568034557235 second. The communication distance d_{com}=300m, and the speeds of vehicles are V_1=89 km/hr, V_2=102 km/hr, V_3=117 km/hr, V_4=127 km/hr, T_{veh1}=0.0157 hr = 0.942 minute =56.52 second, T_{veh2}=0.0135 hr = 0.81 minute =48.6 second, T_{veh3}=0.0083 hr = 0.498 minute =30 second, T_{veh4}=0.0077 hr = 0.462 minute =27.72 second, W_{t1} =12.13 seconds, W_{t2} =10.59 seconds, W_{t3} =9.23 seconds, W_{t4} =8.50 seconds and Bw = 75 MHz and the other parameters are listed in the table below.

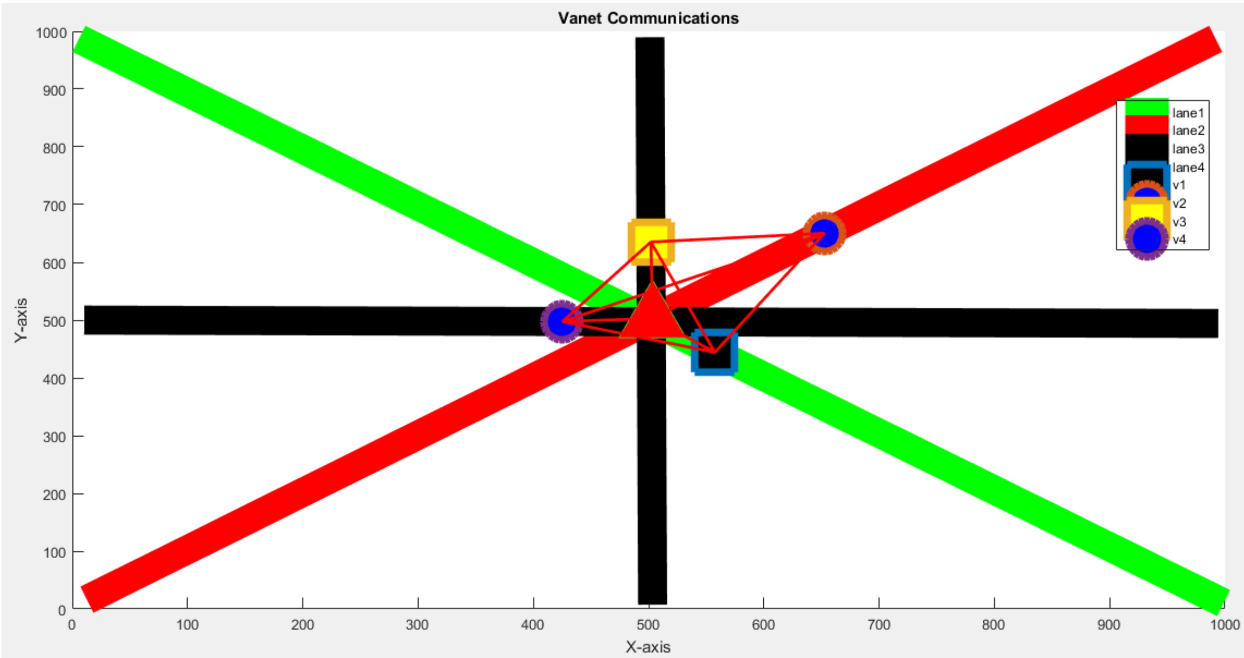


Figure 4.15: Communication of Road Side Unit with Vehicles in Range 300m

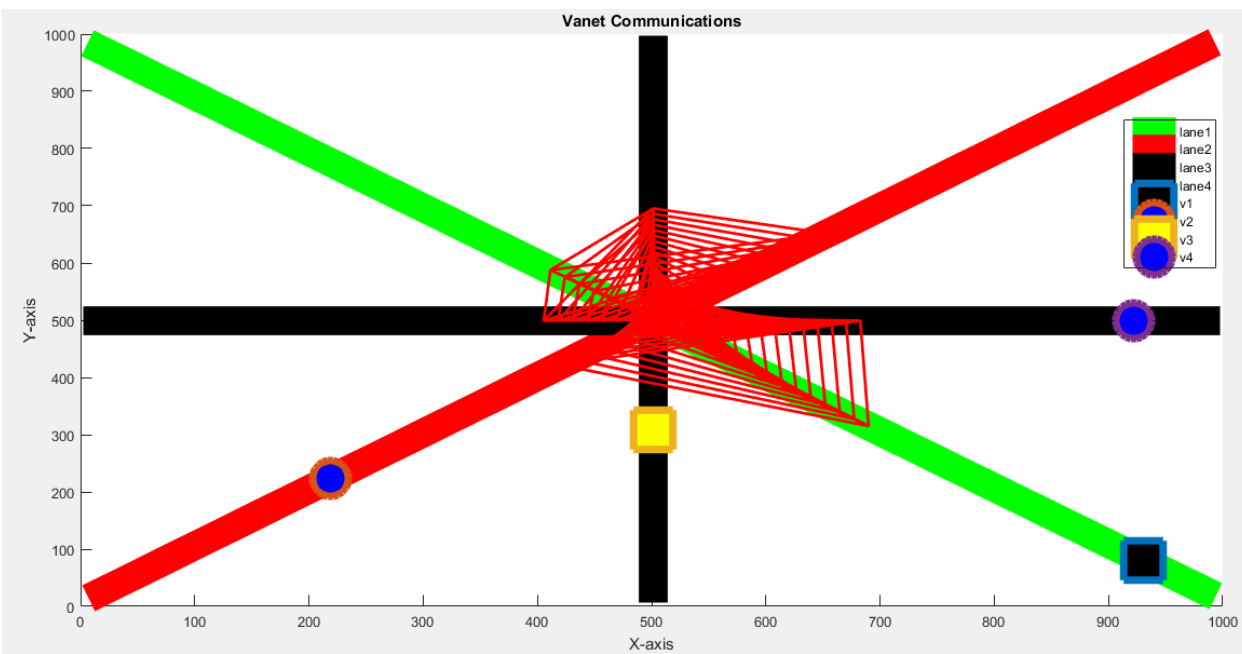


Figure 4.16: Range Communication of Road Side Unit with Vehicles in Range 300m

Table 4.14: Parameters of the communication of Road Side Unit with Vehicles

Distance points of Road(m)		Distance between vehicle and RSU(m)	Random times	Vehicles Speed(km/hr)	Distances of roads(m)	Time taken of vehicles (hr)
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)	d_1=b/n V & RSU_1 d_2=b/n V&RSU_2	R_t(1,2,3,4)	V_{veh}(1,2,3,4)	Distance Lane1-4	T_{veh}(1,2,3,4)
117.6749	229.2453		$R_{t1=}$18	V_1=89	1.40e+03	0.015659
314.4612	26.6457	d_1=282.4	$R_{t2=}$19	V_2=102	1.38e+03	0.0135
876.6541	776.4151		$R_{t3=}$20	V_3=117	976.6791	0.0083
314.4612	26.6457	d_2=937.1	$R_{t4=}$30	V_4=127	981.5712	0.0077
117.6749	229.2453					
774.7847	975.5765	d_1=994.3				
876.6541	776.4151					
774.7847	975.5765	d_2=223.7				
117.6749	229.2453					
12.7599	918.3019	d_1=696.				
876.6541	776.4151					
12.7599	918.3019	d_2=875.				

4.16 Theoretical Communication of Vehicle to Vehicle with Road Side Unit and Satellite

This is theoretical simulation that covers larger coverage area of communication range. If a road accident occurs outside of the sight of the vehicle, the road may be temporarily suspended. Google imagery can be taken from the satellite to take a picture of the crash and change lanes to avoid interruptions. So the problem can be solved by connecting the Road Side Unit to the

Satellite. The simulation in the figure below solves this problem. Figure 4.18 shows coverage area of the range of communication between vehicles and the Road Side Unit and Satellite. d_{com}=1000m, V_1=89 km/hr, V_2= 102 km/hr, V_3 = 117 km/hr, V_4= 127 km/hr, T_{veh1} = W_{t1} = 0.0157 hr = 0.942 minute =56.52 second, T_{veh2} = W_{t2} = 0.0135 hr = 0.81 minute =48.6 second, T_{veh3} = W_{t3} = 0.0083 hr = 0.498 minute =30 second, T_{veh4} = W_{t4} = 0.0077 hr = 0.462 minute =27.72 second, and Bw = 75 MHz.

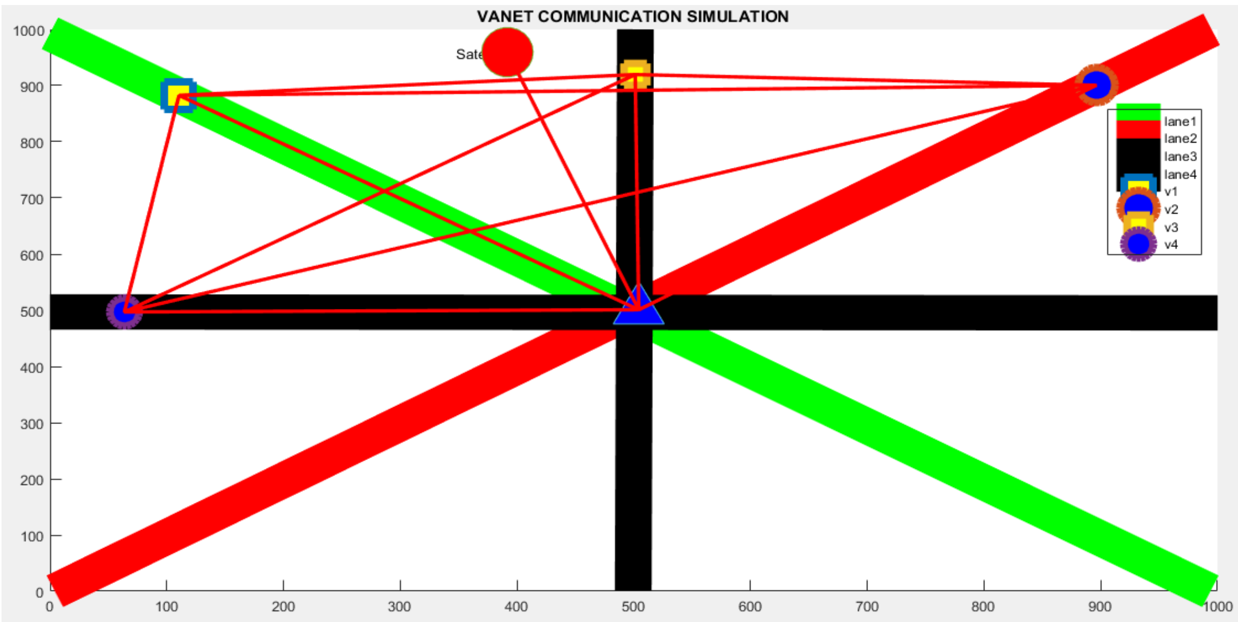


Figure 4.17: Theoretical VANET Full range Communication

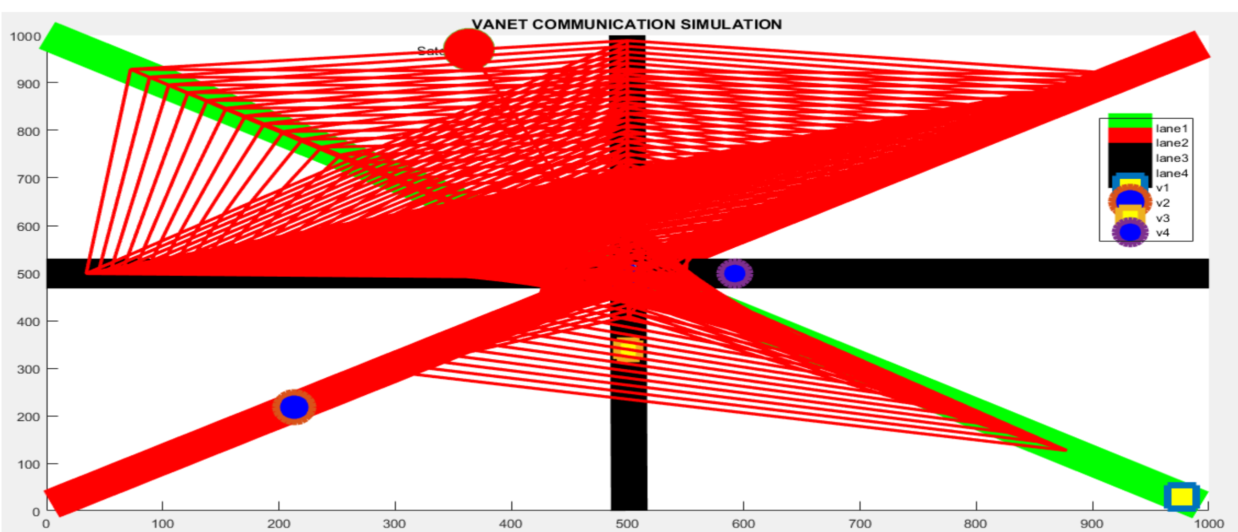


Figure 4.18: Full range of VANET communication with satellite

Table 4.15: Parameters of theoretical VANET communication

Distance points of Road(m)		Distance between vehicle and RSU(m)	Random times	Vehicles Speed(km/hr)	Distances of roads(m)	Time taken of vehicles (hr)
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)	d_1=b/n V & RSU_1 d_2=b/n V&RSU_2	R_t(1,2,3,4)	V_{veh}(1,2,3,4)	Distance Lane1-4	T_{veh}(1,2,3,4)
117.6749	229.2453		$R_{t1=}$18	V_1=89	1.40e+03	0.015659
314.4612	26.6457	d_1=282.4	$R_{t2=}$19	V_2=102	1.38e+03	0.0135
876.6541	776.4151		$R_{t3=}$20	V_3=117	976.6791	0.0083
314.4612	26.6457	d_2=937.1	$R_{t4=}$30	V_4=127	981.5712	0.0077
117.6749	229.2453					
774.7847	975.5765	d_1=994.3				
876.6541	776.4151					
774.7847	975.5765	d_2=223.7				
117.6749	229.2453					
12.7599	918.3019	d_1=696.				
876.6541	776.4151					
12.7599	918.3019	d_2=875.				

4.17 VANET Communication of single RSU connected to Satellite

As we have seen so far, the data transfer capacity of one radio side unit does not exceed 300 m, so it is possible to expand the distance coverage by adding other Road Side Units. As you can see in the figure below, infrastructure development has increased. With the expansion of infrastructure, the distance of data received by vehicles from the Road Side Units will double. By connecting only one Road Side Units channel to one to the satellite, one can save radio energy units, but it has its own advantages and disadvantages. The advantage is that it saves energy and the disadvantage if the line that connected to the Satellite is disconnected that the satellite is disconnected from the entire radio side units. Figure 4.23: shows the coverage area of range of communication. d_{com}=600m V_1=89 km/hr, V_2=102 km/hr, V_3=117 km/hr, V_4=127 km/hr, T_{veh1} = W_{t1} = 0.0157 hr = 0.942 minute =56.52 second, T_{veh2} = W_{t2} = 0.0135 hr = 0.81 minute =48.6 second, T_{veh3} = W_{t3} = 0.0083 hr = 0.498 minute =30 second, T_{veh4} = W_{t4} = 0.0077 hr = 0.462 minute =27.72 second, and Bw = 75 MHz.

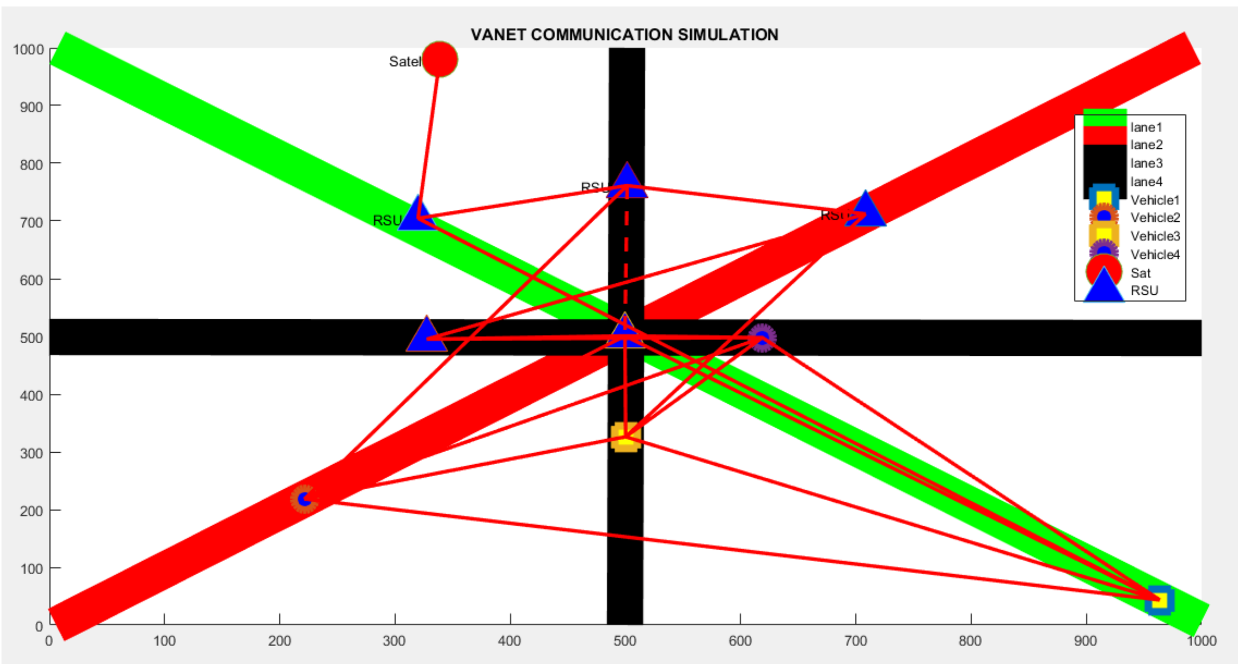


Figure 4.19: Expanding Vehicle to Vehicle communication

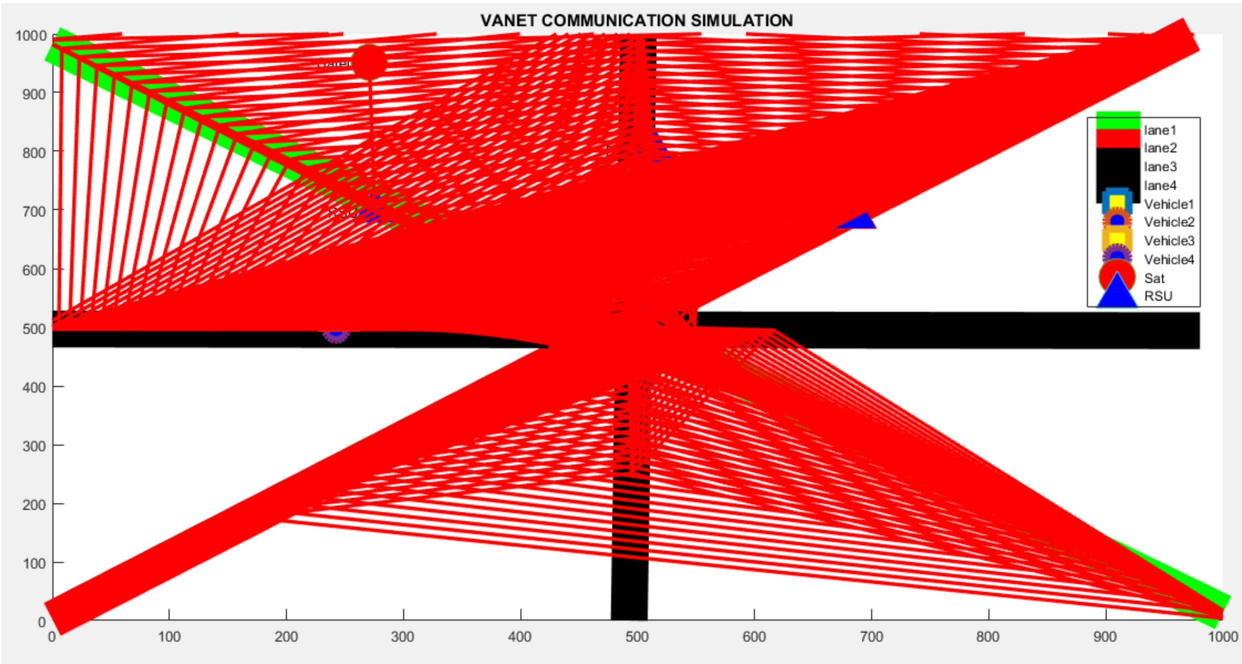


Figure 4.20: Range of expanded Vehicle to Vehicle communication

Table 4.17: Expanded parameters for Vehicle to Vehicle communication

Distance points of Road(m)		Distance between vehicle and RSU(m)	Random Speeds	Vehicles Speed(km/hr)	Distances of roads(m)	Time taken of vehicles (hr)
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)	d_1=b/n V & RSU_1 d_2=b/n V&RSU_2	R_t(1,2,3,4)	V_{veh}(1,2,3,4)	Distance Lane1-4	T_{veh}(1,2,3,4)
117.6749	229.2453		R_{t1}=18	V_1=89	1.40e+03	0.015659
314.4612	26.6457	d_1=282.4	R_{t2}=19	V_2=102	1.38e+03	0.0135
876.6541	776.4151		R_{t3}=20	V_3=117	976.6791	0.0083
314.4612	26.6457	d_2=937.1	R_{t4}=30	V_4=127	981.5712	0.0077
117.6749	229.2453					
774.7847	975.5765	d_1=994.3				

876.6541	776.4151					
774.7847	975.5765	d_2=223.7				
117.6749	229.2453					
12.7599	918.3019	d_1=696.				
876.6541	776.4151					
12.7599	918.3019	d_2=875.				

4.18 All Road Side Units connected to Satellite

The figure below illustrates how to remove the disadvantage of Figure 4.22 and Figure 4.23 above. By connecting all road side units to the satellite, we can fix the limitation mentioned at the above figure. The advantage is if one of the Road Side Units disconected from the satellite all remaining Road Side Units keep connected to the satellite. The disadvantage is more energy will be consumed. Figure 4.25 shows the coverage area of range of communication. Here, two road side units are installed per lane or in each road, as we calculated the waiting time during the communicating coverage area in a single road side unit let's to calculate it's waiting time, the coverage communication distance divided by standard speed of the vehicle Based on IEEE 802.11p standard as: maximum W_{time}= $d_{com}/V_{maxstandard}$ = 600m/200km/hr = 10.79913606911447 second. When we compare the waiting time for the single road side unit which is being calculated on the above in figure 4.19 W_{time} = 5.399568034557235 second and Here waiting time $W_{timenew}$ = 10.79913606911447 second. So $W_{timenew}$ = $2W_{time,}$ as the waiting time during communication time increase the probability of receiving information that comes from the infrastructure increase also. Here the waiting time increased by 100%. Simulation parameters d_{com}=600m V_1=89 km/hr, V_2=102 km/hr,V_3=117 km/hr, V_4=127 km/hr, T_{veh1}=0.0157 hr = 0.942 minute =56.52 second, T_{veh2}=0.0135 hr = 0.81 minute =48.6 second, T_{veh3}=0.0083 hr = 0.498 minute =30 second, T_{veh4}=0.0077 hr = 0.462 minute =27.72 second, and Bw = 75 MHz, wt1 =24.27 seconds, wt2 =21.18 seconds, wt3 =18.46 seconds, wt4 =17.01 seconds.

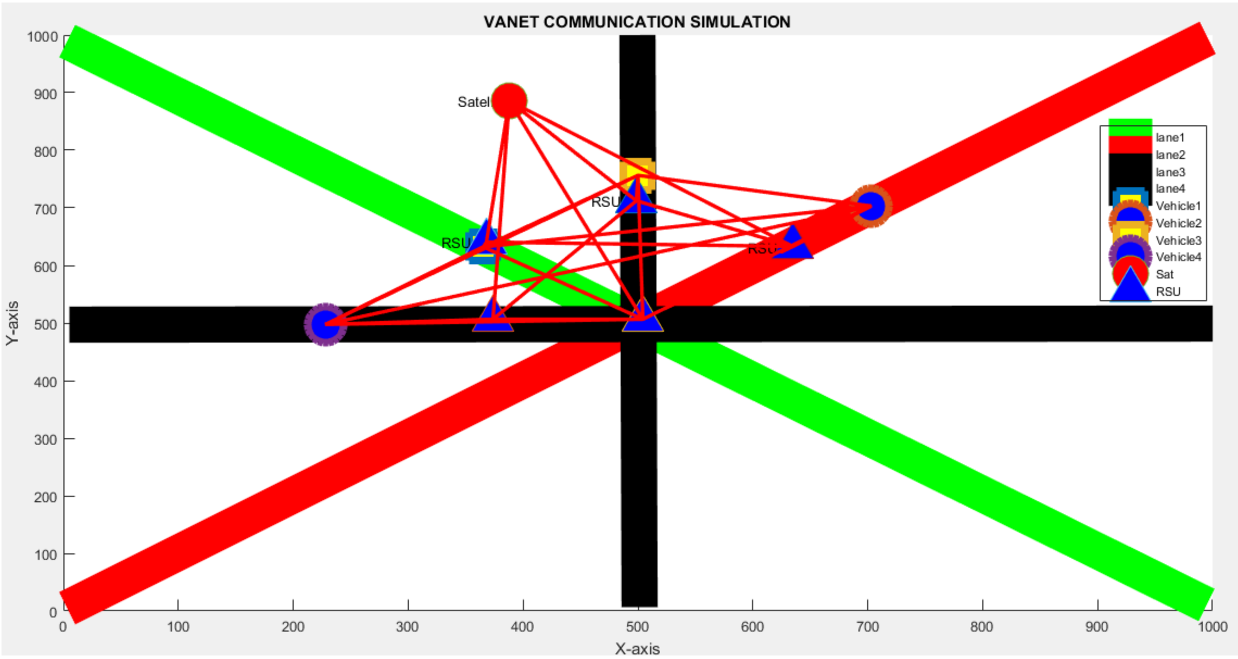


Figure 4.21: All Road Side Units connected to Satellite

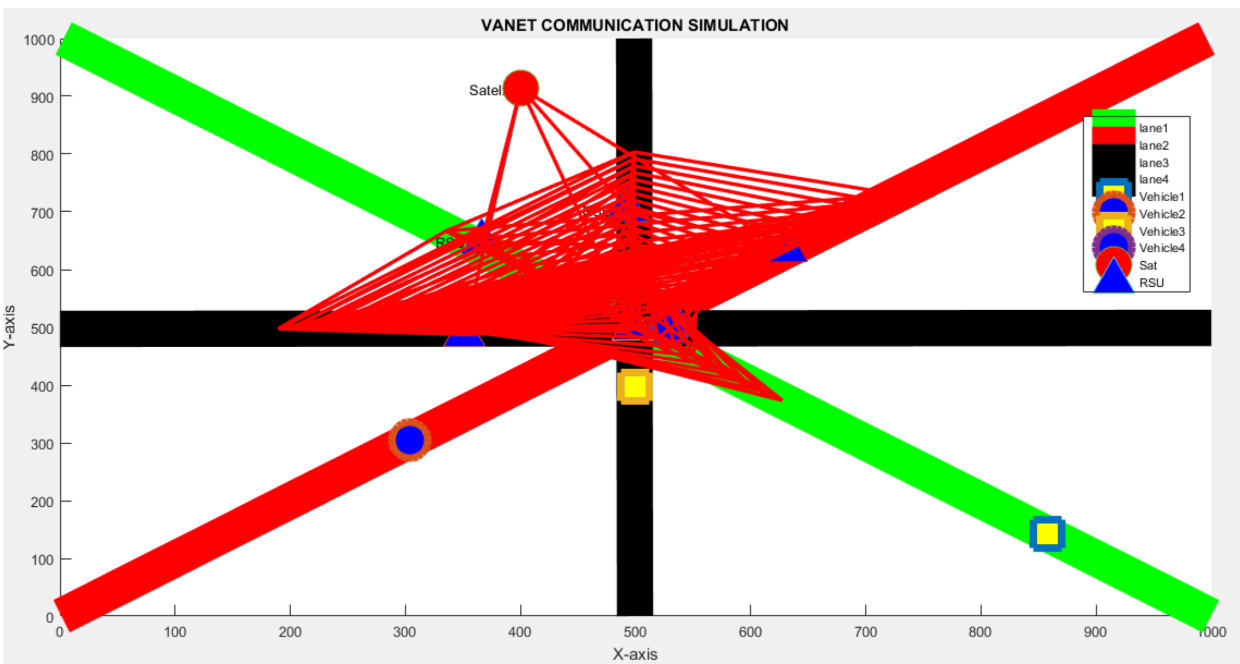


Figure 4.22: Range of All Road Side Units connected to Satellite

Table 4.18: Parameters of infrastructures connected to Satellite

Distance points of Road(m)		Distance between vehicle and RSU(m)	Random times	Vehicles Speed(km/hr)	Distances of roads(m)	Time taken of vehicles (hr)
X_i(i=1,2,3,4)	Y_i(i=1,2,3,4)	d_1=b/n V & RSU_1 d_2=b/n V&RSU_2	R_t(1,2,3,4)	V_{veh}(1,2,3,4)	Distance Lane1-4	T_{veh}(1,2,3,4)
117.6749	229.2453		$R_{t1=}$18	V_1=89	1.40e+03	0.015659
314.4612	26.6457	d_1=282.4	$R_{t2=}$19	V_2=102	1.38e+03	0.0135
876.6541	776.4151		$R_{t3=}$20	V_3=117	976.6791	0.0083
314.4612	26.6457	d_2=937.1	$R_{t4=}$30	V_4=127	981.5712	0.0077
117.6749	229.2453					
774.7847	975.5765	d_1=994.3				
876.6541	776.4151					
774.7847	975.5765	d_2=223.7				
117.6749	229.2453					
12.7599	918.3019	d_1=696.				
876.6541	776.4151					
12.7599	918.3019	d_2=875.				

4.19 Compare and contrast

Here, we are going to compare and contrast previous work versus our proposed work. As we can see from the figure bellow there are two graphs the first graph with the red color which represents the previous work where as the second with the green color which represents the proposed work. The previous work waiting time is 5.4 seconds where as the proposed work waiting time 10.8 seconds and the previous work covered communication distance about 300 meters where as the proposed covered communication distance about 600 meters. So this thesis increased the probability of on time receiving information increased the waiting time and the communication distance by 100%.

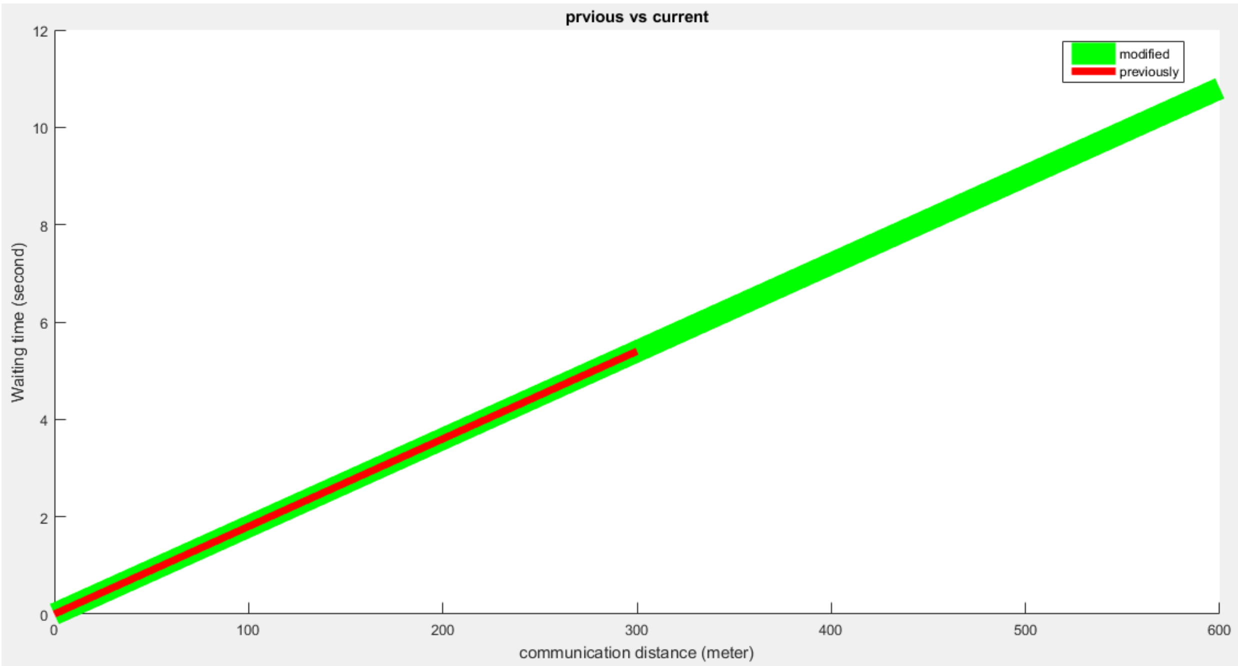


Figure 4.23: compare and contrast previous and current work

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this thesis, collision and time delays are the gaps that we identified to be solved. The main problem of time delay is due to the shortage of enough waiting time during communication in the coverage areas. The collision occurs due to the absence of a speed control system. In order to solve those problems, we have applied Euclidean distance algorithm. Depends on our simulation result, the following conclusion can be drawn.

- In order to solve the collision between the vehicles, when the vehicles get in to the communication coverage area manage the vehicles speed by giving different speeds for each vehicle and this thesis could controlled the vehicles speed.
- In order to solve the time delay of transmitting and receiving information, by adding additional infrastructure on the road side the waiting time of the vehicles with in the communicating coverage area increased the probability of receiving information and this thesis increased the waiting time by 100% .

5.2 Recommendations

In this thesis the capacity of the communication range between the mobile driving vehicles and fixed infrastructures is enhanced by adding infrastructures on the road side and the movement of vehicles could be controlled by making control the vehicles speed. In this thesis we have been worked traffic transportation system which the driver helps partially.

The future works of this thesis are listed below:

- In this thesis Euclidean distance algorithm is evaluated under the proposed technique. This method could be done in different ways using different algorithms such like Manhattan distance algorithm and Minkowski distance algorithm for the transportation sector driver helping system. The main function of this simulation is to transmit an information or data from sender to destination and to receive an information or data from other nodes of the infrastructure in time with minimum amount of delay. As a future it could be done decision maker system using A* algorithm, AODV algorithm, and ORPA algorithm for self driving vehicles in transportation system.
- This thesis was conducted only by simulation due to the absence of the kits in our country. If the tool kits for VANETs are imported into our country it is possible to implement practically using real-time platform using open source IEEE802.11p wireless protocol.

REFERENCES

[1] S. Zeadally, R. Hunt, Y.-S. Chen, A. Irwin, and A. Hassan, "Vehicular ad hoc networks (VANETS): status, results, and challenges," *Telecommunication Systems,* vol. 50, no. 4, pp. 217-241, 2012.

[2] Y. R. B. Al-Mayouf, O. A. Mahdi, N. A. Taha, N. F. Abdullah, S. Khan, and M. Alam, "Accident management system based on vehicular network for an intelligent transportation system in urban environments," *Journal of Advanced Transportation,* vol. 2018, 2018.

[3] V. Gautam, "Analysis and application of vehicular ad hoc network as intelligent transportation system," in *Mobile Radio Communications and 5G Networks*: Springer, 2021, pp. 1-17.

[4] T. Sujitha and S. P. Devi, "Intelligent transportation system for vehicular ad-hoc networks," *International Journal of Emerging Technology and Advanced Engineering,* vol. 3, no. 6, pp. 56-60, 2014.

[5] T. S. Gomides, M. L. Fernandes, F. S. H. de Souza, L. Villas, and D. L. Guidoni, "Fire-nrd: A fully-distributed and vanets-based traffic management system for next road decision," in *2019 15th International Conference on Distributed Computing in Sensor Systems (DCOSS),* 2019, pp. 554-561: IEEE.

[6] D. D. Nguyen, J. Rohács, D. Rohács, and A. Boros, "Intelligent total transportation management system for future smart cities," *Applied Sciences,* vol. 10, no. 24, p. 8933, 2020.

[7] J. Guerrero-Ibáñez, S. Zeadally, and J. Contreras-Castillo, "Sensor technologies for intelligent transportation systems," *Sensors,* vol. 18, no. 4, p. 1212, 2018.

[8] P. Papadimitratos, A. De La Fortelle, K. Evenssen, R. Brignolo, and S. Cosenza, "Vehicular communication systems: Enabling technologies, applications, and future outlook on intelligent transportation," *IEEE communications magazine,* vol. 47, no. 11, pp. 84-95, 2009.

[9] T. Zaheer, A. W. Malik, A. U. Rahman, A. Zahir, and M. M. Fraz, "A vehicular network–based intelligent transport system for smart cities," *International Journal of Distributed Sensor Networks,* vol. 15, no. 11, p. 1550147719888845, 2019.

[10] S. S. Pawar, P. V. Chaudhari, A. B. Deokate, and S. P. Wankhede, "Road Traffic Management using VANET," *International Journal of Advanced Research in Computer and Communication Engineering,* vol. 6, no. 4, pp. 642-646, 2017.

[11] M. Ren, L. Khoukhi, H. Labiod, J. Zhang, and V. Veque, "A mobility-based scheme for dynamic clustering in vehicular ad-hoc networks (VANETs)," *Vehicular Communications,* vol. 9, pp. 233-241, 2017.

[12] M. Azees, P. Vijayakumar, and L. J. Deborah, "Comprehensive survey on security services in vehicular ad-hoc networks," *IET Intelligent Transport Systems,* vol. 10, no. 6, pp. 379-388, 2016.

[13] E. C. Eze, "Achieving reliable and enhanced communication in vehicular ad hoc networks (VANETs)," 2017.

[14] M. S. Sheikh and J. Liang, "A comprehensive survey on VANET security services in traffic management system," *Wireless Communications and Mobile Computing,* vol. 2019, 2019.

[15] T. Clausen, C. Dearlove, and B. Adamson, "Jitter considerations in mobile ad hoc networks (MANETs)," ed: February, 2008.

[16] U. Herberg, T. Clausen, and C. Dearlove, "Integrity Check Value and Timestamp TLV Definitions for Mobile Ad Hoc Networks (MANETs)," 2070-1721, 2014.

[17] S. S. Kaushik, "Review of different approaches for privacy scheme in VANETs," *International Journal of Advances in Engineering & Technology,* vol. 5, no. 2, p. 356, 2013.

[18] J. Yapp and A. J. Kornecki, "Safety analysis of virtual traffic lights," in *2015 20th International Conference on Methods and Models in Automation and Robotics (MMAR)*, 2015, pp. 505-510: IEEE.

[19] T. Neudecker, N. An, O. K. Tonguz, T. Gaugel, and J. Mittag, "Feasibility of virtual traffic lights in non-line-of-sight environments," in *Proceedings of the ninth ACM international workshop on Vehicular inter-networking, systems, and applications*, 2012, pp. 103-106.

[20] G. Dimitrakopoulos and P. Demestichas, "Intelligent transportation systems," *IEEE Vehicular Technology Magazine*, vol. 5, no. 1, pp. 77-84, 2010.

[21] F. Pereñiguez, J. Santa Lozano, P. J. Fernández, F. Bernal, A. F. Skarmeta, and T. Ernst, "Vehicular ad hoc Networks: Standards, Solutions and Research," 2015.

[22] B. Ayyappan and P. M. Kumar, "Vehicular ad hoc networks (VANET): architectures, methodologies and design issues," in *2016 Second International Conference on Science Technology Engineering and Management (ICONSTEM)*, 2016, pp. 177-180: IEEE.

[23] S. Deivanayagi, N. Gopinath, V. Nagaraju, and K. Venusamy, "Emerging Technologies in Engineering Research."

[24] S. Rani, "Infrastructure based routing protocols in vehicular ad hoc network: A review," in *2017 International Conference on Computing, Communication and Automation (ICCCA)*, 2017, pp. 476-481: IEEE.

[25] M. Alowish, Y. Takano, Y. Shiraishi, and M. Morii, "Performance Evaluation of a Cluster Based Routing Protocol for VANETs," *J. Commun.*, vol. 12, no. 2, pp. 137-144, 2017.

[26] N. Panjrath and M. Poriye, "A Comprehensive Survey of VANET Architectures and Design," *International Journal of Advanced Research in Computer Science,* vol. 8, no. 5, 2017.

[27] R. Adrian, S. Sulistyo, I. W. Mustika, and S. Alam, "A Preliminary Performance Evaluation of Population-Based Algorithms in VANET," in *2019 International Conference of Artificial Intelligence and Information Technology (ICAIIT)*, 2019, pp. 220-224: IEEE.

[28] R. Adrian, S. Sulistyo, I. Mustika, and S. Alam, "ABNC: Adaptive Border Node Clustering Using Genes Fusion Based on Genetic Algorithm to Support the Stability of Cluster in VANET," *Int. J. Intell. Eng. Syst,* vol. 13, no. 1, pp. 354-363, 2020.

[29] F. Domingos, L. Villas, and A. Boukerche, "Data Communication in VANETs: Survey, Applications and Challenges," *Ad Hoc Networks,* vol. 44, no. C, pp. 90-103, 2016.

[30] A. Katiyar, S. K. Gupta, D. Singh, and R. S. Yadav, "A dynamic single-hop clustering algorithm (DSCA) in VANET," in *2020 11th international conference on computing, communication and networking technologies (ICCCNT)*, 2020, pp. 1-6: IEEE.

[31] H. Du, W. Li, N. Zhang, K. Zhao, J. Wang, and Z. Shao, "A vehicle cooperative positioning enhancement for GNSS-dark areas based on GRW model," in *2015*

International Conference on Wireless Communications & Signal Processing (WCSP), 2015, pp. 1-6: IEEE.

[32] I. Radhakrishnan, R. Souay, M. R. Palattellaz, and T. Engel, "An efficient service channel allocation scheme in SDN-enabled VANETs," in *2017 16th Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net)*, 2017, pp. 1-7: IEEE.

[33] F. Benabdallah, A. Hamza, and M. Bechrif, "Simulation and analysis of VANETS performances based on the choice of mobility model," in *2017 Computing Conference*, 2017, pp. 1238-1242: IEEE.

[34] K. Kamini and R. Kumar, "VANET parameters and applications: A review," *Global Journal of Computer Science and Technology,* 2010.

[35] A. Sumalee and H. W. Ho, "Smarter and more connected: Future intelligent transportation system," *Iatss Research,* vol. 42, no. 2, pp. 67-71, 2018.

[36] C. Jayapal and S. S. Roy, "Road traffic congestion management using VANET," in *2016 International conference on advances in human machine interaction (HMI)*, 2016, pp. 1-7: IEEE.

[37] C. Campolo, A. Molinaro, and R. Scopigno, "Vehicular ad hoc Networks," *Standards, Solutions, and Research,* 2015.

[38] E. A. Shams, A. Rizaner, and A. H. Ulusoy, "Trust aware support vector machine intrusion detection and prevention system in vehicular ad hoc networks," *Computers & Security,* vol. 78, pp. 245-254, 2018.

[39] K. B. Kelarestaghi, M. Foruhandeh, K. Heaslip, and R. Gerdes, "Survey on vehicular ad hoc networks and its access technologies security vulnerabilities and countermeasures," *arXiv preprint arXiv:1903.01541*, 2019.

[40] B. Cucor, "Outlines of Vehicular Ad-Hoc networks," *Transportation Research Procedia,* vol. 55, pp. 1312-1319, 2021.

[41] J. M. León-Coca, D. G. Reina, S. L. Toral, F. Barrero, and N. Bessis, "Intelligent transportation systems and wireless access in vehicular environment technology for developing smart cities," in *Big Data and Internet of Things: A Roadmap for Smart Environments*: Springer, 2014, pp. 285-313.

APPENDIX

```
%VANET Communications
%window size 1000 by 1000
axis([0 1000 0 1000]);
%initializes the delays
del=0.05;
del1=0.00045;
WmaxT=(0.6/200).*3600;
%given IEEE802.11p based bands of frequency in (in Hz)
Flower= 5.850.*10.^9 ;
Fhigher = 5.925.*10.^9;
Bw=Fhigher-Flower;
%Bw=75000000;
%msg=['The Value is ' num2str(Bw) 'Hz'];
disp(['The maximum waiting time in second at 200km/hr speed is =' num2str(WmaxT) 'second'])
disp(['Bandwidth = ' num2str(Bw) 'Hz'])
%road1 input from user
[x1,y1] = ginput(2);
line(x1,y1,'color','green','Linewidth',25);
hold on ;
%road2 input from user
[x2,y2] = ginput(2);
line(x2,y2,'color','red','Linewidth',25);
%road3 input from user
[x3,y3] = ginput(2);
line(x3,y3,'color','black','Linewidth',25);
hold on ;
%road4 input from user
[x4,y4] = ginput(2); % To take input from user for line 2
line(x4,y4,'color','black','Linewidth',25); % draw the line (Road 2)
%generating random number
Rt1=randi([18,28],1,1);
%disp(['random time Rt1=' num2str(Rt1) 'second'])
%Calculating the length or distance of the road1
droad1=sqrt((x1(2)-x1(1))^2+(y1(2)-y1(1))^2);
disp(['The distance of road is dr1 = ' num2str(droad1) ' meter'])
% Calculating the speed of vehicle1
V1=round((droad1/Rt1)+10);
disp(['Vehicle speed V1=' num2str(V1) ' Km/hr'])
T1=0.001.*droad1/V1;
disp(['The time taken by vehicle  T1=' num2str(T1) ' hr'])
%generating random number
Rt2=randi([10,20],1,1);
droad2=sqrt((x2(2)-x2(1))^2+(y2(2)-y2(1))^2);
disp(['The distance of road is dr2 = ' num2str(droad2) ' meter'])
```

```
% Calculating the speed of vehicle2
V2=round((droad1/Rt1)+25);
disp(['Vehicle speed V2=' num2str(V2) ' Km/hr'])
T2=0.001.*droad2/V2;
disp(['The time taken by vehicle  T2=' num2str(T2) ' hr'])
%roads start and end points
P1=linspace(x1(1),x1(2),V1);
P2=linspace(y1(1),y1(2),V1);
P3=linspace(x2(1),x2(2),V2);
P4=linspace(y2(1),y2(2),V2);
%genrating random number
Rt3=randi([15,20],1,1);
%disp(['random time Rt3 = ' num2str(Rt3) 'second'])
%Calculating the length or distance of the road3
droad3=sqrt((x3(2)-x3(1))^2+(y3(2)-y3(1))^2); % Distance between two points is calculated
disp(['The distance of road is dr3 = ' num2str(droad3) ' meter'])
% Calculating the speed of vehicle3
V3=round((droad1/Rt1)+40); % This is the new speed for 1st vehicle
disp(['Vehicle speed V3=' num2str(V3) ' Km/hr'])
T3=0.001.*droad3/V3;
disp(['The time taken by vehicle  T3=' num2str(T3) ' hr'])
%genrating random number
Rt4=randi([20,35],1,1);
%disp(['random time Rt4=' num2str(Rt4) 'hr'])
%Calculating the length or distance of the road
droad4=sqrt((x4(2)-x4(1))^2+(y4(2)-y4(1))^2);
disp(['The distance of road is dr4 = ' num2str(droad4) ' meter'])
% Calculating the speed of vehicle4
V4=round((droad1/Rt1)+50);
disp(['Vehicle speed V4=' num2str(V4) ' Km/hr'])
T4=0.001.*droad4/V4;
disp(['The time taken by vehicle  T4=' num2str(T4) ' hr'])
%roads start and end points
P5=linspace(x3(1),x3(2),V3);
P6=linspace(y3(1),y3(2),V3);
P7=linspace(x4(1),x4(2),V4);
P8=linspace(y4(1),y4(2),V4);
%plotting vehicles
Car1=plot(P1,P2,'s','MarkerFaceColor','yellow','MarkerSize',25);% Plot first vehicle on road 1
set(Car1,'LineWidth',15)%magnifying the vehicles size 15x
Car2=plot(P3,P4,'o','MarkerFaceColor','blue','MarkerSize',25);% Plot second vehicle on road 2
set(Car2,'LineWidth',15)%magnifying the vehicles size 15x
Car3=plot(P5,P6,'s','MarkerFaceColor','yellow','MarkerSize',25);% Plot third vehicle on road 1
set(Car3,'LineWidth',15)%magnifying the vehicles size 15x
Car4=plot(P7,P8,'o','MarkerFaceColor','blue','MarkerSize',25);% Plot fourth vehicle on road 2
set(Car4,'LineWidth',15)%magnifying the vehicles size 15x
```

```
legend('lane1','lane2','lane3','lane4','Vehicle1','Vehicle2','Vehicle3','Vehicle4');
%plotting the satellite
[Xcrdt1,Ycrdt1]=ginput(1); % Select a point for Satelite
text(Xcrdt1,Ycrdt1,'Satelite ','HorizontalAlignment','right');
%plotting RSUs
[Xcrdt2,Ycrdt2]=ginput(1);
text(Xcrdt2,Ycrdt2,'RSU 1 ','HorizontalAlignment','right');
plot(Xcrdt1,Ycrdt1,'o','MarkerFaceColor','red','MarkerSize',25); % Sattelite  plotted on the figure window % set(t,'LineWidth',5)
plot(Xcrdt2,Ycrdt2,'^','MarkerFaceColor','blue','MarkerSize',25); % RSU 1 plotted on the figure window
[Xcrdt3,Ycrdt3]=ginput(1); % Select a Position for RSU 2
text(Xcrdt3,Ycrdt3,'RSU 2 ','HorizontalAlignment','right');
plot(Xcrdt3,Ycrdt3,'^','MarkerFaceColor','blue','MarkerSize',25); % RSU 2 plotted on the figure window%set(n,'LineWidth',5)
[Xcrdt4,Ycrdt4]=ginput(1); % Select a Position for RSU 3
text(Xcrdt4,Ycrdt4,'RSU 3 ','HorizontalAlignment','right');
plot(Xcrdt4,Ycrdt4,'^','MarkerFaceColor','blue','MarkerSize',25); % RSU 3 plotted on the figure window
[Xcrdt5,Ycrdt5]=ginput(1); % Select a Position for RSU 4
text(Xcrdt5,Ycrdt5,'RSU 4 ','HorizontalAlignment','right');
plot(Xcrdt5,Ycrdt5,'^','MarkerFaceColor','blue','MarkerSize',25); % RSU 4 plotted on the figure window
[Xcrdt6,Ycrdt6]=ginput(1); % Select a Position for RSU 5
text(Xcrdt6,Ycrdt6,'RSU 5 ','HorizontalAlignment','right');
plot(Xcrdt6,Ycrdt6,'^','MarkerFaceColor','blue','MarkerSize',25); % RSU 5 plotted on the figure window
h=legend('lane1','lane2','lane3','lane4','Vehicle1','Vehicle2','Vehicle3','Vehicle4','Sat','RSU');
h.FontSize = 8;
disp('The Waiting times of the vehicles in the 600m range of communication with their own speed\n')
% sprintf('\n')
w1=(0.6/V1).*3600;
 disp([' wt1 =' num2str(w1) ' seconds'])
w2=(0.6/V2).*3600;
  disp([' wt2 =' num2str(w2) ' seconds'])
w3=(0.6/V3).*3600;
  disp([' wt3 =' num2str(w3) ' seconds'])
w4=(0.6/V4).*3600;
  disp([' wt4 =' num2str(w4) ' seconds'])
%############
title('VANET COMMUNICATION SIMULATION'); % Title for figure
for i=1:1000
  for k = 1:V1 % for all the values in linspace
 Car1.XData = P1(k); %first vehicle's x co-ordinate
 Car1.YData = P2(k); %first vehicle's y co-ordinate
```

```
 Car2.XData = P3(k); %second vehicle's x co-ordinate
 Car2.YData = P4(k); %second vehicle's y co-ordinate
 Car3.XData = P5(k); %first vehicle's x co-ordinate
 Car3.YData = P6(k); %first vehicle's y co-ordinate
 Car4.XData = P7(k); %second vehicle's x co-ordinate
 Car4.YData = P8(k); %second vehicle's y co-ordinate

 plot(P1(k),P2(k),P3(k),P4(k),P5(k),P6(k),P7(k),P8(k));
 a= plot(P1(k),P2(k),P3(k),P4(k),P5(k),P6(k),P7(k),P8(k));
 set(a,'MarkerSize',15)
 %disp('the distance between vehicles and between vehicles and rsu is calculated as below')
 vehicle_dist=[Xcrdt1,Ycrdt1;Xcrdt2,Ycrdt2;P1(k),P2(k);P3(k),P4(k);P5(k),P6(k);P7(k),P8(k)];
xlabel('X-axis')
ylabel('Y-axis')
 d1= pdist(vehicle_dist,'euclidean')
 if d1<=600 % If the distance is within 200 ma\\
%Communication/connectivity of the vehicles and the infrastructure
line1=plot([Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P1(k),P5(k)],[Ycrdt1,Ycrdt2,Ycrdt3,Yc
rdt4,Ycrdt5,Ycrdt6,P2(k),P6(k)],...
[Xcrdt2,P1(k),P5(k)],[Ycrdt2,P2(k),P6(k)],[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P1(k),P
3(k)],...
[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5,Ycrdt6,P2(k),P4(k)],[Xcrdt3,P3(k),P5(k)],[Ycrdt3,P4(k),P
6(k)],...
[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P1(k),P7(k)],[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5
,Ycrdt6,P2(k),P8(k)],...
[Xcrdt4,P5(k),P1(k)],[Ycrdt4,P6(k),P2(k)],[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P3(k),P
5(k)],...
[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5,Ycrdt6,P4(k),P6(k)],[Xcrdt5,P7(k),P1(k)],[Ycrdt5,P8(k),P
2(k)],...
[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P3(k),P1(k)],[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5
,Ycrdt6,P4(k),P2(k)],...
[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P3(k),P7(k)],[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5
,Ycrdt6,P4(k),P8(k)],...
[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P5(k),P1(k)],[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5
,Ycrdt6,P6(k),P2(k)],...
[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P5(k),P3(k)],[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5
,Ycrdt6,P6(k),P4(k)],...
[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P5(k),P7(k)],[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5
,Ycrdt6,P6(k),P8(k)],...
[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P7(k),P1(k)],[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5
,Ycrdt6,P8(k),P2(k)],...
[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P7(k),P5(k)],[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5
,Ycrdt6,P8(k),P6(k)],...
[Xcrdt1,Xcrdt2,Xcrdt3,Xcrdt4,Xcrdt5,Xcrdt6,P7(k),P3(k)],[Ycrdt1,Ycrdt2,Ycrdt3,Ycrdt4,Ycrdt5
,Ycrdt6,P8(k),P4(k)],...
[Xcrdt1,Xcrdt3],[Ycrdt1,Ycrdt3],[Xcrdt1,Xcrdt4],[Ycrdt1,Ycrdt4],[Xcrdt1,Xcrdt5],[Ycrdt1,Ycrd
t5],[Xcrdt1,Xcrdt6],[Ycrdt1,Ycrdt6],...
```

```
[Xcrdt3,Xcrdt6],[Ycrdt3,Ycrdt6],'--','color','red');
set(line1,'LineWidth',2.5)%magnifying the doted or dashed lines 2.5x more greater than the original size
pause(0.05);
 set(line1,'Visible','on'); % Visibility property of line is set to 'off'
 end
 pause(del); % Delay of 0.5
  end
 %Vehicular Visibility back and forth
 set(Car1,'Visible','on');
 set(Car2,'Visible','on');
 set(Car3,'Visible','on');
 set(Car4,'Visible','on');
 end
 hold off;
```