Towards Designing FUZZY Set-Based Intelligent Broadcasting Technique in VANETs

Thesis submitted in partial fulfillment of the requirements for the award of degree of

Master of Engineering
In
Computer Science and Engineering

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Certificate

I hereby certify that the work which is being presented in the thesis entitled, "***Towards Designing FUZZY Set-Based Intelligent Broadcasting Technique in VANETs***" in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Computer Science and Engineering* submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Neeraj Kumar* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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Abstract

Vehicular Adhoc Networks (VANETs) are being used in wide range of applications especially safety related applications from last few decades. To route a packet to its final destination is one of most difficult tasks to be performed in this environment. To address this issue in this thesis, we have designed a novel fuzzy set based routing technique in VANETs. We have designed new algorithms for packet transmission to increase the overall reliability of transmission. Membership functions are also designed for fuzzification and defuzzification processes using various metrics. The performance of proposed scheme is evaluated using various metrics where the performance of the proposed scheme is found to be better than the other existing schemes.

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Abbreviations

AITS	Association for Intelligent Transportation System
AU	Application Unit
C2C	Car-to- car
CALM	Continuous Air interface Long & Medium range
CCK	Complimentary Code keying
DGPS	Differential Global Positioning System
DM	Domain Name Server
DSM	Density Metric
DSRC	Dedicated Short Range Communication
DSSS	Direct Sequence Spread Spectrum
FHSS	Frequency Hopping Spread Spectrum
FSK	Frequency Shift Keying
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
IFUZZY	Intelligent FUZZY
ITS	Intelligent Transportation System
MAC	Media Access Control
MANET	Mobile Adhoc Networks
MIMO	Multiple Input Multiple Output
MM	Mobility Metric
NETCONVERT	Network Converter
OBU	On Board Unit
OFDM	Orthogonal Frequency Division Multiplexing
RSU	Road Side Unit
SUMO	Simulation of Urban MObility
V2I	Vehicle-to-Infrastructure
V2R	Vehicle-to-Road Side Unit
V2V	Vehicle-to-vehicle

VANETs	Vehicular Adhoc Networks
WAVE	Wireless Access in Vehicular Environments

Chapter 1
Introduction

1.1 VANET Overview

Vehicular Adhoc Networks (VANETs) is a latest technology and researchers worldwide are showing great interest in it. It is a special type of mobile adhoc network in which there are vehicles in place of mobile phones or we can also say that vehicles can be simulated as moving nodes. VANETs have two constituents, one is access point (APS), also called road side unit (RSU) and the second one is vehicle. APS are immobile or stationary and are connected to the network of networks, i.e., Internet. These access points are also helpful in providing geographical description of vehicular node. In VANETs, communication is wireless can be categorised into two type’s one is V2V, i.e., Vehicle-to-Vehicle and the other is V2I, i.e., Vehicle-to-Infrastructure. VANETs play a very influential role in the Intelligent Transportation Systems (ITS). In VANETs, each vehicle communicates by sending or receiving the message with help of On-board Unit (OBU), i.e., is a type of transceiver assembled in each vehicle [1].

With continuous decrease in the cost of hardware and increase in advancement of communication protocols available, along with continuous pressure from society due to an increase in number of road accidents, automobile companies are working to enhance the road safety as well as continuous upgrade of automobile technology to meet the market competition, e.g., latest communication systems like GPS are integrated in the vehicles to make vehicles as computers on wheels.

There are many applications of VANETs such as vehicular collision detection, planned driving, security warning about distance, relaying information about the road, location tracking, automatic parking, access to Internet and cars which can be ridden without a driver. The properties of VANETs which resemble those of MANETs are operational technology, i.e., self-organizing capacity of vehicular nodes and radio transmissions used by the nodes. The thing which makes VANETs differ from other adhoc network is very fast speed and highly uncertain mobility pattern of the vehicular nodes along the path. It is clear that routing protocols which are currently used for MANETs can’t be used for VANETs. So, these protocols need an upgradation to handle such fast speed of vehicular nodes in an efficient manner. Due to its vast applications, capability and features, VANETs have attracted the attention of government, education institutes and industry worldwide, which has led to a surge in high scale research by researchers from every field, academia, industry and public sector alike to develop applications and standards to use VANETs to its full potential and to make VANETs an international standard for communication of vehicles [2], [3].

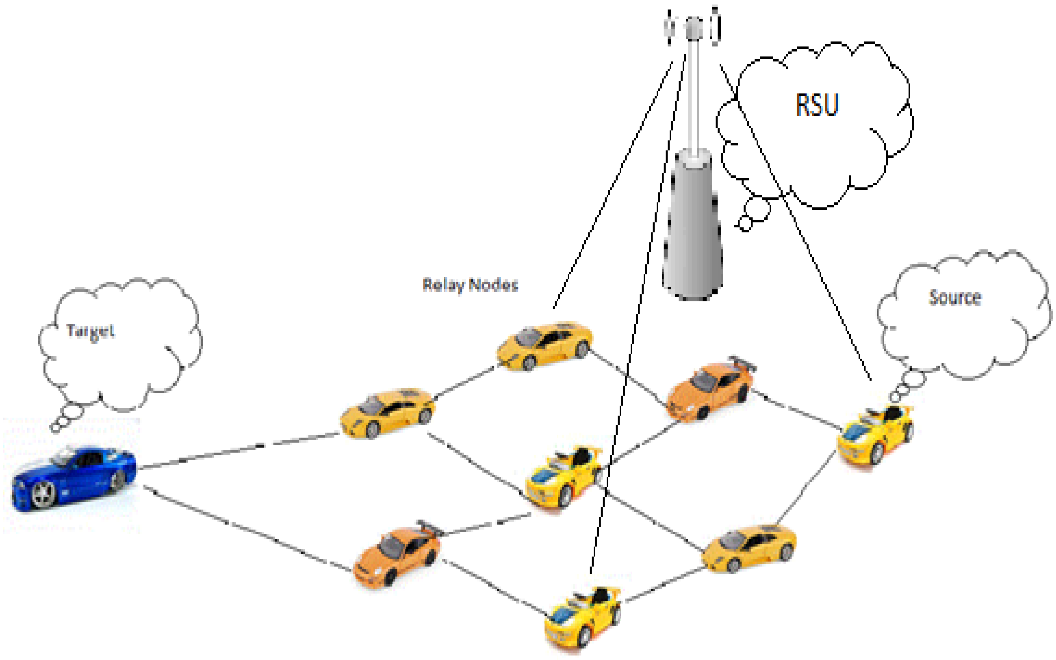

Figure 1.1 General VANETs Scenario

We all know that the most common and one of the biggest problems in large cities is traffic congestion which is accompanied by a menace of accidents due to presence of loop holes in the road safety rules and tremendous increase in number of vehicles moving with high speed which poses a danger to invaluable human life and irreversible danger to environment. According to National Highway Administration report, about 6.3 million accidents were reported, in which 43,000 people lost their lives and about 2 lakhs became physically disabled. The effect on economy due to these accidents were estimated to be about $230 billion, not to mention the unfathomable grief to bereaved family members and friend of those who fall prey to these accidents [2], [3].

Fundamental safety equipments like seat belts, helmets and air bags can decrease the threat but cannot eradicate it as driver is unable to predict the situation before it actually happens [2]. Real-time speed of other vehicles cannot be predicted by the vehicle or driver while moving on the road; neither can he accurately judge the topology of road ahead him. Therefore, to solve this problem, we must predict the speed of other vehicles and it should be transmitted timely as a warning message, which can be done by using some technologies like wireless communication equipment, sensors, and transceivers.

1.2 Intelligent Transportation System (ITSs)

Intelligent Transportation System (ITS) is a generic term which defines the techniques practised in transportation systems to manage traffic effectively in all modes of transportation, i.e., road, water, rail and air. ITS deals with the framework required for both intra and inter-mode transmissions of important information between vehicles, which increases the level of traffic safety, enhances efficiency of vehicles and reduces ill-effects on environment, which directly cuts money spent on maintenance of vehicles, roads and cost of fuel [1].

Intra-mode transmission means flow of information between vehicles travelling in same mode of transportation, like roadways to roadways or airways to airways etc. Inter-mode transmission means flow of information between different modes of transportation, e.g., roadways to railways, roadways to airways, airways to waterways, etc.

ITS handles telemetry and communication which can either be car-to-car communication or car-to-some fixed infrastructure. In ITS, each vehicular node acts as a sender, receiver or router at different time to broadcast a message to other vehicles in the network or to some centralized agency of transportation whose duty is to ensure hassle free and safe flow of traffic. For the communication between the vehicles or between a vehicle and RSU, which is fixed on either side of road, there must be a radio transceiver integrated in the vehicles, which can enable vehicular nodes to create a short range wireless adhoc network. Differential Global positioning System (DGPS) and Global Positioning System (GPS) must also be fitted in the vehicles for determination of position of vehicles.

Projects operating in world for the development of Intelligent Transportation System at present are:

- Continuous Air Interface Long and Medium range (CALM): It is working on the communication of vehicles with the RSUs by using different types of media used for communication like infra red links, cellular links and some dedicated wireless links. Its applications include safety of vehicles and drivers, flow of information between vehicles and applications related to the live entertainment for passengers and drivers.

- Dedicated Short-Range Communication (DSRC): It is working on the communication between vehicles and particular locations on roads like Toll booths facilitating operations like Electronic Fee Collection at toll booths and prepaid parking's operating under DSRC [1].
- In India, Association for Intelligent Transportation System (AITS), a non profit organisation with an objective to save lives, time, money and environment, is engaged in a billion dollar project since 2001 for the development of self reliant Intelligent Transportation system for Indian cites without any foreign assistance. Researchers from academia and industries have joined hands with government to work on this project based on the rules and regulation of Indian government with a shared vision of making India one of the countries with safest and most efficient transportation network.

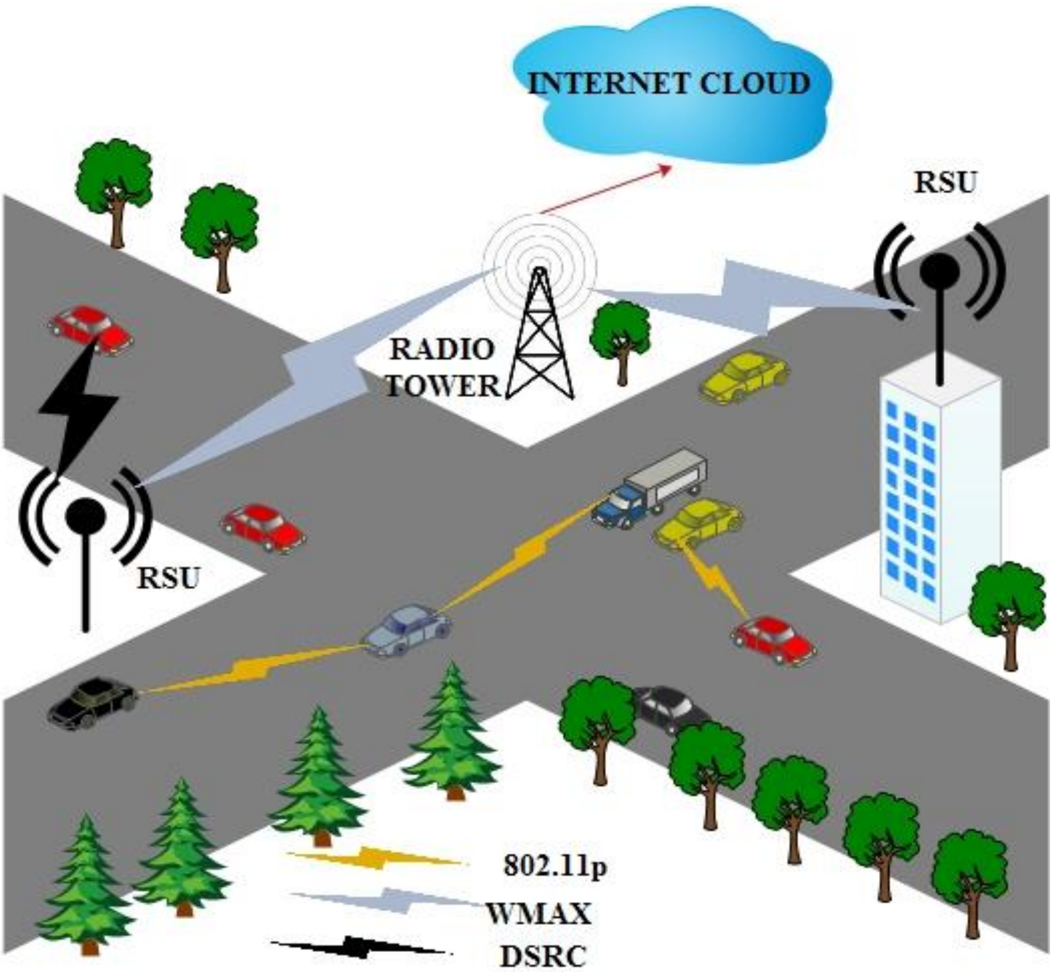

Figure 1.2 Intelligent Transportation Systems Scenario

RSUs must be properly arranged to facilitate the communication. The number, arrangement and distribution of RSU heavily depends on the type of road and protocol used, e.g. requirement of some of the protocols is to distribute the RSUs evenly throughout the whole road, while some require RSUs to be present on border of the transmission region and others require RSUs to be present only at the point of intersections.

1.2.1 Types of communication

Communication is the act of receiving and sending of ideas in form information, either in oral or written forms. In VANETs, communication includes vehicle-to-RSU communication, inter-vehicular communication and communication based on routing. All these types of communications are based on the up-to-date and accurate information of the surrounding environment, for which system requires good communication protocols and accurate positioning devices in order to send and receive information in the network accurately. Communication medium is shared among all the vehicles and is very unreliable. Due to this unreliability and limited bandwidth, there is a need for smart communication protocols in order to execute quick and efficient broadcast of messages to all the vehicles [1].

1.2.1.1 Inter-Vehicle Communication

In inter-vehicle communication, multi-hop multicast or broadcast is done to forward information related to traffic and situation of roads over multiple hops, i.e., to a group of receivers [4].

In ITS, only thing that matters to the vehicles is the incidents in forward direction, not the incidents in the backward direction like broadcasting of emergency message related to environment warning or any collision related message. In inter-vehicle communication, there are two types of message dissemination techniques; one is naïve broadcasting and the other is intelligent broadcasting.

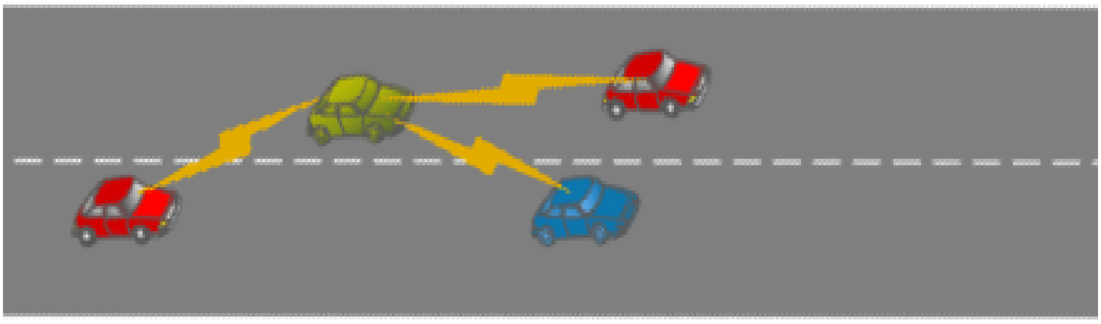

Figure 1.3 Inter-Vehicle Communication

In naïve broadcasting, each vehicle in the road network disseminates a message after a predefined period of time to all the vehicles in its transmission range. The vehicles receiving this message drop this message packet if it is coming from the vehicle which is in backward direction to them, but if this message came from the vehicle which is in forward direction to them, the receiving vehicles keep this message and rebroadcast it to other vehicles which are in backward direction to them. This naïve broadcasting assures that the vehicles which are moving in the forward direction have up-to-date information. This naïve broadcasting also has some limitations like broadcast storm problem, i.e., very large number of broadcast messages which increases the collision and causes inefficient use of bandwidth [1].

Intelligent broadcasting has decreased the problem existing in naïve broadcasting to some extent by making an assumption that if a vehicle receives a message which it has already received from the vehicle in the backward direction to it, then the receiving vehicle assumes that the some vehicles in the backward direction have already received this message and so it stops the broadcasting of that message as shown in Figure 1.3. Green car sends message further if it came from blue car which is in front direction to it, but if it came from red car which is behind it, then green car blocks the message. If a vehicle gets multiple copies of same message then only the first copy is considered valid and all others copies are considered invalid.

1.2.1.2 Vehicle to Road Side Unit communication

Vehicle-to-RSU communication is a type of single-hop broadcast in which RSU having the message, broadcasts the message to all vehicles which are in its transmission range [1]. A high bandwidth link is provided between the RSU and the vehicles for the transmission of an emergency warning or some message from authorities with high priority as shown in Figure 1.4.

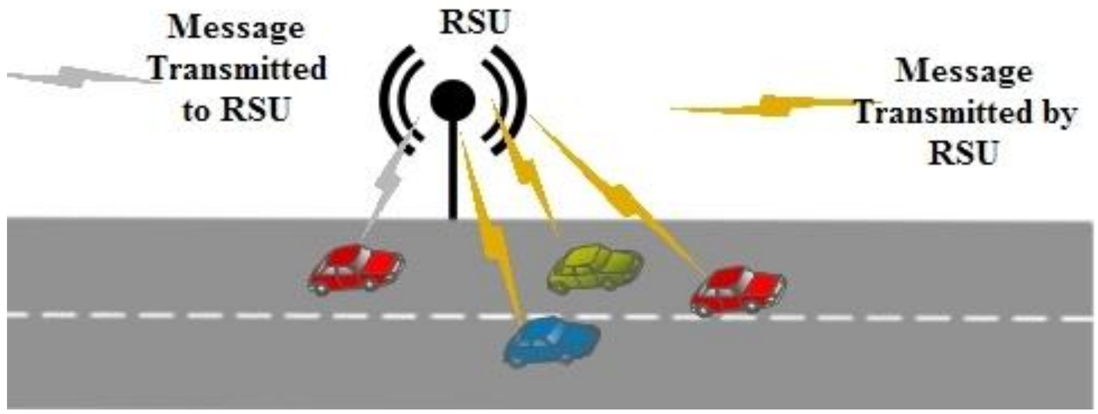

Figure 1.4 Vehicles to Road Side Unit Communication

In Figure 1.4, Red car transmits an urgent message to RSU (shown by gray colour) to broadcast in the entire network.RSU then broadcasts that message to the all three cars ,i.e., blue, green and red one shown by yellow-coloured wireless link. RSUs can be evenly distributed throughout the whole road or they can be present on border of the transmission region or they can be present only at the points of intersections. RSUs keep on monitoring the dynamic speed limit of vehicles. At the same time, RSUs keep running the internal algorithm continuously to calculate the ideal speed limit for the current situation on the basis of past archived data, real-time traffic density and real-time condition of environment and keep on broadcasting this calculated speed at regular intervals to all the vehicles in its transmission range. RSU continuously monitors the vehicles in its vicinity to ensure they are following speed limit broadcasted by it. In case, RSU finds that a vehicle is not following its instructions, then it issues a warning message for that vehicle requesting its driver to follow speed limits.

1.2.1.3 Routing Based Communication

Routing based communication is a type of multi-hop unicast in which a message from a source reaches the desired vehicle with the help of multiple numbers of hops present in the path between source and the destination as shown in Figure 1.5 [1]. Red car has some message which it wants to send to the black car, so it formulates a packet and sends it in direction of the black car by taking help from different relay vehicles by establishing an Adhoc wireless link with them. Here, green and light orange cars are acting as relay for the message which is to be transmitted to the black car. The decision of direction and path of transmission of message packet is taken at each and every relay node between the source and the destination on the basis of unique identification number which is assigned to each vehicle by some centralised authority.

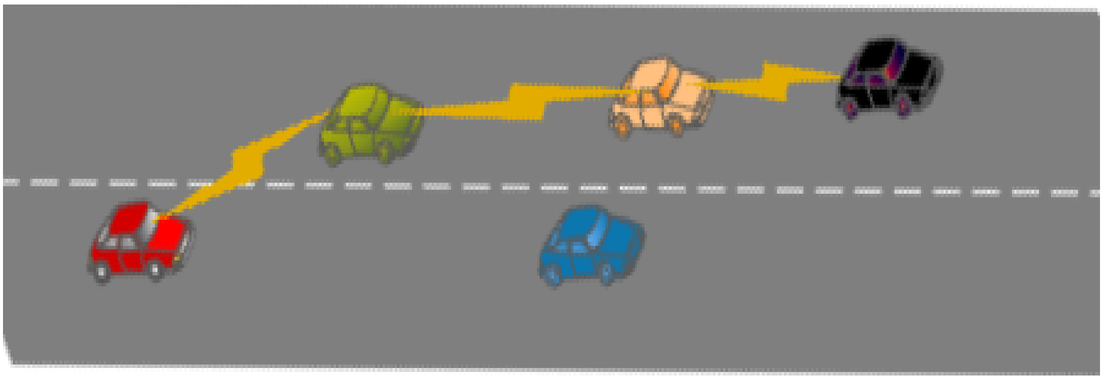

Figure 1.5 Routing Based Communication

1.3 Challenges and Issues

- **Mobility: -** The core idea while developing the Adhoc networks is that the nodes should be mobile, i.e., they can move freely in the network within the transmission area. The speed or mobility is under control in mobile Adhoc networks (MANET), but in VANET's, the speeds of nodes are higher. Therefore, the connection between vehicles in VANETs lasts just for a few seconds because vehicles go out of each other transmission range in a very short span of time due to their high speeds and may not come in each other's range again. So mobility poses a big problem.
- **Standards: -** Current available features of IEEE802.11 standards are not capable enough of providing robust network connectivity and handling such a high mobility. Besides that, presently available parameters of media access control of IEEE802.11 do not have potential to accommodate such a large density of vehicular nodes. Routing protocols presently available are not sufficiently efficient to accommodate such high mobility and uncertainty.
- **Mobility patterns: -** Predefined prediction means to have knowledge of roads topology, design and present condition on roads and speed of node, which is very difficult as the mobility pattern of vehicles depends on various factors such as roads structure, traffic, vehicles' speed, driver's driving behaviour and so on.
- **Frequent disconnection: -** Nodes in VANETs are vehicles which are moving with high speed, due to which, nodes frequently go from range of one RSU to other RSU which can lead to a disconnection of it from a network. Disconnection might be for micro seconds under normal circumstances, but even these very short spans of disconnection can cause failure of transmission.
- **Network Scalability: -** The scalability of network means that network should function properly and efficiently whenever there is any change in size and volume of network, whatever be the reason behind this change. The span of vehicular Adhoc networks in the word is about 550 million nodes and is increasing exponentially. This leads to a problem to handle such a big network as there is no standard governing authority to tackle this ,i.e., DSRC

standards in Asia are different from DSRC standard in America and these are not designed to handle such a large number of nodes.

- **End-to-End Delay: -** It is the time required to send a message from the original source of message, i.e., place of origin or generation of message to the final destination of message where the message is used for some processing. Numerically, End-to-End delay is the sum of the propagation delay, transmission delay, queuing delay and processing delay. In case of VANETs, the communication is mostly broadcast-based and end-to-end delay is not uniform for the entire network, as there is much deviation between the speed and inter-vehicular distances between pairs of vehicles which directly affect the propagation delay, which is directly proportional to inter-vehicular distance and inversely proportional to speed. Due to this large deviation, chance of packet loss increases or time for successful transmission increases which is not desirable in VANETs, e.g. in safety applications like ambulance transmitting a message, distress message related to environmental danger, etc. require immediate relaying of information without the introduction of any type of delay, because a small delay can lead to a loss of life. So, lower value of delay is preferable.
- **Robustness: -** In terms of computer science, robustness means the capability of the system to endure with errors encountered during execution. In VANETs, robustness means the capability of the network to work properly without a multi-point failure or whole network breakdown even if there is a breakdown or loss of some communication links. In simple terms, it means that even if wireless communication link between two cars is lost due to any reason, the network should be capable enough to transmit the message to those vehicles either by other transmission path by using some other vehicle as relay node without wasting time to establish connection again. In case no relay is available, then only the same broken connection should be established again. But in VANETs, due to high mobility and random driving pattern, probability of link breakage is very high; so time and resource wastage to cope up with this situation is also very high which is not desirable for the correct functioning of safety applications and efficient and timely dissemination of message.

- **Redundancy: -** Redundant is something which is not desirable or simply no longer required for the proper functioning of the system. Redundancy can directly affect the performance of the system as in case of database, presence of redundancy can lead to an inconsistency in database. In VANETs, communication is mostly broadcast based which is done with help of other vehicles which act as relay nodes to disseminate the message in entire network. When a vehicle receives a broadcast message and decides to rebroadcast it to other vehicles, receiving vehicles may or may not have already received the message, in case vehicle has already received same message before then this message is redundant and useless for it. So resource waste to transmit this message to vehicles which have already received it is high and this can be received from many other vehicles at the same time by same vehicle.
- **Contention: -** In general English, contention means the competition for the resources. This term is notably used in networks to express a situation in which two or more stations try to access the same network resource at the same time for the transmission of message, which can lead to a packet loss due to collision of message packets. In VANETs, it occurs when neighbour vehicular nodes receive a broadcast message and decide to rebroadcast message in the remaining network .These nodes must contend with each other to get the access to the shared wireless medium to transmit the message. This leads to a message loss due to collision. It is undesirable, especially in cases where message to be transmitted is related to some safety application as the loss of message can have catastrophic implications.

1.4 Application of VANET

According to the DSRC, there are large numbers of VANETs applications which can be separated in two categories, one is Safety applications and the other is non-safety applications. Non-safety applications can be further classified into two categories, one is transport efficiency and other is infotainment. We can also categorise them on the basis of hardware into following two types, one is OBU--OBU and the other in OBU--RSU.

Emergency vehicle alerts and collision alerts come under the category of safety applications. Real-time monitoring of traffic and scheduling of routes come under the category of non-safety and transport efficiency. Applications like electronic prepaid parking, on-road access to internet, enquiry about nearest restaurant or petrol pump which do not require any urgent message priority and are just for the on-road convenience, come under the category of non-safety and infotainment.

Some of the important applications of VANET's are as follows:

- **Cross Points Collision Warning**

  It is a safety and OBU-RSU type of application. A Central RSU is available at point of intersection of roads which keep on monitoring the vehicles in its transmission range and continuously keeps running the algorithms and computations to predict which vehicles can crash into other vehicles on the basis of their dynamically changing coordinates and the speeds with which they are moving. Whenever an RSU finds that the coordinates of two or more vehicles become same at a particular instant, it generates an alert or warning message to warn the drivers of these vehicles that their speeds are high and an accident may occur. This way, drivers can take appropriate actions in order to avoid collision. In Figure 1.6, a warning or alert message transmission is shown by yellow colour wireless link, which is issued to red and blue cars so that they can decrease their speeds in time to avoid accident [3], [5].

  Many automobile industries like General Motors, BMW, etc. are working on the projects to develop wireless automated collision avoidance system for vehicles. If drivers do not respond to warning in predefined time or when distance between vehicles reaches to minimum safety distance, automatic brakes is applied [5], [8].

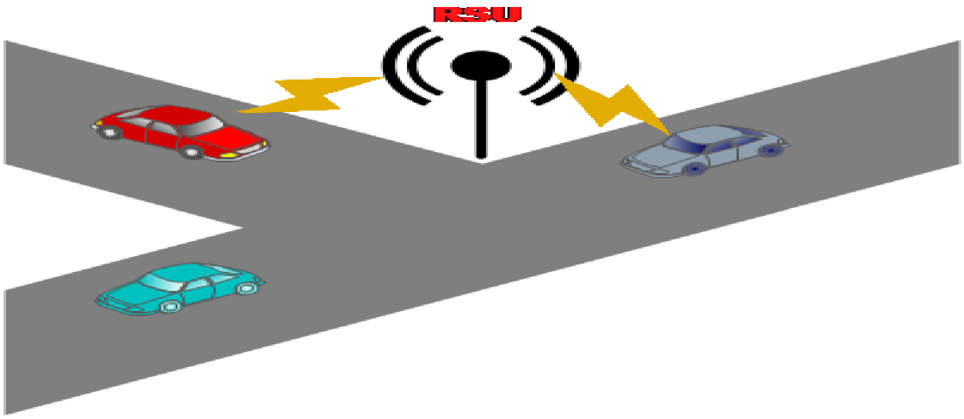

Figure 1.6 Cross Points Collision Warning

- **Mutual Collision Warning**

  It is a safety and OBU-OBU type of application. In VANETs, the mobility and pattern of driving is very random and its prediction is very difficult. Variation in speed and driving pattern can either be intentional or unintentional on the part of driver [2]. So whenever there is a rapid change in speed and direction which can be predicted by the OBU unit fitted in the vehicle, a warning message is issued by OBU to the driver in the form of alarm or some visual message to take appropriate action. If the driver does not respond to warning in some predefined time then OBU generates a message warning for other vehicles on road that the driver or the vehicle is unresponsive and broadcasts it for other vehicles. This way other vehicles take appropriate evasive measures in time to avoid collision. In Figure 1.7, OBU of red car is issuing a warning message to alert green car [6], [8].

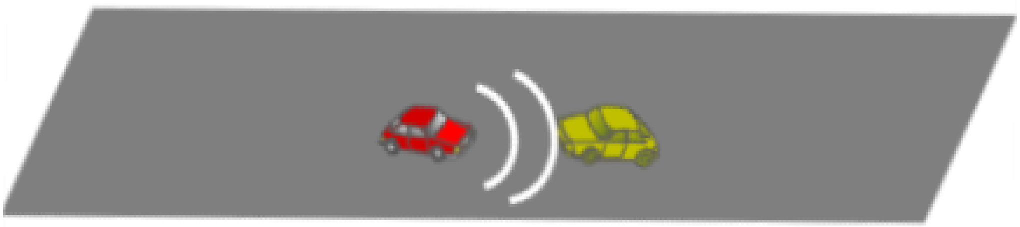

Figure 1.7 Mutual Collision Warning

- **Emergency Vehicle Alerts**

  It is a safety and OBU-OBU type of application. Vehicles like Ambulance, Police vehicle, VIP Transports, military vehicles, funeral vans etc come under the category of emergency vehicles. Emergency vehicle on the road can't afford to waste any time in traffic; ambulance carrying a very serious patient to hospital can't afford to waste even a minute as this one minute can be a deciding factor of patient's life or death, or a police vehicle chasing a fleeing fugitive can't afford to let the fugitive escape due to traffic between Police vehicle and fleeing vehicle [7]. Therefore, whenever there is an emergency vehicle moving on the road, it formulates a message alert and broadcasts it in the entire network with help of its OBU so that other vehicles can clear the whole lane for the emergency vehicle in time. In Figure 1.8, an ambulance is shown formulating a message and broadcasting it, which is represented by red arrows [2], [3].

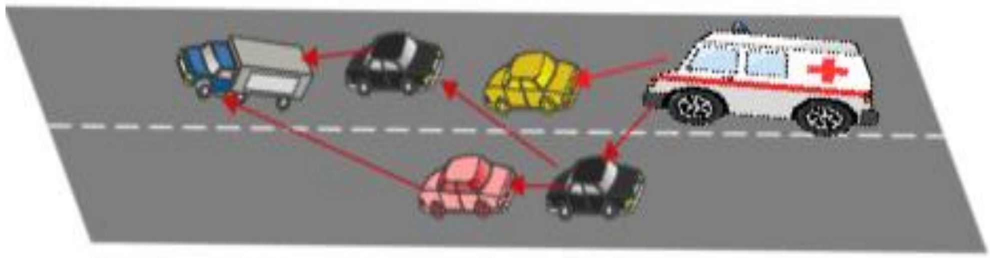

Figure 1.8 Emergency Vehicle Alerts

- **Work Going Ahead**

  It is a safety and OBU-RSU type of application. An RSU is installed on the sites like places where repair work on roads is going on, installation of traffic lights on road, construction of some over-bridge or some place where road is blocked due to an accident. In this case, RSU informs the vehicles on the road that road ahead is closed for work. So by the use of RSU, vehicles can be informed in advance that road ahead is closed due to ongoing construction work be condition that some construction work and workers are working there and road is blocked for traffic so that workers can work without fear of getting hit by vehicles. However, this can lead to inconvenience to others as they don't know in advance that road ahead is blocked, which results in wastage of time. Therefore, timely transmission of alert message by RSU helps vehicles to opt for an alternate route, which saves a lot of time and effort [7].

  The major advantage of this application is in scenarios similar to the one shown in Figure 1.9. If a road is severely damaged due a natural calamity, structural failure or some other reason, it can cause a very serious accident in which probability of survival of passengers is very low as it is not possible for drivers of fast moving vehicles to see the road ahead from long distances due to darkness or poor visibility. Therefore, if RSU is present on the road, it informs the driver about the condition of road ahead well in advance, which can avoid an accident and save precious lives. There are many similar situations where prior information is very necessary as safety and lives of passengers is at stake.

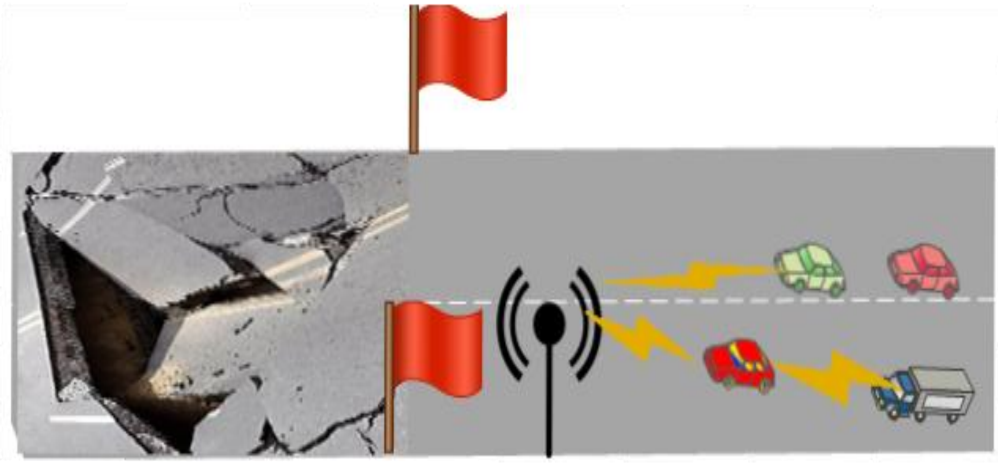

Figure 1.9 Work Going Ahead

- **Post Crash Notification**

  It is a non-safety and safety, transport efficiency, and OBU-OBU type of application. A vehicle which is involved in an accident formulates a message about the incident and its location with help of its inbuilt system and broadcasts it with help of its OBU to all other trailing vehicles to take appropriate measures so that they don't stuck there due to blockage of road caused by accident. Moreover, these trailing vehicles act as relay nodes and help relay this message of accident over to highway patrol vehicle so that Patrol vehicle can reach the site of accident and help the victim in time. Vehicles acting as relay nodes are very important because there are times when it's not possible for driver and passengers of crashed vehicle to inform highway patrol by mobile phone due to poor network or they may be badly injured and not in condition to call somebody for help [9].

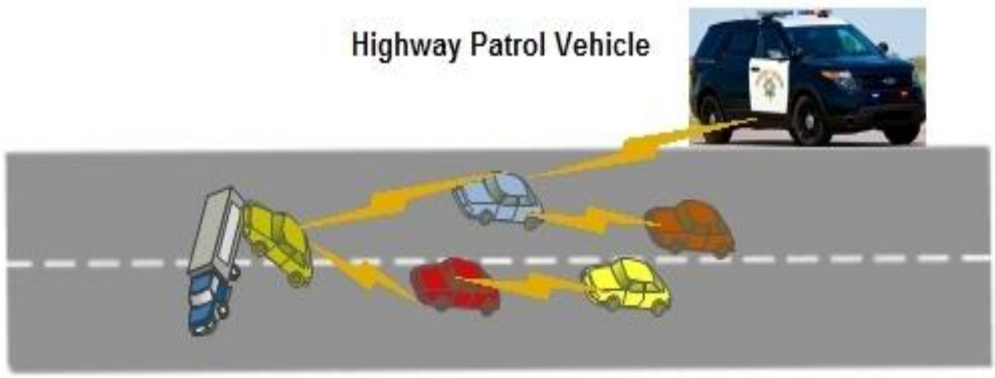

Figure 1.10 Post Crash Notifications

- **Traffic Information**

  It is a non-safety type of application which can either be OBU-RSU type or OBU- OBU type of application. An RSU is installed on the side of the road at intersections, as shown in Figure 1.11. RSU keeps on monitoring the traffic condition on the road continuously and keeps giving real time information of traffic situation to a centralised traffic control room, so that Traffic control room can take appropriate decisions to solve various situations by sending traffic police on the spot to control traffic, moderate confrontations between drivers and to catch those who violate traffic rule. Traffic control room keeps on updating the real-time data on navigation maps or radio devices fitted in vehicles in form of warning with help from network of RSUs in the city, so that drivers can avoid the roads where traffic is already very dense. This real-time traffic information is beneficial as it prevents the aggravation of already existing traffic problem, thus reducing the chances of occurrence of traffic jams. This also helps to control level of air pollution, noise pollution, fuel wastage and most importantly time [9].

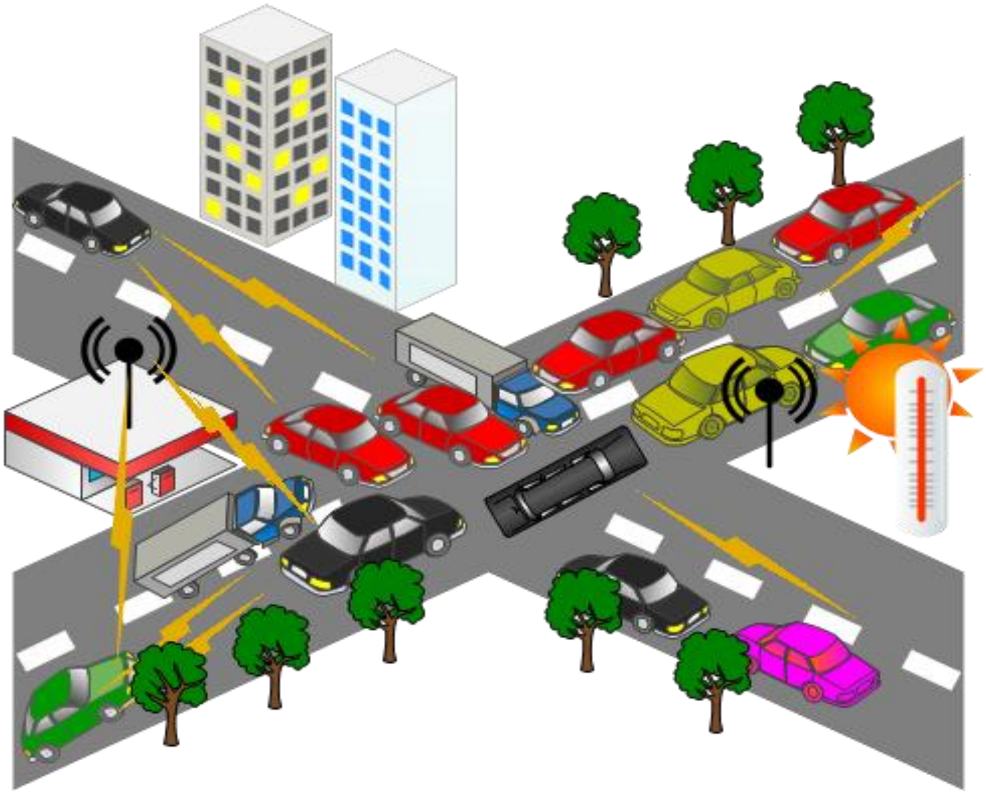

Figure 1.11 Traffic Information

1.5 IEEE 802.11 Standards

IEEE 802.11: It used for the deployment of the wireless networks or in simple terms wireless local area network (WLAN) under the combined guidelines of Physical layer (PHY) and Media Access layer (MAC) layers of OSI model for the communication of systems under different frequency bands. The base and basic version was first released in 1997 and after that the standard has gone under many amendments till now to resolve many issues in previous versions and to make it compatible for different technologies. These versions of 802.11 provide the guideline for wireless communication devices, e.g., WiFi.

The family of 802.11 consists of modulation techniques which use over-the-air type of modulation and are half-duplex in nature. The first member of 802.11 standards family was 802.11-1997 and it was also the first standard in world which was specially developed for the communication in wireless networks, but the most widely accepted standard was 802.11b. The subsequent standards after 802.11b are 802.11a, 802.11g, 802.11n, and 802.11ac. Remaining ones in the 802.11 family, i.e., c-f, h, j all are the standards which are results of modification done due to some need of compatibility and errors in previous specifications [10].

Table 1.1 Comparisons of different standards of 802.11

802.11 protocols	**Release Date**	**Frequency (GHz)**	**Bandwidth (MHz)**	**Modulation Used**	**Indoor Range (meter)**	**Outdoor Range (meter)**
802.11-1997	Jun 1997	2.4	2.2	DSSS,FHSS	20	100
802.11a	Sep 1999	5	20	OFDM	35	120
802.11b	Sep1999	2.4	22	DSSS	35	140
802.11g	Jun 2003	2.4	20	OFDM,DSSS	38	140
802.11n	Oct 2009	2.4-5	20,40	OFDM	70	250
802.11p	July 2010	5.85 – 5.925	10 MHZ	OFDM	NA	200

The 2.4 GHz ISM band is used in the 802.11g and 802.11b standards in The United States of America under the rules and regulations of Federal Communication Commission (FCC) of The United States. Due to this frequency band, the components which are equipped with 802.11b and 802.11g often face interference caused due to cordless phones, microwaves from ovens and Bluetooth device signals. The direct-sequence spectrum (DSSS) and orthogonal frequency-division multiplexing (OFDM) methods for signalling are used for precaution from loss of message due to interference. Similarly 5GHz band is used in 802.11a standard to offer 23 non-overlapping channels which provide some different performance from 802.11b.So depending on requirements of performance level and environment available, different frequency bands are used. Range of frequency spectrum for 802.11 varies from country to country [10].

IEEE802.11 FHSS: Frequency-hopping spread spectrum (FHSS) technique is used in 802.11 with a frequency ISM band of 2.4GHz. The whole band of 2.4 GHz is segregated into 79 sub-bands with 1MHz is assigned to each sub-band. Together with these 79 sub-bands, some guard bands are also present. The hipping sequence is selected with the help of a pseudorandom number which is generated by pseudorandom number generator. 2 level and 4 level frequency shifts keying (FSK) is used as modulation techniques with a 1 or 2 bits/baud and due to this, data rate of 1 or 2 Mbps can be attained [10].

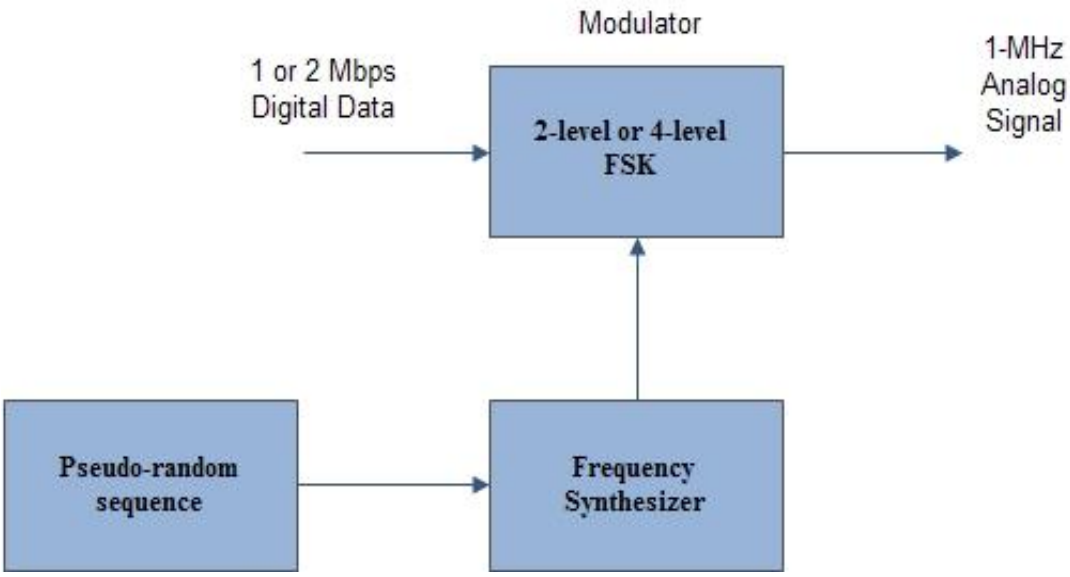

Figure 1.12 IEEE802.11 FHSS

IEEE802.11 DSSS: Direct sequence spread spectrum (DSSS) technique is used in 802.11 with a frequency ISM band of 2.4GHz. Phase shifts keying (FSK) is used as modulation techniques with a 1 or 2 bits/baud (BPSK or QPSK) and due to this data rate of 1 or 2 Mbps can be attained.

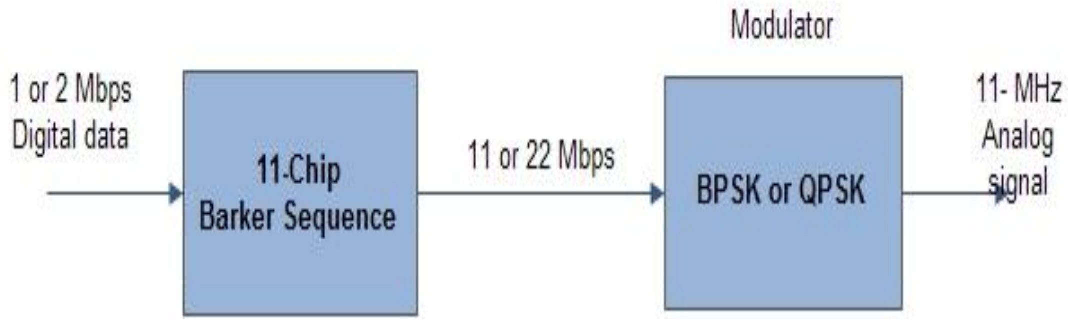

Figure 1.13 IEEE802.11 DSSS

IEEE802.11a OFDM: Orthogonal frequency-division multiplexing technique is used in 802.11a for the generation of signal with a frequency band of 5GHz. At a given time, all the sub-bands are used by one source for which all the sources compete with other sources to get an access at the data link layer. The whole band of 5GHz is segregated into 52 sub-bands out of which 48 are used to send a group of 48 bits at a time and remaining 4 sub-bands are used for information control. The major advantage of this segregation of band is to minimise the interference which arises due to environment and some other factors. Another major advantage of segregation is to increase the security level due to random selection of sub-bands and this makes it very difficult to predict the message and patterns. The popular modulation techniques which are used by OFDM are PSK with data rate of 18Mbps and QAM with data rate of 54Mbps. Selection for technique completely depends on requirement of data rate [10].

IEEE802.11b DSSS: High-rate direct sequence spread spectrum (HR-DSSS) technique is used in 802.11b for the generation of signal with a frequency ISM band of 2.4GHz. The only difference between DSSS and HR-DSSS is the encoding scheme used which is complementary code keying (CCK) in HR-DSSS. A group of 4 or 8 bits are replaced with one CCK symbol in CCK encoding scheme and a data rate of 1,2,5.5 and 11 Mbps are used in HR-DSSS to make it backward compatible with DSSS. DSSS is used for date rate of 1 and 2 Mbps version of 802.11b but for 5.5

Mbps version of 802.11b, BPSK is used and for 11 Mbps version of 802.11b, QPSK is used with 1.375 Mbaud/s transmition rate. The encoding scheme for 5.5 Mbps version is 4 bit CCK and for 11 Mbps version is 8 bit CCK.

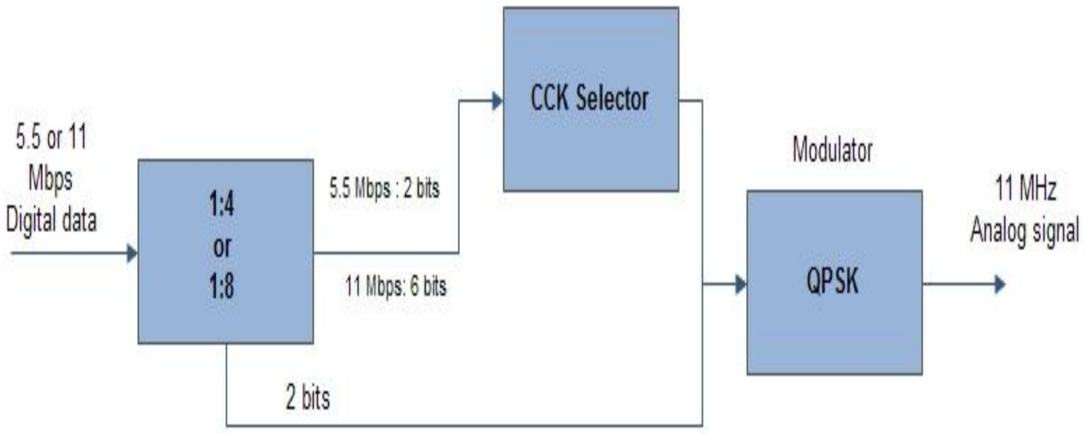

Figure 1.14 IEEE802.11b DSSS

IEEE802.11g: Orthogonal frequency-division multiplexing technique is used in 802.11g for the generation of signal with an ISM frequency band of 2.4 GHz. Forward error corrections is define by the guidelines of IEEE802.11g. The data rate of 22 to 54 Mbps can be achieved in 802.11g. OFDM is used to make it backward compatible with 802.11b.

IEEE802.11n: The IEEE802.11n is the result of modification of the previous standards. The major modification is the addition of multiple-input multiple-output (MIMO). It can support both 2.4GHz and 5GHz frequency ranges with max data rate of 54 to 600Mbit/s. This modification was done in 2009.

IEEE802.11p: Wireless connectivity among the vehicular nodes can be established with the help of currently present protocol 802.11a enables hardware devices which can handle data transmission at the rate of 54Mbps but the traffic pattern of vehicles is a bigger objection than wireless fixed network caused by irregular traffic scenario and speed. There is much depreciation when the conventional 802.11 MAC is used for scenario of vehicular traffic. In order to guaranty rapid exchange of data and in time communication of data related to safety of drivers. Under these conditions channel scanning for signals coming from an access point together with many handshakes needed for connection has too much overhead and complexity like when two vehicles coming from opposite direction has very slight duration of time to talk. So to solve this deficiency of MAC working, DSRC has shifted its focus and efforts from ASTM2313 to IEEE802.11p as and popular by name wireless Access in vehicular Environment (WAVE) [10].

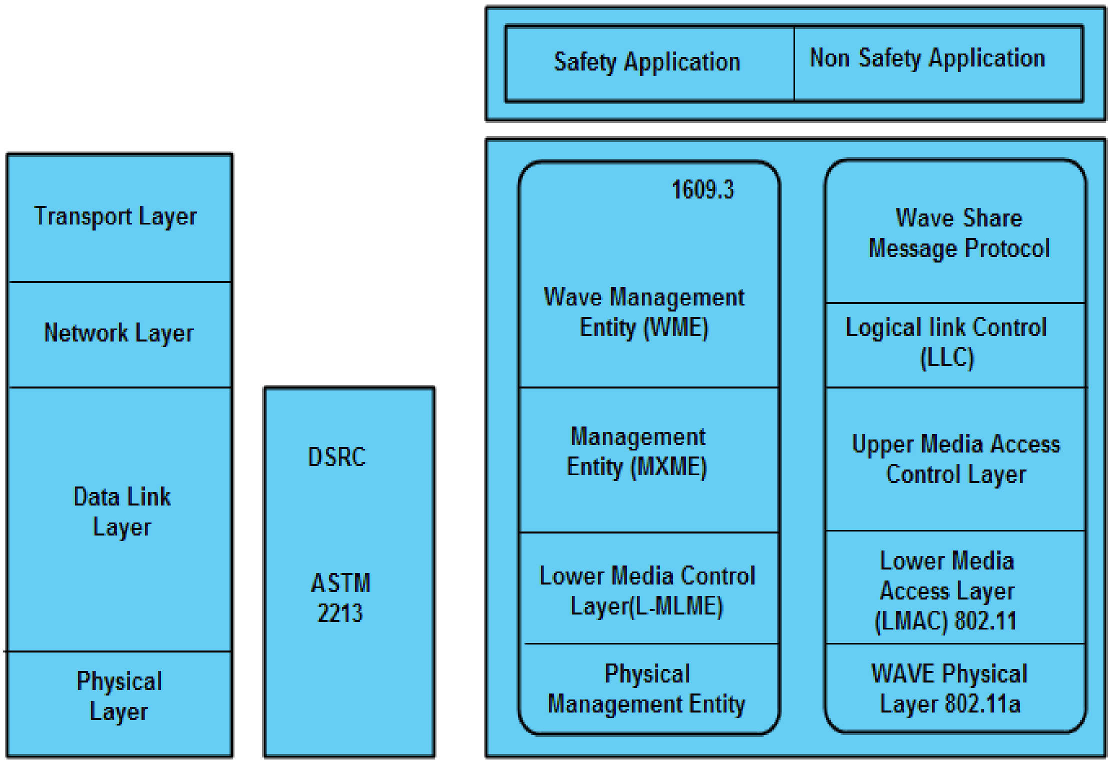

Figure 1.15 WAVE, IEE1609, IEEE802.11p [1]

802.11p is a sub set of 802.11 which only operates on MAC and physical layers. The complexity and functional aspect is handling by upper most layers of IEEE1609 standards. All these standards explain that various applications are working in WAVE environment.

Two types of devices are described by WAVE: One is RSU, i.e., is road side unit which is an immobile station and second one is OBU, i.e., is on Board Unit which is a mobile vehicular mode. Both OBU and RSU can be a sender and receiver of service. But in normal circumstances generally the stationary one is provider and the mobile vehicular node are the users. These RSU can provide access to many remote application to these vehicular nodes application residing on RSU must handle request from multiple OBU's at single time so it should have a support of multithreading. OFDM, i.e., orthogonal frequency division multiplexing is used in WAVE to do distribute the signal into numerous narrow band channels.

1.6 Organisation

Rest of the thesis is organised as follows. Chapter 2 describes literature review about VANETs. Chapter 3 describes problem statement. Chapter 4 describes proposed protocol. Chapter 5 describes simulation settings. Chapter 6 describes result and discussion. Conclusion & future scope is discussed in chapter 7.

Chapter 2

Literature Review

2.1 Broadcasting Techniques

Broadcasting means the method of propagation of message from one node to other nodes in the network. Difficult issues in broadcasting is to reduce number of messages by not re-broadcasting redundant messages, i.e., messages which have same information, and determining appropriate boundary of the transmission. In VANETs, reduction of these messages is very important for efficient transmission [11], [12].

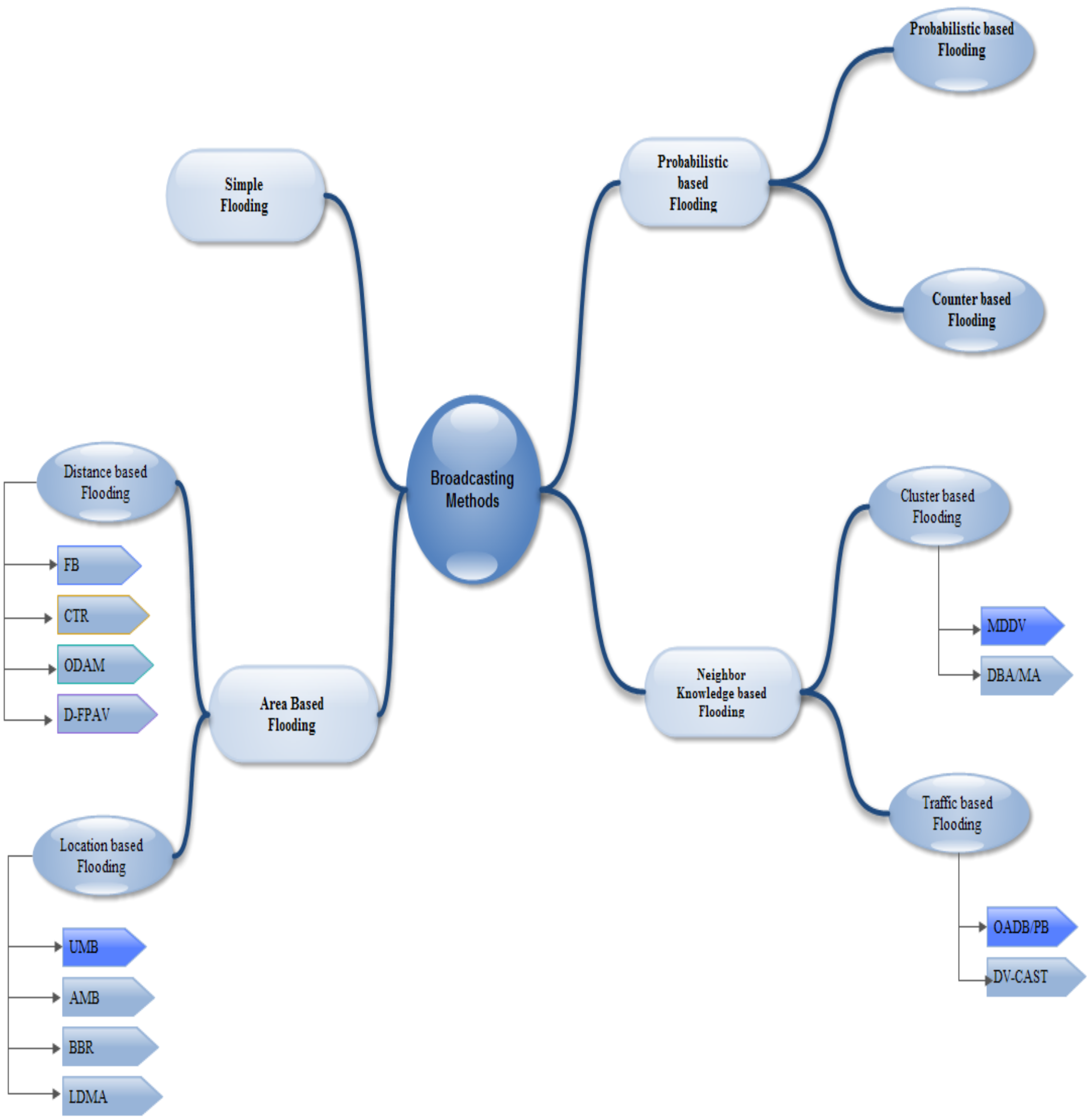

Figure 2.1 Taxonomy of Broadcasting Protocols in VANETs

Following are the different broadcasting techniques:-

2.1.1 Simple Flooding

Broadcasting is the base of all communication in VANETs. In simple terms, a vehicular node transmits a message which is received by all vehicular nodes which are in its wireless range. After receiving the broadcast message, receiver node decides whether to rebroadcast the message or not. This decision of re-broadcasting the message is made on the basis that whether or not same message has been previously broadcasted. If there no previous broadcast record for that message, only then the node rebroadcasts the message. If it finds the record of previous broadcast for that message, then it simply drops the message packet. The whole message rebroadcast procedure terminates only when each node in the network has received the message at least once. The simple flooding is also called blind flooding. Due to the participation of all the nodes, simple flooding leads to a "broadcast storm problem". It's very costly and leads to an inefficient transmission [12-16].

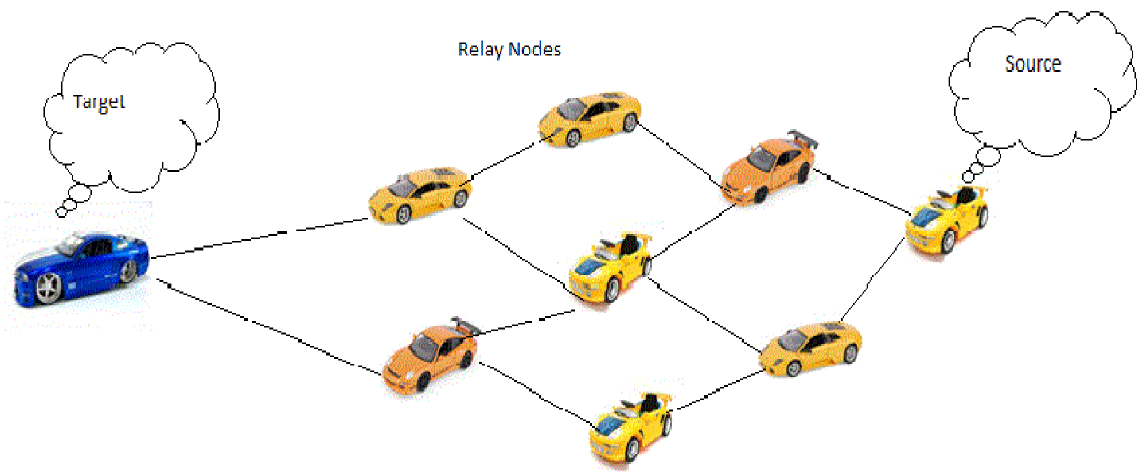

Figure 2.2 Simple Flooding

2.1.2 Probability Based Flooding

In this type of broadcasting technique, the decision for re-broadcasting is made on the basis of probability which is assigned for each and every node in the network. This probability can be chosen randomly or can be computed by complex methods on the basis of parameters like node density, battery power, duplicate packet, etc. Basic scheme under this is p-persistence where p is any predefined probability. That's why this technique is called probabilistic flooding. The selection of the value of p is very challenging task as even a minute mistake can lead to inefficient transmission. The distance between the receiving nodes and the transmitting nodes divided by the average transmission range is helpful in determining the value of p .This broadcasting technique is suitable for dense networks to decrease the impact of broadcast storm problem [13-15].

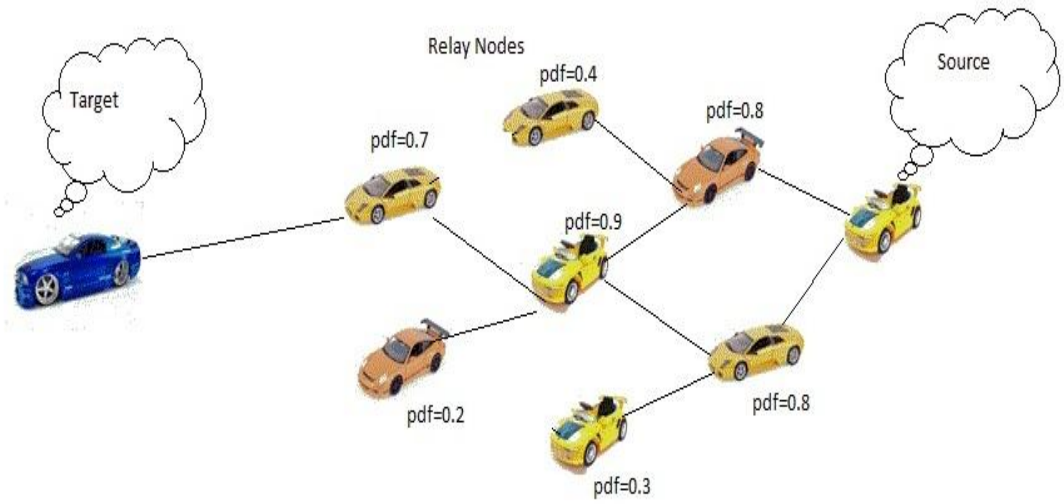

Figure 2.3 Probabilities Based Flooding

2.1.3 Counter Based Flooding

In broadcasting, several nodes rebroadcast the same message due to which many nodes receive the same message no of times. So in this technique, the re-broadcasting decision is made on the bases of number of times same message packet received. Each node calculates the number of times it has received the message packet and then compares it with the predefined threshold value to decide whether to rebroadcast it or simply drop it. The biggest advantage of this technique is that any vehicular node does not need to know anything about the structure of the network, i.e., no knowledge of neighbour is required. But another face of the coin is increase in delay as node has to wait for a predefined period of time so that it can receive same message packet sufficient number of times for making the decision. This method decreases many redundant packets when the network is dense [15], [16]**.**

2.1.4 Location Based Flooding

In Location based flooding, broadcasting is done on the basis of geographic location of the sender and receiving nodes. For this type of broadcasting method, the vehicles must be equipped with GPS for receiving the information. Location based flooding aims to spread the message to particular geographical information. The calculation of coverage area is done on the basis of location of both the sending and receiving nodes.

If the calculate coverage area is less than the threshold value then no rebroadcast is done and receiving node simply drops the message packet. This broadcasting technique gives very good coverage in sparse networks [16].

2.1.4.1 Urban Multi-Hop Broadcast (UMB):- It implements a mixed methodology to broadcast message in the road network of the urban and big metropolitan areas. It elects a distant node in its transmission range to perform the function of the relay node by using the concepts of black-burst method. The moment the node reaches the intersection region, UMB activates the fixed repeaters so that the message can be propagated in every direction except the direction in which the originating source of message is present [17].

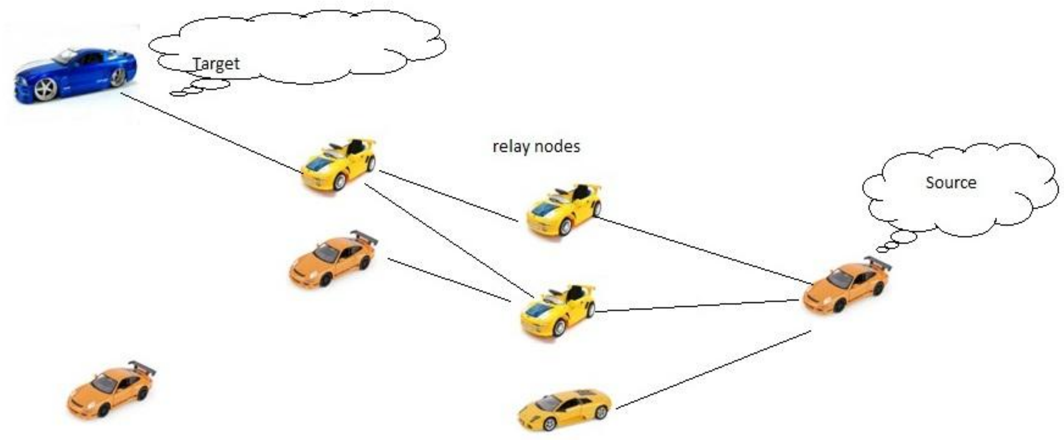

Figure 2.4 Locations Based Flooding

2.1.4.2 Smart Broadcast (SB):- It is very identical to Urban Multi-Hop broadcast but here different schemes for back-off timers are used depending on the distance between the sender and receiver of packet. Only the edge nodes which are elected by the routing algorithm called Border Node Based Routing (BBR) can rebroadcast the message packet as in the case of sparse network, i.e., the network in which the number of vehicular nodes is very less, then the edge nodes are the most suited nodes to provide the better coverage area. Minimum one-hop neighbours, which are common among the sender and receiver nodes, are considered for determination by algorithm [17].

2.1.4.3 Adhoc Multi-Hop Broadcast (AMB):- AMB is an improved version of UMB Protocol which is an infrastructure-less protocol because repeaters are not required in AMB to propagate the message in every direction except the direction in which the originating source of message is present. Here the vehicular nodes which are near to the intersection point are elected as relay nodes to rebroadcast the message. One thing which is common between UMB and AMB is the use of specially built Wireless Simulator modelling at the MAC and Physical Layer of 802.11b [17].

2.1.4.4 Location Division Multiple Accesses (LDMA):- LDMA protocol deals with Media Access Control (MAC) scheme to provide bounded delay in multi-hop vehicular networks. LDMA is one the best scheme as it can eradicate all types of redundant message rebroadcast in nearly all kind of network distribution without hampering the reach of the node.

2.1.5 Distance Based Flooding

In distance based flooding, the rebroadcasting decision is made on the basis of relative distance between the sender and the receiver. Longer the distance between sender and the receiver, greater will be the coverage range. Only the nodes having relative distance more than the threshold value can rebroadcast the message packet and others will drop the packet. GPS is also required in this broadcasting technique. There are two phases in Distance based flooding, one is the estimation phase and the other is broadcast phase. During estimation phase, settings of transmission range are done on the basis of health messages to find all the backward nodes. During broadcast phase, the farthest node in the transmission range of sender node is chosen for the reception of message. This method decreases the number of forwarding hops for the message packet [17-19].

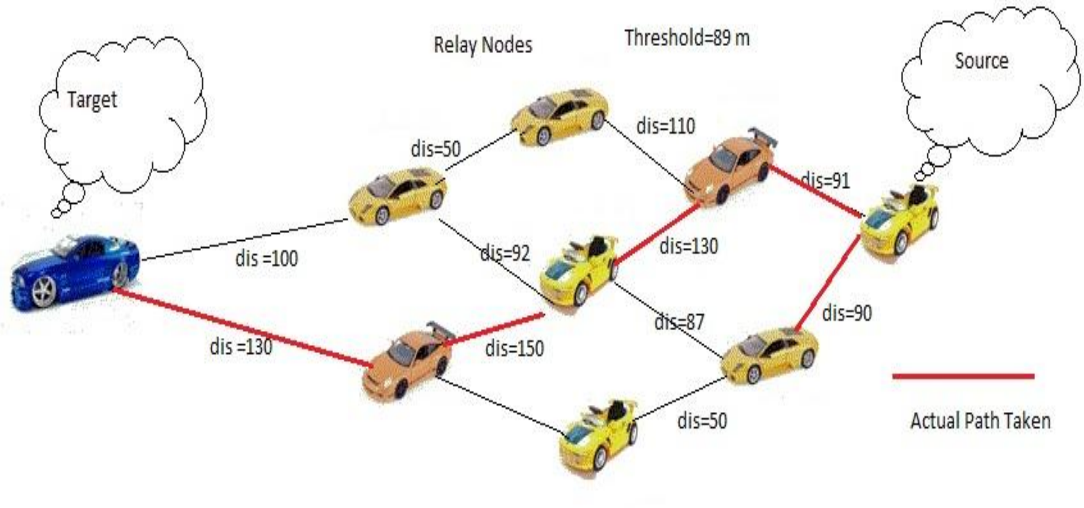

Figure 2.5 Distances Based Flooding

2.1.5.1 Fast Broadcast (FB):- FB protocol uses a distance based approach for selection of the relay node and decreases the number of relay nodes while disseminating the message in the network. The whole working of FB is done in two phases, one is the estimation phase and the other is called broadcasting phase. Transmission range is decided in the estimation phase by using the heartbeat message to detect the backward nodes and the nodes which are at maximum distance from the source node within the transmission range, is selected as the relay node to further propagate the message in the remaining network.

2.1.5.2 Optimized Dissemination of Alarm Message (ODAM):-ODAM broadcasts the message by using the concept of "defer time". Defer time is calculated by using the inverse proportional distance among the sender and receiving node. The main advantage of ODAM is decrease in number of hop count. Alongside the advantage, there is also a disadvantage of this protocol, which is lower delivery ratio, which results due to fall in power of wireless transceiver for larger transmission distances [17].

2.1.5.3 Distributed Fair Transmit Power Assignment for vehicular Adhoc Networks (D-FPAV):- This protocol uses the concept to dynamic adjustment in transmission power of each and every vehicular node by taking in consideration the distances between them and their neighbours in order to provide unbiasedness in broadcast of heartbeat message. Due to this, channel capacity between the nodes can be shared fairly without any biasness as power control is perfectly explored. The main advantage of this protocol is better reachability than protocols which are based on counter based approach; however number of rebroadcast message is more in D-FPAV.

2.1.6 Cluster Based Flooding

In Cluster Based Flooding, the clustering, i.e., grouping of nodes, where each group is called a cluster and each cluster has a representative node which is called the cluster head and all nodes except the representative node in the cluster are called ordinary nodes. There may be a chance that some of the nodes may belong to more than one cluster. Node which belongs to more than one cluster is called as the boundary or the gateway nodes as these nodes act as gates to enter one cluster from another cluster. The message propagation can be only done by the cluster head and the gateway nodes. In cluster based flooding, cluster head receives the broadcast message through the gateway node common between the sender and receiver cluster head. After reception of the message, it's the responsibility of this cluster head to deliver this message to each node in its cluster if the desired target is in the cluster, otherwise rebroadcast it to other cluster heads with help of gateway nodes. Clustering can highly optimize the flooding mechanism. The formation of cluster may be active or passive. In Active Clustering, the cluster is chosen by the cooperation of nodes by periodically exchanging the control information. Election of cluster head is independent of data traffic. Passive Clustering depends on data traffic and control information is send by appending it with the data traffic. This reduces the message overhead [13], [19-20].

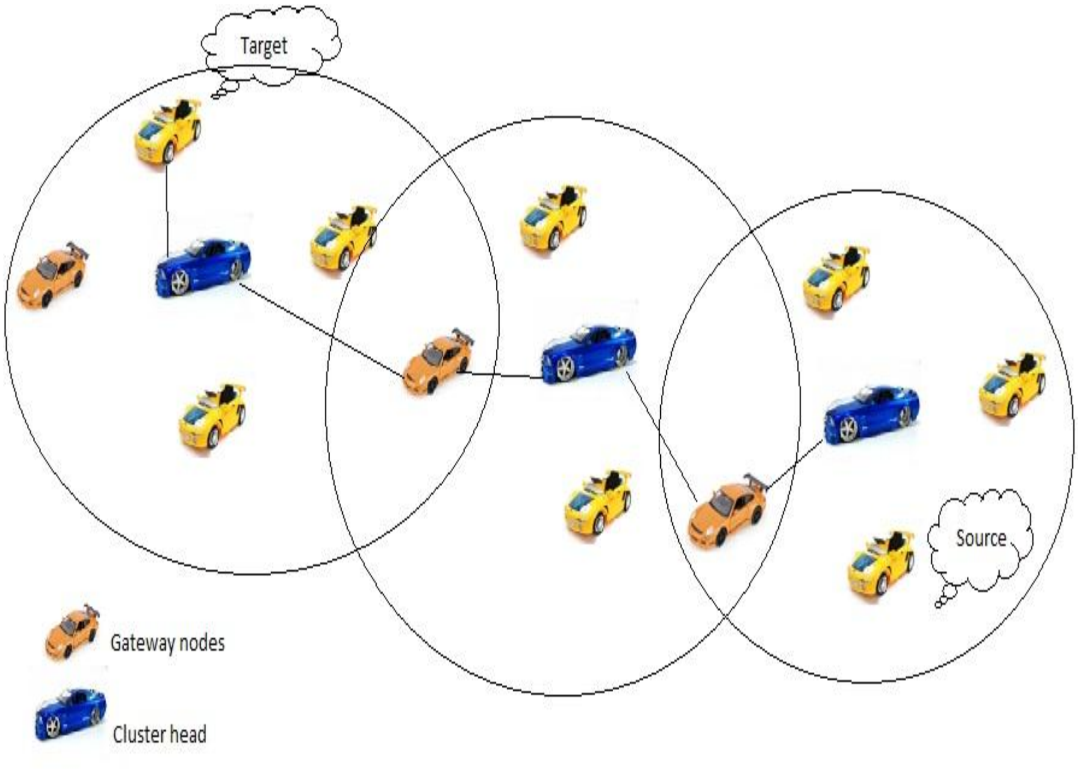

Figure 2.6 Clusters Based Flooding

2.1.6.1 Mobility-Centric Data Dissemination Algorithm for Vehicular Networks (MDDV):- This protocol divides the whole vehicular network space into groups based upon trajectory and geographic travel routes. It runs a localized algorithm for routing of message packet in the forward direction to the node which is appointed as head of the cluster. From this cluster head, message is further broadcasted to proper relay node so that message can reach its desired destination. MDDV proves to be reliable in traffic network which are complex including the low density areas and higher mobility of vehicles. The performance of MDDV completely depends upon the vehicle to vehicle penetration rate and density of traffic on the roads which are different for different times of the day [18].

2.1.6.2 Dynamic Backbone-Assisted MAC (DBA-MAC):- Cross layer intersection in MAC sub-layer is used as a broadcast mechanism for the propagation of message. In the cluster of interlinked vehicles, nodes which are having high priority are selected as the backbone nodes and only these backbone nodes are allowed to broadcast the message to other members. The algorithm which is used to select the backbone node inside a cluster repeatedly executes after fixed time.

2.1.7 Traffic Based Flooding

Traffic based flooding was developed as a part of e-Road project under the name of traffic View for the development of efficient, reliable and scalable framework for inter-vehicular communication. In traffic view, each packet encapsulates the data message and additional information is required for the efficient dissemination of message in the entire network. The additional information consists of unique identification number of vehicle, speed, position and time for which the broadcasting is done. The bandwidth conservation and control on flow are the main features of this broadcasting scheme which is done by gathering messages from different data packets into a single data packet depending on the relative distances between the vehicles and timestamp of the messages. Two protocols under traffic based flooding are as follows [21].

2.1.7.1 Distributed Vehicular Broadcast (DV-CAST):- In DV-CAST, routing decision is made on the basis of local one-hope neighbour topology. The local traffic density is used to adjust the back-off timer and heartbeat messages are periodically used to calculate the backward and forward direction connectivity. DV-CAST works effectively in case of sparse networks or network which is totally disconnected as DV-CAST can hold and wait temporarily until there is some heart beat from other vehicles.

2.1.7.2 Optimized Adaptive Probabilistic Broadcast and Deterministic Broadcast (OAPB/DB):-

Emergency messages are rebroadcasted using an adaptive approach in the incident zone and local traffic density with heartbeat message periodically coming from the vehicles that are a distance of two hops. Generally mobility scheme used in this protocol is orderly traffic with two lane roads.

Table 2.1 Comparative Analysis of above mentioned Broadcasting Techniques on basis of different parameters

Techniques	Redundancy	End-to-End delay	Reliability	Message overhead	Robustness	Scalability	Contention	Collision
Simple Flooding	Very High	Low	Very low	Very High	Very Low	Very High	Very High	Very High
Probability Based Flooding	Low	Low	Low	High	Very Low	Very High	Low	high
Counter Based Flooding	Low	High	Low	Low	Very Low	High	Low	Low
Distance Based Flooding	High	Low	High	Low	Very Low	Very High	Low	Very Low
Location Based Flooding	High	Very Low	High	High	Very Low	Very High	Low	Low
Cluster Based Flooding	Very Low	Low	Very High	Very Low	High	Low	Low	Very Low
Traffic Based Flooding	Very Low	Low	High	Very Low	High	High	Very Low	Very Low

Chapter 3
Problem Statement

3.1 Problem Statement

VANET is a form of MANET which forms communication between vehicles and nearby RSU. VANETs are expected to be able to significantly reduce number of accidents on roads. The communication between the vehicles in almost every application of VANETs is broadcast based and every node which receives this information rebroadcasts it so that this message reaches the desired target. But due to this, there are a lot of redundant messages in the network. Due to this increase in number of redundant messages, the collision rate increases with very high rate. The result of increase in collision rate results in a packet loss which causes further increase in rebroadcast of packets which further increases the collision rate. This leads to inefficient use of bandwidth and makes this communication inefficient. So after reading many protocols and techniques like simple flooding, probability based broadcasting, Distance based broadcasting and cluster based broadcasting to solve this broadcast storm problem, we found out that none of them are efficient enough to solve this broadcast storm problem as all are based on CRISP logic, which is a rigid mathematical formulation with fix boundaries. One more problem which can't be handled by all the above mentioned broadcasting schemes is uncertainty factor which can be there due to sudden change in speed of vehicle and traffic density. So to solve these issues, we have used the concept of fuzzy logic in which we have used a combination of parameters as input for selection of the most appropriate and minimum number of relay nodes. In order to solve these issues, we have developed IFUZZY, an intelligent fuzzy controller-based broadcasting scheme for VANETs. Simulation results confirm the effectiveness of the proposed scheme.

Chapter 4
Proposed Protocol: IFUZZY Controller

4.1 Introduction

To reduce the redundancy caused by high number of rebroadcast messages, IFUZZY Controller (Intelligent Fuzzy Controller) selects a small subset of relay nodes from the pool of nodes available in the transmission range of the sender vehicle which has message to be broadcasted to others in the network. Before transmitting that broadcast message, sender adds the address of relays which are selected by the IFUZZY Controller in header of the message packet. This way, node receiving the message can identify whether it is selected as a relay node or not by searching its address in the list of relays present in message packet. Each vehicle periodically broadcasts a hello message which also contains location, current speed of vehicle etc. to the nodes present in its transmission range, so that every node has updated information about nodes in its transmission range. This location information can be easily found with help of GPS system in vehicles [22], [23].

For the selection of relay nodes, IFUZZY Controller takes mobility, traffic density and inter-vehicular distance as input parameters. All these parameters are contradictory to each other because if we select the farthest node as relay node in order to decrease no of relay nodes, it may result in packet loss as that relay node goes out of the transmission range of the sender due to its high mobility [23], [24]. All the models to solve this relay selection problem are based on CRISP logic, i.e., mathematical formulation which can't handle uncertainty factor due to sudden change in speed of vehicle and traffic density. To resolve these issues, we have proposed IFUZZY Controller based on concept of fuzzy logic for selection of minimum and efficient relay nodes [25], [27].

4.2 Periodical Nodes Evaluation

After receiving the hello message from the nodes in the transmission range, a node evaluates the fitness of each node and assigns a fitness level value to each node in its transmission range with help of IFUZZY Controller. If sender node doesn't receive a updated "hello message" from the nodes in its neighbour list for predefined time T, then it deletes the entry for that node from its neighbour list. The value of T should neither be too high nor too low as it affects the performance of IFUZZY Controller. Following parameters are evaluated in the proposal:

Distance: After receiving the hello message from the nodes in the transmission range, a node evaluates the Distance Metric (DM) for each node as in Eq. (1). In Eq. (1), d(X) is inter-vehicular distance between the sender node and node in transmission range (RG) in meters.

$$DM(X) = \begin{pmatrix} \frac{d(x)}{R}, d(X) \leq R \\ 1, d(X) > R \end{pmatrix} \qquad (1)$$

Traffic Density: After receiving the hello message from the N number of nodes in the transmission range (RG), a node evaluates the Density Metric (DSM) for each node as in Eq. (2).

$$DSM = \frac{N}{RG} \qquad (2)$$

Mobility: After receiving the hello message from the nodes in the transmission range, a node evaluates the mobility metric (MM) for each node by using mobility metric calculation algorithm [28], [29].

Algorithm 4.1

Input: -

neighbour_speed[ ] : array containing speed of nodes present in transmission range of sender node.

vehicle_speed : speed of sender vehicle.

Output: -

MM [] : array containing mobility metric of each vehicle.

Assumption:-

Max speed of each vehicle is 200km\hr.

Min speed of each vehicle is 40 Km\hr.

Begin

For (counter = 0; counter < size of neighbour_speed;counter++) do

MM [counter] = (Neighbour_speed [counter] – vehicle_speed) /200

End

4.3 Relay node Selection

Procedure: For the selection of relay nodes, IFUZZY Controller takes mobility, traffic density and inter vehicular distance as input parameters and calculates the fitness level of each node in the transmission range of sender whenever sender has to send data packet. For calculation of fitness level following steps is followed [24].

- Step1: Fuzzification The process of transforming crisp values into fuzzy values corresponding to membership function for fuzzy set.
- Step2: Mapping of IF/THEN Rules mapping of fuzzy values to predefined IF/THEN rules to get the fitness rank of each node in transmission range.
- Step3: Defuzzification The process of the creation of a crisp value as a surrogate for an existing fuzzy value.

Fuzzification: The process of transforming CRISP value, i.e., numerical values into grades of membership corresponding to fuzzy sets expressing linguistic terms is called Fuzzification.

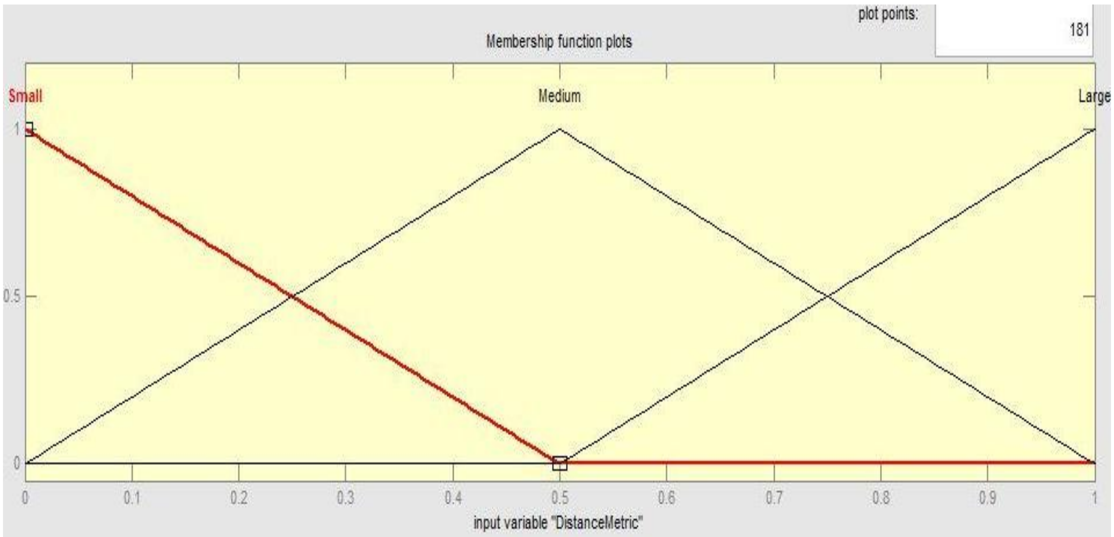

Figure 4.1 Distance Metric Fuzzification

Membership function for the distance metric is shown in Figure 4.1.The sender node which has emergency message to be broadcasted, inputs the distance metric into membership function to evaluate the membership degree of distance metric, which belongs {small, medium, large}.

Membership function for the mobility metric is shown in Figure 4.2.The sender node which has emergency message to be broadcasted inputs the mobility metric into membership function to evaluate the membership degree of mobility metric, which belongs to {slow, medium, fast}.

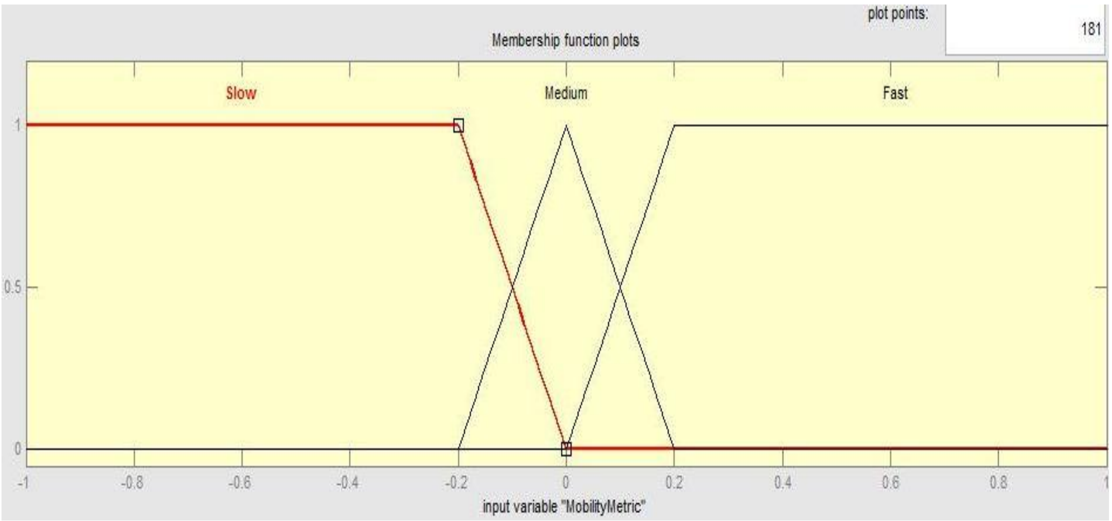

Figure 4.2 Mobility Metric Fuzzification

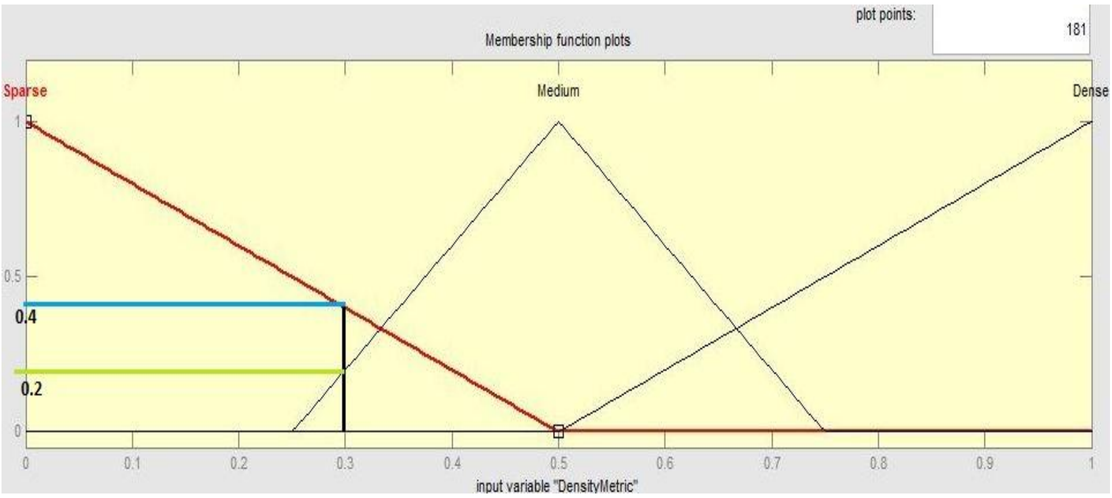

Figure 4.3 Density Metric Fuzzification

Membership function for the density metric is shown in Figure 4.3.The sender node which has emergency message to be broadcasted inputs the density metric into membership function to evaluate the membership degree of density metric, which belongs to {sparse, medium, Dense}. As in Figure 4.3, CRISP value of density metric is 0.3 which is shown by a vertical black line, corresponding to which membership value for sparse density is 0.4 which is shown by blue horizontal line and membership value for medium density is 0.2 which is shown by horizontal green line. Therefore fuzzyfied values for density metric are {sparse: 0.4, medium: 0.2, dense: 0}.

IF/THEN Rules: After fuzzification of Distance metric, density metric and mobility metric, sender node uses IF/THEN rules to evaluate the fitness rank of nodes present in transmission range of sender in terms of linguistic variable, i.e.,{Bad, Not Acceptable ,Acceptable ,Good , Perfect}.

Table 3.1 IF/THEN Rules Repository

Rules	**Distance**	**Mobility**	**Density**	**Fitness Rank**
Rule1	Large	Slow	Dense	Perfect
Rule2	Large	Slow	Medium	Good
Rule3	Large	Medium	Sparse	Not Acceptable
Rule4	Large	Medium	Dense	Acceptable
Rule5	Large	Fast	Medium	Not Acceptable
Rule6	Large	Fast	Sparse	Bad
Rule7	Large	Fast	Dense	Not Acceptable
Rule8	Medium	Slow	Medium	Perfect
Rule9	Medium	Slow	Sparse	Acceptable
Rule10	Medium	Medium	Dense	Acceptable
Rule11	Medium	Medium	Medium	Acceptable
Rule12	Medium	Fast	Sparse	Not Acceptable
Rule13	Medium	Fast	Dense	Not Acceptable
Rule14	Medium	Fast	Medium	Not Acceptable
Rule15	Small	Slow	Sparse	Acceptable
Rule16	Small	Slow	Dense	Bad
Rule17	Small	Medium	Medium	Not Acceptable
Rule18	Small	Medium	Sparse	Acceptable
Rule19	Small	Fast	Dense	Bad
Rule20	Small	Fast	Medium	Bad
Rule21	Small	Fast	Sparse	Bad

IF Distance is small, Mobility is fast and Density is Dense then fitness rank is Bad. As there are many rules applying at the same time, final result is based on the joint effect of all rules, which can be determined by using Min-Max method, i.e., minimum value of IF part of each rule is used as final degree and then maximum value of THEN part is used, during combination.

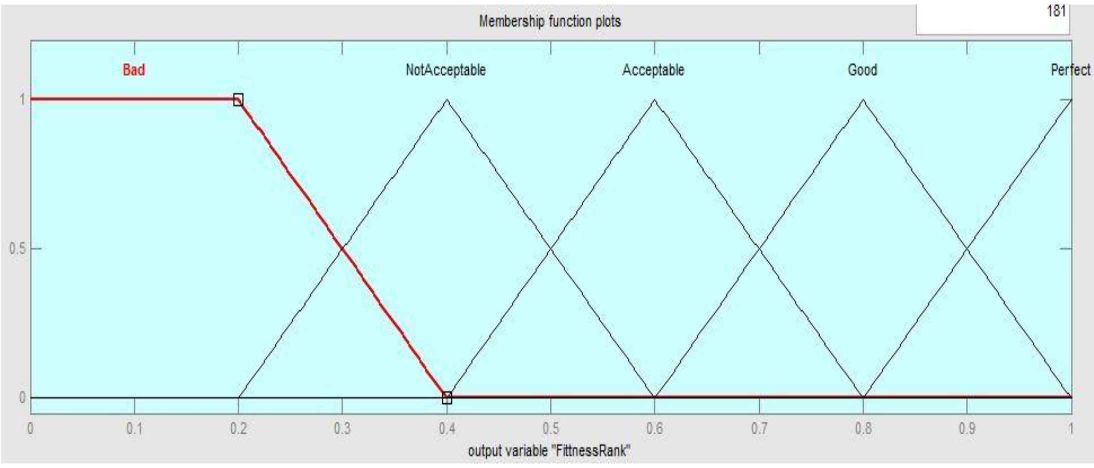

Figure 4.4 Fitness Rank Fuzzification

Defuzzification: The conversion of fuzzy set to Single CRISP value, i.e., numerical value is called defuzzification. Defuzzification produces result on the basis of output membership function as shown in Figure 4.4.

There are many methods available for defuzzification. For centroid method, centre of sum and mean of maxima etc. here we are using centroid method for defuzzification. $\mu(x_i)$ Is membership function, X^* is centroid [24].

$$X^* = \frac{\sum_{i=1}^{n} (x_i(\mu(x_i)))}{\sum_{i=1}^{n} \mu(x_i)} \qquad (3)$$

.

In Figure 4.5, each column shows the set of membership function for particular input. Each membership function is associated with particular rule and particular input. It maps input value corresponding to Distance metric, Mobility metric and Density metric to rule input values. Here each row corresponds to each rule, e.g., 1st row corresponds to 1st rule, 2nd row corresponds to 2nd rule etc. Fourth column, i.e., output column, shows that how each rule is applied to arrive at output corresponding that rule. The blue area in output at extreme bottom of the fourth column represents the final output which is the combined effect of all above outputs in fourth column and small red vertical line shows the defuzzified value of fitness rank of that blue area.

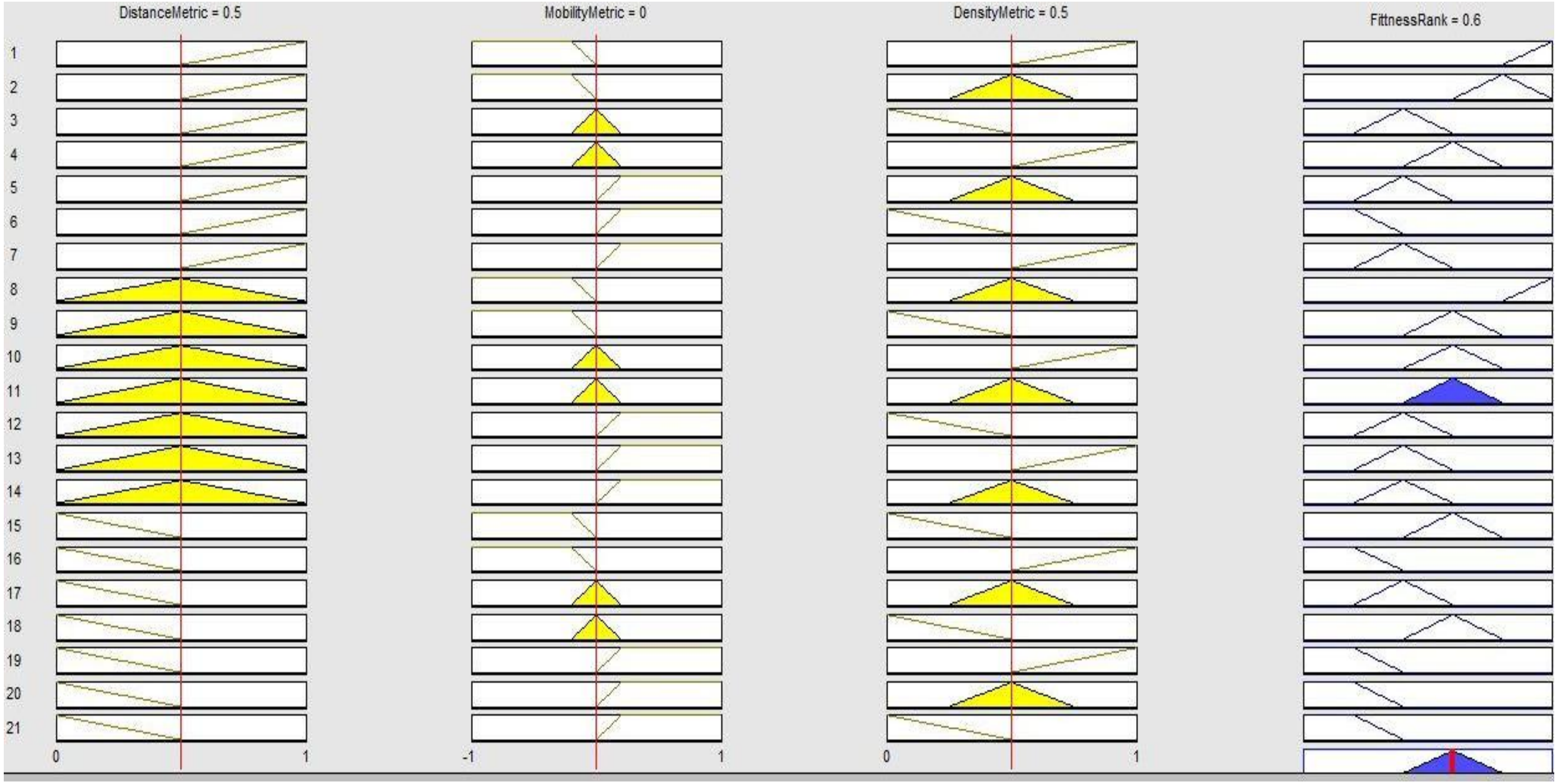

Figure 4.5 Membership Degree Corresponding to Each Rule and Final Defuzzified value

Chapter 5
Simulation Settings

5.1 Simulation of Urban MObility (SUMO)

In 2001, development of traffic simulation package called SUMO was started by the German Aerospace Centre (DLR) which preferred to develop this simulation software package as open source. Since then, the initial package of very limited functionalities and features is continuously evolving and currently it has grown into a full-fledged software suite of modelling utilities of traffic consisting of network of roads able to understand different types of source formats and generation of demand. It is a high performance simulation which can be used at single junction level to simulate whole city or even for whole state including remotely controlled (TraCI) interfaces which can be adapted for online simulations and utilities related to routing which are having its input from different sources like archives of traffic data and destination matrices of origin [30].

Simulator: System that simulates specific conditions or the characteristics of a real process or machine for the purposes of research or operator training.

Traffic Management: It refers to efficient and well-planned organizing and proper servicing of traffic. Traffic management increases the road traffic efficiency to a great extent. The simple and basic need for the process of efficient traffic management is the collection of suitable and real-time traffic information. The task of information collection is divided into many sub tasks such as traffic monitoring, traffic influence methods development, methods to simulate traffic, methods of real time traffic forecast and development of methods to improve transportation quality.

Traffic Simulations: The facility to test and evaluate changes in infrastructure or change in the policy to govern road traffic is called traffic simulation. For example, algorithms to control the traffic lights, effectiveness of constructing new road or bridges and effect of different environmental zones can be tested and analysis of results is done for optimisation of traffic algorithms. Before building a system in real world, it should be tested on the simulation tools for traffic simulation. It helps us predict the whether or not the system will meet our desired requirements in real world. This prevents the wastage of effort and money which may occur if the system proves to be faulty.

“**S**imulation of **U**rban **MO**bility”, (SUMO) traffic simulation tool is an open source and freely available software suite since 2001 with very limited functionalities in the initial suite [26]. Currently available full-fledged suite has almost 50 times more functionalities and support for other modelling tools than the initial suite of SUMO. It permits the modelling of multi-mode traffic simulation with support for all types of road vehicles, pedestrians on road and public transport. It allows one to simulate how a vehicle moves on the road map and variety of traffic scenario. Each and every vehicle is separately modelled, i.e., each vehicle has its own path, own starting and ending points and this shows the microscopic nature of SUMO simulations. SUMO supports a wide variety of tools to perform tremendous tasks like visualisation, import of network files, finding of routes, finding of shortest route to destination, routing tools for message transfer and algorithms for different calculations. SUMO also supports many API to make it interoperable with different simulation tools and simulation which is remotely controlled [31].

To create a network of roads using SUMO, the major and basic requirement is street network which consists of edges, i.e., any street which is connecting two junction nodes. Traffic related section of the roads is described by the network files of SUMO. Network files main component are junctions or intersections, roads and traffic lights [32].

Network Format

- At a macroscopic level, the network in SUMO is a kind of directed graph in which junctions or intersections are represented by “NODES” and roads or street are represented by “Edges” [31].
- At a microscopic level, each and every road or street or edge is a collection of lanes with proper description that which lane of which street is connected with which lane of other street at junction points. Shape, position and speed limit of vehicles for each lane is explicitly defined.

Vehicles Format

- At a macroscopic level, vehicles in SUMO are normal vehicle of different shape and sizes.
- At a microscopic level, description like acceleration, max speed, unique id, sigma driving and colour is explicitly defined.

Files used in network of SUMO to create a simulation of a road map [33]:-

- Node file having extension as .nod.xml.
- Edge file having extension as .edg.xml.
- Route file having extension as .rou.xml.
- Network file having extension as .net.xml.
- Configuration file having extension as .sumo.cfg.xml.

Nodes

Each and every node in node file has specific location which is explicitly defined in the form of x and y coordinates which are showing the distance point of location from the point of origin in meters. A unique id is also assigned to each node which is used to refer the node by connection links etc.

```
<? xml version="1.0" encoding="UTF-8"?>
<nodes >
   <node id="1" x="-1000.0" y="1000.0" />
   <node id="2" x="100.0" y="1000.0" />
   <node id="3" x="100.0" y="-1000.0" />
   <node id="4" x="600.0" y="1000.0" />
</nodes>
```

The file is saved with name shubham.nod.xml where .nod.xml is the extension of Node file.

Edges

Edges are the connection between the nodes which are connected by providing source node id and destination node id. A unique id is assigned to each and every edge which is used for reference by vehicles etc. Edges in SUMO are directed edges therefore vehicles which are using this edge for travelling starts from the node given in `from` part and ends at a node given in `to` part of edge file.

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

<edges>

<edge id="D1" from="1" to="2" type="a"/>
<edge id="D2" from="2" to="3" type="b"/>
<edge id="D3" from="2" to="4" type="b"/>

</edges>
```

The file is saved with name shubham.edg.xml where .edg.xml is the extension of Edge file.

Now we have both files, i.e., Node file and Edge file which are used to generate the network file with extension .net.xml with help of NETCONVERT tool.

```
netconvert --node-files=hello.nod.xml --edge-files=hello.edg.xml --outputfile=hello.net.xml
```

This command generates a network file shubham.net.xml.

Routes

Generation of only network file is not enough, we still require vehicles. In SUMO each vehicle has its own description describing the properties like length, deceleration, acceleration and maximum speed of the vehicle which should be explicitly provided in route file. In addition to above properties, sigma parameter is also provided because it is used to induce random behaviour. For deterministic car, its value is set to 0.

```
<?xml version="1.0" encoding="UTF-8"?>
<routes>
  <vType accel="2.0" decel="5.0" id="CarA" length="5.5"
minGap="3.5" maxSpeed="50.0" sigma="0.5" />
  <vType accel="2.0" decel="6.0" id="CarB" length="6.5"
minGap="3.5" maxSpeed="60.0" sigma="0.5" />
 <route id="route01" edges="D1 D2"/>
 <route id="route02" edges="D1 D3"/>
  <vehicle depart="54000" id="veh0" route="route02"
type="CarA" color="1,0,0" />
  <vehicle depart="53000" id="veh1" route="route02"
type="CarA" />
  <vehicle depart="53000" id="veh2" route="route02"
type="CarB" />
  </routes>
```

The file is saved with name shubham.rou.xml where .rou.xml is the extension of Route file.

Configuration

After the generation of Network file and Route file, configuration file is created by using them as input.

```
<?xml version="1.0" encoding="UTF-8"?>
<input>
        <net-file value="shubham.net.xml"/>
        <route-files value="shubham.rou.xml"/>
 </input>
<time>
        <begin value="53000"/>
        <end value="53900"/>
```

```
</time>
</configuration>
```

Save this file by shubham.sumocfg and do the simulation by command line.

```
Sumo -c shubham.sumocfg
```

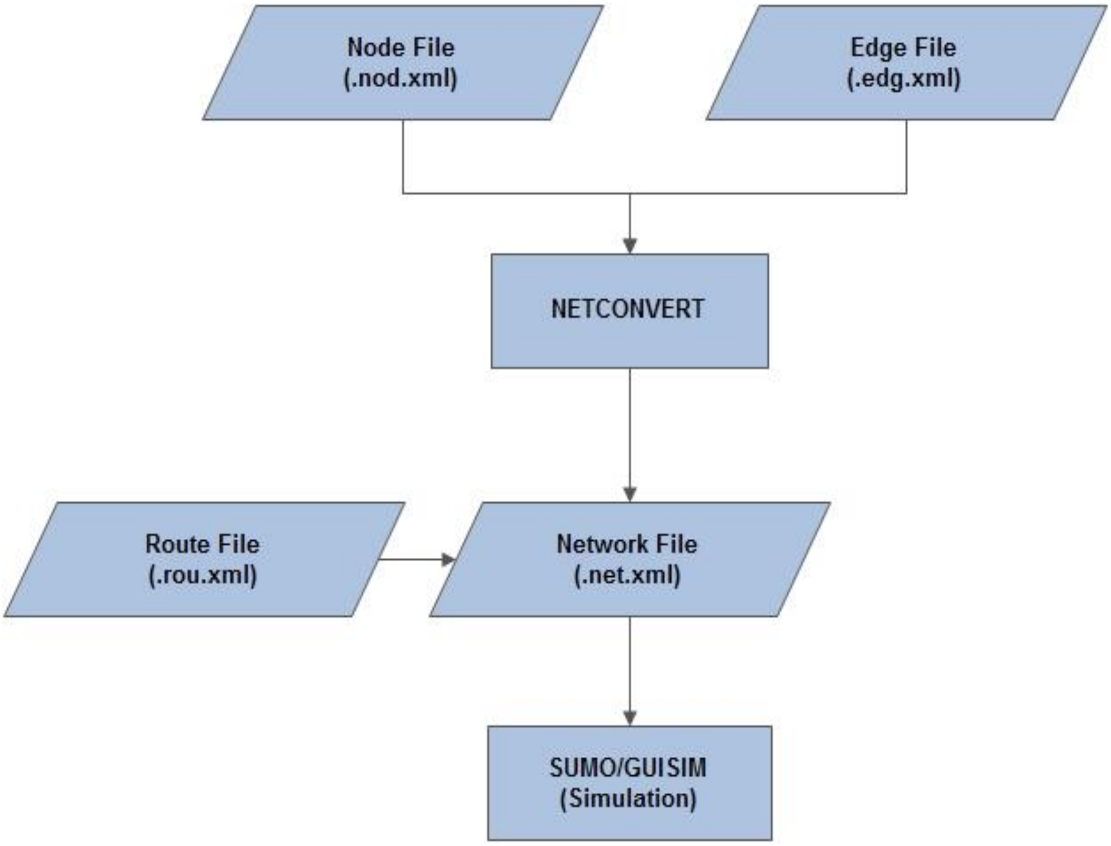

Figure 5.1 Flow Chart for Creation of a Network in SUMO

5.2 Features of SUMO

- Applications required to perform simulation of road network is included.
- Support for discrete and continuous movement of vehicles.
- Support for all types of vehicles ranging from a motorbike to truck or bus.
- Support for lane changing in scenarios of multi lanes.
- Different models for traffic lights algorithms.
- Interface for openGL graphics.
- Support for different level of speed for each vehicle.
- Run time interoperability with different applications.
- Support for output based either on network, edge and vehicle.

- Pedestrian trips are also supported.
- Import network from different sources like Open-Drive, XML-Descriptions and OSM.
- Determine the missing values with the help of heuristics.
- Support for microscopic level of routing, i.e., each vehicle has its own path.
- Support for dynamic user assignments.
- Packages for Linux and window exits.
- Standard portable libraries of C++ are used.
- Interoperability achieved with help of XML.

5.3 Components

- SUMO: Simulation is of microscopic type without any visualization effect; it is completely based on command line simulation.
- SUMO-GUI: Simulation is microscopic with support for graphical user interface.
- NETCONVERT : The network of road is read in different formats which are then convert by it into the format which is understand by SUMO, the import and generation of network also done by NETCONVERT.
- NETGENERATE: For the simulation of SUMO abstract road network is generated.
- DAUROUTER: Demand description of different types is imported, fastest and hassle free route from the network of roads is calculated. Performs the DUA.
- JTRROUTER: Junction is the place where there are many routes for same source and destinations, so to calculate best route junction turning percentages are used.
- DFROUTER: Measurements of induction loops and detector data are used to calculate routes.
- MAROUTER: Capacity functions are used as basis for Macroscopic assignment of users
- ODTRIPS: O/D- matrices are decomposed into trips of single vehicle.
- POLYCONVERT: Polygon and point of interest are imported in different types of formats which are converted by POLYCONVERT into the format which is understand and visualised by the SUMO-GUI.

5.4 Simulation Set Up

The network of road is created using 14 junction nodes and 26 edges. Around 200 vehicles are simulated, having different parameters describing speed, acceleration and colour of vehicles with around 20 to 30 vehicles of each type. Transmission range of OBU fitted on each vehicle is 100 meters operating at a frequency band of 2.4GHz. The time for which vehicles remain in network is 20 seconds.

Table 4.1 Simulation Set Up

MATLAB	R2001b(7.13.0.564) 64 bit
Window	64 bit
Sumo Version	0.22.0
Interface	Wireless
MAC Protocol	802.11p
Network Protocol	IP
Transport Protocol	UDP
Simulation Area	1000*1000
Simulation Time	20seconds
Number of Edges	26
Number of Nodes junctions	14
Number of Vehicles	200
Transmission Range	100 meter
Speed of Vehicle	100meter/sec
Radio Frequency	2.4GHz

Chapter 6

Results & Discussion

For the creation of road network in SUMO, firstly Node file (Thesis.nod.xml) and then, the Edge file (Thesis.edg.xml) is created. After the creation of Node file and Edge file, Network file is created by using NETCONVERT and .nod.xml and .edg.xml file as input parameters.

Command of NETCONVERT

netconvert --node-files=Thesis.nod.xml --edge files=Thesis.edg.xml --output-file=Thesis.net.xml

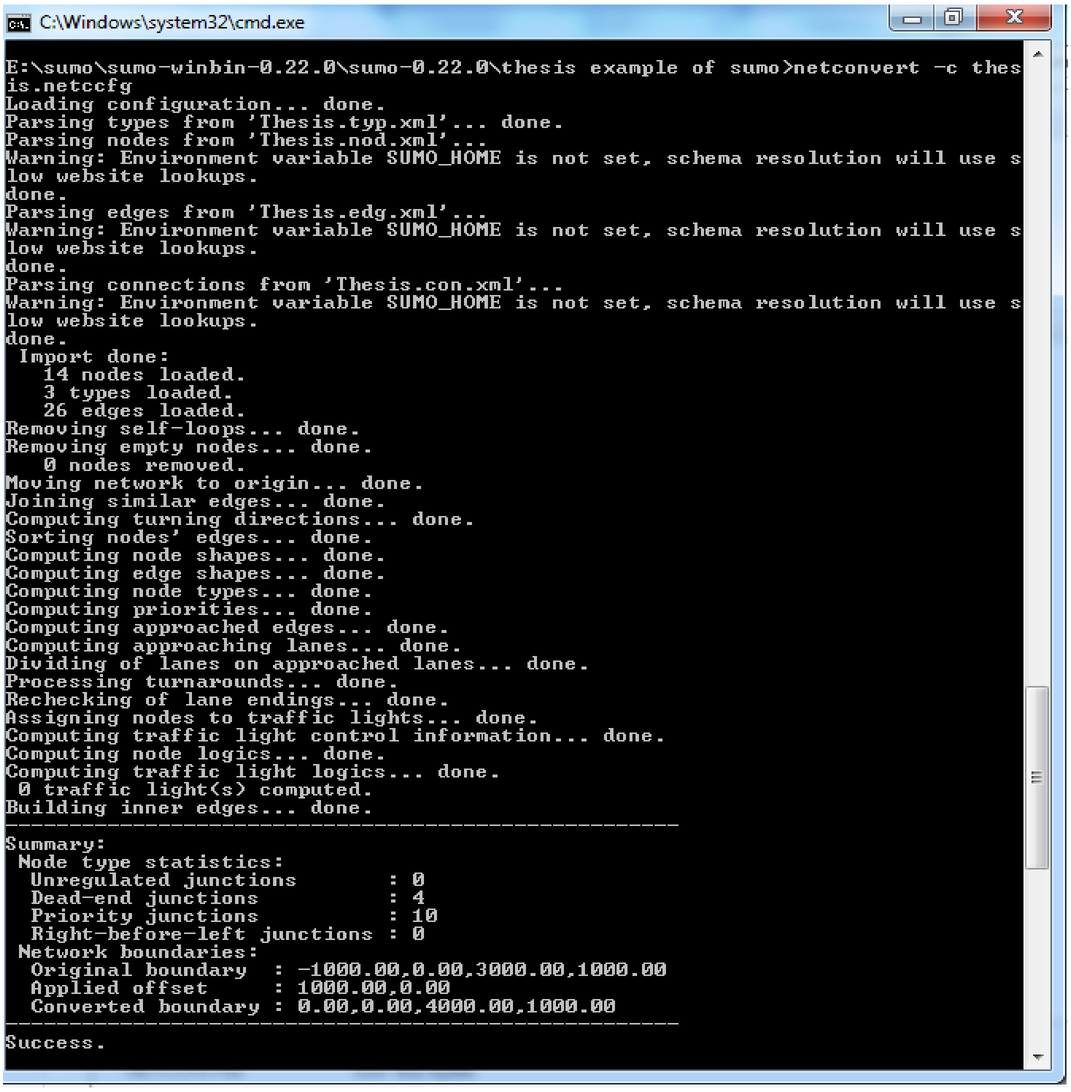

Figure 6.1 Network File Generation

After successfully creating a network file, Route file (.rou.xml) is created to describe the routes taken by vehicles to reach from one place to another. After defining a Route file (Thesis.rou.xml), SUMO configuration file (Thesis.sumocfg) is created using SUMO and Thesis.rou.xml and Thesis.net.xml as input parameters.

```
<?xml version="1.0" encoding="UTF-8"?>
    <input>
        <net-file value="Thesis.net.xml"/>
        <route-files value="Thesis.rou.xml"/>
    </input>
    <time>
        <begin value="54000"/>
        <end value="54900"/>
    </time>
</configuration>
```

The configuration file is executed to generate the graphical view and simulation.

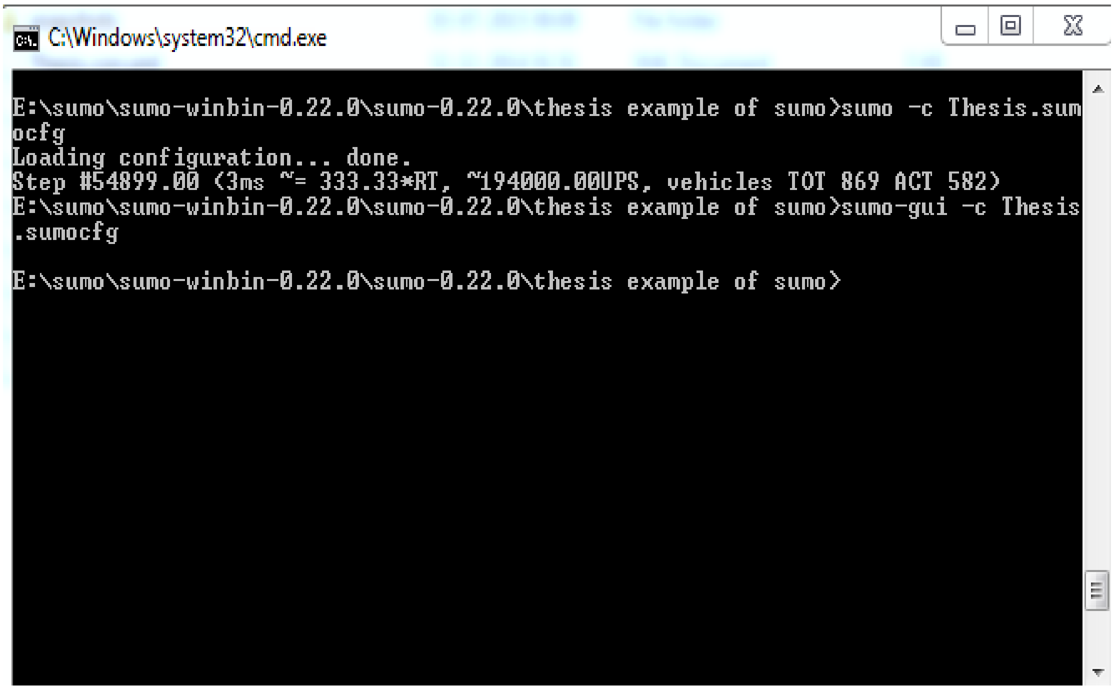

Figure 6.2 Sumo Configuration file Execution

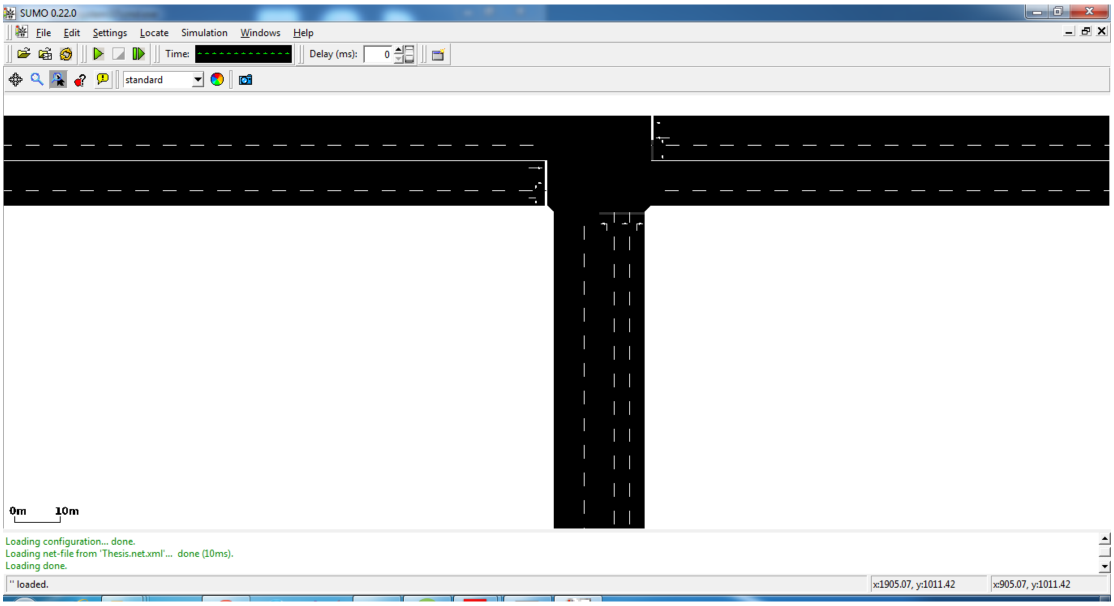

Figure 6.3 Road Network

Traffic Movement

- In a system of two lane, vehicles running from one location to another location.
- Blinking of red coloured light in form of circular shape dot shows that these vehicles are changing their speeds according to vehicles ahead of them.
- Blinking of yellow coloured light in form of circular shape dot depicts the direction in which the vehicle will turn.
- This simulation gives clear idea of original road network

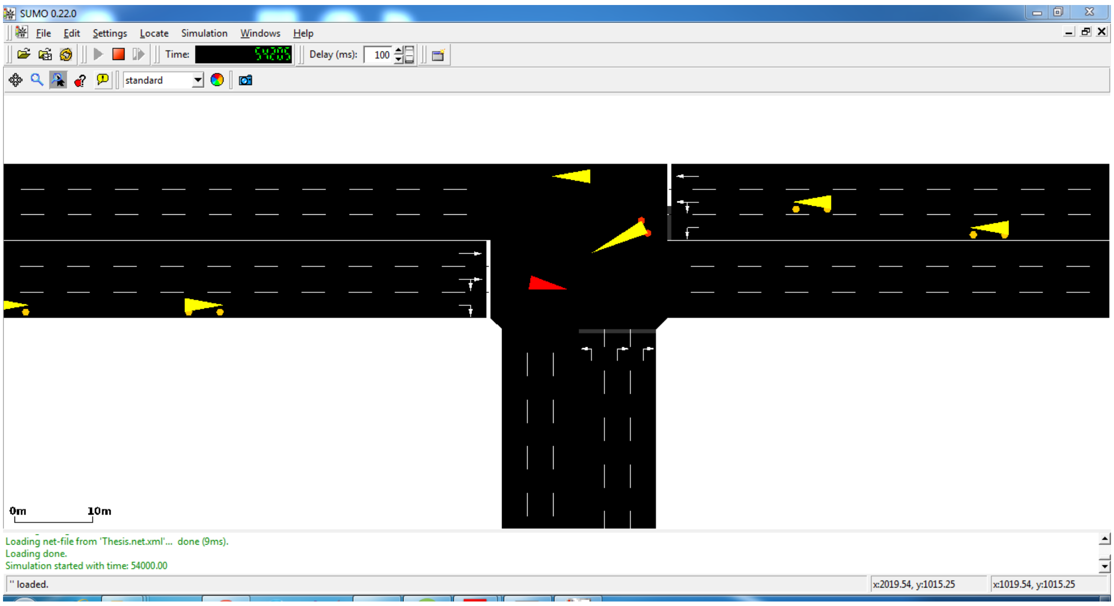

Figure 6.4 Vehicle Movements at First Instant of observation

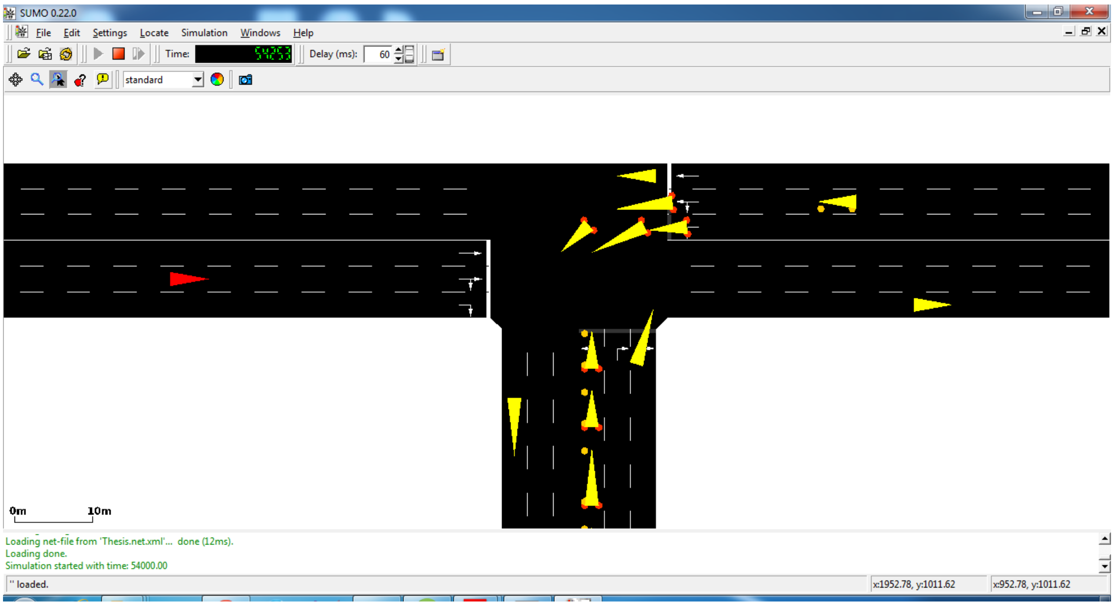

Figure 6.5 Vehicle Movements at Second Instant of Observation

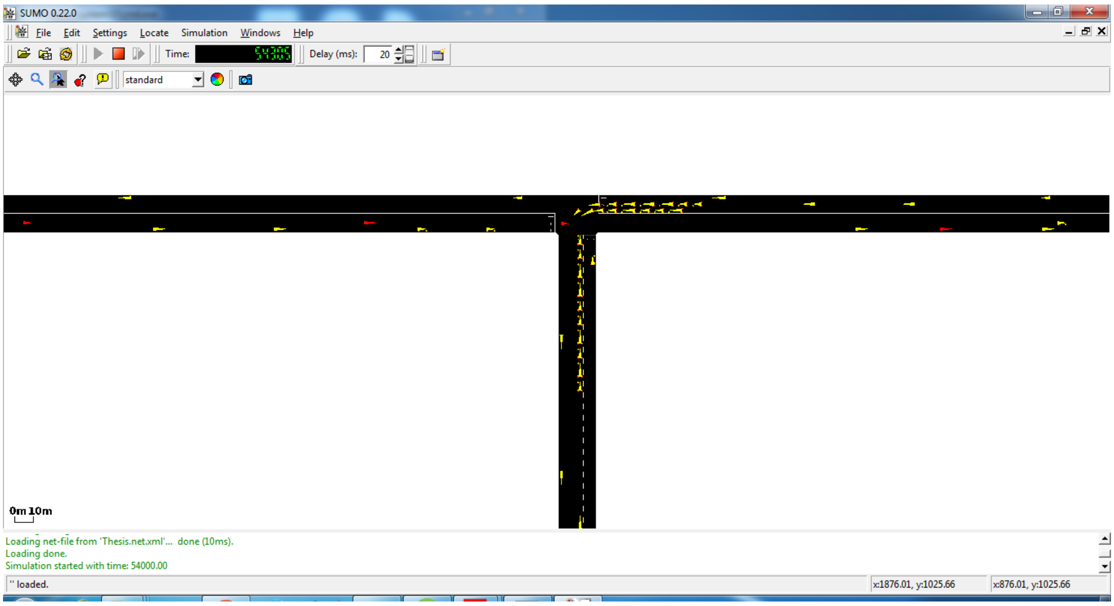

Figure 6.6 Vehicle Movements at Third Instant of Observation

Mobility model is generated from SUMO and this mobility model provides a trace file of vehicles describing properties like speed of vehicles, inter-vehicular distances and real time traffic density. This trace is given as an input to IFUZZY Controller which has taken values of these properties for each vehicle as input parameters and has computed the fitness rank of each vehicle. On the basis of this fitness rank value, decision is made about the eligibility of vehicle to become a relay node. Figures 6.7 to 6.9 show the effect of different input parameters on fitness rank.

In Figure 6.7, a surface is plotted to show the impact of mobility and density metrics on the fitness rank of a vehicular node, i.e., to show how much the node is fit to be selected as relay node to rebroadcast the message to the remaining area. For example, for low density and low mobility, fitness rank is about average, as shown with cyan colour surface but as soon as mobility increases the fitness rank drops as shown with blue colour surface. When density metric is around 0.6 and mobility metric is between -0.5 and 0, the fitness rank is maximum as shown with yellow colour but as the density metric increases and fitness rank decreases again.

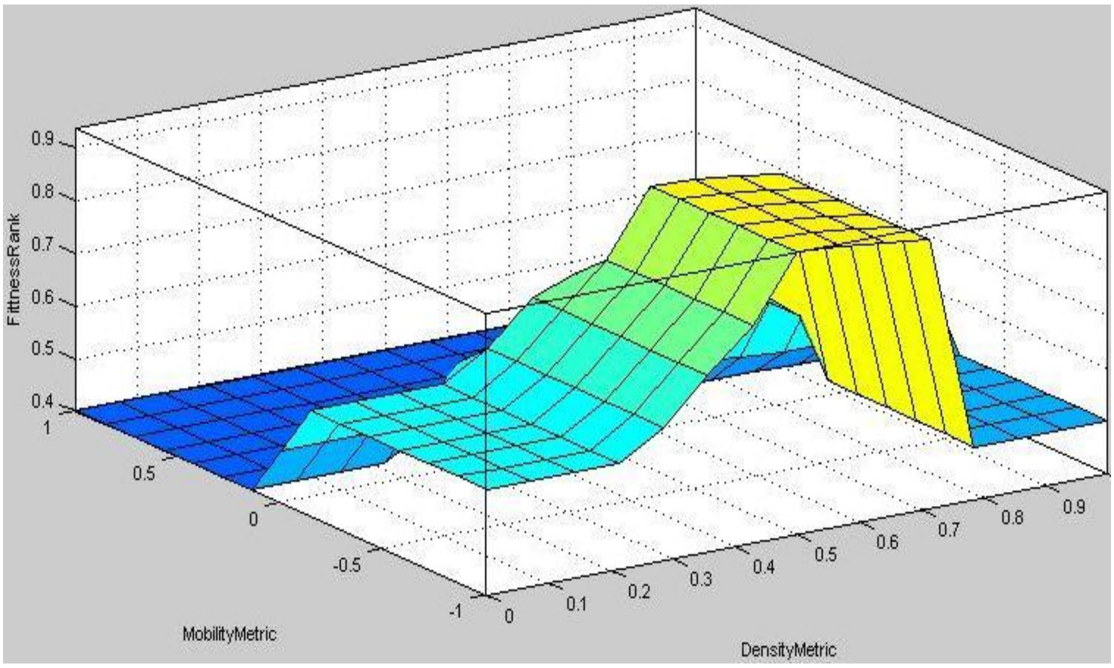

Figure 6.7 Effect of Mobility and Density on Fitness rank

In Figure 6.8, a surface is plotted to show the impact of distance metric and mobility metric on the fitness rank of a vehicular node, i.e., to show how much the node is fit to be selected as relay node to rebroadcast the message to the remaining area. For low distance and high mobility, fitness rank is low as shown with blue colour surface but as soon as distance metric starts increasing, fitness rank starts increasing as shown with steep surface of blue colour inclined upwards. When distance metric is between 0 and 0.5 and mobility metric is between -1 and 0, the fitness rank is maximum as shown by yellow colour. But if distance increases, then fitness rank slightly decreases again

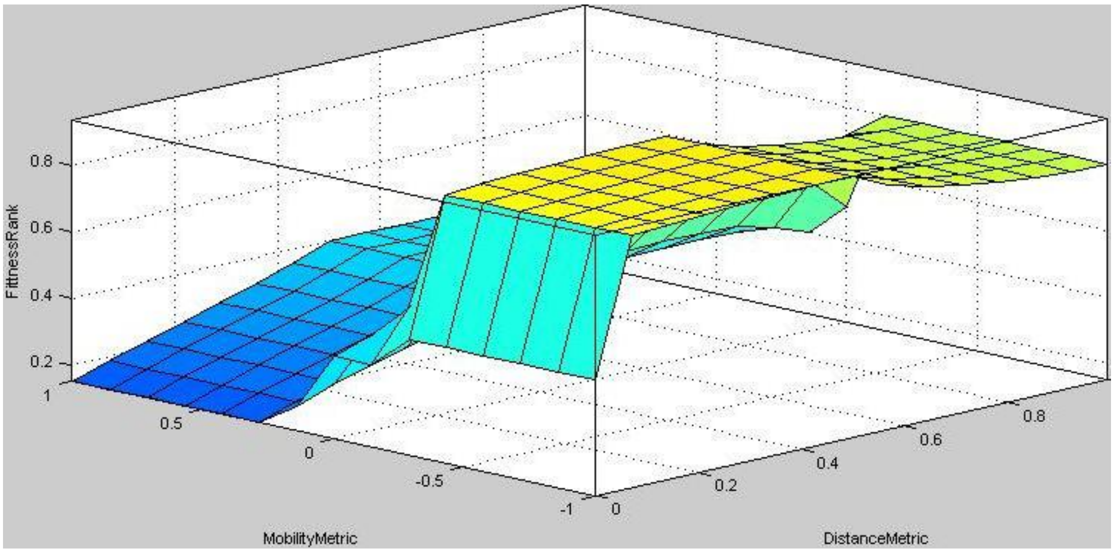

Figure 6.8 Effect of Mobility and Inter-Vehicular Distance on Fitness rank

In Figure 6.9, a surface is plotted to show the impact of distance and density mobility metric on the fitness rank of a vehicular node, i.e., to show how much the node is fit to be selected as relay node to rebroadcast the message to the remaining area. Like for low distance and low density the fitness rank is high shown with yellow colour surface but as soon as distance and density metric start increasing, the fitness rank start decreasing as shown with valley as shown by cyan and blue colour.

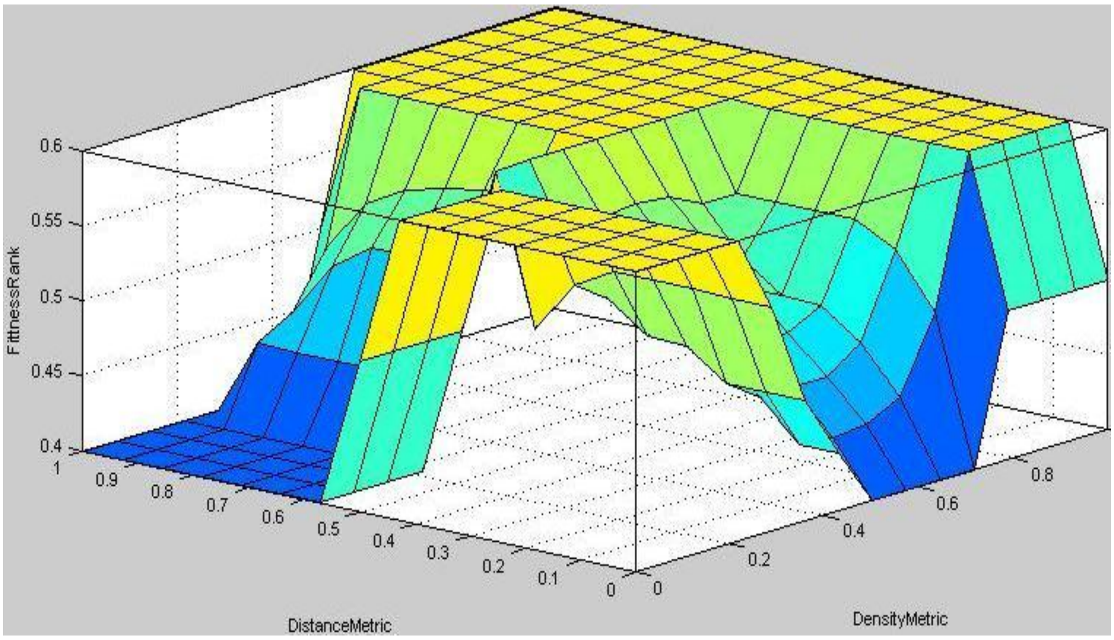

Figure 6.9 Effect of Density and Inter-Vehicular Distance on Fitness rank

Chapter 7

Conclusion & Future Scope

We proposed an Intelligent FUZZY (IFUZZY) Controller in which we have developed a multi-hop broadcast protocol for VANETs which is based on the concept of fuzzy logic. IFUZZY Controller selects the minimum subset of relay nodes from the pool of neighbour nodes in the transmission range of sender for transmitting the broadcast message and successfully reduces the number of re-broadcast messages to minimum. The selection for minimum subset is based on traffic density, mobility of vehicles and inter-vehicular distance. The protocol uses the power of fuzzy logic in order to deal with the uncertainty in input parameters and to get the combined effect of all the parameters to select the best relay node for re-broadcast. We have performed the simulation in MATLAB for evaluating the performance of our protocol and results which we got from simulation confirmed that IFUZZY Controller produces far better performance than the existing proposals.

7.1 Future Scope

In the future, we would like to explore the security feature of the proposed scheme. Also various types of attacks in VANETs would be explored.

List of Publications & Video Link

1. **Shubham Goel**, Neeraj Kumar "**IFUZZY:Inteligent Fuzzy Controller – based Boradcast Protocol for Vehicular Adhoc Networks**" accepted in 3rd International conference on ERCICA-2015,Banglore.

2. **Shubham Goel**, **"Comparative Analysis of Broadcasting Techniques in VANET's",** In proceeding of National Workshop on Emerging Trends in Science , D.A.V. college(Lahore), Ambala City, February 2015,pp 126-130.

Video Link

http://bit.do/Towards-Designing-FUZZY-Set-Based-Intelligent-Broadcasting-Technique-in-VANET

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January 2015

Before January 2015, I was doing my course work of Master of Engineering in Computer Science and Engineering. At the same time, I started exploring different domains of computer science like Computer networks, Mobile ad-hoc networks, Flying ad-hoc networks and some concepts of statistical and simulation mathematics for my research work. Reason for doing statistical and simulation mathematics was to get an idea of calculations and results present in the papers of MANETs, FANETs and VANETs. Firstly, I decided to work on FANETs and started searching for various study material and simulators available on FANETs but was not able to find much material and good simulators, hence started working on VANETs.

In January 2015, I started working particularly in the domain of VANETs. By mid-January, I was able to understand basic concepts of many sub domains of VANETs and relevance of VANETs in real world. VANET is a type temporary network which is created by vehicles on the roads to send important information to other vehicles. This information can range from anything like traffic related information to emergency messages. All the information transmission in VANETs is broadcast based and if there is a single mistake in choosing relay node, it can lead to a problem like “Broadcast Storm Problem” which has a very catastrophic effect on whole information broadcast. So I decided to work particularly in the sub-domain of broadcasting in VANETs as it was backbone of all other sub-domains in VANETs. I then started creating a repository of previous work done on broadcasting in VANETs by other authors. I collected papers from the journals and some good conferences on broadcasting protocols, broadcasting techniques, 802.11p standards and approach to solve different problem related to broadcasting.

February 2015

In February 2015, I started analysing and doing comparison between different broadcasting schemes in VANETs, as proposed by many authors like S. Siva Sathya and M. Chitra, in order to solve “Broadcast Storm Problem”. This analysis of different broadcasting techniques provided me a first hand knowledge of many broadcasting techniques. This knowledge gained from proposed schemes of other authors helped me to write my first paper which was a review paper titled "Comparative Analysis of Broadcasting Techniques in VANETs", published in a national workshop on "Emerging Trends in Science". In that paper, I compared simple flooding, location based flooding, distance based flooding, probability based flooding and cluster based flooding on the basis of parameters like redundancy, end-to-end delay, reliability, message overhead, scalability and contention rate. The aim of this review paper was to help others to find best suitable broadcasting scheme for them as per their requirements and hence, I finalize solution for "Broadcast Storm Problem" as problem statement for my thesis research.

March 2015

Upon studying different research papers in February 2015, I observed that almost all authors tried to solve the Broadcast storm problem by decreasing number of relay nodes by using one parameter only. Due to this, uncertainty due to all other parameters was not taken into account. This led to partially efficient protocols. I then started working to find out a method which could handle the uncertainty of all parameters simultaneously. During this study, I realised the capability of FUZZY logic to handle uncertainty problem. I used the concept of fuzzy logic in which I used combination of parameters as input for selection of the most appropriate and minimum number of relay nodes. The parameters which I chose as input are Inter-Vehicular distance, Mobility and traffic density. As range of all input values was very high, I developed algorithms to convert them to workable range. I also designed membership function of each input parameter for fuzzyfication of values, i.e., to convert CRISP values to fuzzy values. In order to do this, I had developed IFUZZY, an intelligent fuzzy controller-based broadcasting scheme for VANETs.

Besides developing this controller, I wrote a research paper on the use of this scheme. In the month of March, I completed my research paper for this scheme. I submitted this research paper in the conference "Emerging Research in Computing, Information, Communication and Applications", i.e., **ERIRCA'15,** for the approval. I got positive result by the 31 March, 2015. After the acceptance of paper, I registered myself for conference**.** Conference will be held during 31 July - 01 August, 2015 at Nitte Meenakshi Institute of Technology, Bangalore.

April 2015

In April 2015, I did implementation of this Controller in MATLAB by using the FUZZY Tool box available in it. I used both sigmoidal and trapezoidal curves for membership function of the parameters. I made 80 rules for IF/THEN rule section of controller on the basis of which it decided under which membership function curve of traffic density, i.e., small, medium or high, given input value comes under. Similarly, curves are also designed for mobility and inter-vehicular distance.

To generate the mobility modal, I used Simulation of Urban MObility (SUMO) tool, in which I took approximately 200 vehicles, each having its own speed and acceleration while going from one to another place. This mobility modal is used to generate trace file which used as input to MATLAB. In MATLAB, various parameters of these vehicles are evaluated and fitness rank for each vehicle is calculated, on the basis of which that vehicular node is chosen as relay node for re-broadcasting the information packet.

May 2015

In the month of May, I wrote my dissertation using this scheme and its results.