ENHANCEMENT OF PERFORMANCE CAPABILITIES AND QUALITY OF SERVICE (QOS) FOR VEHICULAR AD HOC NETWORK (VANET) PROTOCOLS

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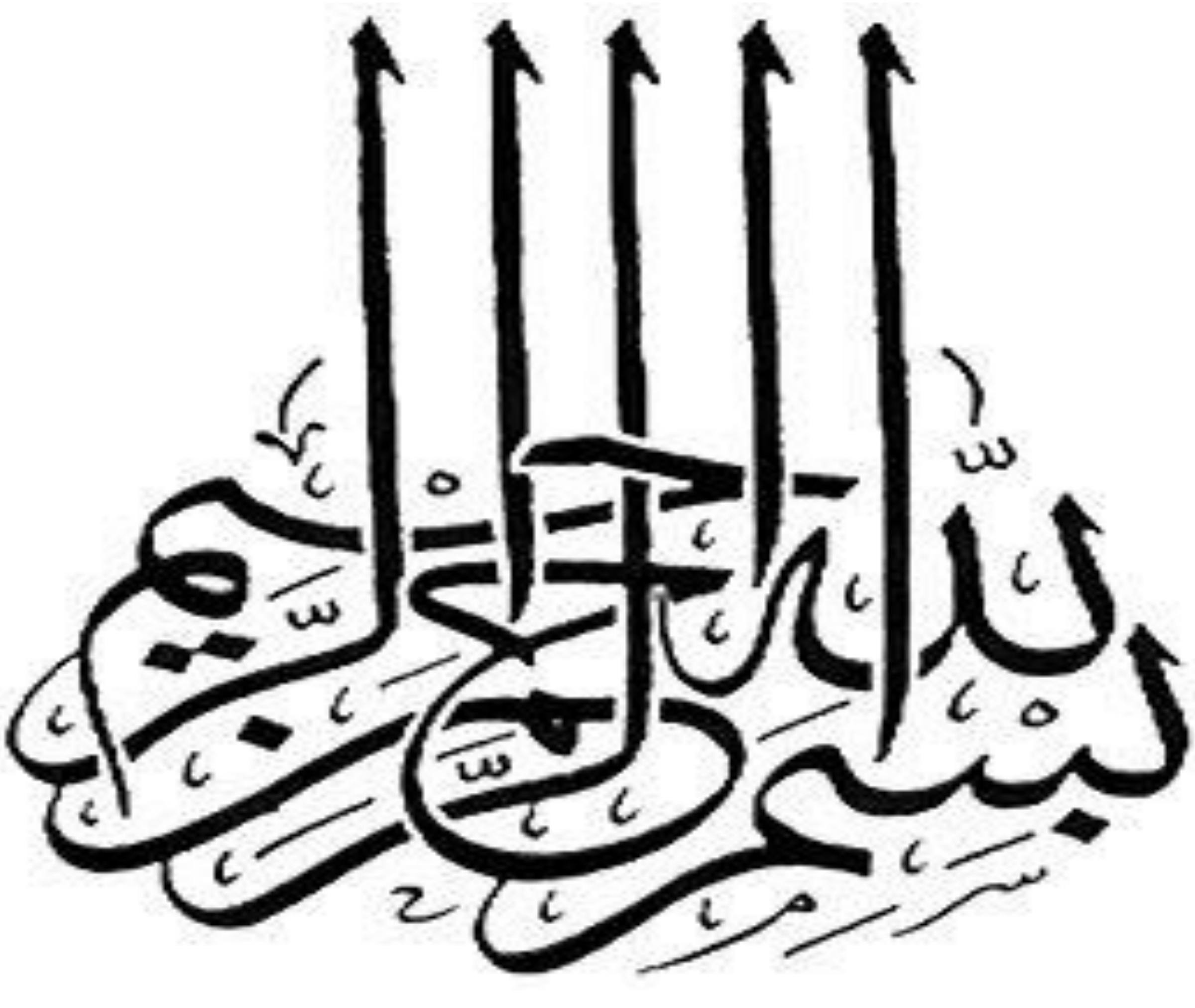
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ABSTRACT

The ecosphere of communication structures has arisen frequently from wired sphere to wireless sphere. Though, wired sphere is still live as a dynamic part, fluctuating in the track of wireless sphere deliver much assistances by means of infrastructure-less planning, low fee installments, remote administration and low power feeding. Continuing in the that same sphere, an attractive zone of research under much attention during current era stands Vehicular Ad-hoc Network (VANET). Vehicular ad-hoc networks (VANETs) can play a vital part to change our native road transport scheme into an "Intelligent Transportation System".

This portrays the prerequisite to design road safety applications for public travelling through road transport system, especially in developing countries like Pakistan to reduce the root cause of expiries and amount of injuries owing to accidents taking place in various regions of world.

VANET, in a significant characteristic, is considered as a distinct category of MANET (Mobile ad-hoc network) in which automobiles or its neighboring units are measured as wireless nodes. Vehicles in the setup of VANET, travel without restrictions as supposed to be in real-time traffic situation, communicating with each other as mobile. Empowering a vehicle to interconnect via VANET with further vehicles on highways or with neighboring road-side units (RSUs) to send its info to the vehicles away from its wireless range will support a driver in an improved manner to select the right pathway for his vehicle.

This research focuses on enhancement of the protocol being used for VANET via user-cooperation to boost performance parameter and a better Quality of Service in response. This assures all safety actions after gathering precise transport data using this improved platform from its environment for a harmless drive and avoids fatal road accidents. This validates such kind of VANET employment and enhancement of its protocol as a main source to rescue human life along with enormous investment by means of vehicles and infrastructure.

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LIST OF ACRONYMS

Abbreviation	Meaning
WLAN	Wireless local area network
WSN	Wireless sensor network
MANET	Mobile adhoc network
VANET	Vehicular adhoc network
IEEE	Institute of Electrical and Electronic Engineers
RSU	Road Side Unit
V2V	Vehicle to Vehicle
V2I	Vehicle to Infrastructure
WAVE	Wireless Access in Vehicular Environment
MAC	Medium Access Control
QoS	Quality of Service
OFDM	Orthogonal Frequency Division Multiplexing
ITS	Intelligent Transportation System
LAN	Local Area Network
Wi-Fi	Wireless Fidelity
VLC	Visible Light Communication
3G	3^{rd} Generation
LTE	Long Time Evolution
Mbps	Mega Bits Per Second
Km	Kilometer
GHz	GigaHertz
WHO	World Health Organization
LCD	Liquid Crystal Display

LED	Light Emitting Diode
VMS	Variable Message Sign
PER	Packet Error Rate
SNR	Signal To Noise Ratio
Non-HT	Non High Throughput
UDF	User Defined Function
MCS	Modulation and Coding Scheme
PSDU	Physical layer Service Data Unit
AWGN	Additive White Gaussian Noise

PUBLICATIONS

Conference Papers

1. **Syed Waqar Alam**, Bilal Khan, "Implementation of VANETs using FPGA-based hardware test-bed approach for Intelligent Transportation System", *1st International Conference on Dependable Embedded Wireless and Sensing Networks 2015*, 26th December, 2015.

HEC Recognized Journal Paper

1. **Syed Waqar Alam** and Bilal Muhammad Khan, "Implementation of VANETs using FPGA-based hardware test-bed approach for Intelligent Transportation System", *BUJICT Journal, Volume 9, Special Issue, September 2016, pp. 30-34.*

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CHAPTER ONE

INTRODUCTION

1.0 PROBLEM STATEMENT:

1.0.1 INTRODUCTON:

Vehicular Ad-hoc Network (VANET) is a very dynamic and challenging research area in current times that plays a major part in road safety applications [1]. VANET in a much wider view, is called as a distinct category of MANET (Mobile ad-hoc network) [2] in which vehicles or its neighboring units are supposed as wireless nodes. Vehicles in the picture of VANET travel freely as they are supposed to be in real-time traffic situation and the communication among them is mobile. Allowing a vehicle to communicate via VANET with vehicles or nearby road-side units (RSUs) during transportation to deliver its message to vehicles away from its radio range will help a car user in a considerably improved way to pick the right path for his vehicle. This assures all the security procedures after meeting exact transport data from its surroundings for a harmless drive and stops lethal road accidents. This justifies such type of VANET execution as a main cause to save human life as well as huge investment made in terms of vehicles and infrastructure.

1.1 THE PROTOCOL – 802.11P (WAVE):

While working in the domain of VANETs, the protocol that is preferably being used is IEEE 802.11p [3]. This protocol is for wireless communication is an extended form of WLAN standard of IEEE 802.11 [1], having similarities with IEEE 802.11a [4] in terms of physical layer [5] with Orthogonal Frequency Division Multiplexing (OFDM) & with IEEE 802.11e [6] in terms of MAC (Medium Access Control) layer [7] for QoS. IEEE 802.11p is also named as Wireless Access in Vehicular Environments (WAVE) [8,9].

1.2 CLASSIFICATION OF VANETS:

VANETs are primarily classified into the following three categories [3,10]:

1.2.1 VEHICLE TO VEHICLE (V2V) COMMUNICATION:

In **V2V communication**, a central unit (similar to an access point in WLAN standard) is not compulsory as means of communication between vehicles travelling on the roads [1]. This evidently specifies that the moveable vehicles travelling at liberty on the streets can directly connect with each other or may formulate a small cluster to send & receive data to neighboring nodes using different routing algorithms. As several vehicles may be there in such communication state, the routing protocols that allows exchange of information between the nodes may formulate a multi hop network. Throughout the communication in the scenario of V2V communication, the information exchange in precise time with reduced latency is very important being time-sensitive, else may result as a serious loss.

1.2.2 VEHICLE TO INFRASTRUCTURE (V2I) COMMUNICATION:

The **V2I communication** permits communication between a vehicular mobile node and a static road side unit (RSU) to interchange data globally on large scale. Straight communication between a vehicle and RSU for data exchange formulates a single hop network [1]. Then the RSU can broadcast the collected information globally so that the information concerning vehicles from one part of the city can be shared with other part of city by first having V2I communication and then I2V communication.

1.2.3 VEHICLE TO VEHICLE TO INFRASTRUCTURE (V2V2I) COMMUNICATION:

This third category is a hybrid one combining V2V and V2I communication formulates **V2V2I communication** [1]. In this case, one collaborating vehicle is considered as "master vehicle".

This master vehicle can exchange data with other vehicles as well as RSUs that are in wireless range simultaneously.

1.3 REASON / JUSTIFICATION FOR THE SELECTION OF THE TOPIC:

Attached below is the data collected from Pakistan Bureau of Statistics as annual report 2014 for traffic accidents in Pakistan.

Data on Traffic Accidents

Year/Month	Total Number of Accidents	Accident		Persons		Total Number of Vehicles Involved
		Fatal	Non - Fatal	Killed	Injured	
PAKISTAN						
2004-05	9896	4250	5646	5112	12401	10912
2005-06	9492	4115	5377	4868	11415	10565
2006-07	10466	4535	5931	5465	12875	11481
2007-08	10466	4610	5856	5615	12096	11456
2008-09	9496	4145	5351	4907	11037	10322
2009-10	9747	4378	5369	5280	11173	10496
2010-11	9723	4280	5443	5271	11383	10822
2011-12	9140	3966	5174	4758	10145	9986
2012-13	8988	3884	5104	4719	9710	9876
2012Nov	742	327	415	404	844	827
Dec	698	297	401	345	717	764
2013Jan	671	294	377	336	638	738
Feb	565	252	313	320	708	616
Mar	770	316	454	454	865	844
Apr	724	318	406	412	776	829
May	723	303	420	353	829	724
Jun	762	341	421	408	812	839
Jul	766	319	447	397	912	847
Aug	840	355	485	415	938	931
Sep	816	364	452	430	793	920
Oct	827	345	482	410	969	906
Nov	704	289	415	356	814	798
Dec	717	326	391	381	810	802

Figure 1.1: Data of traffic accidents in Pakistan [11]

In order to reduce the increasing no. traffic accidents in Pakistan and the casualties occurring due to them on a huge scale, implementation of research-based application under the area of Vehicular Ad Hoc Networks [12] (VANETs) in essentially required in present traffic environment of the country.

1.4 THESIS APPROACH / OBJECTIVES:

To enhance road traffic environment, transformation of current transportation system into an intelligent transportation system (ITS), reduction of traffic accidents and casualties, provide a smart system to avoid traffic jams and reduce travel time, assurance of safe and secure drive for passengers during travel. In order to achieve the mentioned objectives, the research tends to formulate a proposed network for inter-vehicular and vehicle to infrastructure communication that is capable to work with following relative network performance parameters:

- High throughput.
- Better Quality of Service (QoS).
- High reliability.
- Reduced/low latency.
- Low jitter.

1.5 RELEVANCE TO NATIONAL NEEDS:

A better, safer, time saving and satisfying traffic environment for countrymen. A better image of country for tourist, technologist as well as foreign investment to take interest in.

1.6 ADVANTAGES:

Vehicles having advanced technology. Smart units for real-time traffic monitoring and on the spot vehicular communication. Driver's and passenger life no longer at risk during travel.

1.7 AREAS OF APPLICATIONS:

1. Safety Oriented [13]: Enhanced mobility of Real-time traffic, co-operative inter-vehicular message transfer, post-crash notification, road hazard control notification, cooperative collision warning and traffic vigilance [14].

2. Commercial Oriented: Remote vehicular personalization and diagnostics in error cases, internet access for vehicles, value added services.

3. Convenience Oriented: Route diversions, electronic toll collection, parking availability [14], active predictions, enforce vehicles to follow traffic rules.

4. Productivity oriented: Environmental benefits for travelers, time utilization and fuel consumption.

1.8 THESIS ORGANIZATION:

The study comprises of the following sections:

- Chapter 2 gives literature review as in-depth study of VANETs, its classification, protocol and requirement in our society.
- Chapter 3 describes the technique followed for designing network flow model based on 802.11p protocol and the enhancement made in this protocol via user cooperation.
- Chapter 4 shows simulation results of both simulation of 802.11p in standard simulation mode and then using cooperative communication as an enhancement to get better parameters on the designed network.
- Chapter 5 gives conclusion of the research and discusses possible futuristic approach.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

The concept of VANET is relatively new. Not much content related to the systems of VANET is available. Therefore, for this research in depth analysis of different hardware and software solutions was required to identify the components that can help in successful implementation of research and propose an acceptable solution. The concept, classification, the protocol VANET follows and the areas where and how it may be used needs to be clear first.

2.1 CONCEPT OF VANET

2.1.1 INTRODUCTION TO VANET

Vehicle Ad hoc Network (VANET) was first commercially introduced in 2001 as car to car ad hoc mobile communication and network. The main concept of VANET comes from Mobile Ad hoc Network (MANET) [2,15] which refers to the automatic creation of short range wireless networks for sharing of data. VANET brings the concept of MANET to vehicular domain. VANET is also referred to as Intelligent Transportation System (ITS) [16] because it fulfills almost all the requirements of intelligent transportation.

The networks in VANET are short ranged Local Area Networks (LAN) with a span of 0.3 km to 1 km. The networks use mesh network topology in which each node is connected to every other node with a dedicated link independently. Mesh networks provide more reliability as a broken link could be bypassed by the data packets by hopping from one node to another until reaching the destination.

The nodes in these networks are vehicles, road side infrastructure like traffic signals, street lights, toll booths, and base stations. The network is built up between these nodes which continuously share data with each other. The type of data shared between nodes depends on the type of vehicle or infrastructure node. For example, an emergency vehicle might send a message to the vehicles in front and also to the road side infrastructure to clear the route.

VANETs can use already existing short-range radio communication technologies [17] such as:

- WLAN (Wi-Fi) [18]
- ZigBee
- Visible Light Communication (VLC) like infrared transmission and reception
- 3G/LTE

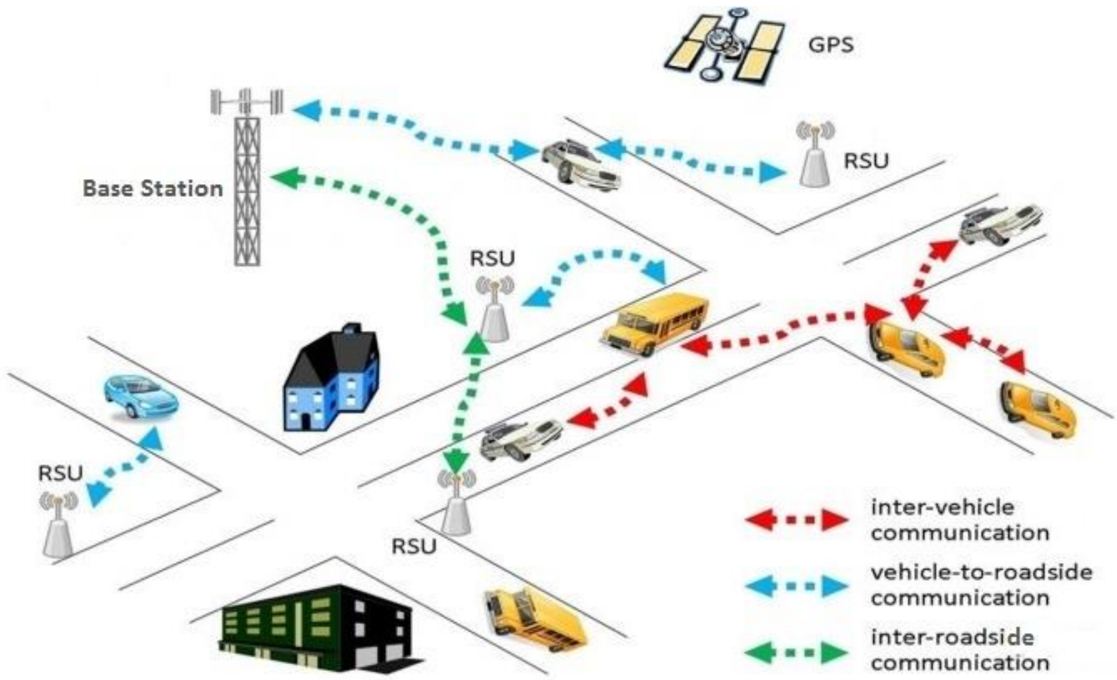

Figure 2.1: Visualization of VANET [19][20]

2.1.2 BENEFITS OF VANET

VANETs provide various technological and financial benefits to the modern world [13,21]. It provides realistic and economical methods of managing modern vehicular environment and making it more secure. Some major benefits of VANET [20] are as under:

- Accident Prevention is the main benefit of VANET. An integrated module is installed in vehicles which shows the geographical location of nearby vehicles and also alerts the driver when a possible collision situation is detected. This enables the driver to take necessary actions timely and prevent collision.
- Each vehicle on the road shares data such as speed, location, direction etc. with the road side infrastructure [22] which can then use the data to detect any traffic rules violations.
- Road side infrastructure can detect incoming emergency vehicles and alert other vehicles on the respective road to clear a route. This can greatly speed up the emergency rescue operations.
- On high speed roads such as highways, where it is possible to miss a gas station due to high speed, VANET can come in handy where if an infrastructure point is installed at a gas station it can advertise its services to vehicle which are in near vicinity.
- Toll booths on highways usually have long lines of vehicles. Toll collection can be sped up by giving each vehicle a unique identity and by identifying this identity using VANET infrastructure units and automatically deducting the toll amount from the drivers linked account.

2.1.3 VANET PROTOCOL IEEE 802.11P

IEEE 802.11p standard has been developed to add wireless access in vehicular environments (WAVE) [3,6,23,24]. Technical details of IEEE 802.11p are as under:

	Data Rate (Mbps)	**Range (Km)**	**Frequency Band (GHz)**
IEEE 802.11p	3-21	0.3-1	5.9

Table 2.1: IEEE 802.11p Protocol Parameters [25]

2.2 CONCEPT OF ACCIDENT PREVENTION

2.2.1 ACCIDENT

Accident is an event that is not planned & is purely unexpected which happens by chance & causes injury or loss & a lessening in worth of the resources.

It is an unwanted, unintended, unreasonable event that often cause harm to individual who is affected and create negative impact on individual's activity.

Figure 2.2: A severe car accident [26]

2.2.2 ROAD TRAFFIC ACCIDENT

That accident which involves at least one vehicle moves on public road that strike with other object (Vehicle, Infrastructure, living object) that may cause to injure any living person and/or damage to other vehicle & infrastructure.

2.2.3 STATISTICS OF ROAD TRAFFIC ACCIDENT

Here are some stats that shows the number of loss of human's life and human's disability in Road Traffic accident.

2.2.3.1 Statistics Of Road Traffic Accident In Pakistan

According to Pakistan Bureau of Statistics from 2006 to 2016, in Pakistan there took place average 9335 per year accident in which average 10350 vehicle involved which caused average 4870 people lost their lives and average 10,000 people got injured.

Year	Total Accidents	Accident		Persons		Number of vehicles involved
		Fatal	**Non-Fatal**	**Killed**	**Injured**	
PAKISTAN						
2015-16	**9100**	**3591**	**5509**	**4448**	**11544**	**10636**
PUNJAB						
2015-16	**3288**	**1576**	**1712**	**2053**	**4550**	**3288**
SINDH						
2015-16	**924**	**634**	**290**	**749**	**754**	**1144**
KHYBER PAKHTUNKHWA						
2015-16	**4287**	**1083**	**3204**	**1299**	**5527**	**5490**
BALOCHISTAN						
2015-16	**357**	**178**	**179**	**207**	**504**	**470**
ISLAMABAD						
2015-16	**244**	**120**	**124**	**140**	**209**	**244**

Table 2.2: Statistics of Traffic Accidents in Pakistan

2.2.3.2 Global Statistics Of Road Traffic Accidents

According to World Health Organization (WHO) [26,27] here are some Statistics of Death & Injuries Related to Global Road Traffic Accident.

2.2.3.3 Number Of Global Road Accident Deaths

- According to a Survey "Global Health Observatory Data" conducted by World Health Organization in 2013,[26] "there were number of 1.25Million death in 2013 related to road traffic accidents [10] across the whole world".
- According to survey almost half number of road traffic death are motorcyclist, cyclist & pedestrian due to least protection.

2.2.3.4 Number Of Global Road Accident Injuries

- Road traffic injuries are key factor for death of individuals among aged between 15-29 years.
- Road traffic accident cost most of countries 3% of their gross local product.
- According to survey conducted by WHO 20-50 million people are affected by road traffic accident which causes non-fatal injuries, most of them suffer disability because of their injury.
- Road traffic accident are considerable loss to individual, to their family and to whole nation because it arises from treatment cost & loss of creativity of injured people by their death or their disability for whole period of life.

2.2.4 ROOT CAUSES OF ROAD TRAFFIC ACCIDENT

The potential leading cause of Road Traffic Accident can be Over speeding, unsafe overtaking, carelessness, distraction of driver, driver's fatigue and disobey the traffic rules and regulations.

The aim of our research is to provide solution to prevent road traffic accident thorough utilization of our technology.

There can be so many other potential causes of road traffic accident but our focus on the following causes which are common and technical, also can be solved through our research technology.

2.2.4.1 Over Speed

The most common leading cause of road traffic accident is overspeed of vehicle. It is common in youth because speed thrills. It is common on highway. Most of the drivers ignore speed limit set by government's highway authority. In most of cases overspeed leads to death directly because when you drive fast, the lower your reaction time that leads to fatal/non-fatal injury.

2.2.4.2 Unsafe Over-Taking

Everyone on road seems to be becoming late for their work so they overtake other near-by vehicles to reach at their work quick as possible regardless of taking safe/unsafe overtake. In most of cases when drivers overtake without any safe condition causes to road traffic accident to them along with other near-by vehicles. Most of times on highway these unsafe over taking leads to serious injury because of high speed of vehicles.

2.2.4.3 Violation Of Traffic Rules & Regulation

It is the natural law whenever there is violation of any Rule then there will be undesired and unfavorable consequences because these laws are made for human and other environment's surrounding's safety.

2.2.5 TRAFFIC RULES & REGULATION

Traffic violation laws deal with the all illegal and unlawful activities that involves moving vehicle. These unlawful activities include disobediences of traffic signal, ignoring the speed limit, driving wrong on one-way road etc. Government of any country make these laws to provide security, safety and make their traffic system smooth without any barrier.

2.2.5.1 Violation Leads To Road Traffic Accident

Whenever these laws are violated like when Traffic signal shows red light means "to stop your vehicle and be patient until it becomes green" but some people don't take it as commandment and ignore it by moving their vehicle, that is dangerous for themselves and other by-passing vehicles, this unlawful act may lead to Fatal/non-fatal injury. Taking another example of exceeding the speed limit, while many upper-class people choose to pay speed limit challan fined by traffic police easily but next time they don't hesitate to violate speed limit, this is the key cause leads to road traffic accident.

Therefore, road traffic accidents are not complete prevented by Traffic laws & regulation, despite of traffic laws many people lost their lives and got some serious injuries that leads to disability. So, our aim is to prevent these accident by use of technology which will be fit to the vehicles, provide each & every data (like speed, brake status, number of vehicles on a specific road) of vehicles [24] moving near their vicinity to alert drivers.

2.2.6 ACCIDENT PREVENTION BY IMPLEMENTATION OF VANET

Three types of networks, based on the concept of VANET, are considered in this research to prevent accidents. The networks and their contribution in accident prevention is explained below [3]:

- Vehicle-to-Vehicle Network (V2V).
- Vehicle-to-Infrastructure Network (V2I).
- Infrastructure-to-Infrastructure Network (I2I).

2.2.6.1 Vehicle-To-Vehicle Network (V2V)

In this network, the data is shared between the vehicles which includes speed of vehicle, geo-location of vehicle, direction of travel & possible collision warning (based on brake status) [24]. Whenever these data are received at vehicle's device then driver of the vehicles can see collected data on display unit (touch panel graphic LCD/LED). So, driver takes all safety caution [28] to prevent himself from any misfortune event. Drivers have also access to send short message to other vehicles that are connected to its vehicle-device network to alert them such as safe overtaking and other emergency messages for help to prevent accident.

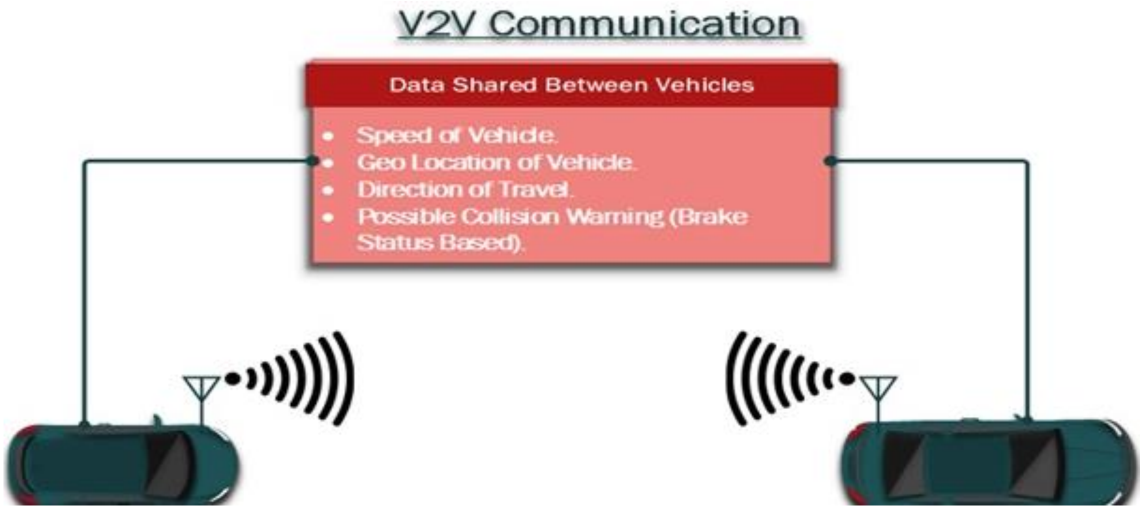

Figure 2.3: Shared data in V2V communication

2.2.6.2 Vehicle-To-Infrastructure Network (V2I)

In this network, the data is shared between vehicles and road-infrastructure devices. All vehicles which are near roadside infrastructure units [29], are connected to that infrastructure and exchange data with it through V2I network [30]. When all near-by vehicles are connected, then infrastructure-device shows that specified numbers of vehicles as a traffic ratio. This traffic ratio data is transmitted to connected vehicles. Thus, drivers will come to know the traffic ratio on that specified road. So, they can use alternate route. Hence there will be less chance for traffic jam which leads to reduction of chance for road-traffic accident.

2.2.6.3 Infrastructure-To-Infrastructure Network (I2I)

In this network data is shared between roadside infrastructure devices to connect entire city's traffic system and update the system each & every time with traffic situation. This network is connected by point to point communication and transmit each & every data to central server, which is controlled by government authority to monitor the traffic system. So, at the time of any emergency whenever a barrier is occurred in city's traffic system, authority takes necessary steps to eliminate that barrier to prevent any road-accident & makes entire city's traffic system smooth & regulated.

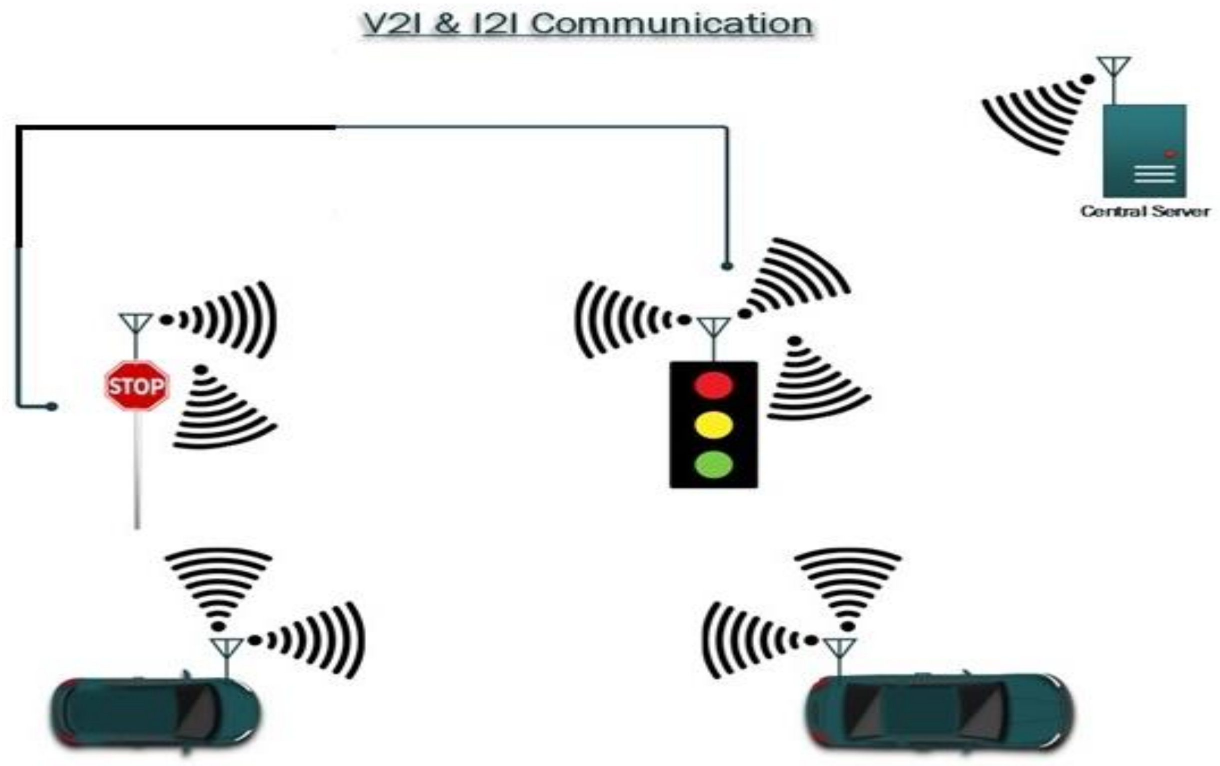

Figure 2.4: Visualization of V2I and I2I communication

2.3 CONCEPT OF TRAFFIC REGULATION

2.3.1 INTRODUCTION

Traffic regulation governs those laws which are required to keep the vehicular traffic flowing on roads and ensuring the safety standards. In every country these laws are codified by concerned government authorities and punishments are set for those who violate or break these laws. For example, in Pakistan driving is on the left side of the road instead of right as in US, age of driver must be 18 years or above, driving on drugs is not allowed, changing lanes with proper signaling etc. Breaking these rules are punishable and person is fined for such act.

2.3.2 TRADITIONAL METHODS OF TRAFFIC CONTROL

The traffic control [31] is done by following means:

a) Rules & regulations

b) Traffic signs

c) Traffic Lights

d) Electronic signs (variable message signs)

e) Channeling Devices

f) Road Markings

a) Rules And Regulations

In Pakistan there are several rules set by traffic police department, some of them are described briefly. The application of this research in traffic control [32] and regulation will be discussed in later sections of this chapter so discussion of these rules is mandatory.

- Keep the vehicle on left side of the road and let the vehicles coming from opposite side to go from right side of the road.
- Never stop on zebra crossing.
- Do not over take if there is any bend or hill crossings near, or the driver ahead has not signaled that he is ready for you to pass.
- Slow the speed near the pedestrian crossing, road junction and road intersection.
- Follow the right of way situation, and wait until you are allowed to move, such as pedestrian crossing and zebra crossing.
- Use proper hand gestures to signal if you are turning left or right, going for U-turn on busy road, slowing down for a reason or stopping.

b) Traffic Signs

Traffic signs are those informative boards standing by the sides of the roads which remind us the rules during the travelling. These boards carry symbols and words to convey the information visually. These boards have retroreflective surface which reflects head light of vehicle to ensure the visibility at night. These boards are classified by the information they convey and can be easily spotted by the shape of board. Following are different types of signs.

Mandatory or regulatory signs are circular shaped boards, these boards carry important information that everyone should follow. Those drivers who do not follow these signs are strictly dealt with because it is a serious offence to violate these regulatory signs.

Figure 2.5: Mandatory or regulatory road signs

Warning signs are those boards in triangular shape, they convey cautionary information about the hazards coming ahead. Driver must follow these signs for his own safety.

Figure 3: 2.6: Warning based road signs

Informatory sign boards convey the information such as distance for destination, directions, road side facilities etc.

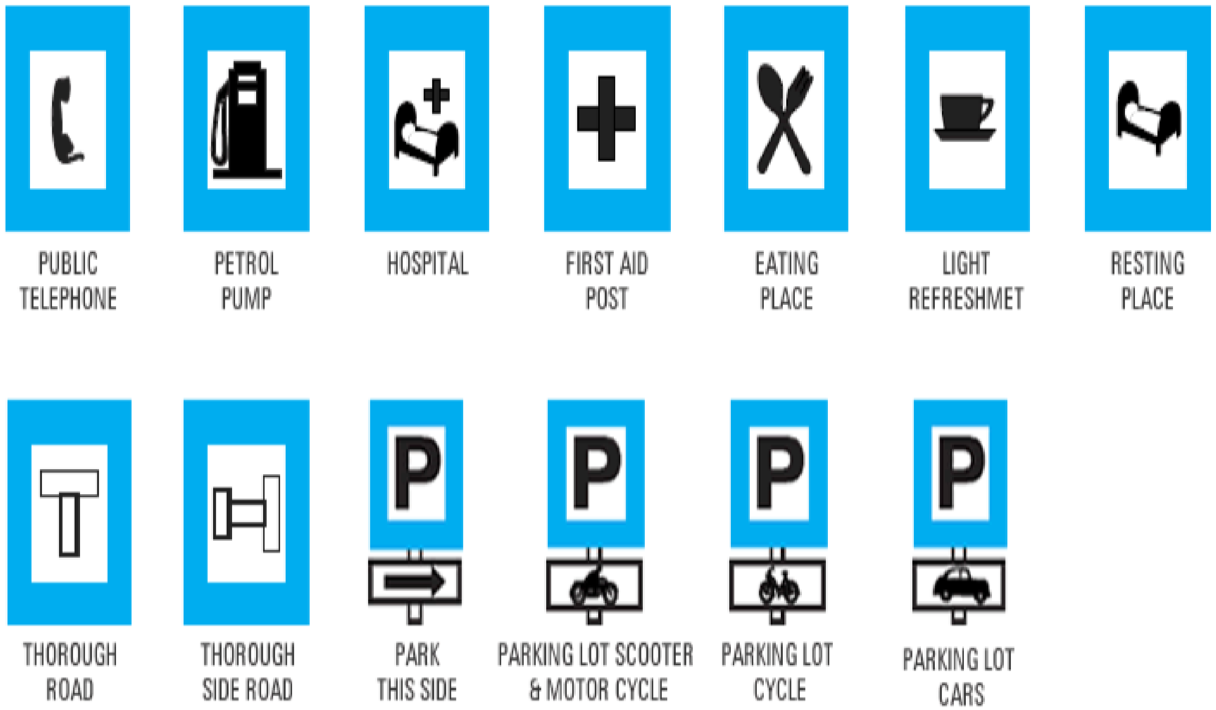

Figure 2.7: Informatory road signs

c) Traffic Lights

These lights are used on intersection points or the places where traffic from conflicted direction meet. It conveys the message of right of way, helps the vehicles to cross the intersection easily on their time, prevents traffic jams, reduces chance of vehicular traffic congestions and also helps pedestrian crossings. Traffic lights have three different colored lights which provide different information.

Red light indicates that vehicles facing red light should completely stop, Yellow light indicates that drivers should be ready to go but red still apply and green allows the vehicle to cross.

d) VMS

Variable message signs boards are the screens erected on the roads and the top of tunnels and flyovers to convey random messages or messages related to current situation necessary to be delivered.

Figure 2.8: VMS road signs

e) Channeling Devices

Channeling devices are used on the roads to convey a message of construction work ahead and guides the drivers to pass through construction zone or site of work, generally cones are used to make path for the vehicles while the area under construction is left. Depending on the work type the barricades and barrel drums are also used as channeling devices. All of these devices have orange and white stripes.

Figure 2.9: Channeling devices

f) Road Markings

Bare roads without marks on surface create total confusion, therefore markings are done for different purposes, and some of the uses of markings are described below:

- Stripes on roads are made to separate lanes and also to help oppositely moving vehicles to remain on the sides.
- Arrows for U-turn are also painted on roads.
- Zebra crossings are marked to facilitate the people walking on roads.
- Cat eyes are mounted on roads that help the drivers to easily see the road and lanes, they are also mounted in rows to show speed breaker ahead.

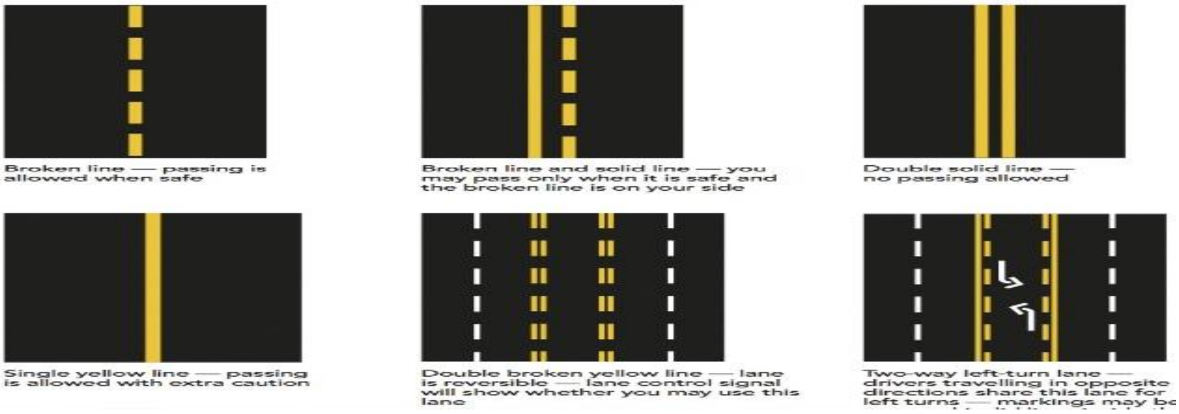

Figure 2.10: Road lane markings

2.3.3 WHY TRAFFIC REGULATION IS REQUIRED

As the world population is increasing with alarming pace, the traffic on roads is also increasing because more and more people are adopting private conveyance for travelling. This increase is creating overload on roads. The increase in vehicular traffic is uncontrollable but it is not a bad thing because it is in direct relation with economic prosperity of the state. But keeping the traffic regulation and control devices updated is a thing that metropolitan regions like Karachi can do to cope with the traffic overload on roads. So, there is need of more efficient form of controlling to keep the traffic flow at best possible state. Traffic regulation helps vehicles to move in an organized way, that is the reason that there are regulatory authorities in every country.

What would be the ratio of accidents in big cities like Karachi assuming if there were no traffic signals on intersection points of roads. It would have 10 times more than it is in present. Consider if there were no punishments on breaking the laws, no one would have cared to follow these laws. Traffic regulation and control is hence a necessity because it creates awareness, safety, organizes the flow of vehicles, reduces traffic congestions, reduces risk of accidents and facilitates the driver on roads.

2.3.4 MAJOR TRAFFIC PROBLEMS

2.3.4.1 Traffic Congestion

Traffic congestion [33] is the state when the road traffic reaches its saturation which means that road capacity to accommodate vehicular traffic is reached. In such case the vehicles queue up for longer times and trip time for each vehicle increases. This situation is not good for traffic because many problems arise with it such as emergency vehicles cannot move because no space left on roads. This mainly happens during peak hours and roads get clogged due to high density of vehicular traffic. The growing population cannot be blamed for such traffic problems. The authority should take counter steps to overcome such problems.

2.3.4.2 Traffic Signal Violation

There are some points on roads such as junctions or intersections where vehicles conflict and can cause accidents. To avoid this the traffic signals are used to display which vehicle should move and which should not. It is called right of way for vehicles.

Although there are traffic signals on intersections to ease the flow of traffic the problem still persists. Many people who are in hurry, do not care about signal light and speed up to cross the intersection which causes right angled collisions.

2.3.4.3 Wrong Parking

Parking the vehicles on sides of the roads is common in big cities of Pakistan which engulfs the capacity of roads. In market areas this act create problem for the pedestrians who are walking on sides of the roads. Some people park their vehicles outside the hospitals, educational institutes and other public places blocking the way of vehicles such as ambulances and public transport.

2.3.4.4 Over Speeding

In every city the rules are made to make the flow of traffic on roads better, on the road sides there are elevated sign boards indicating the speed limits. Speed limit signs communicate the maximum or minimum speed limits with the drivers and these limits are variable. Over speeding can cause accidents producing fatalities or injuries. Speed limits are set by traffic engineers according to the requirement of the area keeping the capacity of road and traffic flow at peak hours in mind. Over speeding is more dangerous than any other traffic rule violation, not only for the pedestrians but also for the driver and other vehicles. Speed limits are most common on highways, near school or colleges, construction areas, hospitals etc.

2.3.4.5 Moving In Wrong Direction

In Pakistan the driving side of vehicle is on left which means that driver should keep the vehicle on left side of road. Following this rule helps in avoiding head to head collisions on single two-way roads. But what happens if a vehicle is moving wrong side on a one-way road? There is no way to avoid the accident in such cases. Although such person is charged with fine and punishment but still a problem remains because people take wrong turns to avoid long driving which they face while following the rule. In many cases these vehicles moving in wrong direction go unnoticeable.

2.3.5 TRADITIONAL SOLUTIONS

2.3.5.1 Solution Of Traffic Congestion

The traffic congestion occurs when a road fails to accommodate vehicles. There are some proposed solutions such as the methods to increase the capacity by widening the road so that more vehicles can be passed from a given point of road with in the windowed time slot, making the roads or intersections signal free and making elevated U-turns to minimize the interference of vehicles. These classical solutions of reducing traffic congestions are expensive and require time consuming processes and a lot of resources.

2.3.5.2 Coping With Signal Violation

Those who violate signals are fined and punished according to the traffic law. Those who run away are chased by the traffic police and are imprisoned for running away because it is considered as crime in the law. Cameras are also used to capture the vehicle registration number and the fine voucher is sent to the person who owns the vehicle. All of these methods are being implemented in many areas. Permanently deploying the police near traffic signals is wrong use of human resource and also dangerous for the health of police man. Use of cameras is expensive and requires timely maintenance, also troubleshooting is a problem when they malfunction.

2.3.5.3 Parking Solutions

People park their vehicles on road sides which causes congestion of traffic, in Pakistan the traffic police lift those wrongly parked vehicles and take to their vicinity, owner has to come and pay the fine and go through legal process to get back his vehicle. But there are no such devices which can inform the police instantly about any wrongly parked vehicles, so police have to patrol on roads to check wrong parking. Sometimes they get too much late in doing so and traffic density increases. Also, to avoid parking on prohibited places there are sign boards which convey the message, but it does not guarantee that the driver will follow the information of sign board.

2.3.5.4 Solution To Speed Limit Violations

Currently used method of detecting the speed of vehicle is done by Doppler guns which work on principle of Doppler Effect or Lidar guns which work on laser for detecting the change of object distance to calculate speed. When a violator is found he is chased and forced to stop the vehicle, and is fined for over speeding. All these methods require constant deployment of police under speed limit sign boards. Also, there are speed breakers on roads used to ensure that vehicle reduces the speed, this is applicable on busy roads so more efficient way is required to cope with the problem.

2.3.5.5 Direction Control

Direction of vehicle on road is controlled by using spikes on roads which allow the traffic to move in one direction only, it damages the tires of vehicle moving in wrong direction. Also, it is detected by cameras mounted on road side infrastructure. But the spikes cannot be used on all over the path and in between these patches no vehicle can be stopped from moving in wrong direction. There is the need of efficient way which can instantly notify the police about the wrong moving vehicle to take steps against the driver.

2.3.6 VANET AS A SOLUTION TO TRAFFIC PROBLEMS

VANET stands for vehicular ad hoc network, it is built to share the information between vehicles, vehicles and infrastructures, infrastructures and central server etc. It is created to exchange data such as speed, location in form of geographical coordinates, direction of movement to aid the traffic regulation and control [34]. It is a modern concept and is being implemented to create autonomous cars. As the word ad hoc says for it that nodes can directly communicate without the need of any server node. It enables the networks to make and break automatically and creates flexibility so that moving vehicles enter and leave the networks easily. Three main parts of a vehicular ad hoc network are:

1. Infrastructure node

2. Central node
3. Pseudo node

In modern traffic systems the concept of VANET can be used to increase the efficiency [30] of control. In such systems infrastructure node can be any road side object such as sign boards, traffic signals, and buildings, bridges and other object which share and receive information. Central node is a server which can be a mainframe or any computer while pseudo nodes are the moving vehicles.

Vehicles within the range of transmission can share information such as speed, location, direction, brake status to reduce the accident chances and to drive safely. These parameters are processed by the device mounted in the vehicle and the useful outputs are produced, for example the coordinates received by vehicle from nearby vehicle is processed and location is tagged in map displayed on the screen of vehicle. Similarly, if vehicle stops due to some fault it can broadcast sudden failure alert to avoid the collisions. These vehicles continuously share the parameters such as speed with the infrastructure, consider the example of a sign board as infrastructure which indicate speed limit of 40 mph, if any vehicle violate this limit the information is automatically received by sign board because each vehicle is designed to share the speed status with surrounding nodes of VANET.

Infrastructures can perform different roles, sign boards can share their information electronically by transmitting the messages, they can also detect if any vehicle violate the rules accorded by them. Hotels, hospitals, fueling pumps can advertise their services and can aid the drivers by sharing information for example a car moving on highway receives message that there is fueling station 500 meters ahead, this will remind the driver to check the fuel level and if it is necessary he may refill the fuel. Toll collection can be done automatically which reduces queue time of vehicles. And traffic jams can be reduced to make optimum use of road capacities. Collecting the information of traffic density, the route planning can be done efficiently to choose the best path which take less time to destination.

Central server node is of essential requirement to broadcast news of common interests. For example, the weather condition or law and order situation of the area. It can also be used by the authorities to make statistical predictions for betterment of traffic situation, such as they can collect the data of road accidents for periodic quality check and balance of traffic control. Using the statistical measure, the points on routes can be spotted which require more attention regarding traffic congestion.

2.3.7 TRAFFIC PROBLEMS SOLVED BY THIS RESEARCH

There is always room for improvements in everything, this research is aimed to bring some improvements in present traffic regulation systems of Pakistan. It uses the concept of Vehicular ad hoc networks but is a modified form of it, and provides more cost effective and improved version of VANET in terms of modification in its protocol. Some solutions to the problems in current traffic control systems are provided by this research and some of the features are futuristic and can be done in future for the sake of country progress.

2.3.7.1 Solving Traffic Congestions By Vanet

Traffic congestions are the head ache for authorities all over the world. When country makes progress and achieve the economic prosperity, this economic prosperity brings traffic congestions with it because every person is financially well enough to afford their own private conveyance. This creates more traffic on roads and to overcome this situation many of the roads then go through the widening stage in which walking lane for pedestrians are shrunken to get the required capacity of roads. These classical approaches give some relief, but they are so costlier and time consuming. Beside all the classic approaches VANET provides the alternate solution in vehicular ad hoc network traffic control system [35]. This solution is related to traffic density on a route, as the vehicles are communicating with infrastructure nodes the number of vehicular can be estimated and using this density one can plan their route and choose the best alternative route where density is less and time to reach destination is minimum.

2.3.7.2 Controlling Over Speed Problems

There are several ways to cope with overs speeders, besides all those solutions VANET provides more efficient and cost-effective solution. The devices that may be developed using this research may have GPS modules integrated with the system board, as the GPS can provide the parameters such as speed, coordinates and direction. These values are transmitted by the vehicles to its connected nodes. Thus, speed of each vehicle can be monitored at infrastructures by using speed parameter of each vehicle. In this way those speed indicating sign boards can also see the speed of vehicles and when over speeding vehicle is detected the information is sent to central server via infrastructures and also the fine voucher is generated on the vehicle ID. Nearby police is alerted about the violator and police can block the way for over speeder.

2.3.7.3 Combating Signal Violators

Traffic signals which provide right of way assistance to drivers and pedestrians. Violating these signals cause accidents. In this research, the infrastructure device that may be developed as a futuristic approach using the modified protocol, is also equipped with the GPS module. We know that every vehicle is continuously sharing the coordinates, speed and directions so when any vehicles breaks the red signal, the infrastructure device sends the message to server about rule violation. During red state the signal compares the coordinates of vehicles to its fixed set of coordinates to check that if any vehicles violated the signal. Besides the GPS data the information of vehicle and owner may also be shared when nodes connect with each other. This information is sent to the server by the infrastructure device and the bill is generated against the violator.

CHAPTER THREE

METHODOLOGY - NETWORK DESIGN FLOW AND USER COOPERATION

3.0 OVERVIEW:

This chapter mainly focuses on the mechanism of the work done over the protocol that is mainly used by Vehicular Ad-hoc Network (VANET). Wireless Access in Vehicular Environment (WAVE) [36] as discussed earlier follows IEEE WLAN standard of 802.11p. Since the thesis aims towards enhancement of performance parameters for Vehicular Ad-hoc Network (VANET) protocol, the technique selected for this purpose chose the concept of User-Cooperation [37]. After the overview of this chapter, the selected idea i.e Cooperative Communication is being discussed in the first part. The path moving towards the designing of network and enhancement of protocol by means of selection of research tool used is discussed in second part. Third part discusses network design model and simulation flow of the protocol using the tool selected in detail. The last part of this chapter elaborates the method of incorporating the first part (user cooperation) in our third part (network design model) to simulate the enhanced protocol and get the outcome which surely be better than the one we obtain from the third part. Following are the result parameters that are set as our outcome after simulating the protocol in our network:

- Packet Error Rate (PER) against Signal to Noise Ratio (SNR) [38].
- Throughput with respect to number of users in a network.
- Channel bandwidth with respect to throughput.
- Latency per user.

It is to make clear that following outcomes are first calculated, simulated and observed in normal mode i.e using actual 802.11p (WAVE) protocol in VANET. Then user cooperation is incorporated in our designed model and simulated again to get the same but better outcomes from our enhanced protocol.

3.1 COOPERATIVE COMMUNICATION

Out of bundles of techniques to enhance the performance of a network, user cooperation [39] is the one which has its own importance. The protocol of a network may give a better outcome in terms of better throughput, reduced latency, longer network lifetime [40] etc. once cooperative communication is applied to it. As the data is shared between the transmitter and receiver or one may say between sender and receiver of a network, cooperative communication adds the concept of resource sharing between the two with the introduction of a relay node between them [41]. Incorporation of relay channel in the network transforms a two-node network into a three-node network.

Consider the case when a stream of data is being sent from sender to receiver. This reception of data at the receiver end formulates a two-hop network [35,37]. But in case the distance between the two-node are relatively longer or even mobile, this direct communication may lead to fading of data or loss of packets when the issues of unreliable communication occur. Power consumption and other resource parameters are equally utilized but the output doesn’t seem much fruitful due to longer path delays. To overcome this issue, user-cooperation introduces relay nodes in the path of sender and receiver to share the resources of the network. This also forms a multi-hop network [42]. The hierarchy goes like that the data in now sent from the sender and firstly it is received in the relay node as both nodes cooperate with each other. This relay node is now responsible for sending this relayed data via relay channel to the receiver and ensures its proper reception [43]. This technique not only share the resource in terms of power consumption of each node etc, but also ensures that data packets are not being dropped or loss even if the transmission channel is a fading one. Multiple relay nodes may be incorporated [44] usually between the path of data travel, depending upon the distance between sender and receiver as well as strength of the network to ensure proper transmission and reception [45]. The concept used in this research goes with the same idea that'll be discussed in later sections of this chapter after the detailed description of complete methodology used.

3.2 RESEARCH TOOL – THE CHALLENGE

This research is carried out through a number of stages in terms of selection of an efficient research tool [46]. Starting with hardware test bed approach [47], the initial simulation is tested using multiple conditions on timing diagrams of Xilinx ISE Suite. Focusing on the protocol that is supposed to be incorporated in VANET, the research shifted its dimension towards VANETsim [22,48], a Java based VANET simulator where simulation of vehicular nodes may be observed on maps downloaded from Google. Network strength and their respective communication between the nodes can be easily observed using the described tool. A couple of more tools [49] were brought under consideration but the main target was to move towards the protocol simulation [49] of WAVE which doesn't seem possible using the above-mentioned tools. The next option selected was working on WSN toolkit introduced by National Instruments for NI-LabVIEW. The limitation of this tool comes with WSN based [50] NI developed hardware equipment without which simulation only cannot be achieved.

➢ 3.2.1 MATLAB – WLAN SYSTEM TOOLBOX

The ice broke down as the research tool gets finalized with the introduction of WLAN System Toolbox by Mathworks in their widely used application oriented tool MATLAB [51]. WLAN System toolbox adds valuable command libraries in MATLAB library functions that enable the tool to create WLAN configuration objects. These objects can be then configured as per user as well as network requirement and hence a successful network which is solely based on the protocol used in it, can be designed in an efficient way using MATLAB now.

3.3 NETWORK DESIGN MODEL

Using MATLAB [51] to go with research work, the design model is initiated with creation of multiple WLAN configuration objects. 802.11p (WAVE) falls under non-high throughput domain (nonHT) category of MATLAB library function in comparison to other IEEE WLAN protocol standards (802.11x). Therefore, multiple NonHT objects are supposed to be created and simulated together using 802.11p protocol where each object indicated a single user / node / vehicle running on road traffic environment using the concept of VANET.

Our main code comprises of a user-defined function (UDF) which is an integral part of this research and some other library functions. Further organization of this chapter explains the methodology of the research carried out and the path toward its successful completion.

To keep the things simple, following section explains each function of the main code separately, while the flow chart attached as Figure 3.1 describes the complete picture.

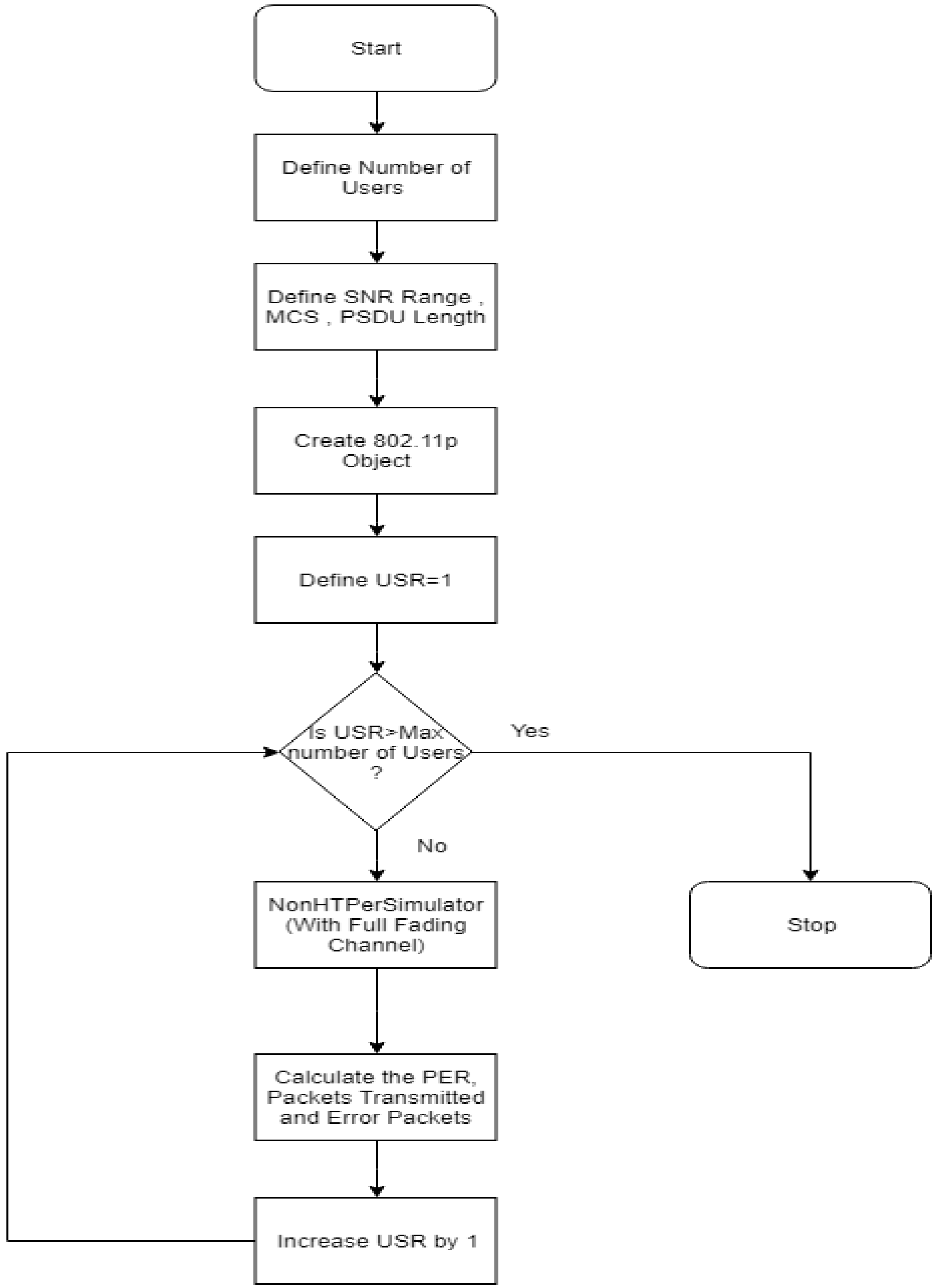

Figure 3.1: Simulation model of 802.11p protocol with multiple users

➢ 3.3.1 Number Of Users

```
%Define Number Of Users
USR=4;
```

Here the maximum number of users or nodes receiving the data is to be specified. For 802.11p protocol, these defined no. of users or nodes are considered as vehicles communicating with each other.

As the network is a shared one, according to that concept as the number of user increases, the throughput of the network must decrease due to mutual sharing of data.

➢ 3.3.2 SNR Range

```
%Define SNR Range here
snr=5:10:25;
```

The ranges of SNR points for which we want to see the simulation are to be specified here.

This could be a single number or a range on which we want to simulate our packets to be transmitted. Its proper transmission and reception is being tested in later section by calculating Packet Error Rate (PER).

➢ 3.3.3 PSDU length and MCS

```
% Link parameters
mcs = 4;              % QPSK rate 1/2
psduLen = 10;         % PSDU length in bytes
```

After that the Modulation and Coding Scheme (MCS) and PSDU length is to be specified for 802.11p configuration whose values used are specified above.

➢ 3.3.4 Creating 802.11P Object

```
% Create a format configuration object for a 802.11p transmission
for i=1:USR
cfgNHT10 = wlanNonHTConfig;
cfgNHT10.ChannelBandwidth = 'CBW10';     % 10 MHz channel bandwidth
cfgNHT10.PSDULength = psduLen;
cfgNHT10.MCS = mcs;
end
```

The “for loop” is then used to create multiple number of configuration objects based on 802.11p protocol. The number of objects created equals the number of users or nodes in the network.

Since the 802.11p comprises of Non-HT configuration, hence we are creating the object as NonHT.

“WlanNonHTconfig” library function is used to create an object with NonHT properties.

- **3.3.5 Simulation Parameters**

```
maxNumErrors = 20;    % The maximum number of packet errors at an SNR point
maxNumPackets = 250; % Maximum number of packets at an SNR point
```

After that, maximum number of error packets allowed at any SNR point and maximum number of packets to be transmitted at any SNR point are to be specified.

- **3.3.6 Calculating Number of SNR points**

```
S = numel(snr);
```

“Numel” is a library function in MATLAB used to calculate the number of elements in the input.

So numel is used to calculate the number of SNR points defined.

- **3.3.7 Nested For Loops**

```
for j=1:USR     % Loop For Number Of Users
for i = 1:S     % Loop For SNR point
```

There is a Nested for Loop in the Code.

The inner For Loop executes for each SNR point specified by the User. While the outer for Loop executes the number of users being used by the network.

Hence the outer loop specifies the number of users on the network, and then the inner loop simulates the SNR point at the outer loop's specified number of users.

- **3.3.8 Maximum Number of Packets**

As it is a known fact that if the number of users or nodes increases, the number of packets to every individual user is decreased as the total transmitted packets are being shared by the network mutually.

```
%Maximum Number of Packets
maxNumPacketsPerUser=maxNumPackets/j;
```

Hence for this reason, while designing our network, this formula is used to share the number of packets as the user increases. The variable "J" is used here to indicate the number of users.

- **3.3.9 NonHT Simulation**

For simulation of these non-high throughput configuration nodes / users, "NHTPERSIMULATOR" a user-defined function (UDF) is designed to simulate Non-HT configuration and calculate the Packet Error Rate (PER) and other required network parameters.

The main aim of this UDF is to decrease the number of lines from our main code and make the main code as simple as possible.

Another reason was to decrease the number of variables from our simulation, hence the data is generated, transmitted, and received inside the UDF and once the UDF is completed the data packets are destroyed. While in another case they would have existed, and consumed our workstations memory for no good cause.

The line by line description of the UDF is given below right after its flowchart as shown in Figure 3.2:

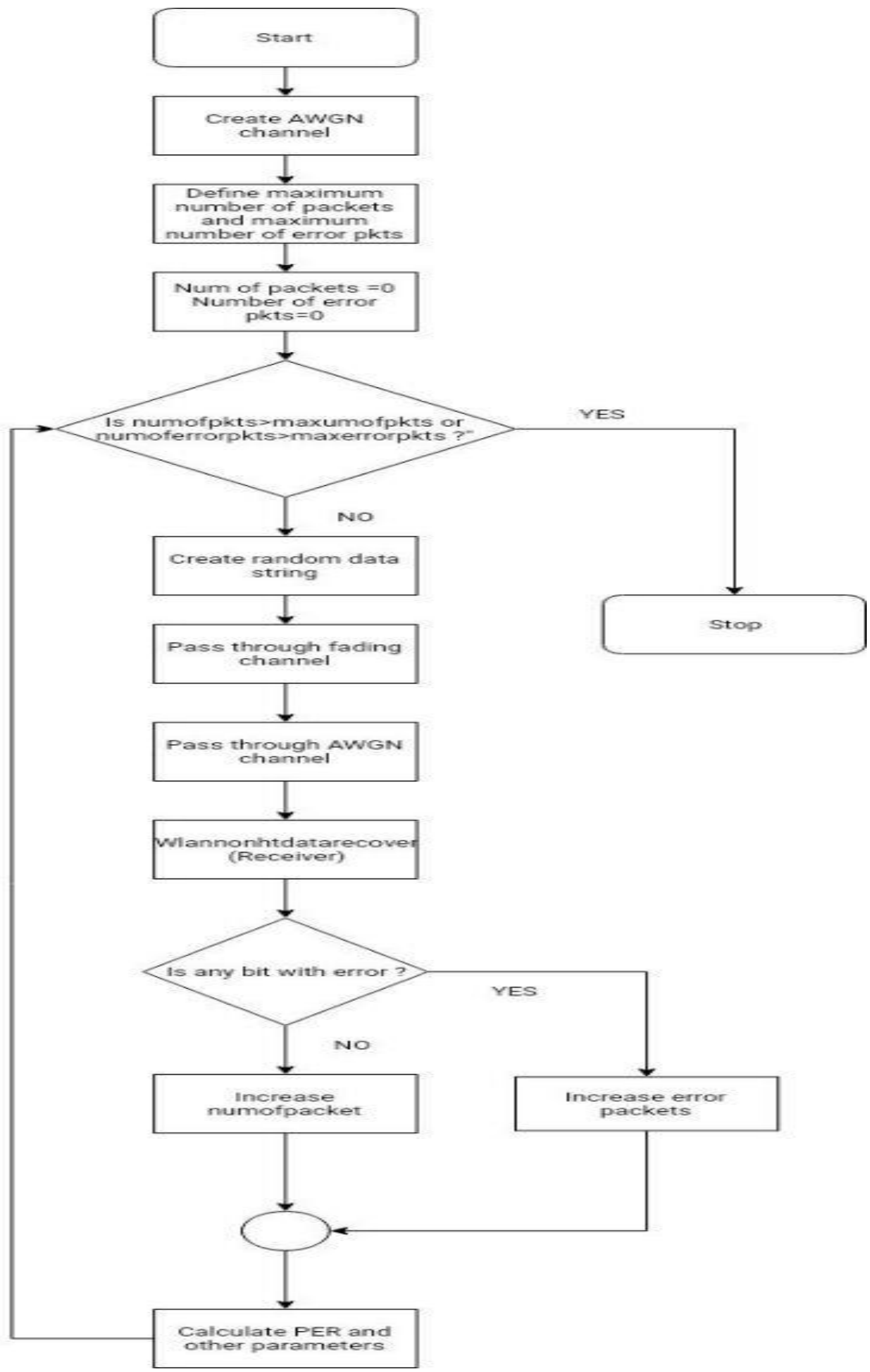

Figure 3.2: Non-HT Simulator (UDF)

- **3.3.9.1 Function Arguments**

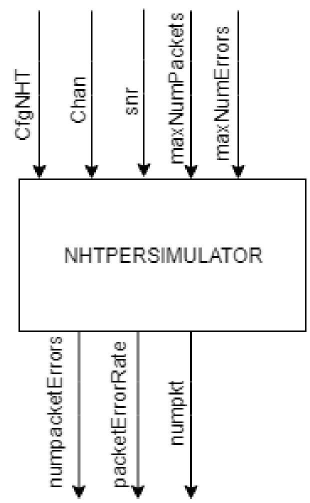

Figure 3.3: NHTPERSimulator

The function takes 6 inputs from the users, i.e;

- ✓ NonHT Configuration Object (cfgNHT)
- ✓ Fading Channel (chan)
- ✓ SNR Value (snr)
- ✓ Maximum number of error packets at any SNR point (maxNumErrors)
- ✓ Maximum number of Packets at any SNR point (maxNumPackets)
- ✓ Front End Receiver status (enableFE)

And the Outputs of the functions are,

- ✓ Calculated Packet error rate in simulation (packetErrorRate)
- ✓ Total number of Packets Received [52] (numpkt)
- ✓ The number of Packets which were not Received properly(numpacketErrors)

- **3.3.9.2 Additive White Gaussian Noise Channel**

After the function is called, UDF calculates some fundamental parameters (such as Sampling Frequency) from the data provided.

After that an Additive White Gaussian Noise Channel is created, which will be used to add some noise in our transmission.

```
% Create an instance of the AWGN channel per SNR point simulated
AWGN = comm.AWGNChannel;
AWGN.NoiseMethod = 'Signal to noise ratio (SNR)';
AWGN.SignalPower = 1;                 % Unit power
AWGN.SNR = snr-10*log10(Nfft/Nst); % Account for energy in nulls
```

- **3.3.9.3 Randi Function**

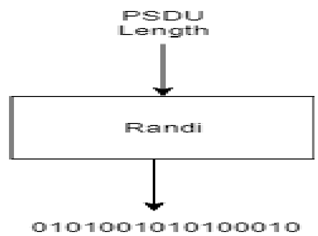

Figure 3.4: Random Data Stream

Randi function is a MATLAB library function, used to generate random data.

This function is used to create a random data (consisting of 1 and 0) which could be transmitted in the simulation. This stream is considered as our information Signal or data.

- **3.3.9.4 WlanWaveformGenerator**

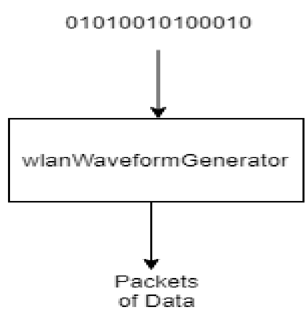

Figure 3.5: Waveform Generator

This MATLAB Library function is used to generate a WLAN waveform for the transmission.

The data generated in the Randi function is fed in this generator as an information data.

This function converts our information data into number of packets we require.

Other than this some other parameters are used as an input in this function which are;

- ✓ NonHT Object which was given as an argument in UDF (cfgNHT)
- ✓ Idle time added after every Packet (idleTime)
- ✓ Number of packets to be generated in a single function call (numPkts)
- ✓ Duration of Window Transition applied to every OFDM Symbol [53] (winTransTime)

➢ 3.3.9.5 Adding Fading

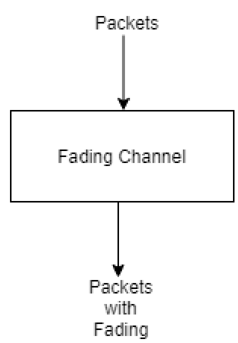

Figure 3.6: Rayleigh Fading Channel

Fading is introduced in our signal using Filter Command.

Filter is also a MATLAB library function used to apply any channel model on the data.

Rayleigh Fading channel is given as an input from the user as an argument to UDF, that fading channel is applied to the data stream, which makes the realization as the data is passed from the medium between Transmitter and Receiver.

The fading channel properties are directly dependent upon the distance between the Transmitter and Receiver and its path delays are of considerable importance.

➢ 3.3.9.6 Adding Noise

An AWGN channel was created some instances back; the data is passed from that channel using step Function.

Our data stream is now summed up with noise data coming from AWGN channel.

The noise which is introduced in the data depends upon the SNR value [53]. As the SNR value increases the Noise decreases and vice versa.

➢ 3.3.9.7 Recovering Data At Receiver

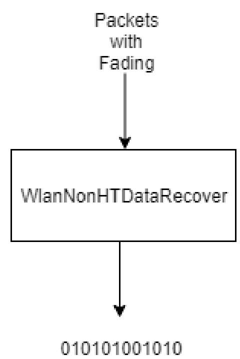

Figure 3.7: Data Recovery

WlanNonHTDataRecover function is MATLAB Library function used to recover the data.

Now the data is again recovered from the fading channel and is in the Binary form (zeros and ones). This data consist of both, the combination of number of packets transmitted and number of error packets added. The error packets are supposed to be calculated from this data stream in the next step.

➢ **3.3.9.8 Calculating Error Packets**

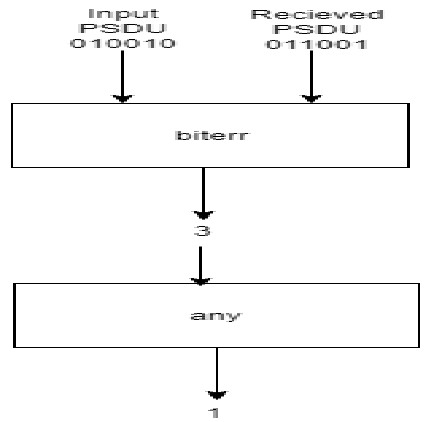

Figure 3.8: Error Packets Calculation

To find the number of error Packets, two functions are used i.e.

- ✓ Biterr
- ✓ Any

"Biterr" is the MATLAB function which inputs two streams of binary data of same size. Both the streams are compared bit by bit (Using XOR). If any bit is not same it will be considered as an error bit. "Biterr" calculates the total error bits and return it.

"Any" is another MATLAB function which calculates the number of nonzero elements. If there is any nonzero element in the input data, the function will return 1 else 0 will be returned.

Summing up both the functions it could be concluded that, first of all the transmitted bits stream and received stream of bits are fed into "biterr" function to calculate the number of bits which are not same (i.e. Error Bits). The number of error bits are fed into "any" function to see that is there any Error bit or not.

If a single bit in the received stream is not matched with the transmitted one, the biterr function will return “1”, since “1” is nonzero element hence any will also return “1” and the Packet will be marked as Error packet.

- **3.3.9.9 Calculating Packet Error Rate**

```
% Calculate packet error rate (PER) at SNR point
packetErrorRate = numPacketErrors/numPkt;
```

To calculate Packet Error Rate, the total number of error packets calculated from previous step are then divided by total number of packets transmitted. Its working mechanism is explained in the next chapter along with its results.

- **3.3.9.10 Working Of UDF**

As the individual working of every line is explained, now the overall working of the UDF could be easy to understand.

First of all the UDF is given a Non HT Object, a Fading Channel, an SNR value, Max number of error packets and maximum number of packets.

After that, SNR value is used in creating AWGN (Additive White Gaussian Noise) Channel.

Then a while loop is initiated which specifies that the loop will work until the number of error packets transmitted are not equal to maximum number of error packets or until the number of packets transmitted not equals maximum number of packets. Maximum number of error packets and maximum number of packets are given in input as an argument to UDF.

```
while numPacketErrors<=maxNumErrors && numPkt<=maxNumPackets
```

The main aim of this loop is to continue the simulation until maximum number of packets are not transmitted (i.e. there is very low noise at that SNR point) or until maximum number of error packets are detected (i.e. there is too much noise at that SNR point).

In the while Loop, first of all we create a random stream of bits (Figure 3.4) using "Randi" library function.

The "Randi" function returns us an array of elements which are 1 and 0 only.

```
>> inpPSDU
  Columns 1 through 20

    1    0    1    1    0    0    0    0    0    1    0    0    0    1    0    1    1    1    1    1

  Columns 21 through 40

    0    0    0    1    1    0    1    1    1    0    0    0    0    1    1    1    1    0    1    0

  Columns 41 through 60

    0    1    1    0    0    0    1    0    0    0    1    0    0    0    0    1    0    0    1    1

  Columns 61 through 80

    1    0    1    1    1    0    1    0    0    0    0    1    1    1    1    1    1    0    1    0

  Columns 81 through 100

    1    1    1    0    1    1    1    1    1    1    0    0    1    0    1    0    0    0    0    0
```

This randomly generated stream is sent to "WlanWaveformGenerator" to create required packets as defined as input argument out of the data stream.

The data is now converted into packet form and is ready to be transmitted.

The next task for the data is to pass through some fading channel. So, to achieve this, the data is passed through the Rayleigh fading channel provided as an input argument to the UDF. This Rayleigh fading channel provides path for data transmission which depends on the distance between transmitter and receiver. Hence path gain and path delay of this channel is significantly important.

After the data is passed from the Rayleigh fading channel, it then passes through AWGN channel to get some noise (Depends upon SNR Value). Now the data had passed the medium and is ready to be sent to receiver side.

At receiver Side, the passed data is Recovered using “wlanNonHTDataRecover” function. And then we again get the stream of 1 and 0’s at receiver side.

Now at this spot, we have input PSDU which is our actual information signal, and an RX PSDU which is the signal we received after passing through the medium.

Both the signals are compared bit wise using XOR and the number of error bits are calculate using “biterr” function.

If the received packet has any error bit, it is considered as error packet, and number of error packet increases by one.

And either the received packet is an Error Packet or not, the total number of packet will increase as the packet is received.

Hence after that the while loop is again executed, until the terminating conditions of the loop are not fulfilled.

As the while loop stops, the simulation had either achieved maximum number of error packets or the simulation had successfully sent the maximum number of packets at that point.

So, to calculate Packet Error Rate, number of error packets received is divided by number of total packets received.

Then the UDF returns Packet Error Rate, Number of Error Packets Received and Total number of Packets Received.

- **3.3.10 Working mechanism of main code**

The main code could be divided into three main sections or parts. The first part is the initialization of the objects and parameters. The second part is actual simulation part. And the third part is to calculate parameters and plot their respective outputs.

So, first all the code initializes the number of maximum users in the network.

After that, SNR points are initialized for which our simulation will be completed and parameters would be calculated.

Then different objects or nodes are created using “wlanNonHTconfig” function. The number of objects depends upon the number of users.

Numel function is used then to calculate the number of SNR points. This will be used in for loop.

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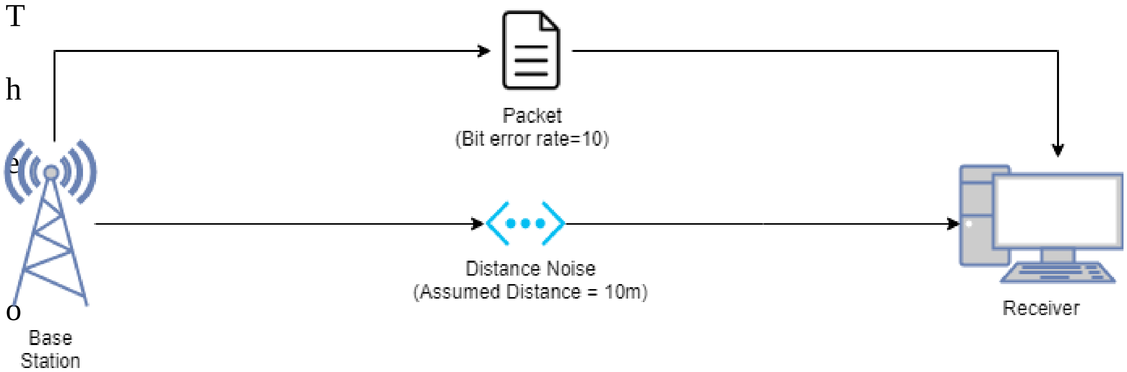

Figure 3.9: Direct Communication of 802.11p protocol model in normal mode

The outer for loop is used to increase the number of users in the network one by one. In other words, for loop will start with 1 and the whole simulation will run considering 1 user in the network. Then after the simulation is completed, the number of users will be increased to 2 and until the maximum number of users in the network.

The inner for loop is used to run the simulation at every SNR point. The loop will start with 1, and hence the first index or first value of SNR will be used in calculation (in our case it is 10). As the simulation ends, the loop increases by one and the 2nd SNR point will be used in calculations (in our case 1).

Inside for loop, the first instruction is dividing the maximum number of packets by the number of users [54] currently available in network. As the number of users increases, the packets are shared among the users present in the network.

The shared number of packets are given to the UDF "NHTPERSimulator". This UDF simulates and returns the Packet Error Rate (PER), Total Number of Packets transmitted and Number of error packets. These returns from function are stored in variables for later calculations.

The throughput is calculated in percentage by dividing the total number of Packet Transmitted (From UDF) by the maximum number of packets per user. Similarly, latency and bandwidth utilization is also calculated from the data packets received above.

3.4 CONTRIBUTION IN 802.11P NETWORK MODEL VIA USER COOPERATION

Cooperative communication is implemented in our designed network model [55] as a contribution in this research to enhance the protocol for Wireless Access in Vehicular Environment (WAVE) [6]. This is being done by adding a relay node [56] between sender and receiver across each communication mode. This scenario is picturized in Figure 3.10, where Base Station 2 is acting a relay node between sender (Base Station) and receiver.

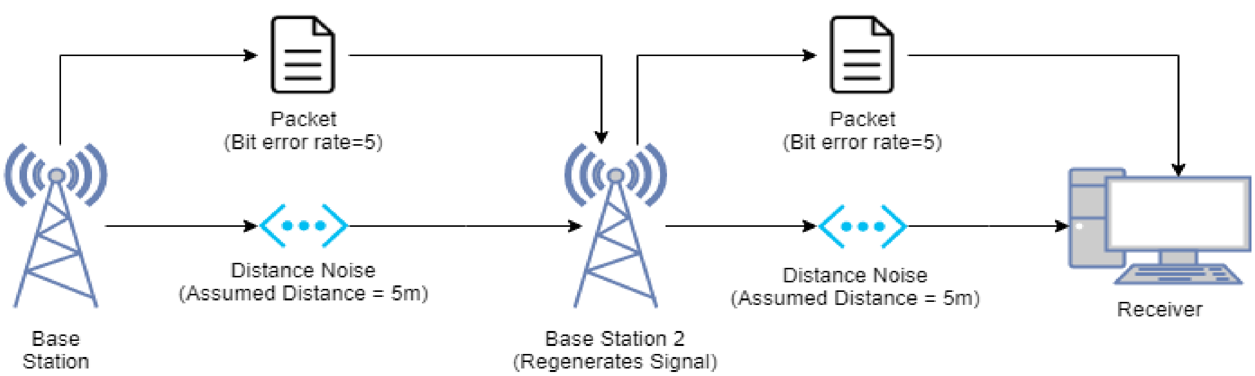

Figure 3.10: Cooperative Communication implemented in 802.11p protocol model

Working mechanism is described in the following flowchart in Figure 3.11:

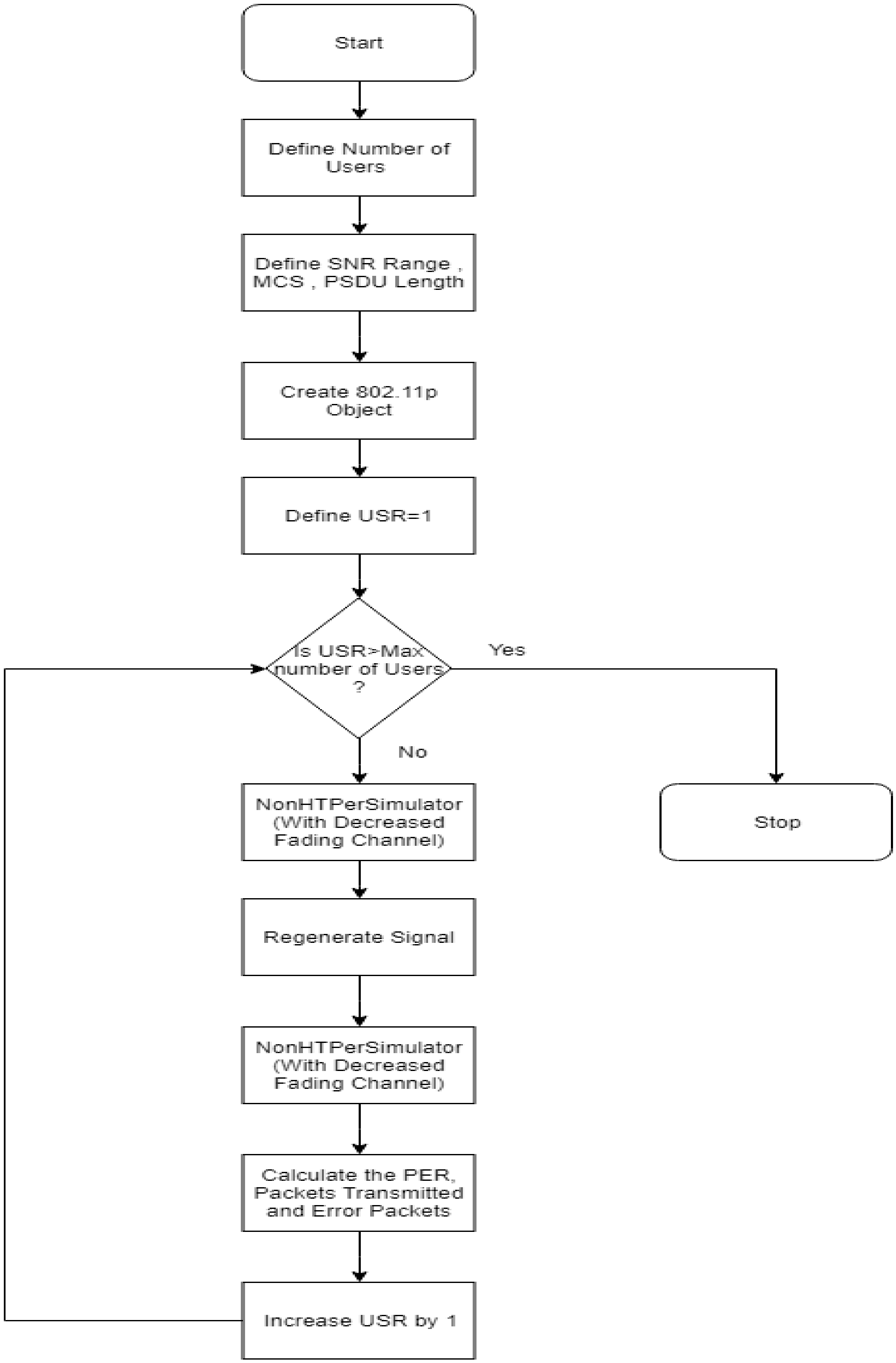

Figure 3.11: 802.11p protocol simulation model with Cooperative Communication

As the communication in our research through the path between sender and receiver uses Rayleigh fading channel. The relay node is set between the two keeping in view that the path delay of Rayleigh fading channel must get reduce [35]. This facilitates the packets not to get faded or dropped during its travel path from sender to receiver [57]. If the data travel path is longer enough, longer will be the fading margin for packets due to longer path delays and lesser path gain. This relay node is therefore, in this concept is supposed to be placed right in the center of the path [58] of data travel (as shown in Figure 3.10). This helps in reducing the path delay by half and increase path gain. So now, the data is first travelled from sender to relay node with half of the path gain of fading channel, and then the relay node scales and retransmits those packets received from sender and forward it to receiver using the same path delay and average path gain. The technique used by scaling the packets in reduced path delays and forward it to receiver defines "*amplify and forward mode of cooperative communication"*[43]. The benefit of this technique helps in reducing the path length for data travel to almost half by mutual sharing of resources through the relay channel, reduces path delay and maintaining average path gain to make sure that packets are not faded during longer path delays and provides quality reception and better outcome on the network as our result. Hence, enhancing Wireless Access in Vehicular Environment (WAVE / 802.11p) protocol for Vehicular Ad-hoc Network (VANET) using cooperative communication now gives better and enhanced calculated and simulated performance parameters (as discussed in above sections) [59].

CHAPTER FOUR

SIMULATION RESULTS AND PROTOCOL ENHANCEMENT

4.0 SIMULATION PARAMETERS:

This chapter discusses the outcomes of the simulation made for Vehicular Ad-hoc Network (VANET) protocol [60] in our designed network model for the performance parameters mentioned in section 3.1. This chapter comprises of two sections. The first section of the chapter shows normal simulation mode of Wireless Access in Vehicular Environment (WAVE) [61] protocol in our designed network model. The second part shows the outcomes of enhanced WAVE protocol for VANET using Cooperative Communication.

4.1 802.11P NORMAL SIMULATION

Following are the parameters used for normal simulation mode of 802.11p in our designed network model as discussed in section 3.3:

- SNR points range= 10:20;
- MCS = 4
- PSDU Length = 10
- No. of Users = 20
- No. of Packets = 1000
- No. of Packet Errors = 50

➢ 4.1.1 SNR-PER Graph

This section gives the outcome in Figure 4.1 as calculated Packet Error Rate (PER) with respect to the number of Signal to Noise Ratio (SNR) points simulated [38]. In this case, 1000 data packets are first created as discussed in section 3.3 and then are passed through

Additive White Gaussian Noise (AWGN) channel to be simulated on SNR points mentioned. Here, packets are simulated from SNR range of 10 to 20 with an interval of 1. Detailed results in the form of exact numeric values of Packet Error Rate (PER), number of packets correctly received at each SNR point and number of error packets [62] are discussed and given as outcome received on MATLAB command window in section 4.1.5.

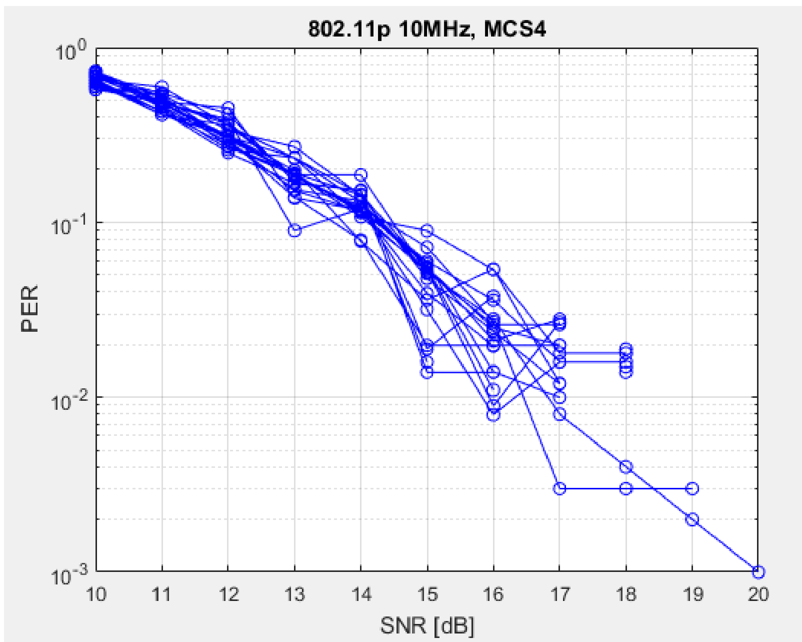

Figure 4.1: SNR-PER Simulation at 802.11p normal mode

4.1.2 Throughput in percentage per User

This section gives throughput in percentage of the network in Figure 4.2. The throughput we are getting against each user / node is being simulated using standard / normal conditions of 802.11p protocol [63] against the packets transmitted at each SNR point. We can clearly see that as number of users / vehicular nodes in Vehicular Ad-hoc Network (VANET) is increasing, the throughput across each user in percentage is being decreased. This is due to the fact in wireless networks that packets are being shared on the network with the increase in number of users, hence decreasing the throughput. The exact value of throughput in percentage against each user is mentioned as MATLAB command window output in section 4.1.5 after SNR-PER values.

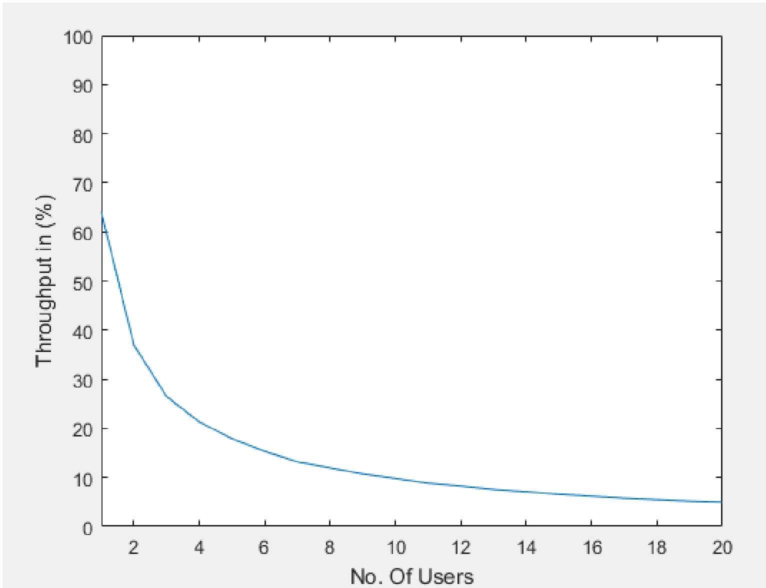

Figure 4.2: Throughput in % per user for 802.11p normal mode

➢ 4.1.3 Bandwidth Utilization

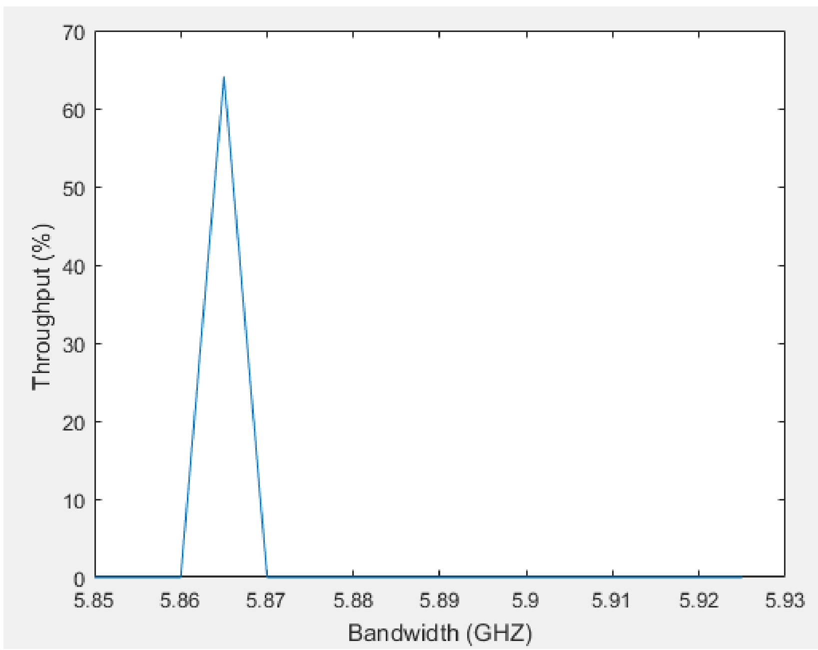

Figure 4.3: Bandwidth utilization at 802.11p normal mode

This section shows bandwidth utilization of 802.11p protocol against the highest percentage of throughput received on the network. As 802.11p uses 10MHz channel bandwidth in the frequency range of 5.85 GHz to 5.925 GHz [44,63,64], the exact utilization of its 10 MHz usage can be seen in Figure 4.3.

➢ 4.1.4 Latency per User

Network latency per user against the throughput received [62] on the network can be seen in Figure 4.4. As number of users on the network in increasing, latency per user in also increasing. This indicates that as the network get busier with the increase in number of vehicular nodes, it will take more time to share data packets between then as throughput across each user decreases.

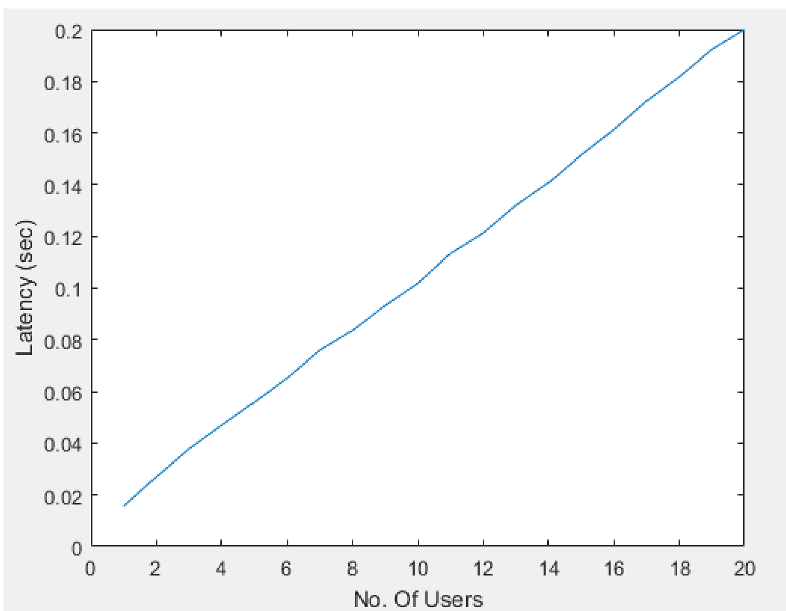

Figure 4.4: Latency per user for 802.11p normal mode

4.1.5 Data Results on Command Window for 802.11p Normal Simulation:

This section explains the output waveforms of the first four sections. These values are obtained as MATLAB command window outcome of normal simulation mode of

802.11p protocol. As discussed in methodology section of 3.3, the values of how packets are transferred at each SNR point against each user can be seen below. As 1000 packets are transmitted with 50 Error Packets at an SNR range from 10 to 20, below mentioned values in Table 4.1 give complete simulation range of each user at every SNR point.

Considering the below mentioned outcome of USER 1, 72 packets are first transferred at SNR value of 10, which gives PER of 0.708 as No. of error packets [65] received are 51 and PER is calculated by dividing number of error packets by number of packets correctly received [66]. It is to make clear that actually 72 packets are not transferred due to the presence of 51 error packets. Hence:

- *Number of Packets [52] correctly received = Number of Total Packets received at an SNR point – Number of Error packets received at that SNR point.*

Therefore, here for first value of USER 1 at SNR = 10, number of actual corrected packets received = 72 – 51 = 21.

Means 21 packets are correctly received and rest 51 are error packets [66] which is still present. Similarly, at SNR = 16 for USER 1, we can see that number of packets transferred has reached to its maximum limit as 1001. But number of error packets have started decreasing now to 28. This show that still complete 1000 packets are not transferred properly through an SNR range and correctly received packets at SNR = 16 using same formula mentioned just above is 1001-28 = 973 correctly received packets and 27 packets are still left. From here on, number of error packets which was maximum at packets = 0 started decreasing to correctly transmit total number of corrected packets [67] and at SNR = 20, number of error packet is reduced to 1 only mentioning that all 1000 packets are correctly transmitted now.

This is the reason of selecting SNR range from 10 to 20. Because packets at 802.11p non-HT configuration object starts transmitting packets from SNR = 10 and almost complete its transmission at SNR = 20.

Same mechanism goes for USER 2 in Table 4.2 and onwards till reaching maximum number of users. The only change we can see is that as number of user increases, total number of transmitted packets is being mutually shared between the users available on the network accordingly and so as its impact on SNR points simulated.

USER: 1

Table 4.1: Simulation values of User 1 in normal simulation mode

SNR value	Packets transferred	Packet Error Rate (PER)	No. of error packets received
10	72	0.708	51
11	107	0.477	51
12	172	0.297	51
13	269	0.190	51
14	451	0.113	51
15	987	0.052	51
16	1001	0.028	28
17	1001	0.008	8
18	1001	0.004	4
19	1001	0.002	2
20	1001	0.001	1

USER: 2

Table 4.2: Simulation values of User 2 in normal simulation mode

SNR value	Packets transferred	Packet Error Rate (PER)	No. of error packets received
10	70	0.729	51
11	98	0.520	51
12	189	0.270	51
13	275	0.185	51
14	437	0.117	51
15	501	0.058	29
16	501	0.014	7
17	501	0.010	5
18	501	0.000	0
19	501	0.000	0
20	501	0.000	0

And so on till USER 20…..

Table 4.5 describes performance parameters as received on command window of MATLAB for both simulation techniques in terms of Throughput comparison.

4.2 802.11P SIMULATION WITH COOPERATIVE COMMUNICATION

Same parameters as used in section 4.1 are used here. But for enhancement of 802.11p in our designed network model, user cooperation is used adding relaying [44] concept reducing path length and delays as discussed in section 3.4:

- SNR points range= 10:20;
- MCS = 4
- PSDU Length = 10
- No. of Users = 20
- No. of Packets = 1000
- No. of Packet Errors = 50

➢ 4.2.1 SNR-PER Graph

The response of user cooperation can be seen in Figure 4.5 in the form of SNR – PER graph as enhanced 802.11p protocol is now simulated here after implementation of cooperative communication. We observe more packets received at each SNR point with the implementation of this technique which is discussed in section 4.2.5 as outcome received on MATLAB command window interface as exact numeric values. It is to make clear that same number of packets are simulated even after incorporation of cooperative communication with same number of error packets and same SNR points to be simulated to get a comparative analysis between the actual normal mode present simulation results of 802.11p protocol and the enhancement made via user cooperation.

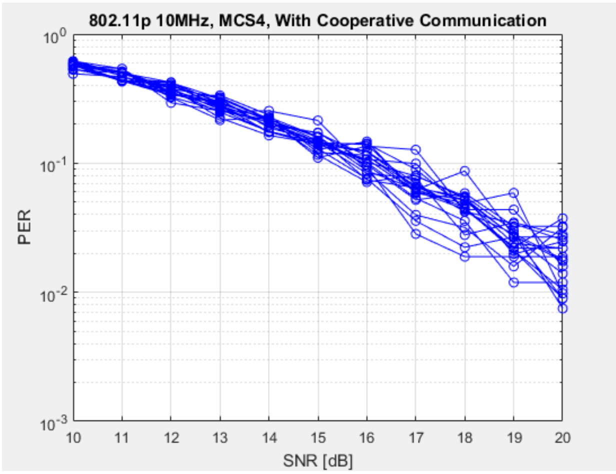

Figure 4.5: SNR-PER Simulation at 802.11p with cooperative communication

➢ 4.2.2 Throughput in Percentage per User

Network throughput [68] in percentage per user can be seen in Figure 4.6. Highest network throughput in normal simulation on a shared network was found 64%. But this throughput considerably increases to more than 90% when the node / users cooperates with the relay nodes incorporated. The detailed results as numeric values can be seen in section 4.2.5.

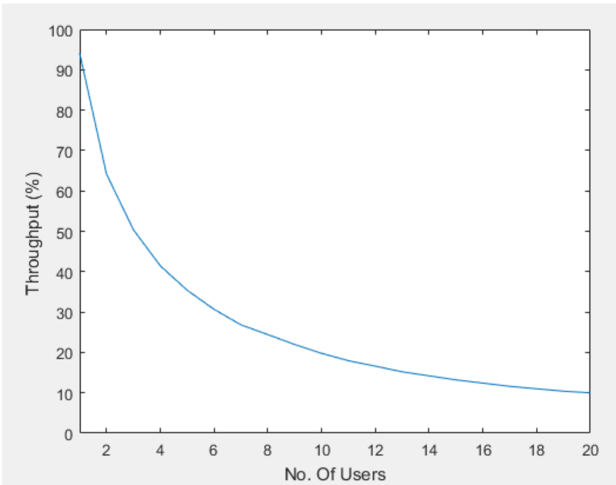

Figure 4.6: Throughput in % per user for 802.11p with cooperative communication

➢ 4.2.3 Bandwidth Utilization

The enhancement in bandwidth utilization [69] due to better throughput received in that same 10 MHz channel of 802.11p [70] in Figure 4.7 with incorporation of user cooperation. The channel in this scenario is also using that same range of 10 MHz between 5.86 GHz and 5.87 GHz for enhancement is in the form of better throughput against network usage.

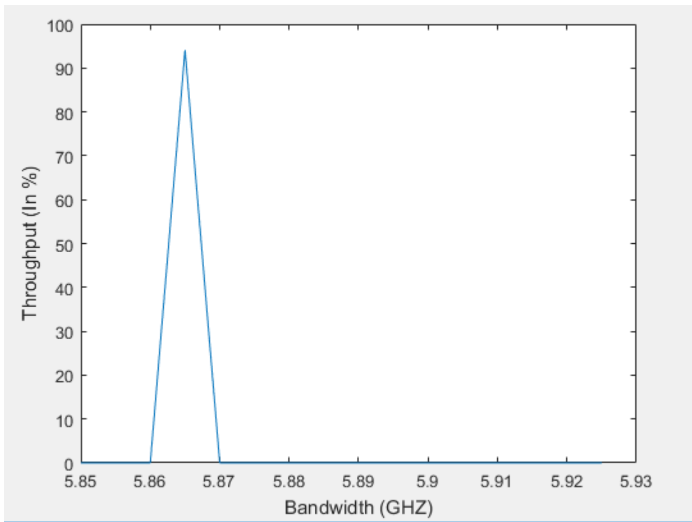

Figure 4.7: Bandwidth utilization for 802.11p with cooperative communication

➢ 4.2.4 Latency per User

User cooperation clearly shows a fair decrease in network latency per user in Figure 4.8 as compared to section 4.1.4. Likewise, the latency is increasing with the increase in number of users on a network and decrease in throughput [68] respectively. But the users need not to take longer time enough as earlier with the incorporation of cooperative communication and can be more quick and reliable with the help of relay nodes due to better throughput on enhanced protocol.

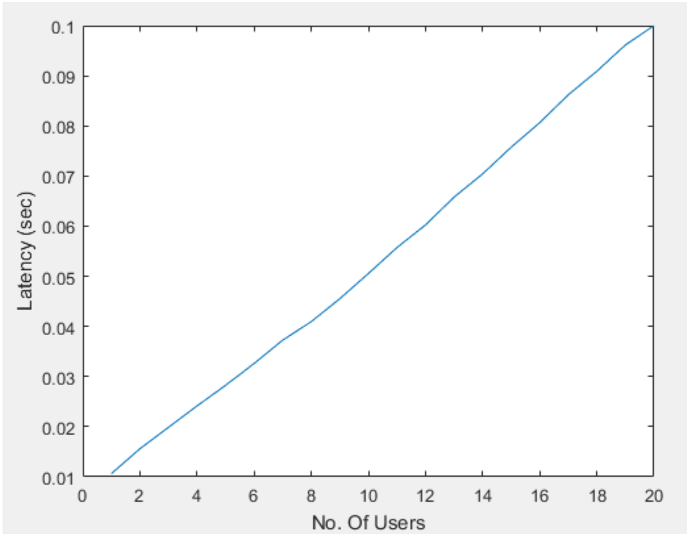

Figure 4.8: Latency per user for 802.11p with cooperative communication

4.2.5 Data Results on Command Window with User Cooperation:

After the implementation of cooperative communication for enhancement in 802.11p standard protocol, the results in this section as exact numeric values received on MATLAB command window interface shows a fair improvement [71] in the form of more number of packets transmitted at each SNR point. This can be checked and verified by observing any number of packets received at any SNR point for any USER below and compare it with the ones received in section 4.1.5 in normal simulation mode of 802.11p standard protocol.

Rest methodology in terms of number of packets received at an SNR point, number of error packets received and total number packets correctly receive are same. The only difference is due to the cooperation of packets received at an SNR point, as aggregated data packets due to relaying through Rayleigh fading channel via relay nodes.

USER: 1

Table 4.3: Simulation values of User 1 with User-Cooperation

SNR value	Aggregated Packets transferred after user-cooperation	Packet Error Rate (PER)	No. of error packets received
10	85	0.600	51
11	109	0.475	51
12	157	0.326	51
13	201	0.255	51
14	246	0.208	51
15	350	0.146	51
16	412	0.124	51
17	742	0.070	51
18	1001	0.042	42
19	1001	0.028	29
20	1001	0.018	18

USER: 2

Table 4.4: Simulation values of User 2 with User-Cooperation

SNR value	Aggregated Packets transferred after user-cooperation	Packet Error Rate (PER)	No. of error packets received
10	95	0.542	51
11	117	0.439	51
12	128	0.399	51
13	184	0.282	51
14	250	0.204	51
15	299	0.171	51
16	447	0.114	51
17	501	0.066	33
18	501	0.052	26
19	501	0.027	14
20	501	0.014	7

And so on till USER 20…..

Table 4.5: Throughput in percentage for both simulation techniques

Number of Users	Throughput in percentage with normal simulation	Throughput in percentage with user-cooperation
1	64.11 %	94.11 %
2	36.95 %	64.15 %
3	26.47 %	50.38 %
4	21.30 %	41.44 %
5	17.89 %	35.40 %

6	15.34 %	30.67 %
7	13.17 %	26.84 %
8	11.96 %	24.42 %
9	10.72 %	21.96 %
10	9.82 %	19.78 %
11	8.82 %	17.95 %
12	8.25 %	16.60 %
13	7.57 %	15.20 %
14	7.10 %	14.20 %
15	6.60 %	13.20 %
16	6.20 %	12.40 %
17	5.80 %	11.60 %
18	5.50 %	11.00 %
19	5.20 %	10.40%
20	5.00 %	10.00 %

CHAPTER FIVE

CONCLUSION AND FUTURE WORK

5.0 CONCLUSION:

The implementation of Intelligent Transportation System (ITS) [72] is a priority demand in almost any part of the world due to increased number of vehicles on roads. Specially in a country like Pakistan, where population is increasing day by day with limited resources to survive. Continuous jam-packed roads are very common nowadays which lead to an increase in travel time of vehicles from minutes to hours. Deadly accidents on highways due to smog or non-indication are no more any new thing that may suddenly have happened. This give rise to introduction of Vehicular Ad-Hoc Networks (VANETs) in such type of traffic environment.

This research focuses on the protocol used for VANET i.e Wireless Access in Vehicular Environment (WAVE) [73] which uses IEEE WLAN protocol standard of 802.11p. A type of Cooperative communication with modified functions are used on the designed network flow of 802.11p protocol in order to enhance its performance parameters and Quality of Service (QoS) [74] of Vehicular Ad-Hoc Network (VANET) [75]. This research contribution towards society may help in making Intelligent Transportation System (ITS) [76] even better, safer and faster as mobile communication between vehicular nodes of Vehicular Ad-Hoc Network becomes more reliable [50].

5.1 FUTURE WORK:

As this research focuses on the protocol to enhances performance parameters of Vehicular Ad-Hoc Network (VANET), leading towards hardware realization may contribute practically very well to society as its futuristic work. It is a fact that hardware of 802.11p [77] protocol is still in research and development phase. Hence, its hardware is not readily available in open market. In a country like Pakistan where hardly any vehicle moving on the roads are smart vehicles, a complete kit as a solution of VANET incorporation needs to be installed in these manual vehicles. It's up to the developer whether he uses normal WLAN standard kits (like the one using 802.11n standard Wi-Fi protocol) or develop a kit that solely work on 802.11p standard WAVE protocol filling this gap from market. This makes these manual old vehicles smart enough to communicate with each other and transform this heavily jam-packed and dangerous transportation system into an Intelligent Transportation System.

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