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TÍTOL DEL TFG: Vehicle to Vehicle (V2V) Wireless Communications

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Title: Vehicle to Vehicle (V2V) Wireless Communication

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Overview

This work focuses on the vehicle-to-vehicle (V2V) communication, its current challenges, future perspective and possible improvement.V2V communication is characterized by the dynamic environment, high mobility, nonpredective scenario, propagation effects, and also communicating antenna's positions. This peculiarity of V2V wireless communication makes channel modelling and the vehicular propagation quite challenging.

In this work, firstly we studied the present context of V2V communication also known as Vehicular Ad-hoc Netwok (VANET) including ongoing researches and studies particularly related to Dedicated Short Range Communication (DSRC), specifically designed for automotive uses with corresponding set of protocols and standards.

Secondly, we focused on communication models and improvement of these models to make them more suitable, reliable and efficient for the V2V environment. As specifies the standard, OFDM is used in V2V communication, Adaptable OFDM transceiver was designed. Some parameters as performance analytics are used to compare the improvement with the actual situation.

For the enhancement of physical layer of V2V communication, this work is focused in the study of MIMO channel instead of SISO. In the designed transceiver both SISO and MIMO were implemented and studied successfully.

Keywords: ITS, V2V, WAVE, OFDM, VANET, DSRC, SNR, BER, PER

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Resumen

Este trabajo consiste en estudiar la situación actual de comunicaciones entre vehículos, problemas actuales y posibles mejoras.V2V, comunicación vehículo a vehículo está caracterizado por factores como entorno dinámico, alta movilidad, efectos de propagación en dicho ambiente y también dispositivos utilizados para comunicación. Esa peculiaridad de comunicación V2V, eleva la complexidad en el estudio de su funcionamiento como por ejemplo desarrollar un modelo concreto para funcionamiento global.

En este trabajo, primero nos basamos en el estudio de situación y uso actual de las comunicaciones V2V conocidas como Vehicular Ad-hoc Network (VANET), donde nos basamos en investigaciones actuales para tener una visión sobre protocolos, estándares y parámetros de uso actual.

En una segunda parte, una vez situado en el contexto actual de este sector, nos basaremos en las posibles mejoras con el objetivo de desarrollar una comunicación eficiente y estable. Como estándar, para V2V se utiliza transmisión OFDM por esa razón hemos diseñado un sistema de comunicación adaptable basado en OFDM. Se utilizan algunos parámetros para estudiar el rendimiento en la situación actual y también para el caso de posibles mejoras.

Como el objetivo es mejorar la capa física de V2V en sentido de la recepción de la señal, en este trabajo nos basamos en la utilización de canal MIMO en lugar de SISO. En el diseñado sistema se ha implementado y estudiado ambos casos de uso SISO y MIMO.

Keywords: ITS, V2V, WAVE, OFDM, VANET, DSRC, SNR, BER, PER

Dedication

For my parents for the love and inspiration.

For my sister and brother for the courage.

For my friends for the support.

For Dr. Lluis Jofre Roca for his help and suggestion,

Without which this work wouldn't be what it is.

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INTRODUCTION

For their existence in term of business, innovation and human's desire, everything associated to mankind should adapt towards the futuristic changes. Vehicles are one of the most important need for human being in this time and to continue to be important beside of these changes vehicles should be more than a driving and riding vehicles. Autonomous and completely electric vehicles are reality in today's market [**1**]. Following this evolution, in few years we may see a vehicle without steering, it can rather be a meeting place which drives on its own capacity. To achieve this milestone, vehicular communication should be developed for making them secure and reliable. Many researches and studies are being done to implement Vehicular communication. Due to its extensive application, vehicular communication had emerged as one of the important research areas in wireless communication.

For this reason, this work as a Telecommunication Engineering final degree thesis is done in the field of Vehicular communication in the Signal Theory and Communication (TSC) department [**2**]. In which we focus on the improvement of vehicular communication to make them reliable, secure and efficient.

Starting with the analysis of existing studies and researches, in one hand this project tries to have the state of art of vehicular communication and on the other side this project focuses on the improvement of the existing situation. For this improvement some part of V2V communication are simulated by using MATLAB in order to study the performance of the improvement that is proposed in this work. This performance is evaluated for different vehicular communication scenarios to have a generic result.

This thesis is divided in 5 chapters, where first two chapters are about the state of art and communication parameters of Vehicular specially V2V (vehicle to vehicle) communication. In the third chapter, implementation and simulation of V2V communication is explained. Performance metrics are evaluated and analyzed to study the behavior of V2V communication in current and enhanced model. These performance metrics are, path loss or channel gain, Signal to noise ratio, Bit Error Rate and Packet Error Rate. To get the Signal to Noise Ratio, measurement based realistic communication model is used. The fourth chapter contains the conclusion of the work and suggest some workings areas regarding the improvement of V2V communication which may be the continuation of this work.

Chapter 1. V2V Communications

1.1. Introduction

As the vehicles are being important and primary need for humans, it is essential to develop a safer and better transportation system to fulfil the many objectives. On one hand, some of these objectives can be for safety purpose like reducing the fatalities while using vehicles and in other hand these objectives can be for improvement of existing manners and lifestyle like connected car for luxury purpose. But the main purpose for its development should be to enhance safety and eliminate excessive costs of transportation. This cost can be decomeposed in terms of money, time and simplicity.

As the part of Intelligent Transportation System (ITS). Vehicular communications systems are network in which vehicles and other infrastructure like Road Side Units (RSU) communicates with each other in order to provide regarding safety warnings and traffic information in real time.

1.1.1. Necessity

Automobile industry is increasing rapidly, reaching upto 9.3% more sales in EU compared to last year [**3**].Also with this growth, Automobile industry is changing everyday with more concern about safety, sophisticated luxury and autonomous. For the full autonomous capacity, every vehicle should be able to communicate with another one to gather and provide information about traffic information, warnings and concerns and also its driving plan like maneuver.
For this purpose V2V communication is indispensable and essential for future vehicles.

Vehicular users, both drivers and passengers are seeking something new, in the product they buy, either may be for the purpose of safety or may be the purpose of commodity. Due to this tendency, manufacturers are offering various alternatives regarding the demand especially in terms of *infotainmaint* (information and entertainment).

1.1.2. Vehicular communication

Today’s vehicles have increasing communication modules, internal and external ones, whatever may be the final propose. But as we move toward the world of Internet including Cloud based systems and services, Big Data, and Machine Learning, every day connected “smart” cars are securing there position in our lifestyle.

Internal CAN, Bluetooth, NFC, GPS, Broadband internet and Cellular data communications are almost essential and available these days. Many of these services have been used for the commodity purpose but as we move towards autonomous driving safety purpose communication should be given high priority to achieve this milestone. For this purpose many standards and specifications regarding communication between vehicle and other infrastructure like another vehicle, and Road Side Unit (RSU).

Previously, many technologies have been developed and deployed to manage and assist transportation. But many of them were outdated due to the continuous exploration of possibilities by newer techniques. Due to the increase in need of intelligent transportation systems, vehicles need to have computing, communication and sensing abilities. These functions will enhance transportation safety and efficiency. The key aspect of vehicular communication system is to expand the horizon of information relevant to driving safety, transportation efficiency, and thus providing and integrating information services as well as improving the service quality.

1.2. Architecture

Based on its architecture, vehicular communication is divided into three main types which are V2V, V2I and V2X. Also many variation and derived communication types are defined such as Vehicle to pedestrian (V2P), vehicle to Network (V2N) etc. in this work we will associate them as V2X.

1.2.1. V2V Communication Model

Wireless vehicular communication, lets automobiles communicates each other about their activity, using spectrum region of 5.9 GHz.The standard followed is IEEE 802.11p and commonly known as WAVE (Wireless Access for Vehicular Environment) in United States [**4**].

V2V is a mesh network, meaning every node (vehicles) could send, capture and retransmit signals across the medium range. So the network is deployed mainly according to the vehicular density and infrastructural situation.

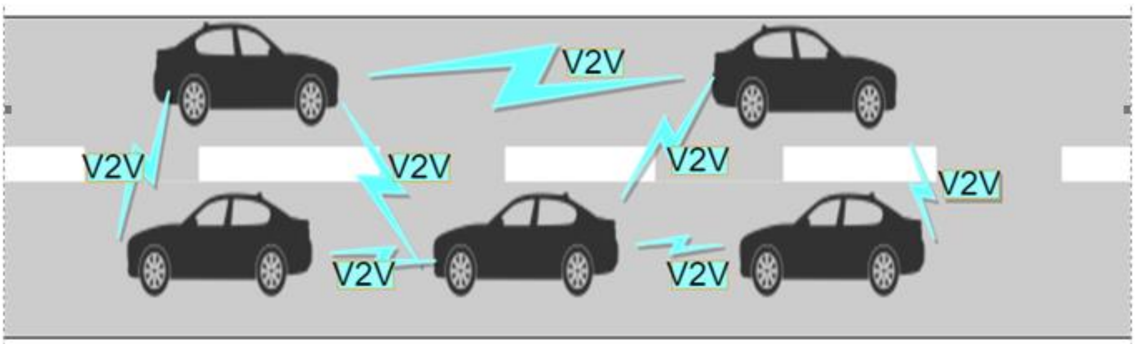

Figure 1: V2V communication scheme

In V2V, communication mechanism is performed by OBUs (On Board Units) which are installed in vehicles. This equipment is responsible for data exchange and data processing. Several standards are present and being used for V2V communication such as Wi-Fi, Bluetooth an Ultra-Wide Band (UWB).But lately, V2V communications are performed using IEEE 802.11p WAVE which operates at 5.9GHz.

1.2.2. V2I Communication Model

V2I provides communication services for critical safety and also for other operational purpose between vehicles and roadside infrastructure. Developed mainly for the purpose of enhancing traffic management and intelligent traffic system by periodically exchanging information between vehicles and infrastructural nodes such as RSU.

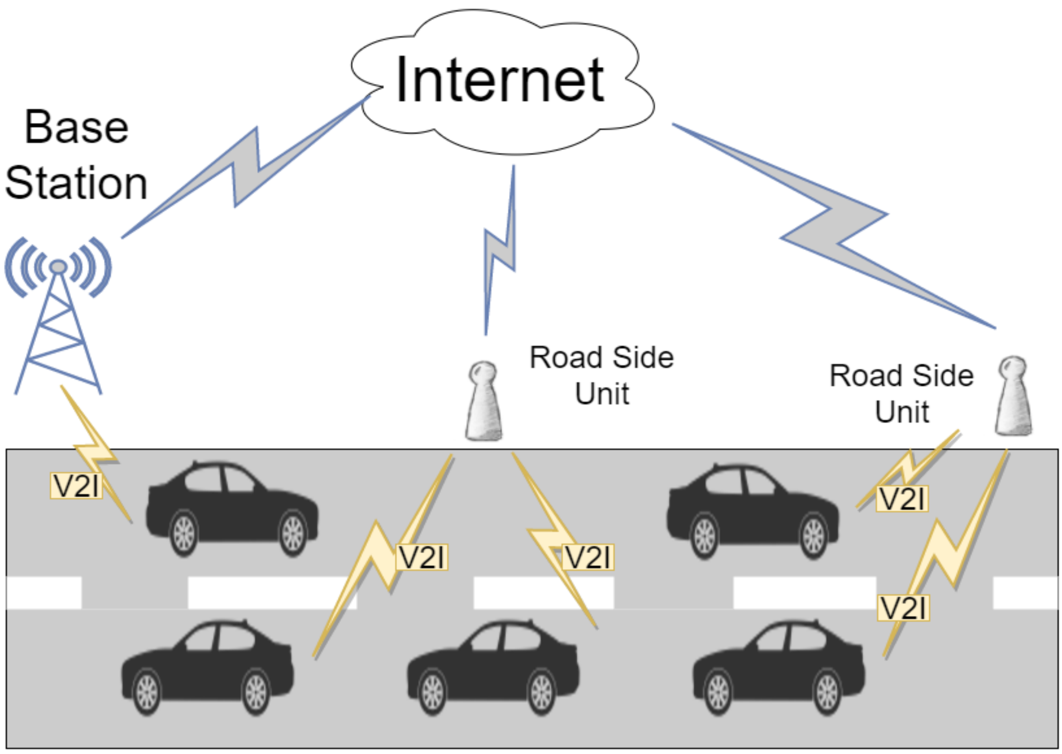

Figure 2: V2I communication scheme

Road Side Unit (RSU) are the main part of V2I communication model from where vehicle exchange the information which may work different according to the technology behind V2I communication, for example RSUs can be repeaters or base stations if cellular network is used.

1.2.3. V2X communication Model

V2X communications is a communication scheme with a intention of connecting vehicles to other external objects like pedestrians, RSU, traffic and network infrastructures and also with other vehicles by the means of communications that may be cellular network, wireless communications like Bluetooth, RFID beacons or Satellites. RSU plays important role as they are the point from where downlink and uplink information is exchanged with vehicles and other infrastructures.

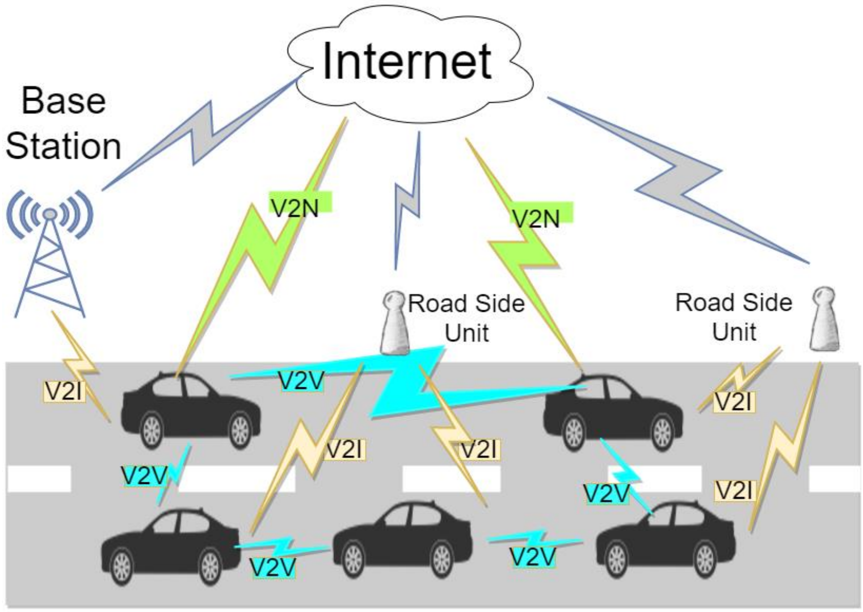

Figure 3: V2X communication scheme

In figure **3**, all of the vehicular communications are illustrated, where V2V forms a small part of it as many applications and service are provided through the V2X and V2I, from which whole environment's situation can be achieved because of its connection architecture. Real time information and data are also available which enhance the transportation situations such as in case of traffic jams, accidents, management of traffic infrastructures etc. The use of this technologies are being used hugely for smart cities.

1.3. VANET Standards

DSRC system is specifically designed for vehicular networks which enables short and medium range communication and is standardized as IEEE802.11p which is an approved amendment to the IEEE802.11 standard to add wireless access in vehicular environments (WAVE).This standard is an enhancement to previous standards of wireless communications IEEE802.11 for supporting stable communication service for Intelligent Transportation Systems (ITS).

Table 1: Frequency allocation for V2V communication

Region	Frequency Bands (MHz)
North America	5850-5925
Europe	5795-5815, 5855/5875-5905/5925
Japan	755.5-764.5, 5770-5850
China, India, Singapore	Studying allocation/allocated in 5.9GHz band

This standard specifies the above enhancement for data exchange between vehicles and also with infrastructures in the licensed ITS band of 5.9GHz (5.85 – 5.925 GHz) and also known as a base of European standard for vehicular communication known as ETSI ITS-G5 [**4**].

1.3.1. Description

IEEE802.11p, with Bandwidth of 75 MHz, is defined for vehicle-based communication networks, particularly such as toll collection, vehicle safety services, and information purpose and commerce transactions via vehicles. In Europe it was used as a basis for ITS-G5 standard, supporting the GeoNetworking protocol for vehicle to vehicle and vehicle to infrastructure communication which is standardized by the European Telecommunication Standards Institute group for Intelligent Transport Systems **[5**].

Wireless Access for vehicular Communications (WAVE) is known as American standard for same purpose working on same frequency band with similar parameters.

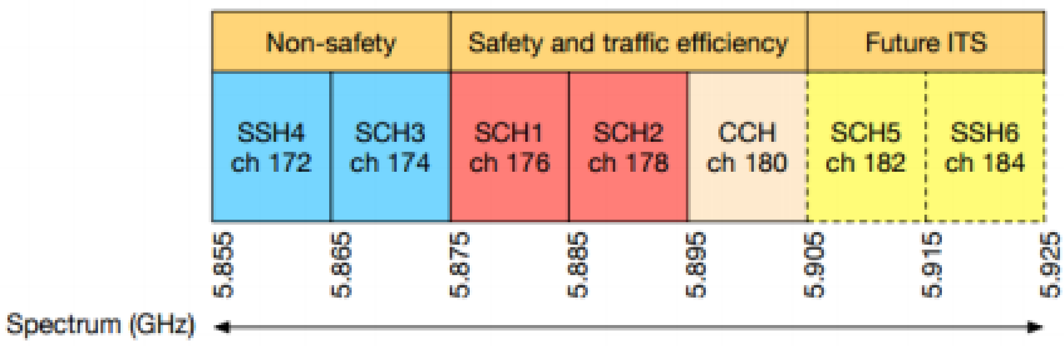

Figure 4: Channel Distribution in IEEE 802.11p

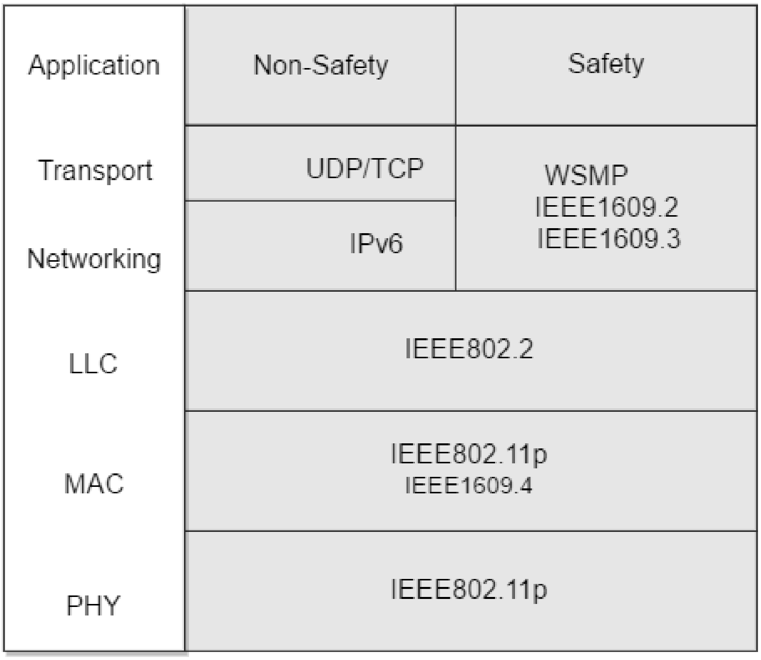

Figure 5: Standards and protocols of VANET

IEEE 802.11p only adopts the physical layer with OFDM on 10-MHz channels in the 5.9GHz frequency band, also three channels are allocated to be used with following bandwidth: 5MHz, 10 MHz and 20 MHz. The 10 MHz channel is designated for safety purpose in VANET communication [**7**]. Compared to the 20-MHz Wi-Fi OFDM PHY, the subcarrier spacing and the supported data rate of IEE802.11P are halved while its symbol interval including cyclic prefix (CP) is doubled. The OFDM channel parameters for the given channel are shown in table 2.

Table 2 : Parameters of OFDM channel in WAVE

Parameters	Values
Frequency Band	5.9 GHz
Channel Bandwidth	10 MHz
Supported Data Rate (Mbps)	3 ,4.5, 6, 9, 12, 18, 24, and 27
Modulation	BPSK,QPSK,16QAM and 64QAM
Channel Coding	1/2 , 2/3 and 3/4
Subcarrier Numbers	48
Pilot Subcarrier Numbers	4
(Subcarrier + Pilot Subcarrier) Number	52
Subcarrier frequency spacing	156.25 KHz
Guard Interval	1.6 µsec
(Symbol + Guard) Interval	8 µsec

The Signal can be modulated differently among modulations such as BPSK, QPSK, 16 QAM and 64 QAM. Based upon the studies in [**6**], for this work QPSK will be used due to its better performance in VANET communication.

1.3.2. Development

As technology is moving towards *data-communication,* each day new applications, services designated to make our livelihood easier are available based on internet and data communications. Every Spaniard spends an average of 260 hours a year in steering, which is equivalent to 11 days [**8**].Communications has been important for the consumer (driver in this case) either it may be external one from the driving situation (Social networks, Contacts circle etc.) or the internal one of traffic situation on including interactions of drivers towards vehicle. Those inter-traffic situations are useful to avoid the accidents and also to exchange the warnings and safety precautions information's among the users.

1.4. Current status

Taking account on this car manufacturers are moving towards connected cars, so self-driving autonomous cars are real things these days. Single device in cars can have various communications services in the same device such as Smart Communication Module (SCM) developed by Ficosa and Panasonic which offers LTE, Wi-Fi, AM and FM, DAB and GNSS positioning for each specific market and the mandatory emergency call in various countries **[9**].

The industry has been developed quite well in V2I communication rather than the V2V communications. Some of the reasons behind this lag are as below:

- *Less Spectrum available for efficient communication*

  For the V2V Communications 75 MHz is purposed for all purpose and only 10 MHz for safety purpose[6], which is extremely low for WAVE as the networking scenario is very random and many propagations factors like Multipath propagation, Doppler shift etc. have huge effect. One of the example can be a vehicle travelling with maximum speed in a highway tunnel. Due to this very reason V2V communication is not very warmly welcomed by the car manufacturers as proper Quality of Service (QoS) is not to be guaranteed in this case. In the context of V2V communications where many users (cars) can be concentrated in small places (for example, in roundabout due to traffic lights or in case of traffic jams) increasing the transmitting power will not make huge improvement in parameters like Signal to Noise Ratio (SNR), Signal to interference plus Noise Ratio (SiNR), so the main current constraint of V2V communications is less Spectrum which is being discussed by authorities like US Department of Transportation [**10**].

- *Lack of strict regulations imposed by authorities*

  Authorities and Regulating bodies have huge impact on every services that have public implementations, in case of V2V communication it's still a matter of doubt on how is to be implemented in our highways. From basic services to other hypothetical cases are still to be analyzed by the authorities in term of V2V communications. As the automobile industry is approaching towards autonomous driving, where V2V communication is to be essential, topics like security (authenticity, encryption) of information, service compatibility between whole traffic are not well developed yet.

- *Absence of compatible products/service among car manufacturers*

  Many vehicles, following the innovation in this modern industry have implemented "connected cars" which doesn't refers to V2V but is more related about the car which is able to get connected by using other infrastructures like cellular communications, GPS and also by the means of Low power communications like Bluetooth, Radiofrequency etc. These types of services, some of them sophisticated, are developed by each manufacturers which are not compatible with other one, resulting *non V2V* communications.

- *Presence of alternative services*

  In today's context, Mobile technology is growing highly making data communication service as mostly used one. Network Operators and other parties related to the Data communications are developing 5G communications and have achieved cumulative 20Gbps a year ago [8]. Defined as Internet of Things (IoT) network, 5G wants to include V2V communication in its environment. With some advantages like Cloud based data, Data Mining, Machine Learning, computer visions etc. can be useful for the autonomous driving so that it may be a hard rival to fight for V2V.

  Beside of 5G, many communication services, like LTE, Radars and Lidars, to make vehicular network can also be used as alternatives. Some of them are present these days with enhanced applications for user's safety and luxury. These types of communications, not designed for VANET have huge advantage in comparison to VANET in term of theirs capacity to communicate with external infrastructure like RSU, BS and then services like clouds, data centers etc.

So, currently V2V is in its initial phase of practical development and is facing the V2I which wants to take place of V2V including it to provide better and complete service of V2I.

1.4.1. V2V versus V2I

Although V2I and V2V were defined for different purpose, today V2I is also approaching to include V2V communications to make a single system with various aspects of benefits. Although V2I may stand as single communication providing multiple services but it may not be as reliable and strong as V2V for VANET in terms of latency, efficiency and authenticity. In current situation these two technology can be compared in below factors:

- *Achievement*

  It's clear that 5G is being real each days and it's trying to include V2V inside its ubiquitous network scheme but time to reach to this step will be higher than to achieve V2V. For V2I, many external communication factors are more essential than the Vehicular communications. RSU, BS, Technology including all related services are to be developed along with V2V itself. Some Limited services of V2I are offered these days by car manufacturers but they are not even closer to replace the V2V due to the diverted objectives for which products like SCM were implemented.

- *Communicating* devices

  To make V2V communications fully operating, each and every cars should be equipped with proper communicating device supporting defined compatible standards and protocols. In other part for V2I communications, including V2X, modules and accessories would work as they need to communicate with pre-existing technology like 5G, 4G etc. Accessories and modules supporting these technology can work so vehicles won't require full communication schematic (Antennas, Feeding, Mod-Demodulators etc. used in V2V).For any of these technology, communication device to be used are known as On Board Units (OBUs) [**11**].

- *Communication architecture*

  For V2I, Communications architecture is more centralized than of V2V where distributed communication (VANET) is defined. For V2V communication, many factors will not fulfil the requirements due to centralized communication, such as latency. Data traffic capacity between back end nodes, routing and coverage can also be taken as counterpart for these types of architecture.

  V2V would be more distributed, one car communicating with few others within some range and so on. Latency, a most important factor, for V2V latency is at least two times lower than in V2I due to the delay in uplink and downlink communication.

- *Authenticity*

  Every communication should be secure and reliable. Receiving party should know that in ongoing communication the transmitting party on another side is authenticated and reliable. More especially in V2V communication for safety purpose authenticity is very important and essential.

  For V2X communication, being a centralized communication either centralized in large scale or better in local scale for example one node, the central element can work as authentication server and only transmitting messages from authenticated sources to other ones but in change in V2V communication, this central element is not present due to its architecture. Authentication process should be done by vehicles before exchanging the information or better some other mechanism should be implemented such as use of algorithms to know give the importance in received messages. This types of algorithms may include methods like approximating the transmitting car's distance be determining angle of arrival and path loss.

- *Implementation cost*

  As estimated by US Federals authorities [**12**], V2V communication would have estimated cost of only about $350 per vehicle in 2020, or about 1.1 percent of the current average cost of a new car which is expected to decrease with years. In comparison with V2V, V2I would have more implementation cost because of other supporting networks fulfilling compatibility between them, external infrastructures like RSU, BS and repeaters. For example, implementation of 5G in motorways and in rural environment only for the purpose of V2I wouldn't be efficient in term of cost and results.

- *Involved parties*

  It is clear that, Transport authorities, car manufacturers and related parties are moving forward in V2V. But to develop the V2I, they need to include network operators and related parties for the development. Data providers will maintain their approach of merchandising data service and related products. If the vehicular communication is to be done through V2I, not only vehicle manufacturers would have principal role, there will the huge involvement of network operators as they will provide the network access. This involvement will be in terms of network infrastructure deployment and also an association of V2I with other communication networks.

1.5. Challenges

Once the current status is described above it is clear how V2V communication still is at development phase even though it came to discussion more than 10 years ago, various articles related to DSRC, VANET were published during 2006 and a patent related to MANET, VANET was filed in 2001 [**13**].Complex Network topology leading inefficient communication in terms of parameters like SNR, BER and PER.

Because of the complexity in topology and huge scale of V2V communications latency is the most effected parameter mainly due to MAD (MAC Access Delay), protocols like CSMA/CA, STDMA and enhanced version of these protocols are being studied but the radio channel performance is quite low and is to be improved for better communication. Although CSMA/CA is being used in family of IEEE 802 [**14**], alternative and dynamic protocols may replace it to achieve that improvement [**15**].

Another Challenge, that is to be studied in this project, is communication efficiency in physical layer level. Either the designated bandwidth or better transmission/reception capacity should by increased to enhance the physical layer. The established challenge for this project is to improve the communication efficiency in terms of transmission and reception by the means of MIMO Antennas under the same established conditions for other parameters like Bandwidth, Transmission power etc. To overcome this challenge, advantage of MIMO system over SISO system will be studied and discussed in this project.

CHAPTER 2. Communication Parameters in V2V

V2V communication has its own communication scenario and parameters which are different from other wireless communication. To establish a stable, reliable and efficient system, these communication parameters should be studied deeply. The main problem for V2V communication, regarding its parameters would be construct a single communication model which can be applied in all situation of V2V environment due to its complex and dynamic network topology i.e. VANET.

2.1. Radio Propagation Characteristics

Wireless communication is characterized by the property of radio propagation depending upon the scenario. In case of V2V, this scenario can be urban city, rural highway or tunnels. Depending upon these scenario behavior of RF propagation varies and notable change in communication is occurred for examples in parameters like path loss, SNR, signal fading etc. Some of the main propagation characteristics that may have significant effect in V2V communication are as below.

2.1.1. Propagation loss

Vehicular communication will have its higher application or use in populous urban area and surroundings as there would be more traffic. In this type of scenario, radio wave propagation is known as “street-canyon” propagation, where waves propagate along the road. So for V2V communication as a basic model of the scenario, which is typical for such case, ITU recommended P.1411-5 Street propagation model is used as a standard model worldwide. But depending upon the application like safety purpose or better other specific ones, several individual propagation models are being developed and used.

2.1.2. Fading

In wireless communication, due to multi-path propagation fading occurs due to which signal reaches the receiver from several different paths with different time delays and gains. These type to time delays causes additional phase shifts to main signal component. Due to multi-path propagation the resulting signal in receiver is the combination of main signal with other ones. Fading can explained in terms of scale, large scale fading and small scale fading.

In V2V environment small scale fading, caused due to reflectors and scatters changing the amplitude and phase of the signal, can be defined as Rayleigh distribution and Rician distribution. Another type of fading, is large scale fading which occurs mainly due to shadowing but in case of V2V small scale fading is more likely to happen than the large scale.

2.1.3. Reflection, Diffraction and Shadowing

For the V2V scenario P.1411 model [**18**] is supposed to predict propagation loss in street canyon environment considering reflection, diffraction and shadowing by the surrounding obstacles. Some of these effects also contributes for fading. Thus, if not specific case like two vehicles separated by obstacle which is very closer to the transmitter and receptor, these type of propagation characteristics should be considered differently.

2.1.4. Doppler Shift

Depending upon each scenario, received signal would be affected due to Doppler shift. In the simple case of communication between two vehicles, only by the movement of one vehicle with respect to another can cause the Doppler shift changing the magnitude of the signal.

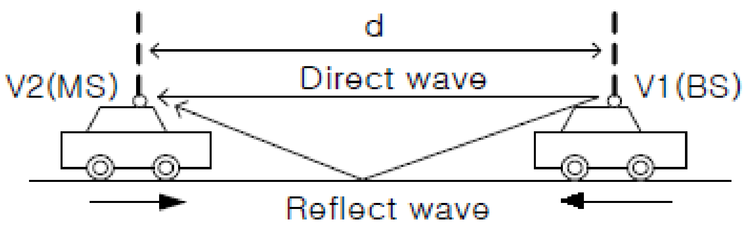

Figure 6: Phenomenon causing Doppler shift in V2V

For two moving vehicles, Doppler shift in received signal can be calculated as indicated in equation 1.1.

$$F_o = F_f \frac{C \pm V_1}{C \pm V_2} \tag{1.1}$$

Where, F_o is Doppler shifted frequency, F_f is original frequency, C is velocity of light, V_1= is speed Vehicle 1 and V_2 is speed Vehicle 2

Using above formula (1.1), frequency shift due to Doppler effect can be obtained for each scenario. For just two vehicles we can have various possibilities of their relative velocity, for example both vehicles moving in opposite direction or in same direction. To study the Doppler shift and its effect in V2V propagation, this work will assume that both vehicles are moving in opposite directions, in which Doppler shift is to be worse than in other cases. In this case above formula is changed to.

$$F_o = F_f \frac{C + V_1}{C - V_2} \tag{1.2}$$

Using this formula (1.2), following Doppler shift is obtained for each scenario.

Table 3 : Doppler shift in V2V scenario

V2V Scenario	Doppler Shift [Hz]
Highway	1311.11
Urban	546.3
Rural	327.78

In the table 3, we can see the Doppler shift is different in each scenario due to the velocity of vehicles. Maximum permitted velocity is assumed to study the worst case.

2.2. Antennas

V2V environment is intended to have small range of communication compared to Mobile communication or other related to infrastructures used by V2I. So, Communication device like antennas should not be essentially directive, Isotropic antennas are more suitable for communication in the maximum range of 1000 meters. Directional antennas also can be used for better coverage for every diverse scenario that V2V communication have.

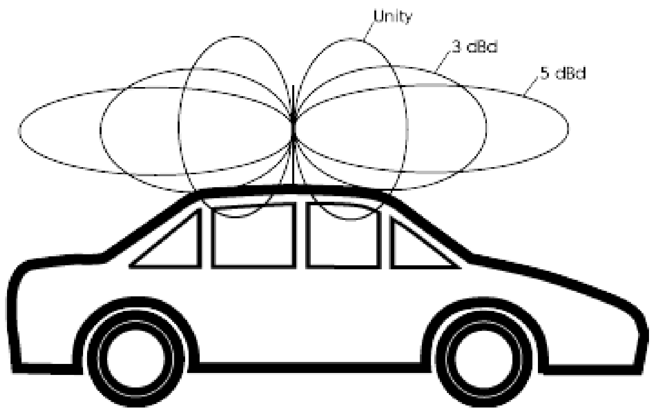

Figure 7: Possible antenna location in vehicle for V2V

As the objective of V2V communication is to reach to make the vehicles communicate with each other making them capable of communicating with vehicles that may be in its surrounding. To do this, antenna with omnidirectional radiation pattern in the horizontal plane is to be used.

For the best case, use of monopole antenna or better patch antennas can be used. Patch antennas can be better in the case of space that is to be occupied by antenna. These two antennas are considered as the best option for V2V communication.

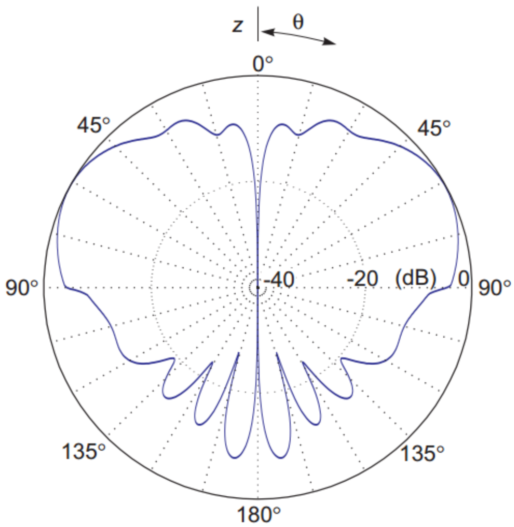

Figure 8: Radiation pattern of Monopole antenna

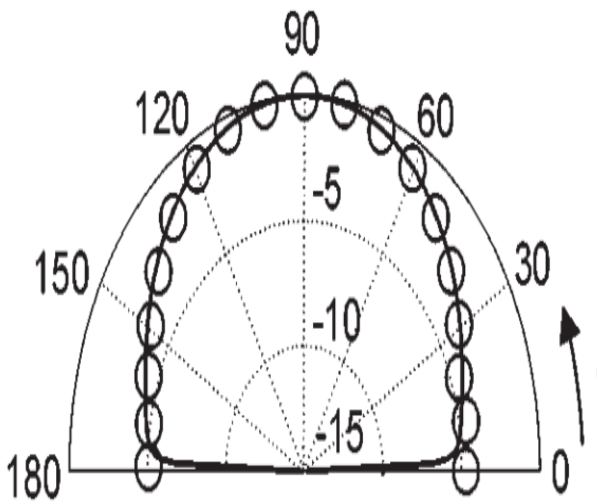

Figure 9: Radiation pattern of Patch antenna

*Theses radiation pattern are taken from the book Antenna [**16**].*

As the communication is to be made in horizontal plane, for θ = 90° or ϕ = 0°, there is certain loss in these antennas. In the case of monopole, this loss in gain due to the effect of finite ground plane. In the figure 8 we can see that, for horizontal plane the gain is around 4 dbs less than in the vertical plane.
For the case of patch antenna, the radiation pattern is as in figure **9** and for the case of θ = 90°, radiation value can be calculated as:

$$E(\theta) = 20\log(cos\frac{\pi \times L}{\lambda}sin\theta) \quad (1.3)$$

Where L is length of antenna which can be expressed as, $\boldsymbol{L} = \frac{\lambda_{eff}}{2}$, and effective wavelength $\boldsymbol{\lambda_{eff}} = \frac{\lambda}{\sqrt{3}}$. So the length of patch antenna is, $L = \frac{\lambda}{2\times\sqrt{3}}$
For the value of θ = 90° (horizontal plane), we can obtain the approximate gain of -4 dBs [**16**]

For this work, this gain will be assumed for both transmitting and receiving antenna. Antenna’s location in the car is also an important for a better communication in terms of radiation. Normally the best idea for cars, is to install the antenna in the roof of vehicles making the roof ground plane. So for this project we assume the antenna with a height of 1.5 meters above the ground level.

To improve the radio propagation through the V2V channel, antennas can be used differently for example simple or multiple antennas. Use of Multiple antennas (MIMO) will be studied in this project to enhance the physical level of V2V communication.

2.2.1. SISO

SISO, standing for Single Input Single Output, is a conventional radio system where single antenna is used for transmitter and also receiver. This system is simple one but can be vulnerable due to multipath effects which may effect in data speed and in error rates.

Signal propagation over wireless channel is characterized into three statistically independent phenomena named deterministic path loss, small-scale fading and large-scale or shadow fading. Path loss is the expected (mean) loss at a certain distance compared to the received power at a reference distance. The wireless signal travels through different paths to reach to receiver with different characteristics so called multipath propagation. While_they are simpler than MIMO transmission system, the efficiency is quite low as compared to MIMO especially for the case like V2Vwhere multipath propagation is a determinant characteristics.

2.2.2. MIMO

This effect of multipath propagation can be improved by the use of multiple antennas either in one side or in both side hence called Multiple Input Multiple Output. MIMO provides considerable advantages including wider coverage are, enhancing multi fading environment and improving data throughput. Currently, providing high data rate at high quality of service (QoS) in VANET is quite challenging.

MIMO is a technique of sending or receiving more than one data signal simultaneously over the radio channel by exploiting the multipath propagation. For this exploitation, 3 main techniques are used i.e. precoding, spatial multiplexing and diversity coding. MIMO can be classified into two main categories smart antennas and spatial multiplexors. Smart antennas uses diversity gain, array gain and interference suppression to offer an increased signal to noise and interference ratio (SNIR) where each antenna sends the same signal but it has a simple gain and delay which is set appropriately to obtain better

SNIR. Main advantage of these techniques are spectral efficiency, greater range or decreased latency. Spatial multiplexors increase channel capacity directly where a transmitter sends independent sub-stream signals with N transmit antennas and are received by N antennas.

$$\begin{bmatrix} y1(t) \\ y2(t) \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \cdot \begin{bmatrix} x1(t) \\ x2(t) \end{bmatrix} + \begin{bmatrix} n1(t) \\ n2(t) \end{bmatrix} \quad (1.3)$$

Where Xn(t) is transmitted symbols vector for n antenna, yn(t) is received symbols vector, h_{mn} is channel characteristics matrix for channel associated with m and n antennas and N is noise vector

2.3. V2V Communication Scenario

Vehicular communication doesn't have single environment on which certain parameters and conditions can be defined or established. Depending on the magnitude of traffic density, infrastructural structure like highways itself, surrounding environment, different scenarios can be defined. Mainly based upon the traffic density, 3 different type of scenario for V2V are defined to analyze the communication parameters and their possible impacts. The communication between vehicles, wireless communication is has also effects of other direct and indirect factors like, driving rules and regulations, driving conditions.

2.3.1. Urban

Urban areas, where the presence of vehicles is high due to concentrated population is the main area of application. Urban scenario may be more diverse than other one as it may have higher variation like infrastructures, underground roads, vehicular stops and stations etc. Depending upon the range, for example for a supposed minimum range of 300m, same vehicle can be composed of more than one area due to presence of junction and cross overs.

Figure 10: Urban vehicular environment

2.3.2. Rural

The Rural environment, with smaller roads, lower variation in infrastructures and lower traffic density V2V communication will have best performance. Communication range can be higher in rural environment as compared to other in same propagating condition due to factors like low interference in same band, simpler and uniform infrastructures, vehicular velocity and density. Due to lower vehicular density, communication range between two nearer vehicles should be comparatively high in rural area to have connection.

2.3.3. Motorway

Motorway is the critical place of V2V application due to vehicle's velocity, physical infrastructure and also traffic density in some peak time. To prevent big and fatal accidents in motorways, application of V2V communication can be the proper solution, but many propagation factors, mostly importantly Doppler shift, should be taken in account while deploying V2V communication.


Figure 11: Highway vehicular environment

2.3.4. Characteristics of V2V Scenario

In this section, characteristics of each scenario that can affect the V2V communication are illustrated in following table 4.

Table 4 : V2V communication parameter for corresponding scenario

	Urban	**Highway**	**Rural**
Transmitted Power	20 dBm	20 dBm	20 dBm
Antenna Gain	-4 dB	-4 dB	-4 dB
Maximum Speed	30 Km/h	120 Km/h	50 Km/h
Doppler Shift	1311.11 Hertz	546.3 Hertz	327.78 Hertz
Road Width	11.2 m (4 lanes of 2.8 m)	18 m (6 lanes of 3 m)	5.4 m (2 lanes of 2.7 m)
Antenna height (Tx and Rx)	1.5 m	1.5 m	1.5 m
Maximum communication distance	150 m	500 m	250 m

In the above table values about, road infrastructure parameters like width is assumed form the dimensions of permitted vehicles in European highway [**17**].Transmitted power is as based by ITU which states, based on the maximum allowed output power on CCH in ITS-GSA of 33 dBm, vehicles are assumed to have a Pt=20dBm [**18**].

2.4. Communication Models

Communication models are designed, established to mirror the functioning of communications using predefined parameters called as standards. These communication models are structured with various elements which varies depending on the circumstance of communication for example OSI model for internet, Radio propagation model for wireless communication.

2.4.1. Wireless communication models

Wireless communication was developed to support the mobility of user by the means of electromagnetic signal propagation from one point (transmitter) to another point (receptor), where these points can be fixed or mobile. The propagation is done by using certain frequency, wave called carrier wave, depending on the application of use. These radiofrequency signals can propagate through medium like air, water or vacuum, so they are called wireless communication making the communication service mobile. These type of communications have their own radiofrequency propagation models depending upon the site of use but can be classified as Empirical (experimental) or Theoretical models. All these models are mathematical formulation for the characterization of radio wave propagation in function of frequency, distance of coverage (range), transmitting and receiving parameters and other conditions. These type of models are established in certain conditions taking in account of all constraints, which can predict the radio wave propagation including dominant factors like path loss or area of coverage.

As commented above, to study the proportion V2V communication there are some models that may result helpful for example one of them is P.1411-5 Street propagation model, recommended by ITU [**19**].this one is general wireless communication model for propagation prediction in radio frequency system working within the frequency range of 300 MHz to 100 GHz. Another one is a measurement base realistic channel developed by Volvo Group that takes in account all of above commented parameters [**20**].

2.4.2. Measurement Based V2V model.

This model provides an approach to realistic path loss for V2V environment, which was developed for each scenario of V2V.Amng other dual slope path loss model is developed which is as mentioned in equation 1.4

$$\mathrm{PL}(d) = \begin{cases} \mathrm{PL}_0 + 10 n_1 \log_{10}\left(\frac{d}{d_0}\right) + X_\sigma, & \text{if } d_0 \le d \le d_b, \\ \mathrm{PL}_0 + 10 n_1 \log_{10}\left(\frac{d_b}{d_0}\right) + 10 n_2 \log_{10}\left(\frac{d}{d_b}\right) + X_\sigma, & \text{if } d > d_b. \end{cases} \quad (1.4)$$

Above model is valid for LOS and is different depending on the distance, where d0 is a minimum distance of 10m and db is the distance where the first Fresnel zone touches the ground or where the first signal bounces of the ground that travels db + λ/4 to reach the RX after reflection. db can be calculated as shown in equation 1.5

$$d_b = \frac{1}{\lambda}(4h_{TX}h_{RX} - \frac{\lambda^2}{4}) \quad (1.5)$$

CHAPTER 3. Implementation MIMO in V2V

3.1. Introduction

The main objective of this work is the enhancement of physical layer of IEEE 802.11p for V2V communication to overcome the existing problems and challenges. Basically this enhancement can provides better results in terms of throughput, packet delivery rate and QoS.

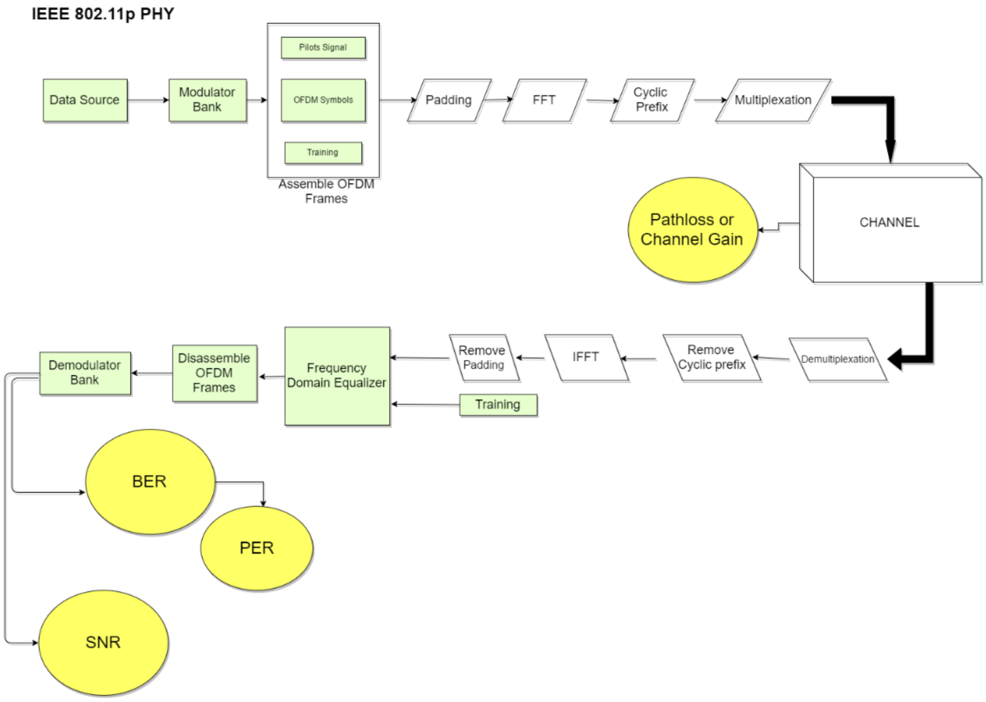

Figure 12: V2V physical level implemented architecture

For above implementation, MATLAB is used to design communication system for V2V parameters with above explained communication parameters. Firstly we will design transmitter, receiver and basic ideal channel, later on the channel will be modified to implement MIMO system and other sides to adapt the channel. MIMO antennas can be very helpful as radio communication efficiency can be increased depending with the number of antennas. For the simulation we will insert the characteristics of MIMO Channel over SISO channel in a simple communication scheme designed in MATLAB R2016a[**21**].So the main focus will based on the performance of radio channel in V2V environment, specifically on multipath channel.

For the comparison for each case, Bit Error Rate (BER) will be studied in function of SNR and also PER for same case. SNR is calculated on the function of pathloss introduces by the channel, which is obtained by using the realistic V2V communication model. As the study and implementation is done for the physical layer, consideration for Medium Access Control (MAC) level is not done in this project.

3.1.1. SNR Calculation

For the calculation of SNR, value of received signal and of noise is to be known. Received signal depends upon the signal transmitted and the channel gain or path loss. Transmitted signal is 20 dBm and the noise power varies between -95 dBm and -112 dBm per 10MHz depending on the quality of the receiver.

$$N = 10Log(KTB) \tag{1.6}$$

Where k is Boltzmann's constant is Temperature and B is Bandwidth. Using respective values in equation 1.6 we can obtain the value of noise power

N= 10*log (1.38 E-23 x 870 x E7) = -99.2 dBm.

For the equation above to calculate the temperature, following can be done, a good guess may be a Noise Factor=NF=10 log (1+T/To) = 6 dB.
In this case T= 3 x 290 degree kelvin.

3.1.2. Bits, Packets Error Rate Calculation

To calculate the errors in bits, originally generated random data will be compared with received and demodulated data depending on the different level of SNR. For the case of PER, same process is done but instead of error in bits, packets' error will be used which is calculated using the following formula.

$$PER = 1 - (1 - BER)^N \tag{1.7}$$

Where PER is Packet Error Ratio, BER is Bit Error Ratio and N is Number of bits in packet. This formula gives us normal relation of BER without PER [**22**].
Above consideration is done without using protocols of MAC level like such as CSMA/CA, TDMA or STDMA even though CSMA/CA is recommended and is being used in family IEEE802.11.

3.2. Implementation

For the above implementation, a complete communication scheme for physical layer of IEEE 802.11p is designed in MATLAB. For the study we have selected the following parameters for each side.

3.2.1. Transmitter side

Firstly random data is generated according to the number of OFDM frames and is modulated using QPSK modulator. After this step, QPSK signal is converted to OFDM signals characteristics as shown in Table (X).
Signal is passed through a channel and later to reciever once it is modulated, In other words OFDM Signal is transmistted to the channel.

3.2.2. Channel

Modulated Signal passes thorough the channel facing the propagation effects that certain channel may have, for V2V environment these channel characteristics are very variable depending on the scenario. In this work, several channel characteristics will be studied. Firstly we will study conventional simple communication system with SISO and MIMO channel, and later on radio channel enhancement techniques in the conventional communication system will be applied.

3.2.3. Receiver Side

Once the signal arrives at the receiver, it passes through every process of transmitter but in reverse order to obtain the initial data which were generated randomly. Modulation and Demodulation process have same characteristics, for example as shown in Table 2.

But in the real case, these data are sent by transmitter which are predefined and structured to follow the protocols for different level such as authentication, access, addressing etc.

3.3. Results

As a first approach of study, SNR is calculated for different distance for specific scenario. For this work, study is done for LOS condition in urban and highway scenario once SNR is obtained, delivery rates in bits and in packets are obtained for each scenario. Obstructed LOS (OLOS), the situation when the LOS between the transmitter and receiver is obstructed completely or partially by another vehicle may be seen to represent an average additional attenuation of 10 dB [**20**].

3.3.1. Signal Reception

To determine the path loss or channel gain for specific V2V environment, a realistic communication model was used, which is shown in equation 1.5.Through this equation following path loss was obtained in function between the distances between two communication vehicles. For each scenario pathloss is obtained as represented in figure 13 and 14.

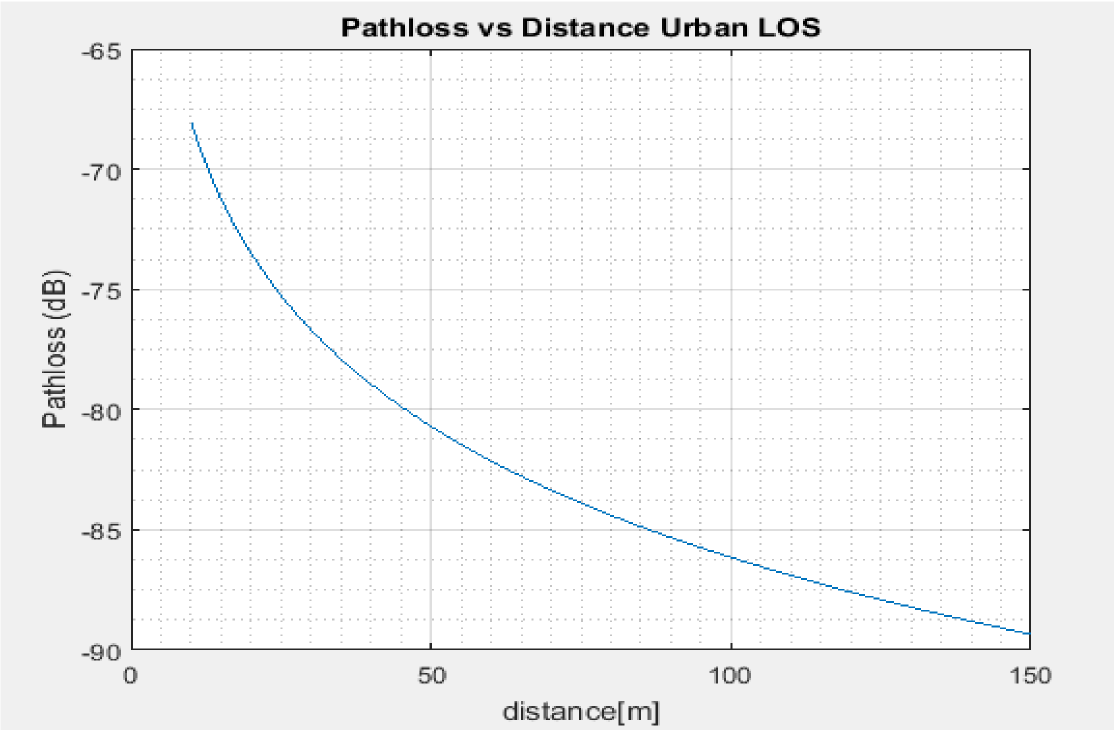

Figure 13: Pathloss for Urban LOS V2V scenario

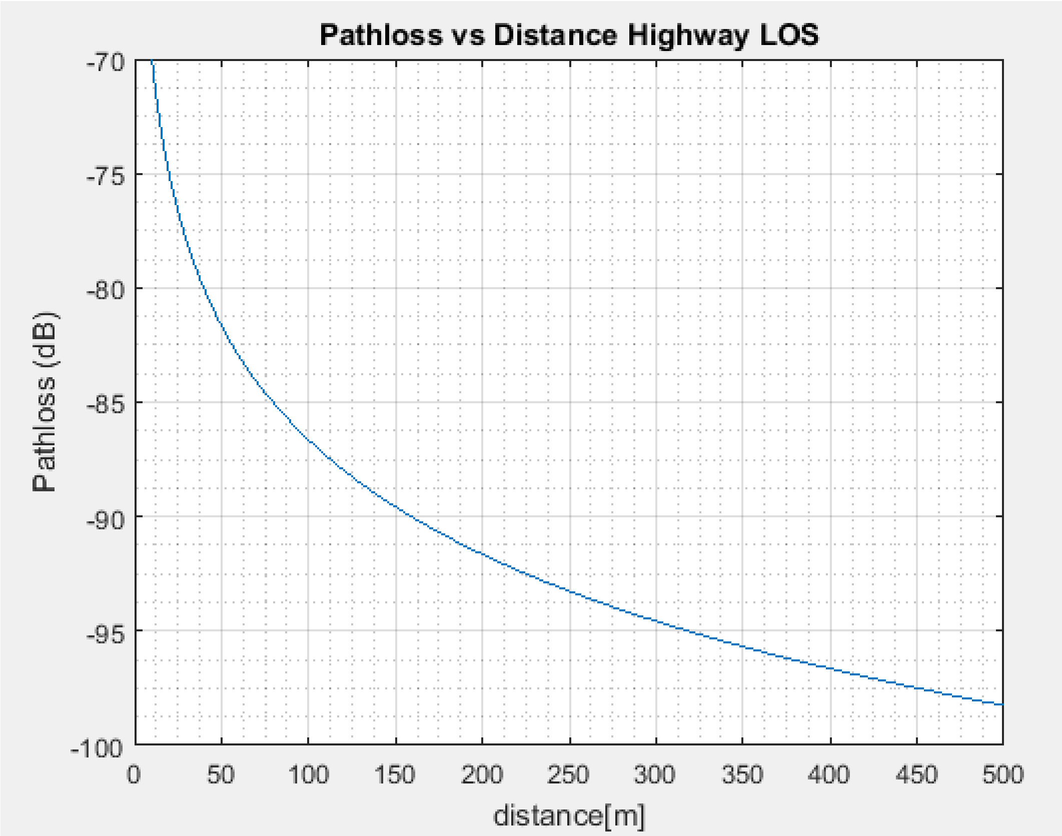

Figure 14: Pathloss for Highway LOS V2V scenario

Once Path loss was obtained, characteristics of V2V channel was known. So to study the signal reception we calculated the received signal which depends on the transmitted power, antennas gain and the above mentioned channel response. As the transmitted power and gain of transmitting and receiving antenna is known, Signal to Noise Reception (SNR) was calculated as,

$$SNR = P_{TX} + Gain_{TX} + Gain_{RX} - PL \tag{1.8}$$

Where P_{TX} is transmitted power, $Gain_{TX}$ and $Gain_{RX}$ are gain of transmitting and receiving antennas respectively. Using this formula following SNR is obtained for each scenario, Highway and Urban. For the both of the scenario, SNR decreases as expected as the distance increase, basically due to propagation loss which can be seen in figure 15 and 16.

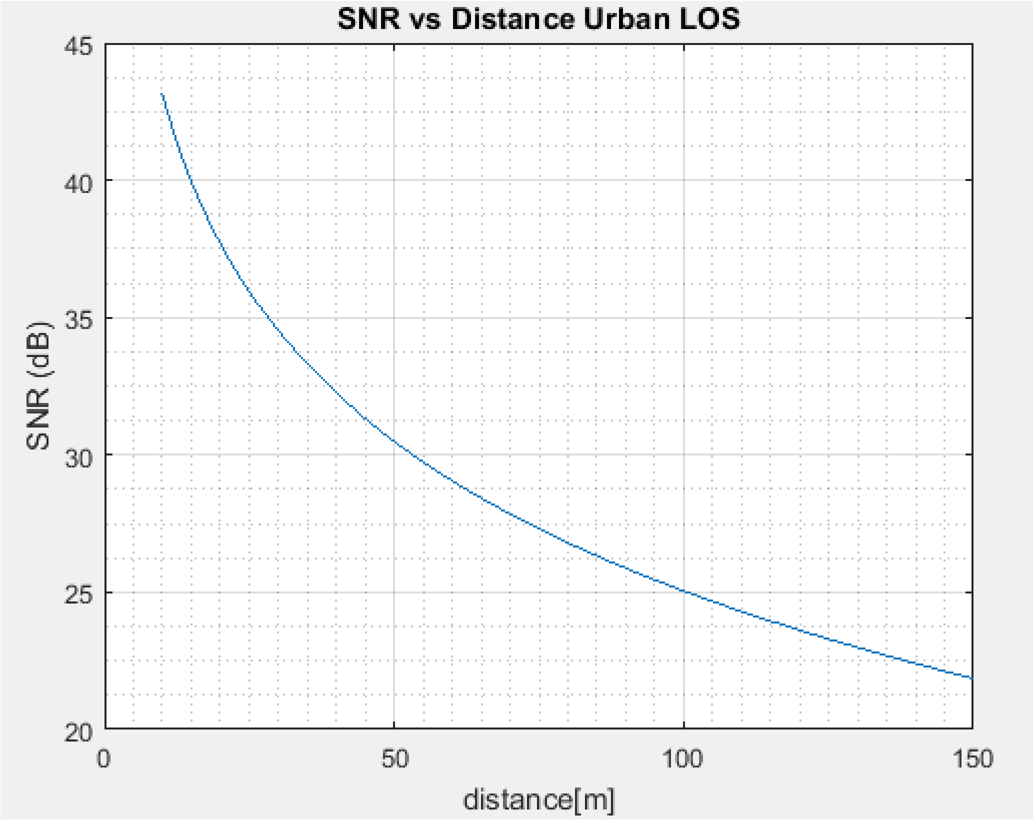

Figure 15: SNR for Urban scenario in V2V

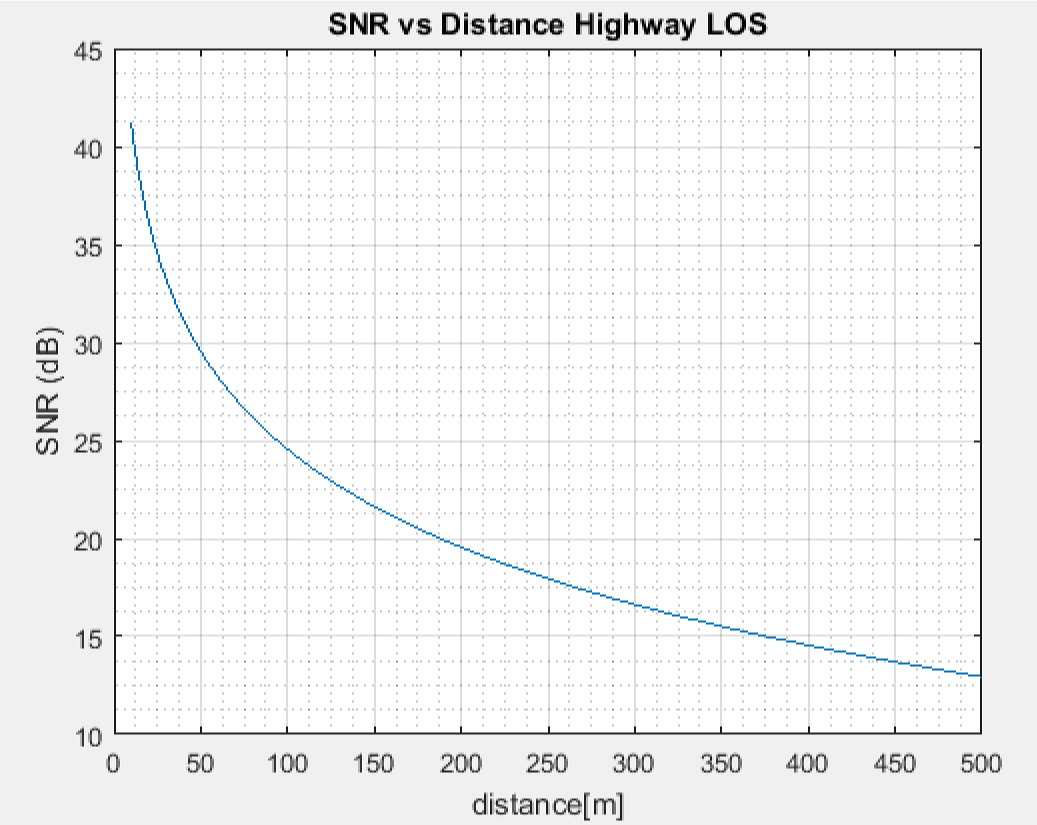

Figure 16: SNR for highway scenario in V2V

3.4. Performance evaluation for SISO

Simple SISO radio channel is simulated for V2V environment, through which we can know about the performance under the current situation, low bandwidth and low communication channel's capacity.

3.4.1. Results

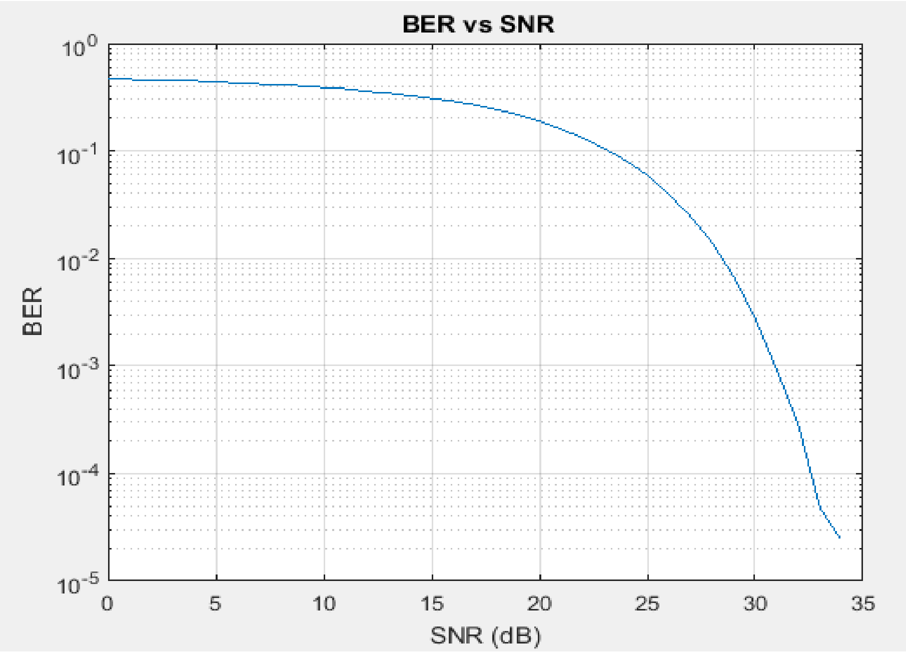

Figure 17: BER in function of SNR for SISO

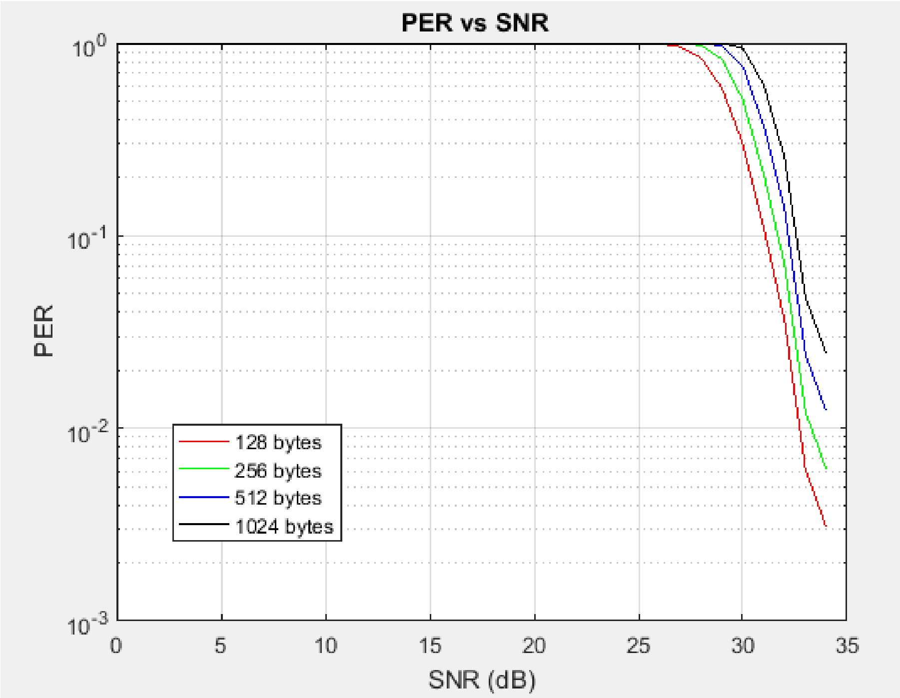

Figure 18: PER in function of SNR for SISO

From these results we can easily deduce that due to current bandwidth, V2V communication is poor and improvement should be done. As shown above, Minimum SNR should be more than 18 dB to achieve BER of value 10^{-5}. SNR value in V2V will not be too high due to high, number of vehicles transmitting in same band with very low bandwidth and also due to propagation effects like Doppler shift due to mobility.

3.5. Performance Evaluation for ideal MIMO Channel

For a general comparison, instead of simple and conventional SISO channel, MIMO channel is used where channel gain is four times greater than of the SISO channel used in 3.3. assuming the ideal MIMO.

3.5.1. Results

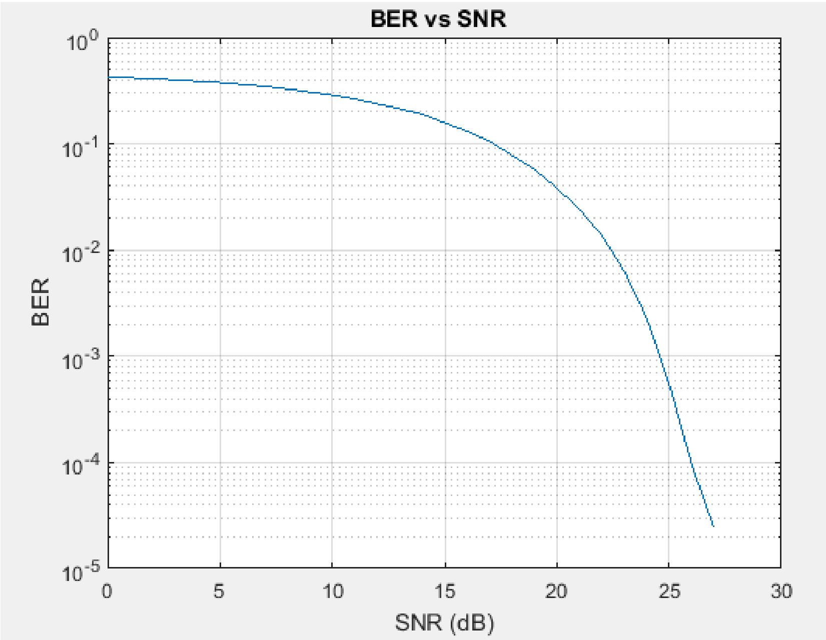

Figure 19: BER in function of SNR for ideal MIMO

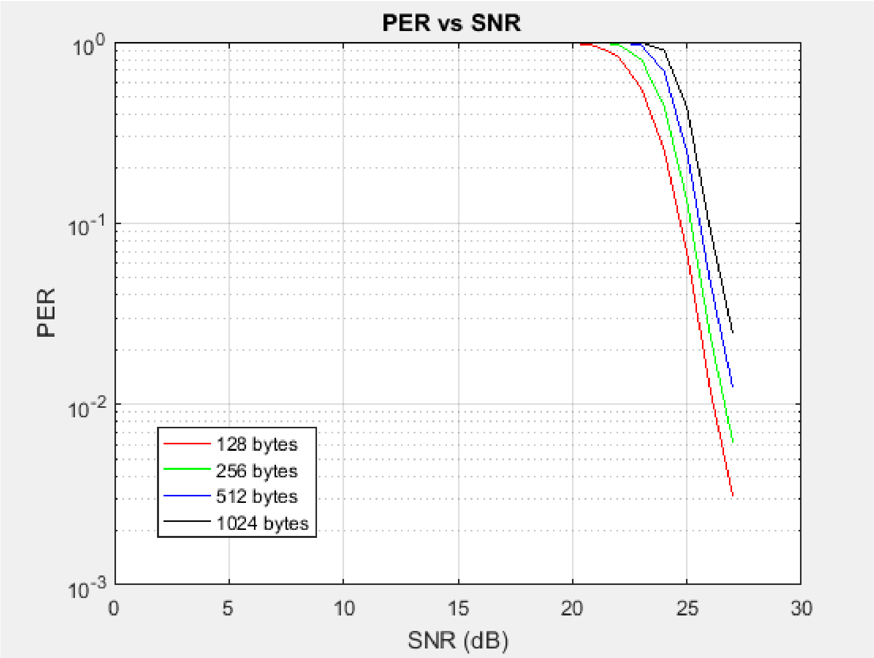

Figure 20: PER in function of SNR for ideal MIMO

In above mentioned figures (19 and 20) the gain in SNR can be observed. This gain provides the improvement of the communication efficiency as compared to the ideal SISO.

3.6. Discussion

As of the nature of V2V communication, due to phenomenon like multi fading, scattering, more challenges are added while estimating the channel characteristics. For this purpose, this work is based on the behavior and advantage of MIMO over SISO. From the general comparison of results for use case of MIMO and SISO, the improvement due to MIMO is significantly notable as compared to SISO. By exploiting the MIMO channel, the distance can be doubled for the same delivery rate under the same propagating condition.

As seen in the figure [Urban LOS and Highway LOS], to double the coverage range maintaining similar performance in terms of error rate, the channel capacity is to be doubled. For the same error rate, both BER and PER, by the use of MIMO, coverage range can reach up to 100 meters which was just around 50 meters with SISO. For the results shown in 3.4, 4×4 MIMO channel was used, where ideal gain in 6 dB.

Once studied, error rate in terms of bits, packet error ratio (PER), was studied for each case. For this, used data as bits were converted into packets using formula 1.7 for standard packet length. From the results obtained, it can be easily assumed that packets with small size have better performance. It's not still standardized the packet lengths for pure V2V communication, but basing upon the standard using in internet, 128 bytes packets can be used for V2V communication. For the V2V communication, packets can be User Datagram Protocol (UDP) packets as they do not establish connection-oriented connection.

If some packets are lost in the middle of communication, next packet is sent without knowing the status of previously sent packets.

For the safety purpose, in V2V communication packets does not need to be necessarily high. Traffic status, vehicle condition and some other safety related parameters are exchanged mostly. These messages are broadcasted periodically initially each 100 milliseconds [**23**]. Also authentication mechanism should be added in the communication, as it has not been taken in account in this work. Packet size would be increased for the authentication as it will have additional parameters like transmitting source's reliability. To calculate the packet error rate, none mechanism access is used in this work, even though Collision Sense Mechanism Access, Collision Avoidance (CSMA/CA) is recommended for IEEE802.11 family. Due to the nature of V2V, the performance of CSMA/CA is not quite enough so the alternatives are being studied for example Time Division Multiple Access (TDMA) or self-organized TDMA (STDMA).

CHAPTER 4. Conclusion and future work

4.1. Main conclusion

Based on the result of this work, for the enhancement of IEEE 802.11p to be able for V2V communication, use of MIMO channel is recommended. Under the same and current propagating condition the use of simple MIMO channel can improve the coverage distance by two times. Use of printed antennas or simpler monopole antennas are suitable for Vehicular communication. Main advantage of these antennas is that the number of transmitting and receiving antennas ($\mathbb{N}$) can be configured easily, as they occupy less physical space.

4.2. Additional conclusions

This work, Vehicle to Vehicle (V2V) Wireless Communication, was done with the main objective of enhancing physical layer to make a stable communication model capable of exchanging reliable and safety related data between vehicles. The preliminary study is conducted in state of art and standards used for V2V communication. A brief study is done regarding the necessity, current status and challenges of V2V communication. This preliminary study helps to situate about the current development and future projection for V2V communication.

In today’s date, still there is huge to develop V2V communication.V2V communication can substitute humans from the vehicle control so, it should be reliable, secure and efficient. For the safety purpose, in today’s date, standards and practical case studies are not quite developed. For example bandwidth available in designated spectrum is only 10 MHz. Due to the nature of V2V communication such as highly dynamic network topology, infrastructure and propagation condition the communication is very inefficient. So for the proper development of V2V communication, it should be enhanced in all the possible ways or it may be substituted by other communication technology.

As the part of this work, possible technologies that may substitute V2V communication are also studied briefly. In today’s context 4G is taking the huge market in all sector, actually there exists a possibility of connecting vehicle with other infrastructure. As the technology is approaching towards the data processing and internet of things era, 5G is also one of the possible candidate to substitute the V2V network. In midterm future vehicle may communicate with each other through 5G.Also the advantages and drawbacks of these possible technologies compared to V2V communication is studied.

Once being familiar with V2V communication, its implementation for practical study was done. MATLAB simulation was carried out in order to analyze IEEE 802.11p physical layer. As the first approach signal reception under LOS condition was studied following one of the best available communication model suitable for the V2V environment. The LOS model is easy to implement in VANET simulators due to the usage of a dual-piece wise path loss model and the shadowing effect is modeled as a log normal correlated variable with a mean determined by the propagation condition.

To analyze the performance in physical layer bit error rate (BER) and packet error rates were studied in function the signal to noise ratio (SNR).Comparison of this performance is done with SNR for two V2V scenario i.e. Highway and Urban. As expected, error rate performance is enhanced for the MIMO when compared with SISO. This analysis stands as foundation for use of MIMO channel to enhance the physical layer.

As the proposal and conclusion of this study, a communication scenario is suggested which may enhance the V2V communication to reach its objective.

4.3. Future works

V2V communication is still in its research phase, few of the practical experiments have been conducted for a real scenario. Some of the future project based on this sector can be:

- Analyzation of performance metrics used in this project practically. For this, communication model is to be obtained practically simulating V2V communication.

- Study of end to end V2V communication, with all of the possible standards associated such as access, addressing and authentication.

- Global study of V2V communication in all of its possible scenario to obtain a global communication model not only for the physical level but also for the upper level of communication

- Improvement of communicating antennas and selection of best site on vehicle in order to make communication more efficient with the possible of use of algorithms to determine the communication vehicle’s position.

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