NEAR EAST UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CELLULAR VEHICLE-TO-VEHICLE COMMUNICATION USING BLOCKCHAIN NETWORK

M.Sc. THESIS

Sara KAYED

Nicosia

September, 2023

SARA KAYED

CELLULAR VEHICLE-TO-VEHICLE COMMUNICATION USING BLOCKCHAIN NETWORK

MASTER THESIS

2023

NEAR EAST UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CELLULAR VEHICLE-TO-VEHICLE COMMUNICATION USING BLOCKCHAIN NETWORK

M.Sc. THESIS

Sara KAYED

Supervisor

Prof. Dr. BÜLENT BILGEHAN

Nicosia

September, 2023

Approval

We certify that we have read the thesis submitted by Sara Kayed titled **"Cellular Vehicle-to-Vehicle Communication Using Blockchain Network"** and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Educational Sciences.

Examining Committee	Name-Surname	Signature
Head of the Committee:	Prof. Dr. Bülent Bilgehan	
Committee Member:	Assist. Prof. Dr. Ali Serener	
	Assoc. Prof. Dr. Huseyin Hacı	
Supervisor:	Prof. Dr. Bülent Bilgehan	

Approved by the Head of the Department

12/09/2023

Prof. Dr. Bülent Bilgehan
Head of Department

Approved by the Institute of Graduate Studies

NEAR EAST UNIVERSITY INSTITUTE OF GRADUATE STUDIES 1988

12/09/2023

Prof. Dr. Kemal Hüsnü Can Başer
Head of the Institute

Declaration

I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

Sara Kayed

Acknowledgments

In the grand symphony of the knowledge, this thesis is nothing but a humble note, and yet, it would not have reached its crescendo without the harmonies contribution of many. Like stars in the academic galaxy, my gratitude shines.

First of all, I would like to thank God for letting me pass through all the obstacles and difficulties that occurred in my Masters journey.

To my brilliant supervisor, Prof. Dr. Bülent Bilgehan, you did not just steer this ships, yet set it on a course for greatness. Your guidance and wisdom were my North star.

To my unwavering family, who have been the constellations guiding me through this journey, thank you for your boundless support and love.

To my incredible fellows and friends, you were the wind beneath my academic wings, lifting me up during the dark nights and turbulent drafts of research.

Finally, to the countless pioneers, researchers and authors whose works illuminated my path, your brilliance shaped the foundation of this thesis.

Sara Kayed

Abstract

Cellular Vehicle-to-Vehicle Communication Using Blockchain Network
Kayed Sara
Prof. Dr. Bülent Bilgehan
MA, Department of Electrical and Electronics Engineering
September, 2023, 49 Pages

Vehicle-to-Vehicle Communication (V2V) has engaged with our daily lives during our normal rides as a crucial technology in the modern transportation disciplines and systems, allowing real-time exchanging of different important information from one vehicle to another in order to improve the traffic management, efficiency and safety.

This thesis investigates the optimization and implementation of dynamic bits' transmission in the vehicle-to-vehicle communication systems. The research focuses mainly on discovering the impact of different factors which includes a known transmitted signal, antenna gain, received power, receiving sensitivity, packet success rate, distances and coordinates of the vehicles and path loss on the V2V communication.

By examining the role of receiving sensitivity and antenna gain, the study aims to improve the overall reliability and performance of V2V communication. Settings of the optimal path will be determined in order to maximize the reception and transmission capabilities of the vehicles which will ensure an efficient data exchange. The knowledge of the coordinates of the vehicles and the distances that separates them, is very important for establishing a reliable communication links. By taking into consideration these factors, this study aims to optimize signal strength and transmission power, ensuring successful data transmission and compensating for path loss.

Frequency allocation plays a pivotal role in indicating the available bandwidth for the V2V communication. This thesis discovered effective utilization of the fixed frequency in order to maintain a reliable communication channels and avoid interference.

The estimation of the path loss is being analyzed in order to compensate for the signal attenuation over a distance which allows the adjustment of the transmission power. By selecting the optimal path after taking into consideration the path loss predictions, this study aims to minimize the packet loss as well as enhancing the communication reliability. At the ends of the receiver, the received power plays as a vital metric for assessing the signal quality and strength. This study spots the light on monitoring the received power in order to implement the necessary improvements and to evaluate the reliability of the communication link. Finally, the packet success rate is evaluated by this thesis as V2V communication's measure of effectiveness while delivering data packets. By optimizing factors such as transmission power, interference and signal strength, the study aims to ensure seamless data exchange and enhance the packet success rate.

The MATLAB simulation is used to validate our aim. The MATLAB simulation results that are obtained after our proposed framework show a huge improvement of the performance of V2V communication generally. The use of the blockchain technology in our project also is expected to improve and enhance the decentralization, immutability and finally and the most important thing is the security of the V2V communication. Through comprehensive experimentation, analysis and simulation, this thesis brings valuable insights into the optimization and implementation of dynamic bits' transmission in the vehicle-to-vehicle (V2V) communication systems. The findings assist in advancing and improving the field of intelligent transportation systems as well as paving the way for improved traffic efficiency, road safety and an overall driving experience.

Keywords: vehicle-to-vehicle communication, optimal path, transmission power, packet success rate, blockchain network.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

V2X: Vehicle-To-Everything

V2V: Vehicle-To-Vehicle

V2I: Vehicle-To-Infrastructure

V2N: Vehicle-To-Network

V2P: Vehicle-To-Pedestrian

CHAPTER I
Introduction

Digital Communication

Digital communication is said to be a means of transmitting different information which are encoded in the binary form, which will be allowing for reliable and efficient data transmission. Digital communication consists of various protocols and technologies that allow the exchanging of digital data among devices (Proakis, 2008).

Digital data, in V2V communication, is encoded in binary form, basically represented, before transmission, as 1s and 0s. This encoding allows for accurate and precise representation of the information, enabling error-resistant and reliable communication among vehicles. Wide techniques of digital communication, such as encoding schemes and modulation schemes are employed in order to efficiently transmit this digital data over a wireless communication channel (Alam, Benmimoun, & Kobbane, 2020).

In V2V systems, digital communication includes the usage of wireless technologies such as cellular networks, dedicated short-range communication (or DSRC), or Wireless Fidelity or Wi-Fi (IEEE 802.11p). These all wireless technologies allow vehicles to form a direct communication link, establishing a dynamic vehicle's network that is capable of transmitting and receiving information in real-time. The transmitted digital signals between the vehicles hold very important safety messages, location information, sensor data and many other relevant data in order to enable intelligent and cooperative transportation systems (Liu, et al., 2017).

Not only that, but also, in V2V systems, digital communication utilizes correction mechanisms and error detection in order to ensure the integrity of transmitted data. Techniques such as forward error correction (FEC) and Cyclic Redundancy Check (CRC) are employed to correct and detect errors that might occur during the transmission, in order to ensure a reliable and accurate exchange of data between vehicles and to improve the reliability of the V2V communication (Al-Sultan, et al., 2014).

Integrating digital communication in the V2V systems gains the potential to significantly improve traffic efficiency, reduce congestion, and enhance road safety. By allowing the vehicles to share real-time information, such as road conditions, traffic flow, and collision warnings, V2V communication allows proactive decision making by the automated systems or drives, and enhances situational awareness (Ling, et al., 2019).

A very important and unique advantage of digital communication can be the wireless communication that has revolutionized and changed the action of which information is received and transmitted (Proakis, 2008).

Wireless Communication

Wireless communication relates to the transmission of data without even the use of wires or physical cables. It depends primarily on the electromagnetic waves in order to transmit signals all over the airwaves which will then enable a seamless communication among devices. This wireless communication became increasingly popular and important due to its flexibility, convenience as well as the ability to overcome any possible physical barriers (Haykin, & Moher, 2011).

The operational principle of wireless communication in V2V systems is using electromagnetic waves as a medium for transmitting the signal. Through the air, these waves propagate allowing communication among the vehicles over a short to medium ranges. These communication signals hold sensor data, important safety messages and many other relevant information in order to enable proactive and real-time decision making in V2V systems (Alam, et al., 2020).

Wireless communication in V2V systems has numerous advantages. It permits for an improved road safety after letting the vehicles to exchange information that holds abnormal road conditions, potential hazards, or nearby vehicles. It can also ease the cooperative driving by which the vehicles are able to coordinate their movements in order to reduce congestion, and increase efficiency. Wireless communication can also enable the incorporation of the autonomous vehicle technologies and the advanced driver assistance systems (or the ADAS) in order to enhance the capabilities of vehicles and the overall intelligence (Papadimitratos, & La Fortelle, 2017).

In order to ensure the secure and reliable wireless communication in V2V systems, wide techniques are employed. They include encryption techniques, error correction mechanisms, signal modulation schemes, and channel access protocols. These measures protect the security and privacy of communication information, improve data integrity, enhance signal quality as well as mitigating the interference (Cheng, & Lo, 2015).

Relationship Between Digital Communication and Wireless Communication

The relationship that exists between digital communication and wireless communication is located in the objective of receiving and transmitting digital signals that they both share. However, digital communication focuses more on processing, decoding and encoding data in a binary format, in contrast to wireless communication that provides the tool to transmit this specific data wirelessly, by removing any constraints that are imposed by the physical connections (Goldsmith, 2005).

These two forms of communication can find an extensive application in various fields. In the kingdom of nodal communication, both wireless and digital technologies play important roles. Nodal communication includes the foundation of communication links among individual nodes that are presented in a network, which will allow in data coordination and exchange. The protocols of digital communication, such as TCP/IP, shall enable a standardized and reliable communication among nodes, meanwhile the wireless technologies, like Bluetooth and Wi-Fi, can provide, for occurring efficiently, a wireless connectivity that is necessary for the nodal communication (Rappaport, 2010).

Not only that, but also the relationship between vehicle-to-vehicle (V2V) communication and device-to-device (D2D) communication are the best examples of the integration of wireless and digital communication. D2D communication means the direct communication occurring between nearby devices but without even the need for network infrastructure which is centralized. D2D communication allows devices to exchange directly the data, which then shall reduce the network congestion as well as improve its efficiency. Simultaneously, V2V communication includes the direct communication among vehicles, which then shall facilitate the exchange of information that are related to collaborative driving, traffic conditions, and safety. Both V2V and D2D communication rely heavily on wireless technologies in order to establish direct connections. meanwhile the digital communication assures the accurate decoding and encoding of the transmitted data between devices.

Concluding what has been discussed before, wireless communication and digital communication are both inextricably connected with the wireless technology in order to serve as an atmosphere for transmitting the digital data. Both of their applications involve various fields which can include the nodal communication, by which both of these technologies assist in affecting the data exchange inside the networks. In addition to that, the relationship between V2V and D2D communication spots the light on the seamless integration of wireless and digital communication, that will then enable efficient data exchange and direct connections between the vehicles and devices (Molisch, 2012).

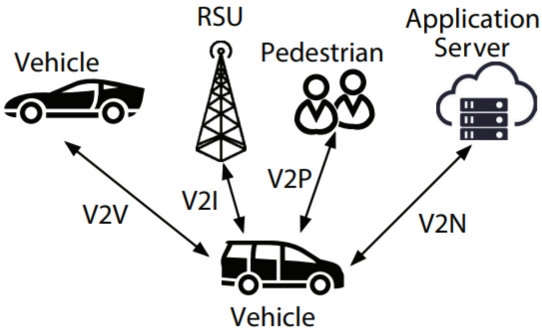
Vehicle-to-Everything (V2X) Communication

Inter-vehicular communications are becoming an important demand after which vehicles are becoming smarter and smarter. This particular idea is not new, in fact, it can be going back to 1999, when the vehicular communication was born and, rapidly, started to be talked about within the academy and industry (Oh, et al., 1999 & Inoue, et al., 2004). It was obviously observed that the very first set of services (day one service) will be related to the basic safety by which vehicles must be broadcasting information that includes their locations, speeds and other characteristics. This specific day one service shall aim to an obvious increase in the road safety after the improvement of the cooperative awareness of the divergent road sharing entities. Afterwards, from day two and moving on, the service will include more developed use cases such as the Automatic Driving Assistance Systems (ADAS), traffic management, platooning, which all can be introduced directly after the rate of the technology penetration reaches a certain peak (Nguyen, et al., 2017).

Moving on with the vast development of the metropolitan areas, highways and city roads have seen serious and important socio-economic impacts because of vehicular congestion and crashes. For instance, the World Health Organization (WHO) has reported 1.25 million deaths occurring from road traffic globally in the year of 2013. Besides, traffic jams also cause a dramatic waste of fuel as well as time which these all lead to serious economic losses (Martinez, et al., 2010 & Zheng, et al., 2015). On the other hand, most of these problems can be controlled by providing dynamic information to the vehicles and/or drivers. Vehicular networking and communications are becoming an important research area in order to optimize the traffic flow as well as improving the vehicular safety, and that shall enable ensure a high quality of users' experiences, and a more efficient use of the transportation resources (Wang, et al., 2017)

Figure 1

Four Types Of V2X Application (Wang, Et Al., 2017)



Speaking generally and as shown in figure 1, the vehicle-to everything (V2X) communication encompasses four different disciplines: vehicle-to-vehicle (V2V) communication, vehicle-to-infrastructure (V2I) communication, vehicle-to-network (V2N) communication, and finally the vehicle-to-pedestrian (V2P) communication (Jameel, et al., 2020).

By integrating "cooperative awareness", these above 4 disciplines of the V2X applications together can be used for end-users' smarter services. For instance, road infrastructure, application services, pedestrians and vehicles can, by receiving different messages from vehicles or from sensors in proximity, obtain local information which are environmental, and that is done in order to enable extra intelligent services as enhanced traffic management, and warning of the autonomous driving vehicle. Just below, the four categories of the vehicle-to-everything applications are discussed (Wang, et al., 2017).

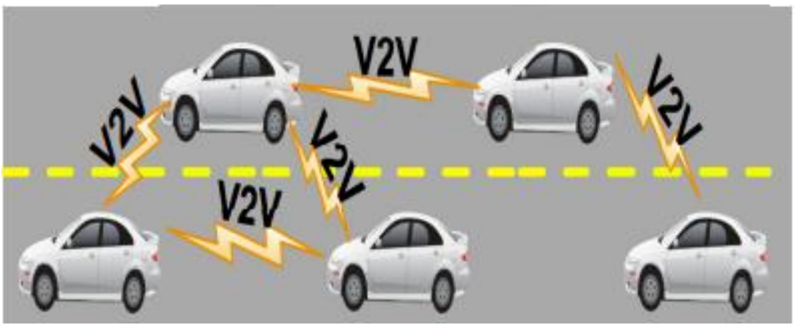
Vehicle-to-Vehicle (V2V) Applications:

Vehicle-to-vehicle (V2V) applications, as shown in figure 2, let the surrounding devices receive and transmit useful information through broadcasting which asks the user equipment (UE) to do a subscription to one of the network's operators and then obtain an authorization. V2V applications require UEs transmit relevant information messages that carry V2V information of the V2V application such as vehicle attributes, traffic location and dynamics. In order to adapt to the wide amount of the information of the V2V application, the message payloads must be flexible (Wang, et al., 2017).

V2V communication allows vehicles to directly exchange information wirelessly, in order to enhance traffic efficiency and road safety. Via V2V communication, vehicles can share data such as status, speed and position, allowing them to be aware of any potential hazards and their surroundings. The direct communication allows applications such as traffic low optimization, cooperative adaptive cruise control, and collision avoidance. V2V communication complements driver perception, provides faster response times, and enhances advanced driver assistance systems. V2V communication carries great promise in creating cooperative and smarter transportation systems (Yang, et al., 2004).

Figure 2

Vehicle-To-Vehicle (V2V) Communication (Cunha Et Al., 2016).

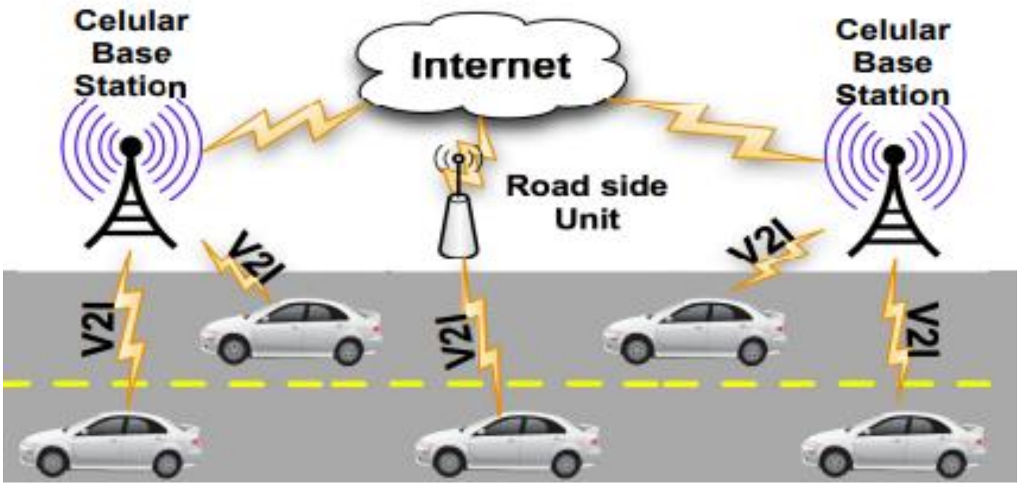


Vehicle-to-Infrastructure (V2I) Applications:

The information of the V2I applications is transmitted from a supporting V2I applications' UE to a roadside unit (RSU) or a server which is a locally relevant application. After that, the application server or the RSU can choose the UE information which is received to it based on the different transmission modes which can be multicast, unicast and broadcast. In addition to that, the application server or the RSU can transmit messages or signals to either one or more UEs that support V2I applications. A server which is a locally relevant application serves a specific geographical area, however servers which are multiple applications can serve up to overlapping areas with the different or same applications (Wang, et al., 2017). An illustrative example of V2I is shown in figure 3.

Figure 3

Vehicle-To-Infrastructure (V2I) Communication (Cunha Et Al., 2016).

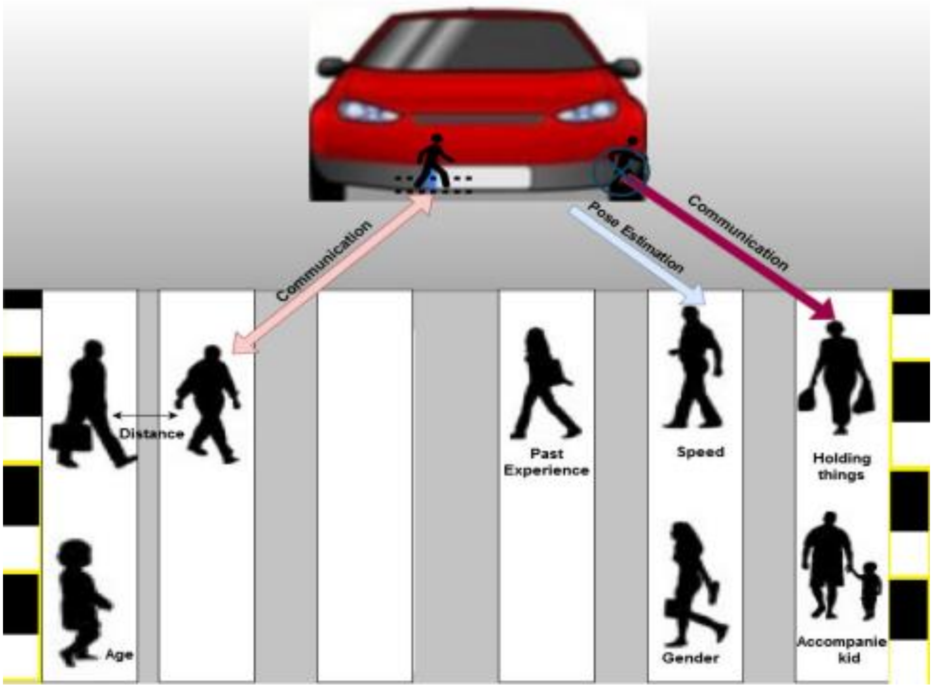


Vehicle-to-Pedestrian (V2P) Applications:

Vehicle-to-pedestrian, which is shown in figure 4, is almost the same as vehicle-to-vehicle applications, except that the V2P service information is transmitted and received between vehicular UEs and pedestrian UEs. Information of the V2P application can be transmitted by a vehicle-to-everything UE inside a vehicle in order to warn a random pedestrian, or even by a user who is a vulnerable road user in order also to warn any nearby vehicle. Aside from V2V, a pedestrian UE who is supporting V2P applications apparently has a battery capacity which is low, and a radio sensitivity which is lower than the vehicular UEs because of the impact of the antenna design. This implies that a UE which supports V2P applications cannot send messages as dynamic as UEs which support V2V applications (Wang, et al., 2017).

Figure 4

Vehicle-To-Pedestrian (V2P) Communication (Hafeez, Et Al., 2020).



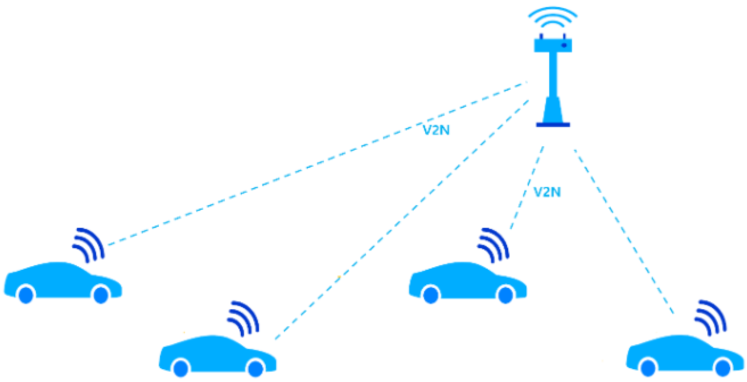
Vehicle-to-Network (V2N) Applications:

Vehicle-to-Network (V2N) communication includes the exchange of data between the network and vehicles. It allows vehicles to connect with cloud servers, traffic management systems, road infrastructure, and other network elements. V2N communication plays a pivotal role in improving traffic efficiency and road safety. Vehicles transmit data such as location updates, sensor data and vehicle status to the network, and on the other side, the network provides vehicles with real-time road condition alerts, traffic updates and many other important information. The integration of V2N communication with the new technologies like cloud computing, edge computing and 5G networks, enhances its capabilities. For example, 5G enables more reliable and faster data exchange, however edge computing enables real-time analysis and processing (Nadeem, Qadir, & Imran, 2020).

A UE which supports V2N applications shall communicate with any application server which supports V2N applications, as long as the parties are communicating with each other through something called Evolved Packet Switching (EPS) (Wang, et al., 2017).

Figure 5

Vehicle-To-Network (V2N) Communication (Everything RF., 2022).



However, this study will focus mainly on vehicle-to-vehicle communication taking into consideration every single parameter integrated into it.

CHAPTER II
Literature Review

Overview

Inter-Vehicle Communication as well as Vehicle-to-Vehicle Communication have been stated as an active research discipline for almost over two decades (Sichitiu, & Kihl, 2008).

Sensing Technologies and Wireless Communication that are involved in vehicles are expected to engage a wide and huge variety of safety-related applications that are presented in vehicular networks. In the future of Intelligent Transportation Systems, wireless communications that support intelligent vehicular sensing will go further, beyond the current applications, it will include video monitoring systems, radar, GPS, traditional GPS's handling emergency, and in addition to road condition perception. Those examples are only applicable in the line-of-sight conditions. But in the non-line-of-sight conditions, an increase in the situational awareness along with connectivity and coverage can be provided by the wireless communication (V. Va, et al., 2015).

In order to achieve an environmental intelligent sensing which is accurate, a huge number of sensing data should be exchanged between vehicles, which leads to an increase in the amount of vehicular sensors (Junil, et al., 2016). Having such huge numbers of vehicular sensors, especially with the high complexity of these sensing systems, it would be more difficult for the vehicles in order to transmit and then process this massive amount of the transmitted and received data from the sensor in real time. Such processing and transmitting are, in general, not supported by the current vehicle-to-vehicle communication systems (V. Va, et al., 2015).

On the other hand, in vehicle-to-vehicle communication, a channel load is the solution for ensuring the appropriate operation of drive-assistance systems as well as safety applications. As the number of vehicles, each year, increases, the number of their communication increases also. Consequently, vehicular communication through channels will significantly increase the efficiency of the driving systems (Aznar-Poveda, et al., 2021).

Related Works

The below mentioned works cover a wide range of subjects within V2V communication which includes future outlook on intelligent transportation, performance analysis, key management, security, protocols, capacity analysis, as well as data forwarding.

The first paper by Li, Zhang, Lu, and Shen, (2013) spots the lights on V2V-based forwarding data in networks of the vehicular ad hoc. The paper discovers the circumstances of forwarding data in such a dynamic vehicular environment and then proposes some solutions for an efficient data dissemination. This paper's authors recommend a forwarding scheme called novel data which takes advantage of the V2V communication in order to disseminate data between vehicles. The paper considers some factors such as data popularity, traffic conditions, and vehicle density in order to determine the appropriate forwarding strategy. This paper also gives a comprehensive analysis of the performance of the proposed scheme by simulations which shall demonstrate the effectiveness of it in the data dissemination improvement in V2V communication systems.

The second paper by Naoumov, Vinel, and Jonsson, (2015) talks about the V2V's capacity safety communication systems. It appears to focus on the analysis of the fundamental limitations of the information exchange system in V2V networks to seek safety applications. The authors of this paper consider different factors which involve channel interference and conditions, and communication range and then develop a comprehensive and easy capacity model for the safety in the V2V communication. After extensive analysis and simulations, the paper delivers insights to the road of achieving a desired capacity of the systems of the V2V communication, in addition, it explains the impact of the implementation of key parameters in the system performance. The results in this paper assist in having a better understanding of the design considerations and the fundamental limitations for V2V safety communication systems.

Thirdly, this paper is by Altintas, Ekici, and Ozguner, (2004) where they show a new protocol which is an urban multihop broadcasting system for the inter-vehicular communication systems. This paper reaches the problems of reliable data dissemination and its impact on the urban environment with frequent mobility changes and high vehicle densities. This paper's authors suggest a protocol which shall enable the vehicles to relay messages, efficiently, to neighboring vehicles, which will then form a multi-hop communication path. This particular protocol gathers a contention-based forwarding methodology in order to reach a reliable message delivery and mitigate packet collisions. Through performance evaluation and simulation results, the paper triggers the effectiveness of that protocol in improving the coverage and reliability of the inter-vehicular communication found in urban settings. The work helps in enhancing the and developing the reliability and efficiency in V2V systems, and in particular, in the urban environment where there exists high vehicular density.

The paper "A survey on key management for vehicular ad hoc networks" supplies an exhaustive outline of the techniques of the key management in vehicle ad hoc networks (VANET). The authors debate about the importance of a key management which is secured in VANETs in order to ensure authenticity, integrity and confidentiality of communication. They review various protocols, and key management architectures, as well as revocation mechanisms, establishment and key distribution. The paper also focuses on open research issues and challenges in key management for VANETs. Overall, the survey offers unique insights into the state-of-the-art key management attitudes for securing the communication in the vehicular networks.

"Secure vehicular communications: Challenges and countermeasures" paper mentions a comprehensive survey of the countermeasures and challenges in securing vehicular communication. The paper's authors discuss the security requirements and unique characteristics of the systems of vehicular communication, that includes integrity, privacy and authentication. They examine potential attacks and threats such as denial of service, message falsification, and location privacy branches, and then review various cryptographic techniques, protocols and security solutions that are proposed in order to mitigate these risks. The paper spots the lights of the importance of a secure version of vehicular communication as well as they offer valuable insights about state-of-the-are countermeasures and security challenges in this domain.

The last paper I want to mention is "A dynamic algorithm for interference management in D2D-enabled heterogeneous cellular networks: Modeling and analysis" by Kamruzzaman, Sarkar, and Gutierrez (2022), that helped me a lot through my researches stage in order to claim my aim. It does not talk about V2V communication, that's right, it focuses on the interference management in device-to-device-enabled heterogeneous cellular networks, and what it handles is very useful for the simulation stage I did. The project aims to analyze and propose a dynamic algorithm for mitigating the interference caused by D2D communication. In order to verify their approach, the authors employed simulation programs to analyze and model the performance of the algorithm. By utilizing these simulation tools, the paper's authors were able to evaluate the effectiveness of the algorithm in improving system capacity and reducing interference. The paper provides useful insights into interference management in the device-to-device-enabled networks which offers a comprehensive analysis of the proposed performance of the algorithm through simulation-based and modeling verification.

CHAPTER III
Methodology

Overview

As said before, whenever there exists two or several nodes in which one of them is the transmitter and the other is receiver, then, there exists something called nodal communication.

Taking vehicle-to-infrastructure communication as an example, this communication consists of a base station where this station is communicating with all the nodes around it in order to be the reference point among these nodes. In other words, all the nodes are being communicated with each other through that base station which is said to be the master node.

However, in vehicle-to-vehicle communication, just as the same concept as the vehicle-to-infrastructure communication, except that there is a direct communication between one vehicle and another, in which one vehicle shall transmit a signal, and the other vehicle shall receive that particular signal. So taking apart each vehicle, one vehicle can be a transmitter, a receiver, or a transmitter and a receiver at the same time (Korkmaz, et al., 2004).

Research Design

Now, talking about our subject, our aim is to be able to transmit and receive messages from one vehicle to another knowing the transmitter and receiver taking into consideration the optimal path between the transmitter and the receiver as well as the maximum power of the receiver vehicle.

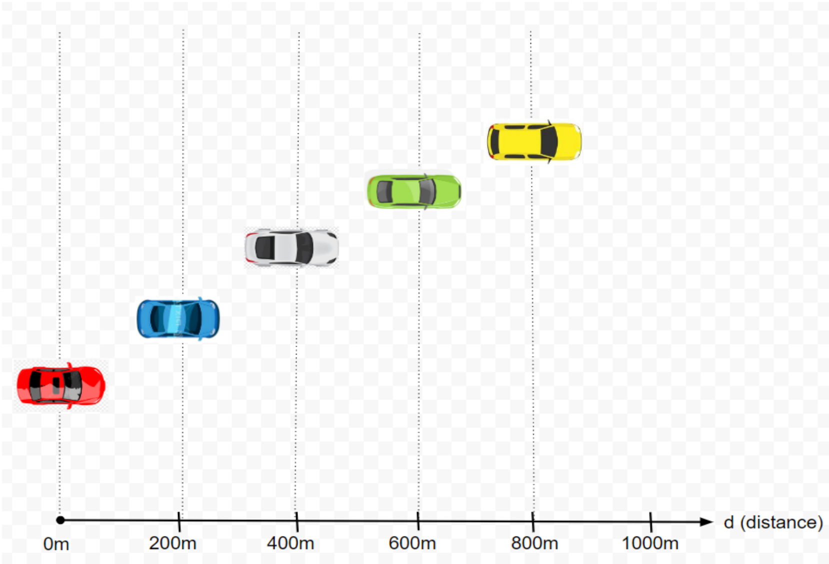
So, the first important thing that we should know before transmitting a signal is the transmission power for each node/vehicle.

A transmission power is said to be the ability of a vehicle to transmit and receive a signal. It refers to how much power is emitted by the vehicle in order to transmit and receive signals in vehicle-to-vehicle communication scenarios. The transmission power performs as the level of electrical power by which the transmitter of a vehicle operates in order to propagate the desired signals. The vehicle's transmission power shall affect the overall performance, coverage range and the signal strength of the vehicle in a vehicle-to-vehicle communication (Dey, et al., 2016).

In our system model, we assumed that there is a road that has five different vehicles acting as nodes, positioned along that 1000m road such that: node 1: red vehicle, node 2: blue vehicle, node 3: white vehicle, node 4: green vehicle and finally node 5: yellow vehicle. These vehicles are found on coordinates such that each vehicle is separated from the other with 200m long. The schematic of these vehicles are shown in figure 6 below.

Figure 6

System Schematic



Besides, each of these vehicles has its own transmission power in such a way that node 1 has 13dB, node 2 has 15 dB, node 3 has 18 dB, node 4 has 20 dB and finally node 5 has 25 dB as a transmission power.

Table 1.

Vehicles Description

Vehicle/Node	Coordinates	Transmission Power (decibel)
Node 1 (Red vehicle)	[0,0]	13dB
Node 2 (Blue vehicle)	[200,0]	15dB
Node 3 (White vehicle)	[400,0]	18dB
Node 4 (Green vehicle)	[600,0]	20dB
Node 5 (Yellow vehicle)	[800,0]	25dB

Parameters Definition

The target of our simulation is to study the impact of the transmission power on the vehicle-to-vehicle communication. So, in fact, we will not focus on the other variables during the simulation process, so we fixed these other variables. For this reason, we will consider a fixed antenna gain which is integrated in all the nodes as 3dBi.

The antenna gain in this project that is integrated in the vehicles relates to the measure of how an antenna can, effectively, receive or radiate electromagnetic signals in a specified direction in contrast to a reference antenna. The antenna gain quantifies the ability of an antenna to concentrate or focus the received power to the transmitted power in a specific direction. Having a higher antenna gain designates having a more directional and concentrated radiation pattern, however having a lower gain refers to having a broader radiation pattern (Stutzman, & Thiele, 2012).

In addition to the vehicle's antenna gain, we also considered the receiving sensitivity to be as -60dBm.

The receiving sensitivity in the vehicles is assigned to the minimum power level of an incoming signal where the vehicle's receiver can successfully demodulate and detect. It acts as the receiver's sensitivity towards weak signals, as well as specifies its ability to reliably decode and capture transmitted information. Having a low receiving sensitivity value specifies having a more sensitive receiver which can decode and detect weaker signals, that shall enhance the overall performance of the receiver (Rappaport, 2010).

During simulation, the transmitted signal is said to be random, which means that it consists of random bits transmitted from one vehicle to another. The reason behind this is that we do not care what kind of signals are being transmitted, what we care about is the transmission phenomenon itself. Because if this particular random generated signal can be transmitted and received successfully, then any other types or sequences of signals or messages that carry specific information can be transmitted and received as well. In our case, we assumed that this random generated signal that will be transmitted consists of 10 bits: [1 0 1 1 1 0 0 1 1 0]

The below table summarizes the parameters integrated and used in our simulation:

Table 2.

Parameters Used

Parameter	Value
Antenna gain for each vehicle	3dBi
Receiving sensitivity	-60dBm
Signal to be transmitted	[1 0 1 1 1 0 0 1 1 0]
Frequency (f) of the signal (hertz)	1G
Speed of light (c) (meters per second, m/s)	3×10^8

Now, in order to know if this random signal has been successfully received or not, we should calculate the path loss (PL) according to following formula:

$$PL = 20 \, log \, 10 \, (d) \, + \, 20 \, log \, 10 \, (f) \, + \, 20 \, log \, 10 \, (4/c)$$

(Saraereh, et al., 2019)

Where:

PL: Path loss in decibels (dB)

d: Distance between the transmitter and receiver in meters (m)

f: Frequency of the signal in hertz (1GHz)

c: Speed of light in meters per second (3 x 10^8 m/s)

The path loss, as Goldsmith, (2005), defined it is the reduction that happens in a signal strength as the radio waves propagate along a wireless channel between the transmitter and the receiver vehicle. Path loss can be influenced by several factors such as environmental conditions, obstacles, frequency and distance. Path loss is a very important parameter in vehicle-to-vehicle communication that can affect the signal quality, coverage, and the range in this communication.

After transmitting the signal, we should now know if it has been received as well as we should know, if received, its receiving power.

Goldsmith, (2005), also defined the received power as the power level of the signal that is received by the antenna of the receiving vehicle after which it has transmitted through the wireless channel. The received power refers to the strength of the signal that is received and it can be affected by various factors which includes environmental conditions, interference, path loss, and the sending vehicle's transmission power.

As the received power increases, this means that this particular path that it went through has the higher possibility of receiving signals. The received power, here, can be calculated using the following formula:

$$PR = TR + TG + RG - PL$$

Where:

PR: Received power

TR: Transmission power

TG: Transmitter antenna gain

RG: Receiver antenna gain

PL: Path loss

Till now, it is not enough to know the received power in order to specify the optimal path, what matters here is knowing something called the packet success rate.

The packet success rate means that this traveled packet, or signal, that is trying to reach that particular destination, or node, is being successfully received or not, without being corrupted or lost. It is a performance metric which quantifies the effectiveness and reliability of the communication link that is found between the vehicles. Having a higher packet success rate refers to a more robust and reliable communication system, in contrast to having a lower rate that shall imply in having higher transmission errors or packet loss (Zhang, et al., 2009).

The packet success rate is determined by the ratio of successfully received beacons by all vehicles to the total number of beacons sent by the transmitter vehicle inside a predefined transmission range as shown below:

Packet Success Rate (PSR) = (Number of successful received signals / Total transmitted signals) x 100

(Qiao, et al., 2012)

If the received power is greater than the receiving sensitivity (which is -60dBm) means that this signal has been successfully received, however if the received power is less than the receiving sensitivity, it means that the signal has failed to be received. Therefore, the node that has the highest packet success rate, is the node that is receiving signals more than the other nodes.

For example, if we are sending signals four times and node 1 received three of these times, this means that the packet success rate of this node 1 is 75%.

This implies that the vehicle that has the highest packet success rate is the vehicle that owns the optimal path for transmission.

Zhang, et al., (2009), defined the optimal path in vehicle-to-vehicle communication as the most favorable sequence or route of communication link that maximizes the reliability and quality of transmitting the data between vehicles. The optimal path requires selecting the path which minimizes the packet errors or loss, maximizes the received signal data as well as minimizes the likelihood of path loss.

CHAPTER IV
Findings and Discussion

MATLAB Simulation

The previously explained system model was verified using MATLAB-based simulation software.

Our aim from this code is to study the effect of increasing the transmission powers on the V2V communication, or on the nodal communication.

We initiated the simulation by defining our parameters and fixing the vehicles with the distances mentioned in the previous section. Tables 1 and 2 were defined in the MATLAB where each vehicle's coordinates and transmission power were fixed, as well as the parameters which are antenna gain for each vehicle, receiving sensitivity, signal to be transmitted, frequency (f) of the signal and the speed of light (c) were also established.

Through this code, we enabled it to run in such a way that the previously defined signal will be sent to each node. This means that each node will send this signal to all the other nodes, but skipping itself, after taking all the predefined parameter into consideration, for example node 1 will send the signals to node 2, node 3, node 4 and finally node 5 but without sending it to node 1, which is itself. This was done according to the algorithm 1 mentioned below;

Table 3.

Algorithm 1

Transmission links iterations

```
% Transmission links ...
numNodes = size(COORDINATES, 1);
receivedPower = zeros(numNodes, numNodes);
currentdistance = zeros(numNodes,numNodes);
% Transmission links iterations
for transmitter = 1:numNodes
for receiver = 1:numNodes
if transmitter == receiver
continue; % Skip self-transmission
```

Before continuing to explain the code, let's explain a very important term which is the transmission link. A transmission link is nothing but the link between each node as one transmitter to another receiver, such as the link between the first node "transmitter", and the second node "receiver". Each vehicle will conduct 4 transmission links (4 receiver nodes, except itself).

For each transmission link, or for each transmission iteration, the transmission range, distance, and path loss will differ which will lead to different received powers. The path loss was calculated based on the below algorithm;

Table 4.

Algorithm 2

Calculating path loss

```
...
distance = norm(COORDINATES(transmitter, :) -
COORDINATES(receiver, :));
pathLoss = 20 * log10(distance) + 20 *
log10(FREQUENCY) + 20 * log10(4 * pi /
SPEED_OF_LIGHT);
...
```

After having the received power for each transmission link, we will compare this received power with the receiving threshold (or as defined as receiving sensitivity which is said to be -60dBm). If the received power is greater than or equal to the receiving sensitivity, then this transmission link is successful. The received power for a specific transmission link is determined by the following algorithm;

Table 5.

Algorithm 3

Calculating received power and comparing it to the receiving sensitivity

```
...
receivedPower(transmitter, receiver) =
TRANSMISSION_POWER(transmitter) + ANTENNA_GAIN +
ANTENNA_GAIN - pathLoss;
% Check if received power exceeds sensitivity
threshold
if receivedPower(transmitter, receiver) >=
RECEIVING_SENSITIVITY
successfulBeacons(transmitter) =
successfulBeacons(transmitter) + 1;
end
...
```

Notes:

1. We added two times ANTENNA GAIN because the ANTENNA GAIN of the transmitter equals the ANTENNA GAIN of the receiver (3dBi).

2. For each time the received power is greater than or equal to the receiving sensitivity, a variable called successful beacon will increase by 1 which indicates the number of successful transmission links.

   After finishing all the transmission iteration of this particular node, we will then calculate the PSR or the packet success rate according to the formula stated in the previous section. The PSR, as explained before, depends on the successful beacons, which means how many times we send a signal and was successfully received. The packet success rate is identified on the MATLAB simulation according to following algorithm;

Table 5.

Algorithm 4

Calculating Packet Success Rate (PSR) for each node
...
PSR = (successfulBeacons ./ totalBeacons) * 100;
...

MATLAB Outcome

Every time the code is repeated, the PSR is being calculated and saved for each node. As a result of this repetition, the PSR for each node, the maximum PSR and its corresponding node, as well as the average PSR for each transmission/reception link was obtained in the command window as shown in figure 7:

Figure 7

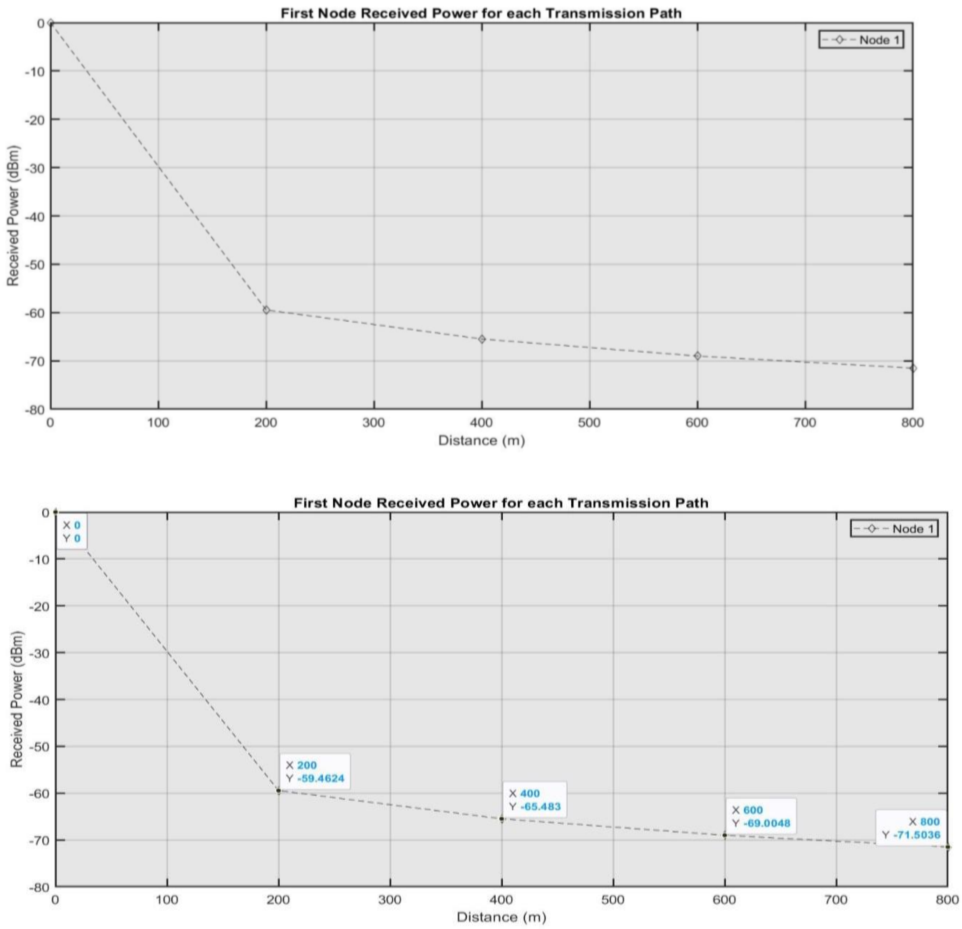
PSR for Each Node (From Command Window of The MATLAB)

```
Command Window
The first node Packet Success Rate Value i 25.00%.
The second node Packet Success Rate Value i 50.00%.
The third node Packet Success Rate Value i 50.00%.
The fourth node Packet Success Rate Value i 75.00%.
The fifth node Packet Success Rate Value i 100.00%.
The best next hop for data transmission is Node 5 with a PSR of 100.00%.
Average PSR for each transmission/reception link:
    60
```

After finishing all the calculations, we will plot the corresponding graphs and tables. The first graph is about the received power for only node 1 transmission links. The results are shown in figure 8 below;

Figure 8

Received Power for Each Node One Transmission Links (From MATLAB)



Secondly, we obtained the table for the received power for each transmission link or path. It is shown in table 3 below;

Figure 9

Received Power for Each Transmission Path (from MATLAB)

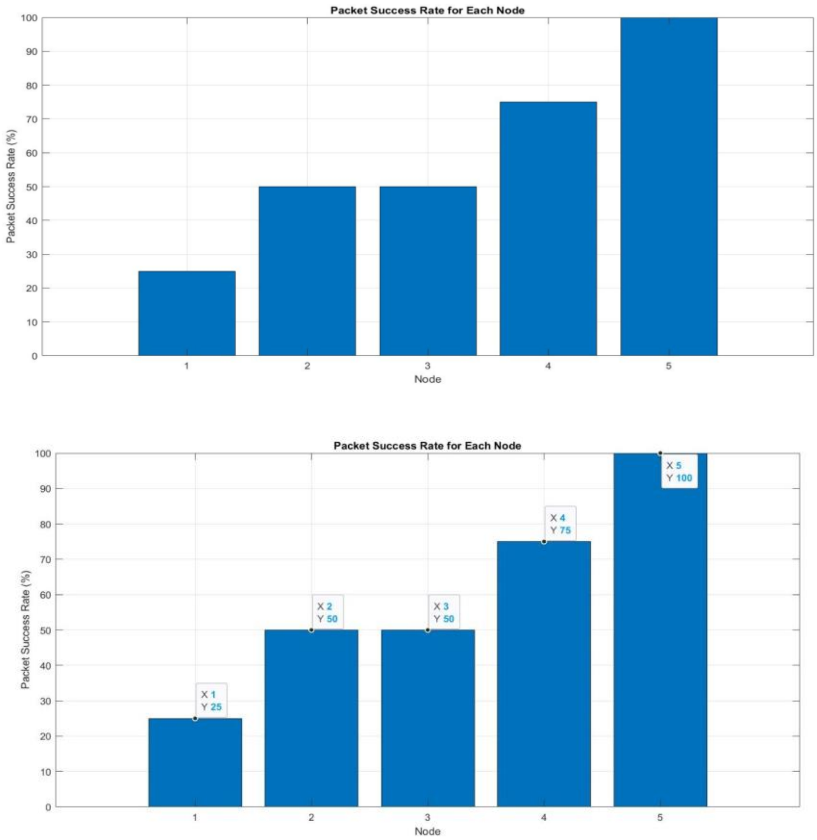
Received Power for each Transmission Path

	NODE 1	NODE 2	NODE 3	NODE 4	NODE 5
NODE 1	0	-59.4624	-65.4830	-69.0048	-71.5036
NODE 2	-57.4624	0	-57.4624	-63.4830	-67.0048
NODE 3	-60.4830	-54.4624	0	-54.4624	-60.4830
NODE 4	-62.0048	-58.4830	-52.4624	0	-52.4624
NODE 5	-59.5036	-57.0048	-53.4830	-47.4624	0

After that, we obtained the histogram of Packet Success Rate for each node, this histogram is shown in figure 9 below:

Figure 10

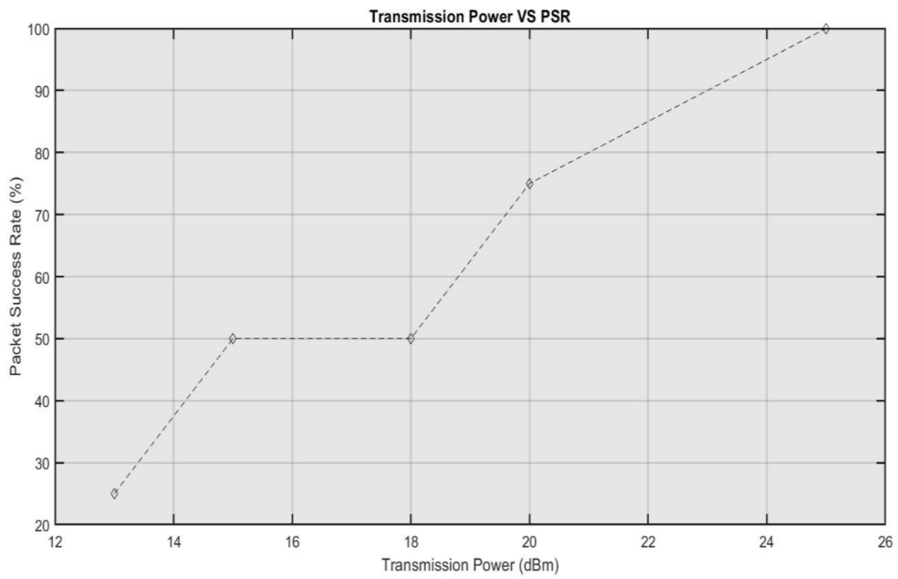
Packet Success Rate for Each Node (from MATLAB)

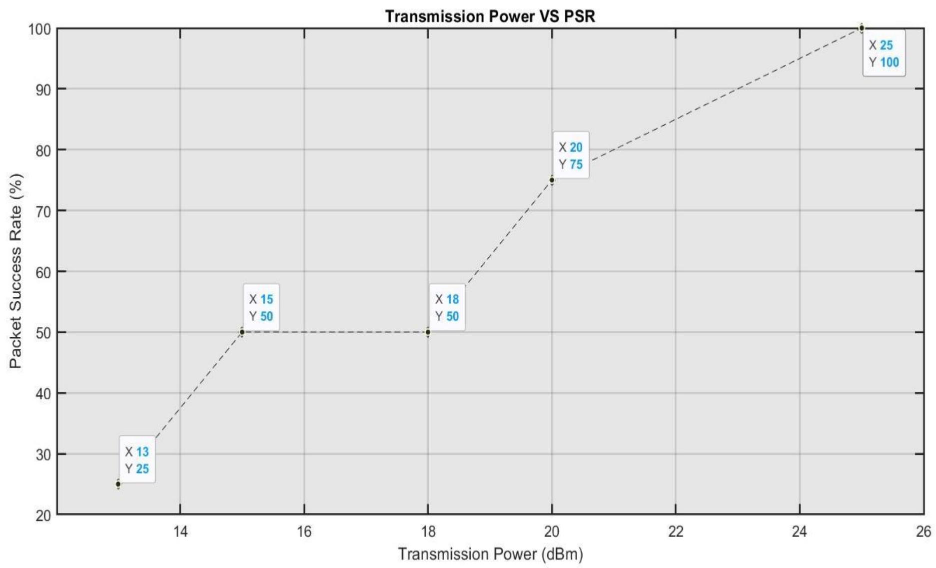


Lastly, we obtained the graph of the increase in the packet success rate with respect to the increase in the transmission power. This graph is shown in figure 10 below;

Figure 11

The Increase in The PSR with Respect to The Increase in The Transmission Power (From MATLAB)





:

CHAPTER V
Discussion

Based on the previous simulation results, we will consider the node/vehicle that has the highest packet success rate as the best next bounce or hop for our data transmission aim. That means that, after we tried all the nodes for transmitting and receiving signals, towards and from each node, we observed that **node 5 (the yellow vehicle)** has the highest packet success rate (100%), so this particular node will be selected as the best hop for our aim, and that vehicle shall own the optimal path.

In addition to that, we shall expect an increase in the packet success rate or PSR average values for all types of transmission and receiving links as long as the transmission power is increasing.

Not only that, but we also foresee that the increase in the transmission range, which are 200m, 400m, 600m, 800m, shall result in larger differences among the PSR average values that are associated with each transmission and reception link found when the transmission power is increased. This was observed when we were trying to send a signal from the first node (red vehicle) to the last node (yellow vehicle), which is different from if we were trying to send a signal from the first node (red vehicle) to the second node (blue vehicle). This was obvious because of the difference in the distances that separates the vehicles which is 800m in the first transmission scenario whereas in the second transmission the distance was 200m. This shall assure our aim which is said to be that the distance shall not affect the optimal transmission path. In fact, the node that has the highest transmission power, will have the highest packet success rate, therefore, it will definitely own the optimal transmission path.

CHAPTER VI
BlockChain Network

A blockchain network is a distributed and decentralized ledger technology which enables data exchanging or transparent and secure transactions between multiple participants or nodes (Kosba, et al., 2016).

Blockchain working principle is based on a chain of blocks, each one of these blocks contains a set of data records or transactions. These blocks are all together linked using something called cryptographic hashes, which form a tamper-resistant and immutable ledger. The nature of the decentralization of blockchain ensures that no single entity has full control over the network, which shall provide resilience, security and transparency (Bilgehan, & Sabuncu, 2023).

How Blockchain Works

The networks of the blockchain operate with the help of a consensus mechanism that ensures an agreement between the participants about the validity of transactions. When initiating a transaction, it is broadcasted towards the network, and the participating nodes verify its validity. After verification, the transaction is tied up with the other validated transactions and then added to a block. Each one of these blocks contains a reference to the block just before, which shall form a chronological chain of these blocks. This blocks' link, using the cryptographic hashes, assure the immutability and integrity of the ledger. In addition, the cryptographic algorithms are being used in order to protect the privacy of the data, authenticate participants, and secure the network (Dorri, et al., 2017 & Zheng, et al., 2017).

Integration of Blockchain Network in Vehicle-to-Vehicle (V2V) Communication

The aim behind integrating the blockchain network in the vehicle-to-vehicle (V2V) communication is basically to offer several potential applications and benefits. Blockchain provides a transparent and decentralized platform for reliable and secure exchange between the vehicles in order to enhance the trustworthiness, efficiency, and safety of V2V communication (Mo, et al., 2019).

The first benefit in the transparent and secure data exchange. Blockchain allows tamper-resistant and secure data exchange among the vehicles. Each V2V data exchange or transaction can be recorded on the blockchain as a transaction, which will form a transparent and immutable ledger. The nature of decentralization of the blockchain assures that no single entity can control or manipulate the data, in order to enhance the trust between the participating vehicles (Conti, 2018).

Secondly, one of these benefits is authentication and data integrity. Blockchain presents a robust mechanism in order to ensure the authentication and data integrity in V2V communication. Each data exchange or transaction is cryptographically verified and signed, which shall ensure the trustworthiness and authenticity of the exchanged data (Zheng et al., 2018).

Not only that, but the access management and decentralized identity are one of the many benefits of blockchain network. Blockchain may enable access management and decentralized identity in V2V communication. Vehicles now can have digital identities which are unique, which are stored on the blockchain, in order to allow for a controlled and secured access to V2V communication networks. This shall assist in preventing unauthorized vehicles from participating in V2V communication, as well as enhancing the overall security of the system (Sharma et al., 2020).

In addition, blockchain technology is known for their ability for cooperative driving through smart contracts. Programmable self-executing contracts, or as known as the smart contracts, which are deployed on the blockchain, can ease cooperative driving in the V2V communication. Also, these smart contracts enable vehicles to enforce and establish agreements, such as collision avoidance mechanisms, priority rules and lane merging protocols, in order to enhance safety and coordination in V2V communication (Bartoletti et al., 2017).

Last but not least, blockchain technology is able to do incentive mechanisms and micropayments. Blockchain enables the integration of incentive mechanisms and micropayments in V2V communication. After utilizing blockchain-based tokens or cryptocurrencies, vehicles can exchange incentives or values for sharing data, and that is done in order to participate in cooperative driving and provide traffic information. This reveals new possibilities for rewarding and incentivizing participation in V2V communication (Zhou et al., 2018).

In conclusion, integrating blockchain technology in vehicle-to-vehicle communication is still an active area of development and research. While the previously mentioned benefits are promising, however, challenges such as standardization, latency and scalability need to be addressed in order to realize the full potential of the blockchain in V2V communication systems.

CHAPTER VII
Conclusions and Recommendations

Conclusion

This work first introduced digital communication, wireless communication and the relationship between these two communication types and vehicle-to-vehicle communication. Then, detailed functions, objectives and definitions of vehicle-to-everything communication were discussed, as well as each type of the vehicle-to-everything communication where explained briefly. After that, the simulation process and its output were interpreted successfully.

To conclude everything mentioned above, vehicle-to-everything (V2X) communication illustrates a transformative paradigm which revolutionizes how the vehicles interact with each other and with their surroundings. With its various disciplines, V2V, V2I, V2P as well as, V2N communications, V2X communication handles the most important key to creating connected, more efficient, and safer transportation systems.

Among these disciplines, V2V communication appears as a pivotal aspect that enables vehicles to transmit and receive real-time information about their intentions, speed and position. This collaboration optimizes traffic flow, reduces accidents, and enhances situational awareness.

Thanks to our MATLAB simulation that proved that the distance between any two vehicles will not affect the optimal path of the transmitted signal, but what will definitely affect the optimal path is the transmission power for each vehicle. Which definitely means that having an obvious increase in the transmission power, shall result obviously in an important increase in the packet success rate which will specify the proper and the optimal path.

As for the integration of the blockchain network into the V2V communication, it puts a layer of security, trust and transparency to the exchanged data. The decentralized nature of the blockchain ensures the immutability and integrity of the shared information, meanwhile, smart contracts enable secure and automated interactions between vehicles.

The fusion of blockchain technology and V2V communication has the potential to unlock remarkable advancements in autonomous driving, traffic management and road safety. By establishing efficient and secure data exchanges, V2V communication, which is empowered by blockchain technology, allows the vehicles to coordinate their movements, avoid collisions, and make informed decisions seamlessly.

Recommendations

However, there are some challenges that need to be overcome, such as interoperability, latency and scalability, in order to successfully realize the potential of blockchain integrated in V2X communication. Ongoing development and research shall aim to refine the technologies and address these challenges for a widespread adoption.

As we continue navigation towards a future where vehicles are seamlessly connected, the integration of blockchain technology and V2X communication will apparently continue to play a very crucial role in shaping and sizing the future of the transportation landscape. Thanks to their combined power, we can generate reliability, efficiency, and safety, ultimately transforming the manner in which we experience mobility.

REFERENCES

Alam, M., Benmimoun, A., & Kobbane, A. (2020). Vehicle-to-Vehicle Communication: Challenges and Perspectives. In International Conference on Communications, Signal Processing, and Systems (pp. 675-683). Springer.

Al-Sultan, S., Al-Doori, M. M., Al-Bayatti, A. H., & Zedan, H. (2014). A comprehensive survey on vehicular ad hoc network. Journal of network and computer applications, 37, 380-392.

Altintas, O., Ekici, E., & Ozguner, F. (2004). Urban multi-hop broadcast protocol for inter-vehicle communication systems. IEEE INFOCOM 2004. Twenty-third AnnualJoint Conference of the IEEE Computer and Communications Societies, Vol. 4, 2558-2569.

Aznar-Poveda, J., Garcia-Sanchez, A. J., Egea-Lopez, E., & García-Haro, J. (2021). Simultaneous data rate and transmission power adaptation in V2V communications: A deep reinforcement learning approach. IEEE Access, 9, 122067-122081.

Bartoletti, M., & Pompianu, L. (2017). An empirical analysis of smart contracts: platforms, applications, and design patterns. In Financial Cryptography and Data Security: FC 2017 International Workshops, WAHC, BITCOIN, VOTING, WTSC, and TA, Sliema, Malta, April 7, 2017, Revised Selected Papers 21 (pp. 494-509). Springer International Publishing.

Bilgehan, B., & Sabuncu, Ö. (2023). An optimized device-to-device (D2D) blockchain network for the insurance industry. International Journal of Communication Systems, 36(6), e5446.

Cheng, J., & Lo, H. K. (2015). Vehicle-to-vehicle (V2V) propagation models for urban environments. IEEE Transactions on Vehicular Technology, 64(4), 1479-1487.

Conti, M., Kumar, E. A., Lal, C., & Ruj, S. (2018). A survey on security and privacy issues of blockchain technology. IEEE Communications Surveys & Tutorials, 20(4), 3361-3391.

Cunha, F., Villas, L., Boukerche, A., Maia, G., Viana, A., Mini, R. A., & Loureiro, A. A. (2016). Data communication in VANETs: Protocols, applications and challenges. Ad hoc networks, 44, 90-103.

Dey, K. C., Rayamajhi, A., Chowdhury, M., Bhavsar, P., & Martin, J. (2016). Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication in a heterogeneous wireless network–Performance evaluation. Transportation Research Part C: Emerging Technologies, 68, 168-184.

Dorri, A., Kanhere, S. S., Jurdak, R., & Gauravaram, P. (2017, March). Blockchain for IoT security and privacy: The case study of a smart home. In 2017 IEEE international conference on pervasive computing and communications workshops (PerCom workshops) (pp. 618-623). IEEE.

Goldsmith, A. (2005). Wireless communications. Cambridge university press.

Hafeez, F., Sheikh, U. U., Alkhaldi, N., Al Garni, H. Z., Arfeen, Z. A., & Khalid, S. A. (2020). Insights and strategies for an autonomous vehicle with a sensor fusion innovation: A fictional outlook. IEEE access, 8, 135162-135175.

Haykin, S. S., & Moher, M. (2011). Modern wireless communications. Pearson Education India.

Inoue, H., Osawa, S., Yashiki, A., & Makino, H. (2004, June). Dedicated short-range communications (DSRC) for AHS services. In IEEE Intelligent Vehicles Symposium, 2004 (pp. 369-374). IEEE.

Jameel, F., Javed, M. A., Zeadally, S., & Jäntti, R. (2020). Efficient mining cluster selection for blockchain-based cellular V2X communications. IEEE Transactions on Intelligent Transportation Systems, 22(7), 4064-4072.

Junil, C., Vutha, V., & Nuria, G. P. (2016). BHAT CHANDRA R.; HEATH ROBERT W.:" Millimeter-Wave Vehicular Communication to Support Massive Automotive Sensing. IEEE COMMUNICATIONS MAGAZINE., IEEE SERVICE CENTER, PISCATAWAY., US, 54(12), 2016-12.

Kamruzzaman, M., Sarkar, N. I., & Gutierrez, J. (2022). A dynamic algorithm for interference management in D2D-enabled heterogeneous cellular networks: Modeling and analysis. Sensors, 22(3), 1063.

Korkmaz, G., Ekici, E., Özgüner, F., & Özgüner, Ü. (2004, October). Urban multi-hop broadcast protocol for inter-vehicle communication systems. In Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks (pp. 76- 85).

Kosba, A., Miller, A., Shi, E., Wen, Z., & Papamanthou, C. (2016, May). Hawk: The blockchain model of cryptography and privacy-preserving smart contracts. In 2016 IEEE symposium on security and privacy (SP) (pp. 839-858). IEEE.

Li, K., Zhang, W., Lu, X., & Shen, X. (2013). V2V-based data forwarding in vehicular ad hoc networks. IEEE Transactions on Vehicular Technology, 62(8), 3864-3875.

Ling, J., Zhu, Y., Chen, X., & Zhang, X. (2019). Vehicular Communication Technologies: Protocols, Security, and Privacy. IEEE Internet of Things Journal, 6(5), 8255-8269.

Liu, K., Li, K., Liu, Y., & Cheng, H. H. (2017). Communication technologies for connected vehicles. IEEE Wireless Communications, 24(2), 8-14.

Luan, T. H., Cai, L. X., Chen, J., Shen, X. S., & Bai, F. (2013). Engineering a distributed infrastructure for large-scale cost-effective content dissemination over urban vehicular networks. IEEE Transactions on Vehicular Technology, 63(3), 1419-1435.

Ma, Y., & Wang, C. (2016). Secure vehicular communications: Challenges and countermeasures. IEEE Communications Surveys & Tutorials, 18(1), 362-385.

Martinez, F. J., Toh, C. K., Cano, J. C., Calafate, C. T., & Manzoni, P. (2010). Emergency services in future intelligent transportation systems based on vehicular communication networks. IEEE Intelligent Transportation Systems Magazine, 2(2), 6-20.

Mo, S., Xu, W., Wang, Q., & Yin, Z. (2019). A survey on blockchain for vehicular networks: Applications, challenges, and solutions. IEEE Internet of Things Journal, 6(5), 8072-8083.

Molisch, A. F. (2012). Wireless communications (Vol. 34). John Wiley & Sons.

Nadeem, Q., Qadir, J., & Imran, M. A. (2020). 5G-enabled V2X communications: Challenges, opportunities, and solutions. IEEE Communications Magazine, 58(4), 87-93.

Naoumov, V., Vinel, A., & Jonsson, M. (2015). On the capacity of vehicle-to-vehicle safety communication systems. IEEE Transactions on Intelligent Transportation Systems, 16(5), 2829-2839.

Nguyen, T. V., Shailesh, P., Sudhir, B., Kapil, G., Jiang, L., Wu, Z., ... & Li, J. (2017, November). A comparison of cellular vehicle-to-everything and dedicated short range communication. In 2017 IEEE Vehicular Networking Conference (VNC) (pp. 101-108). IEEE.

Oh, H., Yae, C., Ahn, D., & Cho, H. (1999, September). 5.8 GHz DSRC packet communication system for ITS services. In Gateway to 21st Century Communications Village. VTC 1999-Fall. IEEE VTS 50th Vehicular Technology Conference (Cat. No. 99CH36324) (Vol. 4, pp. 2223-2227). IEEE.

Papadimitratos, P., & La Fortelle, A. D. (Eds.). (2017). Vehicular Networking: Automotive Applications and Beyond. Wiley.

Proakis, J. G. (2008). Digital communications. McGraw-Hill, Higher Education.

Qiao, Y., Wolterink, W. K., Karagiannis, G., & Heijenk, G. (2012, June). Evaluating the Impact of Transmission Power on Selecting Tall Vehicles as Best Next Communication Hop. In Joint ERCIM eMobility and MobiSense Workshop (p. 15).

Rappaport, T. S. (2010). Wireless communications: Principles and practice, 2/E. Pearson Education India.

Saraereh, O. A., Mohammed, S. L., Khan, I., Rabie, K., & Affess, S. (2019). An efficient resource allocation algorithm for device-to-device communications. Applied Sciences, 9(18), 3816.

Sharma, R., Jain, N., Kaul, A., & Hossain, E. (2020). Blockchain-enabled secure V2X communications in intelligent transportation systems: Challenges, opportunities, and solutions. IEEE Communications Surveys & Tutorials, 22(2), 1343-1380.

Sichitiu, M. L., & Kihl, M. (2008). Inter-vehicle communication systems: a survey. IEEE Communications Surveys & Tutorials, 10(2), 88-105.

Stutzman, W. L., & Thiele, G. A. (2012). Antenna theory and design. John Wiley & Sons.

V. Va, T. Shimizu, G. Bansal, and R. W. Heath, Jr., "Millimeter wave vehicular communications: A survey," Foundations Trends Networking, vol. 10, no. 1, pp. 1–113, 2015. doi: 10.1561/1300000054.

Wang, X., Mao, S., & Gong, M. X. (2017). An overview of 3GPP cellular vehicle-to-everything standards. GetMobile: Mobile Computing and Communications, 21(3), 19-25.

What is V2N?, Dec. 2022, everything RF, retrieved from https://www.everythingrf.com/community/what-is-v2n

Yang, X., Liu, L., Vaidya, N. H., & Zhao, F. (2004, August). A vehicle-to-vehicle communication protocol for cooperative collision warning. In The First Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services, 2004. MOBIQUITOUS 2004. (pp. 114-123). IEEE.

Zang, L., Xu, M., & Zhang, X. (2019). A survey on key management for vehicular ad hoc networks. IEEE Access, 7, 45462-45480.

Zhang, Z., Zhang, W., & Tellambura, C. (2009). Cooperative OFDM channel estimation in the presence of frequency offsets. IEEE Transactions on Vehicular Technology, 58(7), 3447-3459.

Zheng, K., Zheng, Q., Chatzimisios, P., Xiang, W., & Zhou, Y. (2015). Heterogeneous vehicular networking: A survey on architecture, challenges, and solutions. IEEE communications surveys & tutorials, 17(4), 2377-2396.

Zheng, Z., Xie, S., Dai, H., Chen, X., & Wang, H. (2017, June). An overview of blockchain technology: Architecture, consensus, and future trends. In 2017 IEEE international congress on big data (BigData congress) (pp. 557-564). Ieee.

Zhou, L., Kundu, S., & Raychoudhury, V. (2018). Securing the Internet of Vehicles: Challenges, solutions, and future directions. IEEE Internet of Things Journal, 5(6), 4019-4033.

APPENDICES

Appendix A.

Similarity Check Report

\\\\\

INBOX | NOW VIEWING: NEW PAPERS ▾

Submit File

Online Grading Report | Edit assignment settings | Email non-submitters

AUTHOR	TITLE	SIMILARITY	GRADE	RESPONSE	FILE	PAPER ID	DATE
Sara Kayed	abstract	0%	--	--		2158961571	06-Sep-2023
Sara Kayed	Conclusion	0%	--	--		2163964654	12-Sep-2023
Sara Kayed	Blockchain network	2%	--	--		2158962871	06-Sep-2023
Sara Kayed	Literature Review	2%	--	--		2158962167	06-Sep-2023
Sara Kayed	Findings	4%	--	--		2158962545	06-Sep-2023
Sara Kayed	Discussion	5%	--	--		2158962691	06-Sep-2023
Sara Kayed	Methodology	5%	--	--		2158962323	06-Sep-2023
Sara Kayed	Full thesis	13%	--	--		2158961368	06-Sep-2023
Sara Kayed	Introduction	13%	--	--		2158961980	06-Sep-2023