UNIVERSITY of RWANDA

Research and Postgraduate Studies (RPGS) Unit

ACEIoT

“INTEGRITY OF WIRELESS COMMUNICATION IN PLATOON MODEL”

NTIRENGANYA Emmanuel

College of Science of Technology

School of Engineering

Master’s degree

Of

Internet of Things (IoT) / Wireless Intelligent Sensor Networking

(MSc in IoT-WISeNet)

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“INTEGRITY OF WIRELESS COMMUNICATION IN PLATOON MODEL”

Submitted by:

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A Dissertation submitted in partial fulfillment of the requirement for the award of the Master’s degree

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(MSc in IoT-WISeNet)

In

College of Science and Technology

Under the Guidance of:

Dr. Charles KABIRI

Dr. Jean Baptiste MBANZABUGABO

Dissertation, December 2020

DECLARATION

I hereby declare that, the project entitled, "***INTEGRITY OF WIRELESS COMMUNICATION IN PLATOON MODEL*"** is original and has never been submitted to any university or other Institutions of Higher learning. It is my own research whereby other scholar's writings were cited and references provided. I thus declare this is my product and was completed successfully under the guidance of **Dr. Charles KABIRI** and **Dr. Jean Baptiste MBANZABUGABO**

Names: NTIRENGANYA Emmanuel

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BONAFIDE CERTIFICATE

This is to certify that the project report titled "***INTEGRITY OF WIRELESS COMMUNICATION IN PLATOON MODEL***" is the veritable work of **NTIRENGANYA Emmanuel** with reference number of **214003194** in partial fulfillment of the requirement for the award of a Master's degree in Internet of Things - Wireless Intelligent Sensor Networking (MSc in IoT-WISeNet) from College of Science and Technology at University of Rwanda.

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Finally, but not least, I thank all our classmates.

DEDICATION

This thesis is dedicated;

To the Almighty God

To my family

To my college

To my classmates

ABSTRACT

The technology made an easy way of communicating by allowing devices to communicate with each other. The group of mobile devices communicating among each other grouped in small or large cluster is a platooning, where a group of autonomous cars following each other at closer distance with the benefits of increasing road capacity, fuel savings, and quick response at any mission as there is no suddenly halt of human manoeuver. In this work, I consider the platooning made of vehicles communicating wirelessly through any communication channel based on the transmission of any vehicle. Thus, every vehicle is equipped by a group of sensors for facilitating this communication. In some cases, error may occur suddenly. In this regard an integrity of communication between vehicles is in question and needs a deep study, the Symbol Error Probability (SEP) between vehicles is analyzed by considering the transmitted power, M-symbols per bits all- in function of the number of vehicles involved in platooning and the transmitted power in function M-symbols per bit, the variation of M-symbols influence the variation of PSK modulation on different Symbols such as M=2, is BPSK until to M=32 for 32 QAM. The variation of platoon size is analyzed based on transmitted power and M-ary modulation is considered and captured through numerical results and interpreted on graph.

ACRONYMS

V2V	Vehicle –to-Vehicle
LV	Lead Vehicle
FV	Follower Vehicle
PDF	Probability Density Function
VANETS	Vehicle Ad-hoc Networks
CACC	Cooperative Adaptive Cruise Control
ACC	Adaptive Cruise Control
AI	Artificial Intelligence
IoT	Internet of Things
DMV	Department of Motor Vehicles
SEP	Symbol Error Probability
SARTRE	Safe Road Trains for the Environment
OBU	On Board Unit
GPS	Global Positioning System
V2I	Vehicle –to – Infrastructure
SEV	Small Electrical Vehicle
AWGN	Additive White Gaussian Noise
SINR	Signal-to-Interference plus Noise Ratio

RX	Receiver
PSK	Phase Shift Keying
CDF	Cumulative Density Function
ASK	Amplitude Shift Keying
QAM	Quadrature Amplitude Modulation
SNR	Signal to Noise Ratio
GM	General Motors
PCAC	Platooning Cooperative Adaptive Cruiser Control
V2X	Vehicle –to –Everything
V2I	Vehicle –to- Infrastructure
D2D	Device-to- Device
TDMA	Time Division Multiple Access
FDMA	Frequency Division Multiple Access
4G	Fourth Generation
5G	Fifth Generation
Ref. No	Reference Number
ADAS	Advanced Driver Assistance Systems
CAN	Control Area Network
DSRC	Dedicated Short Range for Communication
TX	Transmitter
APLM	Asymmetric Profit-Loss Markov

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CHAPTER 1 : GENERAL INTRODUCTION

Autonomous vehicle systems are growing rapidly in this century, thus vehicle manufacturing companies like Tesla, General Motors (GM), Waymo and others are striving more and more. Each company is trying to be a pioneer (Business insider Africa, 2019). More than forty vehicle private companies are working on autonomous driving in collaboration with software developers like Amazon, Apple, Aptiv, Baidus for making vehicle more intelligent with the use artificial intelligence (AI) in developing different software (epicflow, 2020). An autonomous vehicle refers to a vehicle that uses sensory data of surrounding environment to route without human drivers (TechTarget, n.d). The connected vehicles are always on-links via the internet to the data centers and other infrastructures. Hitachi has developed a diverse range of center services and onboard devices to provide a platform for connected cars from increasing sophisticated navigation, safety and telematics services (Hitachi, n.d).

An adaptive cruise control (ACC) vehicle allows drivers to maintain a desired following gap with respect to a following vehicle based on range sensors (radar or lidar) measurements of distance and speed difference in order to achieve longitudinal control by actuating the brake and throttle of the vehicle in an automated manner (Masoud & Cody, 2017).

In that way the orchestration of autonomous vehicles known as a platoon take place where a group of vehicles can communicate through the use intelligent process systems to communicate with sensors and actuating the vehicle on route with the use of technology like drive assistance systems, automotive radar, ADAS ultrasonic wave components, Lidar system sensors and so forth (Francisca, Pedro, Carlos, & Antonio, 2019).

As vehicles communicate among themselves by the use of internet of things (IoT) sometimes contents can get lost based on weather conditions which can hinder the power to reach on destination successfully (Leonardo & Fernando, 2020). If a car perceived an obstacle on the road, it would communicate the evasive action to all other vehicles giving them time to respond appropriately. Even the slightest break in communications could cause disaster (University of Virginia, 2018).

For example, in September 2014 and November 2015, the autonomous vehicles of Google in California had 272 failures and would have crashed at least 13 times if their human test drivers had not intervened, according to a document filed by Google with the California Department of Motor Vehicles (DMV) (TheGuadian, n.d).

The autonomous technology is classified into five levels which may varies to another level with the impact of technology grow, the genesis level is known as "no-automation" level 0 , the driver has complete control of a vehicle with respect to steering, braking, throttle and motive, the second level is "function specific automation" nominated as level 1, in this level some function are managed by technology where electronic function controlled brake, the third level is "Combined function automation" classified as level 2, main functions such as adaptive cruise control (ACC) in combination with lane centering is automated, the fourth level is "Limited self-driving automation" known as level 3, driver surrenders full control of all safety, critical function and relies on the vehicle to watch for any changes in conditions requiring transition to driver control. The driver will be required to resume control of the vehicle but with sufficient transition time, current level is "Full self-driving automation" nominated as level 4, in this level, the vehicle is intelligently designed to adapt on roadways conditions. It is a fully driverless on an entire trip (Saeed, Madjid, Mahsen, & Tracey, 2016).

A vehicle-to-vehicle communication is made possible due to the internet of things (IoT) devices; thus, vehicles are a "firefighter approach" (Mahmood, 2020). This can cause interference as a lead vehicle disseminates a message to the follower vehicles, message can be limited between platoon members due to the loss of packet transmitted based on the power generated, used channel and platoon size (Lyamin, 2019). In this regard, this research will deal with how the integrity of wireless communication can be granted among vehicles involved in vehicle platooning by driving the theoretical outage probability of platoon size by considering the parameters of transceivers equipped each vehicle such as transmitted power, channel used for establishing an effective communication among vehicles. A vehicle -to-vehicle (V2V) communication technology is analyzed. This research is carried out by evaluating the communication feasibility of vehicles in platoon analytically.

1.1 Problem statement

The challenges of autonomous vehicles are always based on the environment variations where the weather can affect the autonomous communication based on heavy rain or dust than hinder the well working of autonomous vehicle. The major challenges may occur to the deployment of V2Vs include defining management protocols and technical structure of communication like Tam platoon model (Tam, Hung, & Nils, 2018). To address to the consistency of vehicle platooning integrity of an end –to- end communication is an important point to learn. As it is a point to study the necessary parameter is considered for analyzing the end-to-end signal to interference plus noise (SINR) in vehicle-to-vehicle communication (V2V) communicating bidirectional between vehicle v_j and vehicle v_i, forming an orchestration of vehicles known "**platoon**". This research focuses on how to derive the symbol error probability (SEP) of Vehicle-to-Vehicle communication (V2V) for flat Rayleigh fading channel.

Directives point of this research:

1. How the existing platoon model of V2V analyzed and worked?
2. What are the necessary parameters of platoon model based on communication?
3. What is the symbol Error Probability (SEP) of the platoon model in function of platoon size?

The goal of this study is to evaluate analytically the vehicle –to- vehicle communication of orchestration vehicles communicating at closed distance by analyzing the Symbol Error Probability (SEP) among vehicles forming a platoon communicating wirelessly by considering the transmitted power, the used channel gain and M-symbols per bits in function platoon size variation as leading vehicle (LV) transmits a broadcast message to the following vehicles (FV) and use a bidirectional communication between all.

1.2 Study objectives

The aim of this study is based on analysis of Symbol Error Probability (SEP) between vehicles v_j and v_i forming a platoon by considering the impact of transmitted power and M-symbols per bits in function of platoon size.

1.2.1 General objectives

The general the objectives is to evaluate the Symbol Error Probability (SEP) in orchestration vehicles of platoon in consideration of transmitted power and M-symbols per bits in function of platoon size

1.2.2 Specific objectives

- To study the existing platoon model of autonomous driveless cars
- To transform the probability density function (PDF) into cumulative density function (CDF).
- To derive the cumulative density probability of platoon by considering the transmitted power and M-Symbols per bits in function of platoon size by using PSK modulation , with neglecting the effect of noise.
- To analyse the Symbol Error Probability (SEP) of networked vehicles that ensure the performance of Vehicle-to-Vehicle communication in platoon model proposed by Tam ((Tam, Hung, & Nils, 2018). Numerical results will be analysed by considering rayleigh fading channel.

1.3 Hypothesis

As the autonomous vehicle are produced from different levels, growing from level one up to level four nowadays. In level four is a fully driverless system where vehicles are intelligently designed for monitoring roads conditions. It is possible to make a group of driverless cars “platoon”. Therefore, to address to the consistency of vehicle platooning integrity of an end -to- end communication, Symbol Error Probability (SEP) is analytically evaluated.

1.4 Significance of the study

The signficance is must as it will help for the prediction of how many number of vehicles can communicate successfully in orchestraction vehicles known as “**platoon** ”.

1.5 Organization of the study

This work is organised in six chapters shortly described below;

Chapter 1 is the general introduction, this chapter focuses on the the objectives of this study,problem statement, scope, hypothesis and adopted methodology to accomplish this work chapter 2 is the Literature review and rationale.

Chapter 3 is Research methodology , this chapter shows the method adopted for conducting study .

Chapter 4 presents the platoon model. This model was proposed by Tam (Tam, Hung, & Nils, 2018), his study focused on the probability density function (PDF) only . My contribution focuses on deriving the cumulative density function (CDF) by considering the constant angle of modulation, phase shift keying (PSK).

Chapter 5 is numerical results , this chapter is the heart of this work as it depicts the graphs and results findings from deep study by using analytical tool as mathematica.

Chapter 6 is conclusion and recommendation, this chapter shows the summary of this thesis and findings of numerical results interpreted on graphs drawn after capturing the parameter of this research stated in research methodology and introduce further work for anyone to improve this work, As autonomous systems is an interested topic nowadays based on its benefits such as saving time, saving money, accident reduction and perfect productivity in a short time.

1.6 Scope of the study

This study is scoped in evaluating the numerical analysis of orchestration vehicle known as platoon of Vehicle-to-vehicle communication , how to derive its symbol error probability (SEP) based on the number of vehicles and power transmitted, whatever the random noise generated in rayleigh fading channel.

CHAPTER 2: RATIONAL AND LITERATURE REVIEW

2.1 Rationale

The autonomous is a worldwide alarming topic, where many researchers, industries and software developers are working hard for getting humanoid machines by combination of mechanical maneuvers and intelligent software, thus autonomous vehicles grow rapidly as play crucial role of linking smart cities (Ross, 2018) in short period as they can sense its environment with a little or no human input, for the merits of fuel saving consumption, road safety, increase road capacity, reduce driver's stress and saving time. Vehicles can communicate wirelessly via different technologies like Bluetooth, gps, radar-sensing and wireless, the automatic vehicle organized in group known as "platoon" or "convey" lead to vehicle platooning (Leonardo & Fernando, 2020)**.** Autonomous vehicles use an intelligent system that allow sensors talk to each other and the different devices of an entire system, permit vehicles dependability by communicating from one vehicle to another.

Mani adopted the combination of Vehicle ad-hoc Network (VANET) and cooperative adaptive cruise control (CACC) **(**Mani, Hui, Chen-Nee, H., & Dipak, 2015)**,** where vehicle platooning adopt its feasibility on highway to support automated driving and the vehicle assist of vehicle ad-hoc network (VANETs) for intra-vehicle communication, a series of vehicles form a platoon **(**Chong, Shuaizong, Hongye, & Hai, 2018)**.** Vehicle platooning is part of a suite of features that self-driving vehicle might employ. Vehicles can travel very closely together, safely at high speed. Every vehicle communicates with the other vehicles in the platoon. Many countries support this technology research, several projects cover inter-vehicle communication and networks systems (Wang, 2015). Therefore, there are many funded projects implemented in Europe such as Safe Road Trains for the Environment (SARTRE), **(**Carl, Erik, & Daniel, 2012)**,** a research project funded by the European Commission under the Seventh Framework Programme, has developed the technology and the strategy to create fully functional road trains that allow vehicle platoons to operate in public highways (Arturo, Enric, Eduardo, & Freixas, 2013). In US, Asia countries like China, Korea and Japan continue focuses on vehicle communication , the ongoing project as PATH has aim of improving the intelligent communication and iDrive program adopted by carmakers (Wang, 2015). Technology continuing to be a crucial matter of researchers as V2V communication and platooning for SEV COMs by wireless network sensor (Nan, Di, Harutoshi, & Shigeyuki, 2014). Platoon formation comprises the phases of (a) joining/forming/merging platoon , (b)travel and (c) spliting and leaving platoon (Hobert, 2012). The challenges exist here is the lack of connection to the database and identifying such data and processing it using a mix of digital technologies. Vehicle controller area network (CAN) is a serial bus communication protocol that allows access to the vehicle internal system. Other OBUs, sensors and devices should be integrated with CAN to increase efficiency of vehicle VAN. Wireless sensors planted in the vehicle and reporting data to the central system is one of the challenge in CAN (Wang, 2015. For V2V the questions raised are about what happens if one vehicle can or cannot broadcast or receive and how to form the packets for more effective distribution. Such distribution is in particular, challenging due to the time limit (order of several seconds at most) that vehicles are within accessible range of each other (Wang, 2015). For V2I, consideration about the speed adoption in practice, the road side infrastructure deployment and configuration still a big challenge as it uses dedicate short range communication(DSRC) of 5.9GHZ (Sherali, Hunt, Yuh-Shyan, Angela, & Aamir, 2010). This study selects platoon to evaluate the performance of a platoon model of vehicle-to-vehicle (V2V) communication system.

Figure depicts the outlook of vehicle froming a platoon. There are different technologies used in platoon design like Vehicle to Infrastracture (V2I), Infrastructure to Vehicle (I2V), road side communication, Vehicle to Vehicle (V2V) communication , or an hybrid of V2I and V2V.

Figure 1: Image shown how Platoon Vehicle appeared on roadway (Volpe Center, 2017)

2.2 Literature review

In the twentieth century, many researchers and factories invested in the development of an autonomous vehicle since 1970 up to 2020, such development could lead to several benefits such as fuel saving, reduced congestion, substantially shorter commutes during peak periods, but sometimes system can fail due to technology issues (James, et al., 2016). In this regard, Hobert introduced the process of platoon formation such as joining/merging/splitting and leaving of any vehicle from platoon on lane, setup new strategy of transient formation strategy and develop a multicast protocol to improve the reliable communication between vehicles. This thesis shows only the platoon formation strategies no platoon model proposed and the successfulness of reliable communication between vehicles in platoon, propose a vehicle platoon model and derive the successfulness probability of communication in vehicle platoon model (Hobert, 2012)**.**

Jame Fishelson, showed that car in platoon is not physical connected use an internet of things (IoT) and proposed a system power by roadways through inductives method (Fishelson, 2013).

Ikecukwu suggested a security method called Asymetric Profit-Loss Markov(APLM) model to measure the security level scheme for Vehicular ad-hoc network (VANET) over infrastructureless for contents delivery with meaningfullness. This paper reflected only on security, it did not look at how the model is and how a vehicle can communicating successfully (Ikecukwu, Michael, & Liu, 2012). This experimental paper describes V2V communication by assessing the position of two antennas on lead vehicle with the aim of developing an integrated solutions that allows vehicle to drive in platoon by measuring with a comparison communication range with real vehicle in platoon. It is founded by SARTRE in 2012. (Carl, Erik, & Daniel, 2012)**.** This experimental paper designed an electronic system for allowing two vehicles communication by control and path recognize method for helping the aging elder persons in kitatkushu as an aid for driving safely in urban areas and in congestion traffic assisted by technology **.**This paper describes only the position of antennas on the leading vehicle with limited number of three vehicles as platoon, did not evaluate the throughput and examine a large number of vehicle in platoon. (Nan, Di, Harutoshi, & Shigeyuki, 2014)**.** This paper describes the three existing schemes by using lower-power transmission of vehicle identifier to identify a remote attacker in autonomous vehicle platooning by using tx power-based communication constraint checker , as a V2V uses low power cause an attacker to come closer to the platoon , when it come closer the radar or lidar can identifier an attacker. No proposed solution of how that message can successful even if no attackers altered, propose a N vehicle platoon model and Driving the througput with analyis and simulation and set up graphs (Hyogon & Taelo, 2019)**.**

This paper describes the three existing schemes by using lower-power tarnsmission of vehicle identifier to identify a remote attacker in autonomous vehicle platooning by using tx power-based communication constraint checker, as a V2V uses low power cause an attacker to come closer to the platoon, when it come closer the radar or lidar can identifier an attacker, No proposed solution of how that message can successful even if no attackers altered. Propose a N vehicle platoon model and driving the througput with analyis and simulation and set up graphs. This paper describes the falaties accident caused by autonomous vehicle known as self-driving cars where Telsa autopilets crashed as sensors can't react like human being because sensor react at certain degrees said a better model must be proposed and learned for enhance the AVG system**,** No solution proposed only give recommendation of proposed a better model for AVG. That's why we proposed an vehicle platoon model with consistency paramter of networks (Gunnar & S. O. Johnsen, 2019)**.**

This paper describes the effects of platooning on signle stop sign at single 4-way intersection simulation in environment and report in terms of overhead communicatin and average delay in intersection way management and select with prioritize platoon to pass, Only simulate an intersection in road of 4-way intersection no model proposed and driving successfulnes of communication, give an alert only. That's why we proposed an vehicle platoon model with consistency parameter of networks (Masoud & Cody, 2017).

This work describes the cooperative adaptive cruise control(CACC) of companion by developing an archictecture of off-board and on-board control and platoon management with a validation method of system simulation for heavy-duty vehicles, No solution provided because it deals with legistration analysis and optimazation Propose a N vehicle platoon model and Driving the througput with analyis and simulation (Marcos, Karl H., Sonke, & Magnus, 2015). This paper dscribes the VANET and CACC , shows how the leading vehicle can entering and leave the platoon by studing the inter-platoons and inter-platoons distance management protocol , No model proposed and describes how the secured link can be successful transmitted among vehicles Propose a N vehicle platoon model and driving the througput with analyis and simulation (Mani, Hui, Chen-Nee, H., & Dipak, 2015).

Tiago demostrated the prediction of cooperative adaptive cruise control (PCAC) in order to miminize the drawbacks of drivelesss car.

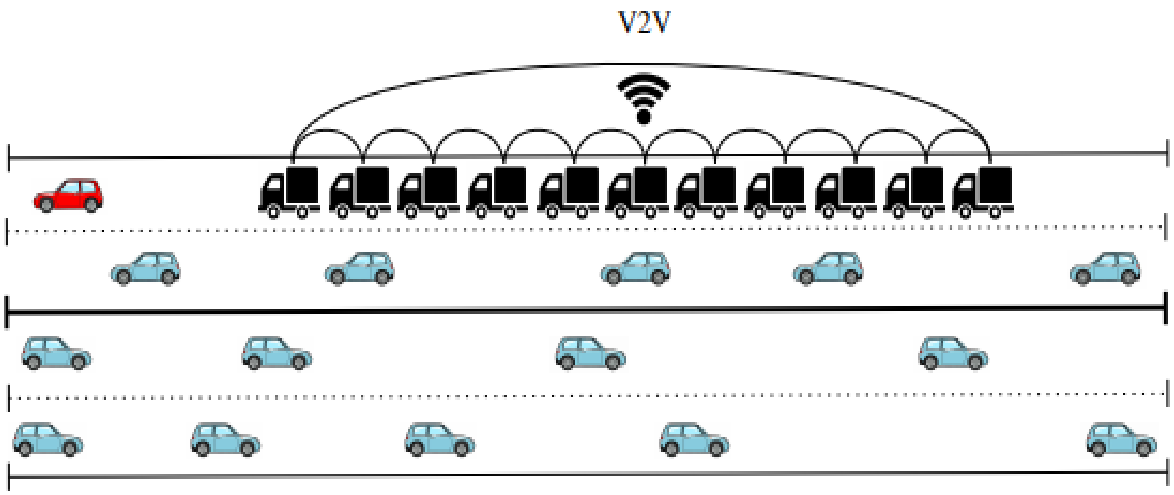

Figure 2: Traffic simulation of platoon V2V Communication View (**Tiago, Vineeth, & Salah, 2020)**

2.3 Rayleigh fading channels

The Rayleigh fading is mostly useful as a linking method between transmitting antenna and receiving antenna where the signal may be considered to be scattered in radio communications channel. Rayleigh fading describes the form of fading that occurs when multipath propagation exists.

Fading is malfunction where signal quality degrades over wide distances without the presence of wide quantities of additive-white-Gaussian-noise (AWGN) and channels that expose these properties are known as fading channels (Skalar, 1997)

White noise is a basic noise model most happened in information communication for minimization the effect of randomization processes that occur naturally. Rayleigh fading deals in two perspectives:

- The spreading time caused by multipath propagation (Time dispersion).
- The variation of time determine the behavior of the channel caused by kinetic energy and concomitant changes in propagation track.

2.3.1 Rayleigh fading PDF

When the incoming signal is arrive at multiple reflective path plus a significant line-of-sight (non faded) component, (Skalar, 1997).
Rayleigh pdf, expressed as

$$P(r) = \begin{cases} \dfrac{r}{\sigma^2} \exp\left[-\dfrac{r^2}{2\sigma^2} \right] & \text{For } r \geq 0 \\ 0 \end{cases}$$

Where r is the envelope amplitude of the received signal, and $2\sigma^2$ is the pre-detection mean power of the multipath signal. The Rayleigh faded component is sometimes called the random or scatter or diffuse component.

2.4 RANDOM VARIABLES

Consider a random experiment to which the outcomes are elements of sample space S in the underlying probability space. In order to construct a model for a random variable, we assume that it is possible to assign a real number $X(s)$ for each outcome s following a certain set of rules. We see that the 'number' $X(s)$ is really a real-valued point function defined over the domain of the basic probability space, (Soong, 2004).

2.4.1. Definition

The point function $X(s)$ is called a *random variable* if (a) it is a finite real valued function defined on the sample space of a random experiment for which the probability function is defined, and (b) for every real number x, the set $\{s : X(s) \leq x\}$ is an event. The relation $X = X(s)$ takes every element in s of the probability space onto a point X on the real line $R^1 = (-\infty, \infty)$.

Notationally, the dependence of random variable $X(s)$ on s will be omitted for convenience.

The second condition stated in Definition is the so-called '**measurability condition'**. It ensures that it is meaningful to consider the probability of event $X \le x$ for every x, or, more generally, the probability of any finite or accountably infinite combination of such events.

To see more clearly the role a random variable play in the study of a random phenomenon; consider again the simple example where the possible outcomes of a random experiment are success and failure. Let us again assign number one to the event success and zero to failure. If X is the random variable associated with this experiment, then X takes on two possible values: 1 and 0. Moreover, the following statements are equivalent:

- The outcome is success.
- The outcome is 1.
- $X = 1$.

The random variable X is called a *discrete* random variable if it is defined over a sample space having a finite or a countable infinite number of sample points. In this case, random variable X takes on discrete values, and it is possible to enumerate all the values it may assume. In the case of a sample space having an uncountable infinite number of sample points, the associated random variable is called a *continous* random variable, with its values distributed over one or more continuous intervals on the real line. We make this distinction because they require different probability assignment considerations (Soong, 2004). Both types of random variables are important in science and engineering.

All random variables are in capital letters for this description, X, Y, Z , . . . The value of a random variable X can arrogate with denoting by corresponding lower-case letters such as x, y, z or x_1, x_2 . . . That's have many occasions for considering the a serial arrangement of random variables $X_j, j = 1, 2, ..., n.$ .In these cases we arrogate that they are determined on the same probability space. The random variables $X_1, X_2, ..., X_n$ will then map every element s of S in the probability space onto a point in the n -dimensional Euclidian space R^n . We note here that an analysis involving n random variables is equivalent to considering a *random vector* having the n random variables as its components. The notion of a random vector will be used frequently in what follows, and we will denote them by bold capital letters X, Y, Z . . .

2.4.2. Probability distributions

The deportment of a random variable is qualified by the distribution probability, that is, by the way probabilities are administered over the values it arrogates. A probability distribution and a probability mass functions are two ways to qualify this distribution for a discrete random variable. They are equivalent in the sense that the knowledge of either one completely specifies the random variable. The corresponding functions for an uninterrupted random variable are the probability distribution function, determined in the closely similar way as in the case of a discrete random variable, and the probability density function.

2.4.3. Probability Distribution Function-PDF

Applied a random experiment with its linked random variable X and given a real number x, let us look at the probability of the effects $\{s : X(s) \leq x\}$,or, simply, $P(X \leq x)$. This probability is clearly dependent on the assigned value x. The function

$F_x(x) = P(X \leq x)$ is determined as the probability distribution function (PDF), or simply the distribution function, of X. In subscript X distinguishes the random variable (Soong, 2004).

This subscript is sometimes neglected when there is no risk of confusion.

Let us repeat that $F_x(x)$ is simply $P(A)$, the probability of an event occurring, the PDF is thus the probability that X will arrogate a value lying in a subset of S , the subset being point and all points lying to the 'left' of. As enhances, the subset covers more of the real line, and the value of PDF increases until it reaches 1. The PDF of a random variable thus accumulates probability as increases, and the name cumulative distribution function (CDF) is also used for this function.

2.4.4. Joint Probability Distribution Function

The joint probability distribution function (JPDF) of random variables X and Y , denoted by $F_{XY}(x, y)$ is defined by

$F_{XY}(x, y) = P(X \le x \cap Y \le y),$. For all x and y. It is the probability of the intersection of two events; random variables X and Y thus induce a probability distribution over a two-dimensional Euclidean plane.

The joint probability distribution function of more than two random variables is defined in a similar fashion. Consider n random variables X1, X2… Xn. Their JPDF is defined by

$$F_{X_1 X_2 \ldots X_n}(x_1, x_2, \ldots, x_n) = P(X_1 \le x_1 \cap X_2 \le x_2 \cap X_n \le x_n)$$

2.4.5. Conditional Distribution and Independence

The conditional distribution function of a random variable X, given that another random variable Y has taken a value y, is defined by

$$F_{XY}(x \mid y) = P(X \le x \mid Y = y)$$

When random variables X and Y are freelance, the definition are freelance too,

$$F_{XY}(x \mid y) = P_x(x)$$

$$F_{XY}(x, y) = f_x(x) f_Y(y)$$

Thus, proven again that the joint density function is equal to the product of the connected marginal density functions when X and Y are freelance ? Finally, let us note that, when random variables X and Y are discrete,

$$F_{XY}(x \mid y) \sum_{i=1}^{i:x_1 \le x} P_{XY}(x_i \mid y)$$

And, in the case of a continuous random variable,

$$F_{XY}(x \mid y) = \int_{-\infty}^{x} f_{XY}(u \mid y) du$$

The cases of more than two random variables are again straightforward. Starting from

$P(ABC) = P(A \mid BC) P(B \mid C) P(C)$.

For three events A, B, and C, in the case of three random variables X, Y, and Z,

$$P_{XYZ}(x, y, z) = P_{XYZ}(x \mid yz) P_{YZ}(y \mid z) P_{Z}(z)$$

$$f_{XYZ}(x, y, z) = f_{XYZ}(x \mid yz) f_{YZ}(y \mid z) f_{Z}(z)$$

CHAPTER3: RESEARCH METHODOLOGY

In this research, I read the different platoon models, these models are formed based on different parameters can be heavy vehicles, small cars or any mobile devices this used device-to- device communication (D2D), Vehicle-to- Everything(V2X) technology has three main components such as Vehicle to Infrastructure (V2I) and Vehicle to Vehicle (V2V) communication and vehicle to pedestrian (V2P). This research focused on single component of Vehicle to Vehicle to analyse an end to end communication by deriving the symbol error probabiliy (SEP) with use of parameters of transceiver device equipped each vehicle. These parameters are transmitted power, and and M-symbols per bits in function of platoon size as worse factor affected communication integrity, thus small scale fading of rayliegh channle is considered, the targert is to analtyical results are computed by using Mathematica tool, and OriginPro for graphical design .

For conducting this research work ,I followed the methodology below,

- To study the existing vehicle platoon proposed in literature review
- To compute Symbol Error Probability (SEP) in function with platoon size by condering the transmited power and and M-symbols per bits as paramters of this system.
- To analyse the effect Symbol error probability (SEP) by using analytical tool as mathematica and plotting its graphs.

The parameters needed for computation and simulation is grouped in the following table.

3.1. Platoon model parameters

In this research , necessary parameters composed an IoT node are considered , the power of a node, what is the channel use, the effect of interference without forget the effect on noise, this reaserch consider the parameters appeared in table depicted below and take into account the η and θ are constants depending on the specific used modulation scheme, for M-PSK or in binary modulation , the number of symbol that can be transmitted (M) is two (M=2) and each bit represent 1 bit of data for (N= 1 bit per symbol). As PSK is in sinusoidal representation, the angle θ, expressed as that $\theta = \sin^2\left(\frac{\pi}{M}\right)$, a modulation constant of BPSK used in this research, M varies based on the number of bits used for PSK modulation.

Table 1: Platoon model parameters

Parameters	Appellations	Unites
P_j	Power transmitted from one vehicle to another	dB
h_{ji}	Channel gain between one vehicle to another	Decibel(dB)
I_i	Interference	dB
M	Symbols per Bits	
No	Noise	Decibel(dB)
θ	Phase angle of modulation scheme	Degrees
N	Number of Vehicles in Platoon	
η	Constant of modulation scheme	

3.2 Scientific results method

In this research, I focused on quantitative results of Symbol Error Probability (SEP) generated by analytical tool after developing and derive the cumulative density function (CDF) by considering digital modulation of PSK, where its angle θ varies between -90^0 and $+90^0$ (Xiong, 2006), afterward were used to draw qualitative graphs show the impact on these parameter in terms of platoon size .

3.3 Documentation

Documentation is the most useful for gathering the ideas of other researchers and scientists in order to fertilize your novel idea or modify the work done by other researcher by completing their recommendation stated for further work. In this research I read the many papers written by different authors, inspired by the work of Tam (Tam, Hung, & Nils, 2018), derived the Outage probability of platoon, for add-on I derived the cumulative density probability in term of analyzing the symbol error probability of platoon size based on parameters of an access point equipped every vehicle of platoon. For this method the electronic books, conferences and journals papers were used and cited.

CHAPTER 4 :PLATOON MODEL

A platoon is a group of vehicles travelling together at aim of same mission or not. This study analyzes the vehicle communication on single–lane where each vehicle is equipped by Transceiver (Transmitter and Receiver) at the same time. The leading vehicle takes a full control of speed and direction of the following vehicles, overtaking is prohibited, this platoon is composed N vehicles, which are communicating bidirectional between vehicle v_j and vehicle v_i, every vehicle are separated by the same distance in platoon, it means distance between v_1 and v_2 , v_2 and v_3, v_3 and v_4 until v_{N-1} and v_N respectively. The power transmitted from one vehicle to another uses a channel which is expressed in dB from channel gain varies from vehicle- to- vehicle.

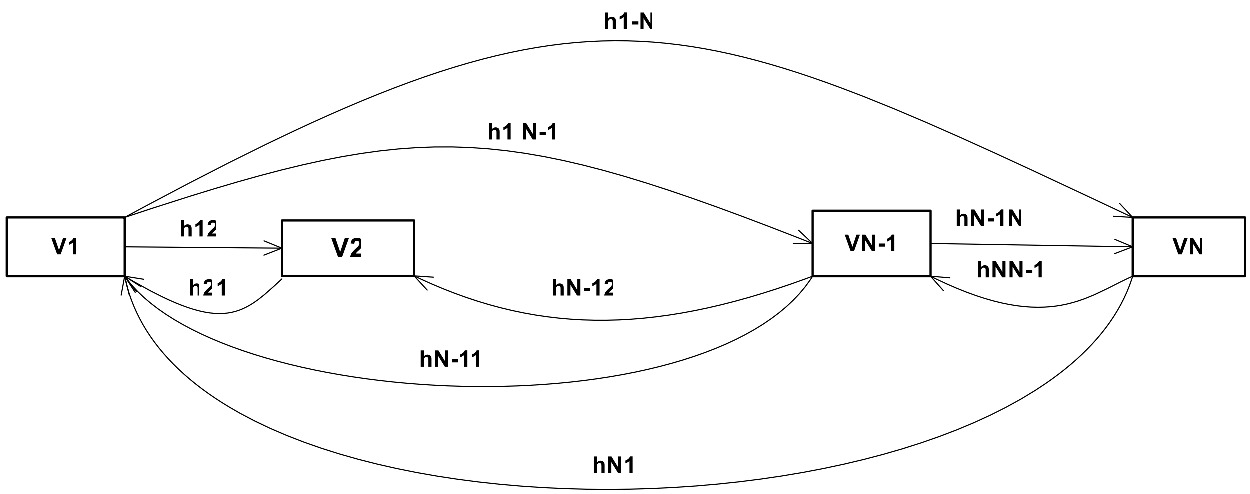

Figure 3: Platoon model **(Tam, Hung, & Nils, 2018)**

A system uses the time division techniques where every vehicle in a platoon receives a disseminated message according its time slots assignment of every platoon –vehicle based on the distance between v_i and v_j. Its time is calculated based the directivity from v_j to v_i. The signal-to-interference plus noise ratio (SINR) received by v_i is denotes as γ_{ji}, formulated as below;

$$\gamma_{ji} = \frac{P_j h_{ji}}{\left(I_i + N_0\right)} \quad , \quad \forall j \neq i , \tag{1}$$

Where P_j is the power transmitted from vehicle (v_j), h_{ji} is a small scale fading coefficient of channel gain, I_i is interference generated randomly at vehicle v_i and N_0 is additive white Gaussian noise (AWGN). Normally $\gamma_{ji} \neq \gamma_{ij}$ as power transmitted by vehicle v_i and v_j are different.

4.1 Symbol Error Probability (SEP) Analysis

In digital communication, the number of bit errors is the number of received bits over a stream data over a communication medium that are altered due to noise and interference, the number of bits may distort when there is a presence of error due to the synchronization mismatching.

The symbol error probability is the expectation values of analyzing the performance of a given or a proposed system, thus the computation of SEP is focused, to know how this system is secured on the link duration among vehicles based on platoon size with reference of threshold γ_{th} .

The end to end communication is defined by instantaneous signal to interference plus noise (γ) is derived in function of platoon size and associated parameters such as P_j power transmitted from vehicle v_j , h_{ji} small fading coefficient of channel gain, I_i an interference randomly generated at vehicle v_i and N_0 is additive white Gaussian noise (AWGN).

$$\gamma = \min_{i \in \{1....N\}} \left\{ \min_{\substack{j \in \{1....N\} \\ j \neq i}} \left\{ \frac{P_j h_{ji}}{\left(I_i + N_0\right)} \right\} \right\} \tag{2}$$

The SEP depends on random variables h_{ji} and I_i which lead to the determination of outage probability of how a platoon can safely communicate.

$$P_{out} = 1 - \Pr\left\{ \min_{i\in\{1....N\}} \left\{ \min_{\substack{j\in\{1....N\} \\ j\neq i}} \left\{ \frac{P_j h_{ji}}{\left(I_i + N_0\right)} \right\} \right\} \leq \gamma_{th} \right\}$$

$$P_{out} = \Pr\left\{ \min_{i\in\{1....N\}} \left\{ \min_{\substack{j\in\{1....N\} \\ j\neq i}} \left\{ \frac{P_j h_{ji}}{\left(I_i + N_0\right)} \right\} \right\} \geq \gamma_{th} \right\}$$

$$P_{out} = \prod_{i=1}^{N} \Pr\left\{ \min_{\substack{j\in\{1....N\} \\ j\neq i}} \left\{ \frac{P_j h_{ji}}{\left(I_i + N_0\right)} \right\} \geq \gamma_{th} \right\} = \prod_{i=1}^{N} I_{1,} \qquad (3)$$

This implies serial probability as all vehicles in platoon are in queue consecutive manner, Let deduce the I_1 expression

$$I_1 = \Pr\left\{ \min_{\substack{j\in\{1...N\} \\ j\neq i}} \left\{ \frac{P_j h_{ji}}{\left(I_i + N_0\right)} \right\} \geq \gamma_{th} \right\} \qquad (4)$$

$$I_1 = \prod_{\substack{j=1 \\ j\neq i}}^{N} \Pr\left\{ \frac{P_j h_{ji}}{\left(I_i + N_0\right)} \geq \gamma_{th} \right\}$$

$$I_1 = \prod_{\substack{j=1 \\ j\neq i}}^{N} \Pr\left\{ h_{ji} \geq \frac{\gamma_{th}\left(I_i + N_0\right)}{P_j} \right\}$$

$$I_1 = \prod_{\substack{j=1 \\ j\neq i}}^{N} \int_0^{\infty} \Pr\left\{ h_{ji} \geq \frac{\gamma_{th}\left(x+N_0\right)}{P_j} \right\} f_{xi}\left(x\right) dx$$

Rayleigh fading is statistical model of radio propagation through a medium by considering the effect of environment is expressed as $f_{xi}\left(x\right)dx = \frac{1}{\Omega_i}\exp\left(\frac{x}{\Omega_i}\right)dx$ (Charles & Emmanuel, 2018). When calling X a random variable, its average is expressed as $\Omega = \mathrm{E}\left\{X\right\}$; where $E[.]$ is the expected or estimated value (Tam, Hung, & Nils, 2018); E refers to the expectation operator (Le Van, Ba Cao, Xuan, & Dung, 2019).

When the received signal is made up of multiple reflective rays plus a significant line-of-sight (non-faded) component, (Skalar, 1997), by replacing rayleigh fading by its expression is shown in equation below of (I_1).

$$I_1 = \prod_{\substack{j=1 \\ j\neq i}}^{N} \int_0^{\infty} \exp\left[-\frac{\gamma_{th}\left(x+N_0\right)}{P_j\Omega_{ji}} \right] \frac{1}{\Omega_i} \exp\left(\frac{x}{\Omega_i}\right) dx$$

$$I_1 = \exp\left(-\gamma_{th} N_0 \sum_{\substack{j=1 \\ j\neq i}}^{N} \frac{1}{P_j\Omega_{ji}} \right) \prod_{\substack{j=1 \\ j\neq i}}^{N} \frac{P_j\Omega_{ji}}{\gamma_{th}\Omega_{Ii} + P_j\Omega_{ji}} \qquad (5)$$

The global outage probability below is formulated by substitution of Equation (5) into Equation (6) its expression is shown below

$$P_{out} = \prod_{i=1}^{N} \left\{ \exp\left(-\gamma_{th} N_0 \sum_{\substack{j=1 \\ j \neq i}}^{N} \frac{1}{P_j \Omega_{ji}} \right) \prod_{\substack{j=1 \\ j \neq i}}^{N} \frac{P_j \Omega_{ji}}{\gamma_{th} \Omega_{Ii} + P_j \Omega_{ji}} \right\} \qquad (6)$$

The outage probability, referencing to Tam (Tam, Hung, & Nils, 2018), he derived the closed-form expression for the communication probability implying safety shown in the above equation (6), the contribution done is to evaluate the symbol error probability by using the cumulative density function (CDF) between vehicles forming a platoon of signal to interference plus noise (SINR).

$$F_X\left(X\right) = \prod_{i=1}^{N} \left\{ \exp\left(-xN_0 \sum_{\substack{j=1 \\ j^1 i}}^{N} \frac{1}{P_j \Omega_{ji}} \right) \prod_{\substack{j=1 \\ j^1 i}}^{N} \frac{P_j \Omega_{ji}}{x \Omega_{Ii} + P_j \Omega_{ji}} \right\} \qquad (7)$$

The Symbol Error Probability (SEP) described between the vehicles forming a platoon, hence the integral of SEP for BPSK is given by

$$SEP = \frac{\eta\sqrt{\theta}}{2\sqrt{\pi}} \int_0^{\infty} F_X\left(X\right) \exp\left(\frac{-\theta x}{\sqrt{x}} \right) dx \qquad (8)$$

The whole expression is given by replacing the

$$SEP = \frac{\eta\sqrt{\theta}}{2\sqrt{\pi}} \int_0^{\infty} \prod_{i=1}^{N} \left\{ \exp\left(-xN_0 \sum_{\substack{j=1 \\ j \neq i}}^{N} \frac{1}{P_j \Omega_{ji}} \right) \prod_{\substack{j=1 \\ j \neq i}}^{N} \frac{P_j \Omega_{ji}}{x \Omega_{Ii} + P_j \Omega_{ji}} \right\} \exp\left(\frac{-\theta x}{\sqrt{x}} \right) dx \qquad (9)$$

Symbol Error Probability (SEP) is derived for eliminating non-numerical warning generated during analysis in analytical tool, η and θ are parameters depending on the specifically-used modulation scheme (Le Van, Ba Cao, Xuan, & Dung, 2019), (Xiong, 2006). For BPSK these parameters are given by $\eta = 2$ and $\theta = \sin^2\left(\frac{\pi}{M}\right)$, and $M = 2$, number of symbols through a table below show how M varies according to type of digital modulation. For Binary phase shift keying BPSK, $M = 2$ as shown in table below

Table 2: Summary of Various digital modulation, shows M symbols, Bits/Symbol and Bandwidth respectively. **(Xiong, 2006).**

Modulation	# Symbols (M)	# Bits/symbol ($N = \log_2 M$)	Bandwidth (BW)
FSK	2	1	$f_{mark} - f_{space} + 2R_b$
ASK	2	1	$2R_{sym} = 2R_b/N = 2R_b$
OOK	2	1	$2R_{sym} = 2R_b/N = 2R_b$
BPSK	2	1	$2R_{sym} = 2R_b/N = 2R_b$
QPSK	4	2	$2R_{sym} = 2R_b/N = R_b$
8PSK	8	3	$2R_{sym} = 2R_b/N = 2R_b/3$
8QAM	8	3	$2R_{sym} = 2R_b/N = 2R_b/3$
16PSK	16	4	$2R_{sym} = 2R_b/N = R_b/2$
16QAM	16	4	$2R_{sym} = 2R_b/N = R_b/2$
⋮	⋮	⋮	⋮

CHAPTER 5: RESULT ANALYSIS

This chapter describes the analytical results of graphs generated in Origin Pro tool after manipulating the parameters of this platoon model. These parameters are power transmitted, channel gain as mean of transmitting medium from vehicle v_j to vehicle v_i. The numerical results of the symbol error probability simulated are analyzed as function of varying platoon size in collaboration of the following parameters;

- Symbol error probability versus variation of power transmitted in function of number of vehicles, this power transmitted varies from 0 to 10 dB, whereas number of vehicles varies from 3 to 15 vehicles in steps of two and three respectively.
- Symbol error probability versus variation of M -Symbols per bits in function of number of vehicles, power transmitted is fixed at 10dB, whereas number of vehicles varies from 5 to 20 in steps of five.
- Symbol error probability versus variation of power transmitted, based on M-symbols per bits variations as platoon size is fixed on 3 vehicles only.

Free from the loss general, let $\gamma_j = \frac{P_j}{N_0}$ as transmission signal –to-noise ratio (SNR) and as average of interference level. This allows the depiction of variation of transmitted power.

5.1 The variation of Transmission Power with platoon size

This illustration below shows the analytical results. It concludes that the error probability of receiving packets increasing with its transmission as power transmitted between vehicles increased, at greater extent, shows that as the power transmitted is closed to the 10 dB its symbol error probability (SEP) increases as well as number of vehicles increased. Thus, number of vehicles is increased in such way respectively 3, 5, 7, 9, 12 and 15.

Table 3: Results of Symbol Error Probability versus Transmitted Power in function of Number of Vehicles

	Number of Vehicles					
P_V(j)_dB	3	5	7	9	12	15
0	0.231490278	0.189497765	0.13578977	0.105746234	0.07937425	0.047107669
1	0.271825853	0.211615362	0.15199176	0.118476542	0.08898651	0.055783382
2	0.316041658	0.236040431	0.17002361	0.132690157	0.09974188	0.06561771
3	0.363619338	0.262909843	0.19005115	0.148540106	0.11176776	0.076688361
4	0.413822106	0.292329055	0.21223905	0.166187236	0.12520232	0.089079062
5	0.465731356	0.324355868	0.2367436	0.185796864	0.1401939	0.102883475
6	0.51830875	0.358981295	0.2637027	0.207535834	0.15689977	0.118208169
7	0.570474706	0.396108606	0.29322266	0.2315779	0.17548376	0.135174038
8	0.621189791	0.435528787	0.32536235	0.258242829	0.19611258	0.1539158
9	0.669526178	0.467166122	0.36013145	0.286253513	0.21895015	0.17457936
10	0.714721823	0.501427502	0.39830463	0.321944251	0.24414967	0.19731686

Table 3 above shows the results generated by Mathematica version 10.4 used as an analytical tool in this thesis. It shows that a small platoon size raised a small percentage of symbol error probability (SEP), when power transmit increases sharply, its symbol error probability increases too at small scale, this is a performance constructive power interference for multi-users systems (here users are number of vehicles) (Adbelhamid & Christos, 2019). Thus, the variation of users required much power but as it constructed a series consecutives node shares errors generated in the channels. This prove that a large size of platoon generates much small error probability as show-on figure four, shows that where transmitted power is 0 dB, its corresponding error probability is approximately 23% compared to 4.7% for three and fifteen vehicles respectively and shows again at 10dB, its error probability is approximately 70% compared 19% for three and fifteen vehicles respectively. The results above are graphical plotted by using Origin Pro. Thus, prove that is performance constructive power interference for multi -vehicles.

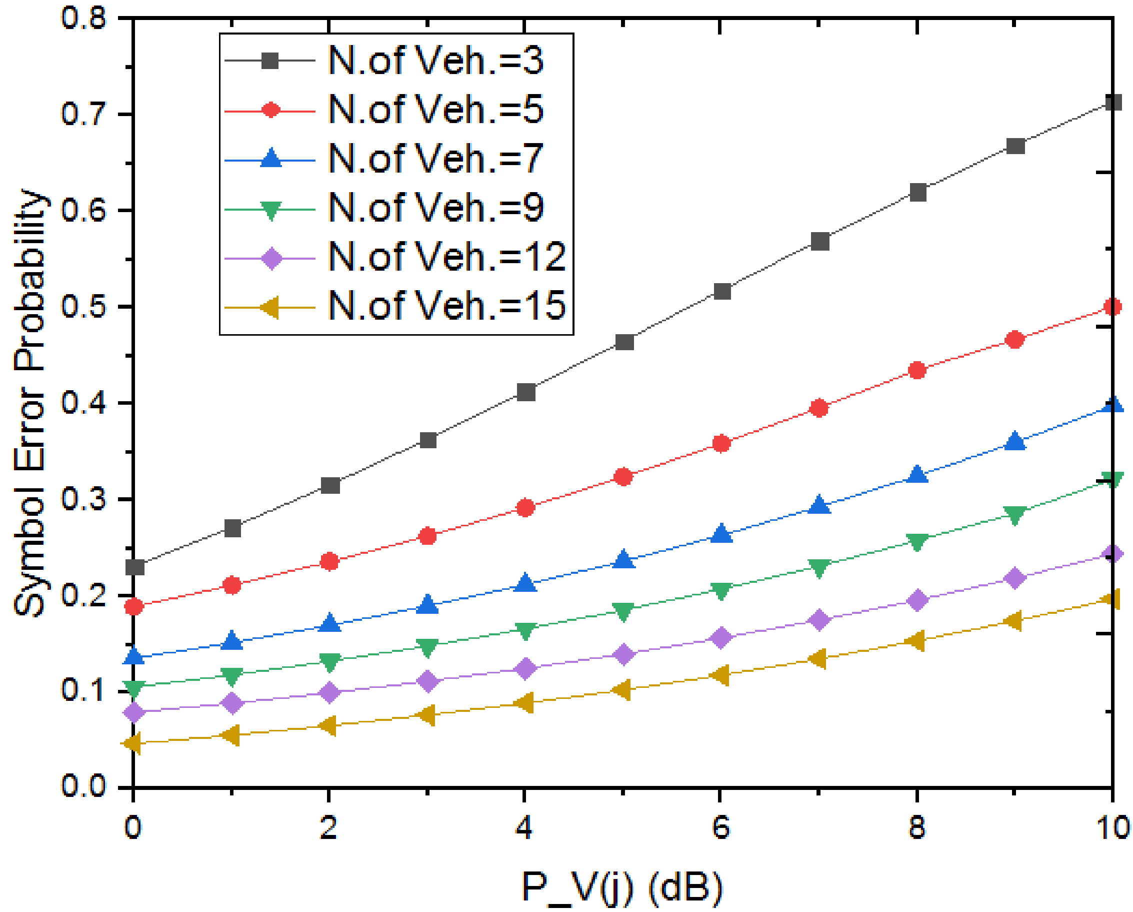

Figure 4: Symbol Error Probability (SEP) versus variation of Transmitted Power

5.2 The variation of M-symbols per bits with platoon size

The table 4 and figure 5 below depict symbol error probability versus symbol per bits as power transmitted, P_j is fixed on $10\,dB$. The number of vehicles grouped from 5 to 20 vehicles in steps of five. This graph is plotted with a reference done by Wemberto Jose Lira de Queiroz analyized the probability versus number of samples. (Wamberto, et al., 2019)

Table 4: Results of Symbol Error Probability vs. M - Symbols per bits, transmit power is fixed on 10dB

M-Symbols per bits	P_V(j)=10 dB			
	No. of Veh. =5	**No. of Veh. =10**	**No. of Veh. =15**	**No. of Veh. =20**
2	0.501427502	0.299243366	0.19731686	0.14918169
3	0.474498763	0.25423883	0.171721347	0.129556588
4	0.395714121	0.209234294	0.140905945	0.106080135
5	0.337360637	0.175023355	0.117490558	0.088333475
6	0.291696816	0.149514256	0.100135163	0.075222224
7	0.255887265	0.130105202	0.087002127	0.065321129
8	0.227388476	0.114969779	0.076800225	0.05764029
9	0.204317121	0.102891099	0.068680446	0.051532786
10	0.185330419	0.093053677	0.062080117	0.04657152
11	0.169470638	0.084900026	0.056617265	0.042467307
12	0.15604607	0.078039218	0.052025592	0.03901891
13	0.144548924	0.072190634	0.048114659	0.036082619
14	0.134600041	0.067148276	0.044745096	0.03355337
15	0.125911637	0.062757851	0.041812762	0.031352724
16	0.118261906	0.058901692	0.03923839	0.029421015

Figure 5 below, shows that the number of vehicles increases from 5 to 20 in steps of five respectively, the symbol error probability decreases whereas M-symbols per bits increases. For example graph of number of vehicles is exactly 20 shows that , when $M = 2$, its probability is 15%, as M -Symbols per bits increases closer to 16, its probability decreases below than 0.5%. A large platoon size requires a big number of M-symbols per bits for symbol error probability whoever its transmitted power is closed to its experimental maximum values, herein this analysis transmitted power varied from 0 to 10dB is considered, means 10dB is a maximum but any other variation range can be fixed.

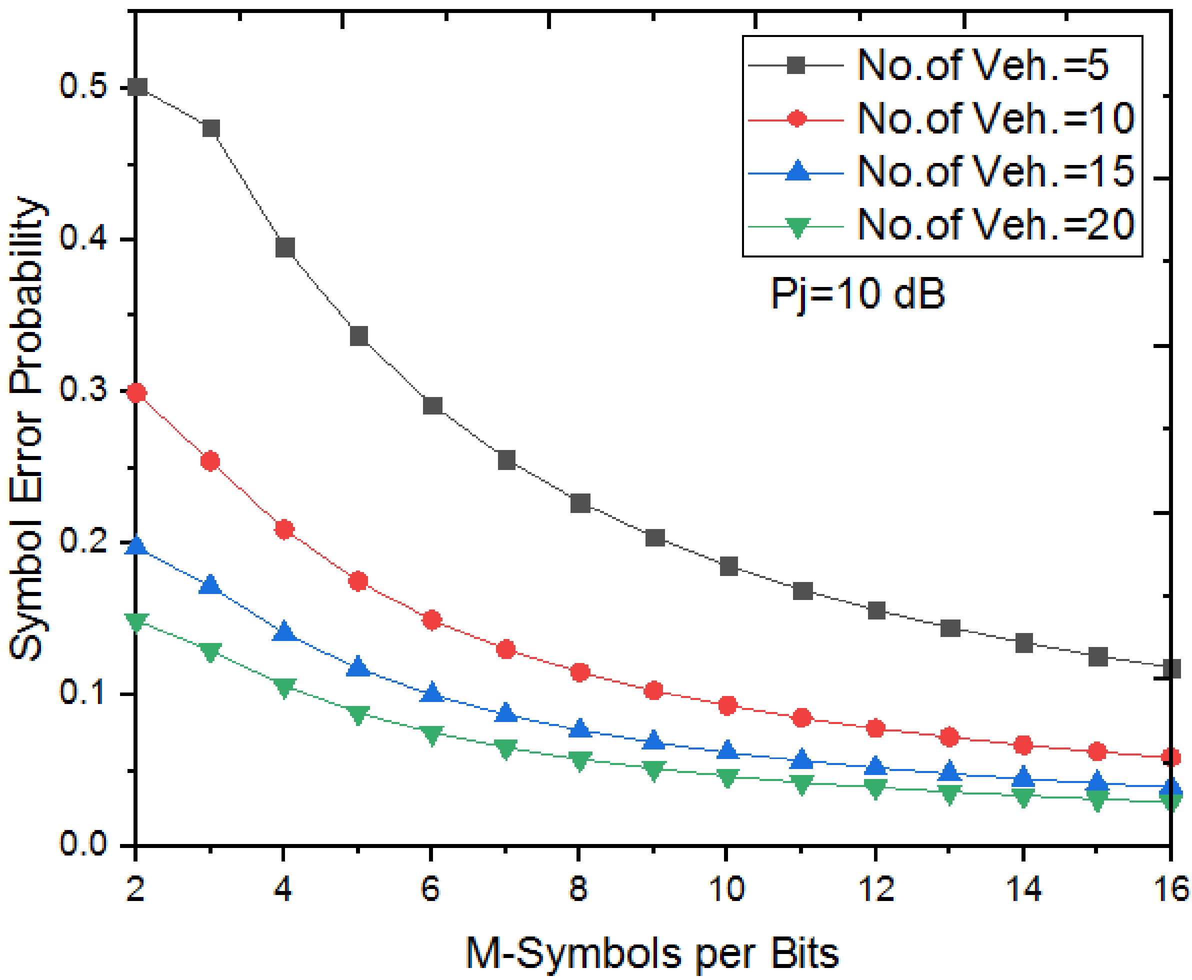

Figure 5: Symbol error probability versus M-symbols per bits with platoon size

5.3 The variation of Transmission Power with M-symbols per bits

This illustration below shows the analytical results. It concludes that the error probability of receiving packets increasing with its transmission as power transmitted between a fixed number of vehicles, the power transmitted is varying from 0 to 10 dB increases as well as number of vehicles increased. Thus, symbol error probability (SEP) decreases as M-symbols per bits varies in such way respectively 2, 4, 8, 16 and 32.

Table 5: Results of Symbol Error Probability vs. transmit power with variation of M - Symbols per bits, platoon size is three vehicles

P_V(j)dB	M=2	M=4	M=8	M=16	M=32
0	0.339058	0.247212	0.136896	0.070298	0.035387
1	0.393863	0.290467	0.162349	0.083626	0.042131
2	0.451485	0.337738	0.191091	0.098846	0.049856
3	0.510301	0.388294	0.22316	0.116085	0.058643
4	0.568553	0.441131	0.258489	0.135461	0.068573
5	0.624592	0.495052	0.296899	0.157077	0.079736
6	0.677079	0.54879	0.338088	0.181022	0.092224
7	0.725093	0.601148	0.38163	0.207367	0.106138
8	0.76813	0.651096	0.426995	0.236156	0.121588
9	0.806045	0.697834	0.473568	0.267397	0.138695
10	0.838956	0.7408	0.520678	0.301057	0.157583

This table 5 above shows the analytical results of Symbol Error Probability versus transmits power with variation of M - Symbols per bits, platoon size is three vehicles.

It shows the small samples of M-symbols per bits raised much error probability as power used to transmit these symbols is varying from 0 to 10 dB. On the contrary with a big sample of M-symbols per bits, its error probability is few compared to small values of M-Symbols. For example, curve of $M = 32$ shows best results than $M = 2$ as its power incremented, thus it in opportunistic communication according to figure 9 plotted by Queiroz shows that on positive side is increasing linearly (**Wamberto, et al., 2019)**.

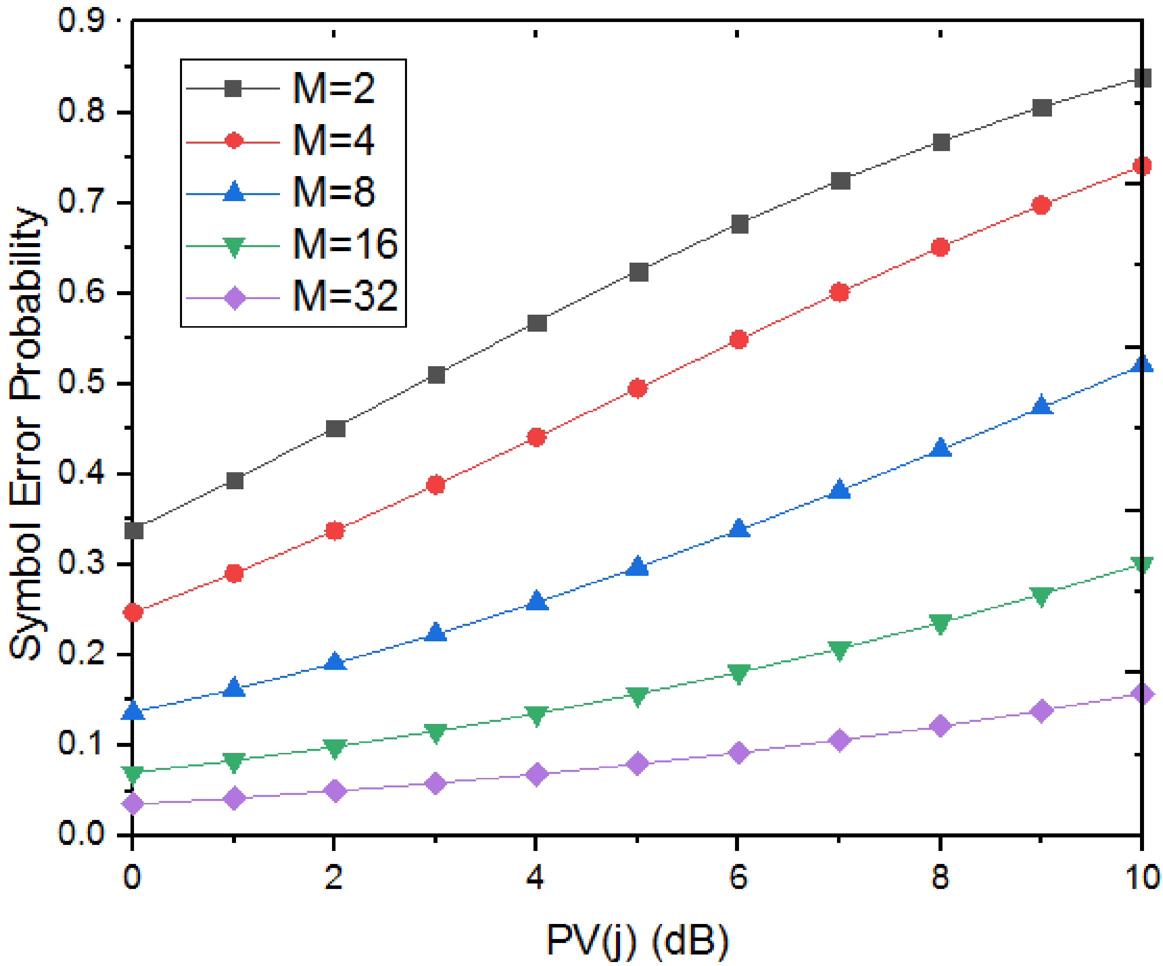

Figure 6: Symbol Error Probability vs. transmit power with variation of M - Symbols per bits

CHAPTER 6:CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

This thesis derived the cumulative density function (CDF) from closed-form probability derived by Tam by its proposed a platoon model with an exponential distribution over channel gain for assessing the performance under varying;

- Transmit power; it is analyzed by fixed other parameters whereas power transmitted and platoon size varies from 0 to $10\,dB$ and 3 up to 15 vehicles respectively in function of Symbol Error Probability (SEP). This graph shows an opportunistic communication among vehicles forming a platoon as referencing on figure 8 plotted by Ngoc Phuc Le (Le N. P., 2017).
- Symbols per bits, it is assessed by fixing power transmitted on 10 dB, it shows that when M-symbols per bits are increasing , the symbol error probability decreases as shown on the table 4 and figure 5 as number of vehicles increases from 5 to 15 Vehicles in steps of 5 on the graphs shows Symbol Error Probability vs. M-symbols per bits. This proves that as M-Symbols per bits increases, symbol error probability decreasing whatever any variation of number of vehicles.
- Symbol error probability versus power transmitted, based on M-symbols per bits variations as platoon size is fixed on 3 vehicles only.

These results are gotten from the analysis generated by closed –form of cumulative density function by using Mathematica by evaluating a targeted parameter of this model, whereas other parameters are fixed to specific values as shown on three graphs analyzed through this study.

6.2 RECOMMENDATION

As technology grows suddenly researchers and industries are reckoned to the humanoid devices for economic acceleration, saving time and producing more is short time with a minimum as number of labors as much as possible, in reflection of digitalization program , need a deep learning of how all parameters needs for an experimental matter on this universe being digital transformed, In this regard a vehicle is equipped by a group sensors worked as team for transmitting all parameters in terms of bits and shifted from one place to another by using different technologies including modulation scheme, here in research PSK modulation technique is considered to analyze the parameter of platoon model which are power transmitted, M-Symbols per bits and platoon size affected –all by modulation angle θ of PSK, symbol error probability is studied in term of these parameters. Everyone interested in this research can analyses it by using other types modulation scheme such ASK, TDMA, FDMA and also can focus on distance between vehicle- to- vehicle until they consider the platoon including partial distance between vehicle by vehicle as well as the position of every vehicle based on longitude and latitude and study what will happen if one vehicle quite a platoon or broken suddenly on road suppose a wheel destroyed or any other malfunction presented unpleasant in orchestration action. Platooning is costly needs first the advanced infrastructure both physical side like road, towers equipped with 4G or 5 G and networking infrastructure.

REFERENCES

1. Adbelhamid, S., & Christos, M. (2019). Error Probability Analysis and Power Allocation for Interference Exploitation Over Rayleigh Fading Channels. *arxiv.org*.

2. Arturo, D., Enric, A., Eduardo, d. P., & Freixas, A. (2013). Environmental Benefits of Vehicle Platooning. *The Automotive Research Association of India*.

3. Business insider Africa. (2019, December 21). *Tesla and rivals like Waymo and GM are locked in a battle over the future of self-driving cars (TSLA)*. Retrieved from https://africa.businessinsider.com/tech/tesla-and-rivals-like-waymo-and-gm-are-locked-in-a-battle-over-the-future-of-self/c2v06gd#:

4. Carl, B., Erik, H., & Daniel, S. (2012). Vehicle-to-Vehicle Communication for a Platooning System. *Procedia - Social and Behavioral Sciences*, 1222-1233.

5. Charles, K., & Emmanuel, N. (2018). Outage Analysis in Wireless-Powered CCRN Networks with Ambient Backscattering. *Proc. IEEEInternational Conference on Advanced Technologies for Communications (ATC)*, (pp. 152-156). HoChiMinh city, Vietnam.

6. Cheein, L. G. (2020). *The Role of 5G Technologies: Challenges in Smart Cities and Intelligent Transportation Systems*. Retrieved from www.mdpi.com: https://res.mdpi.com/d_attachment/sustainability/sustainability-12-06469/article_deploy/sustainability-12-06469.pdf

7. Chong, Y., Shuaizong, S., Hongye, G., & Hai, Z. (2018). Modeling and Performance of the IEEE 802.11p Broadcasting for Intra-Platoon Communication. *Sensors*.

8. epicflow. (2020, March 11). *2020 Automotive Industry Challenges and Trends*. Retrieved from https://www.epicflow.com/blog/2020-automotive-industry-challenges-and-trends/

9. Fishelson, J. (2013). Platooning Safety and Capacity in Automated Electric Transportation. *Utah state University*.

10. Francisca, R., Pedro, J. N., Carlos, F., & Antonio, P. (2019). Systematic Review of Perception System and Simulators for Autonomous Vehicles Research. *mdpi sensor*.

11. Gunnar, D. J., & S. O. Johnsen, T. M. (2019). Accidents with Automated Vehicles -Do self-driving cars need a better sense of self? *26th ITS World Congress, Singapore,*.

12. Hitachi. (n.d). *Connected Car Solutions Based on IoT*. Retrieved from https://www.hitachi.com/rev/archive/2018/r2018_01/10a05/index.html

13. Hobert, L. (2012). *A study on platoon formations and reliable communication in vehicle platoons.* University of Twente: 7500 AE Enschede ,The Netherlands.

14. Hyogon, T., & Taelo, K. (2019). Vehicle-to-Vehicle (V2V) Message Content Plausibility Check for Platoons through Low-Power Beaconing. *Sensor*.

15. Ikecukwu, K. A., Michael, T. F., & Liu, H. (2012). A Security Metric for VANET Content Delivery. *IEEE Global Communications Conference (GLOBECOM).* Anaheim, CA, USA.

16. Le, N. P. (2017). Outage Probability Analysis in Power-Beacon Assisted Energy. *Wireless Communications and Mobile Computing*.

17. Le, V., Ba, C. N., Xuan, N. T., & Le The, D. (2019). Closed-Form Expression for the Symbol Error Probability in Full-Duplex Spatial Modulation Relay System and Its Application in Optimal Power Allocation. *Sensors*.

18. Leonardo, G., & Fernando, A. C. (2020). The Role of 5G Technologies: Challenges in Smart. *mdpi sustainability*. Retrieved from https://res.mdpi.com/d_attachment/sustainability/sustainability-12-06469/article_deploy/sustainability-12-06469.pdf

19. Lyamin, N. (2019). Performance evaluation of safetyn critical ITS-G5 V2V communications for cooperative driving applications. *Halmstad: Halmstad University Press*.

20. Mahmood, Z. (2020). *Connected Vehicles in the Internet of Things: Concepts, Technologies and Frameworks for the IoV*. Springer International Publishing.

21. Mani, A., Hui, D., Chen-Nee, C., H., M. Z., & Dipak, G. (2015). Platoon management with cooperative adaptive cruise control enabled by VANET. *Vehicular Communications*, 110-123.

22. Marcos, P., Karl H., J., Sonke, E., & Magnus, A. (2015). COMPANION - Towards Co-Operative Platoon Management of Heavy-Duty Vehicles. *2015 IEEE 18th International Conference on Intelligent Transportation Systems*.

23. Masoud, B., & Cody, F. (2017). A platoon-based intersection management system for autonomous vehicles. *IEEE Intelligent Vehicles Symposium (IV)*, (pp. 667–672).

24. Nan, W., Di, A., Harutoshi, O., & Shigeyuki, T. (2014). Vehicle to vehicle communication and platooning for SEV COMS by wireless sensor network. *Proceedings of the SICE Annual Conference (SICE)*, (pp. 566-571). Sapporo, Japan.

25. Ross, A. (2018, August 14). *How autonomous vehicles are driving change for smarter cities*. Retrieved from information-age: https://www.information-age.com/how-autonomous-vehicles-are-driving-change-for-smarter-cities-123474171/

26. Saeed, A. B., Madjid, T., Mahsen, A., & Tracey, O. (2016). Autonomous vehicles: challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation*.

27. Sherali, Z., Hunt, R., Yuh-Shyan, C., Angela, I., & Aamir, H. (2010). Vehicular ad hoc networks (VANETS): status, results,and challenges. *Telecommunication Systems*, 217-241.

28. Skalar, B. (1997). Rayleigh fading channels in mobile digital communication systems, Part I:Characterization. *IEEE communication magazine*, pp90-100.

29. Soong, T. (2004). *FUNDAMENTALS OF PROBABILITY AN D S TATIS TICS FOR EN GIN EERS.* New York, USA: Wiley.

30. Synoppsys. (n.d). *The 6 Levels of Vehicle Autonomy Explained*. Retrieved from https://www.synopsys.com/automotive/autonomous-driving-levels.html

31. Tam, N.-T., Hung, T., & Nils, M. (2018). Probabilistic Communication in Car Platoons. *Proc.IEEE International Conference on Advanced Technologies for Communications (ATC)*, (pp. 146-151). HoChiMinh city, Vietnam.

32. TechTarget. (n.d). *self-driving car (autonomous car or driverless car)*. Retrieved from https://searchenterpriseai.techtarget.com/definition/driverless-car

33. TheGuadian. (n.d). *Google reports self-driving car mistakes: 272 failures and 13 near misses*. Retrieved from https://www.theguardian.com/technology/2016/jan/12/google-self-driving-cars-mistakes-data-reports

34. Tiago, R., Vineeth, V., & Salah, E. (2020). Vehicle platooning schemes considering V2V communications: A joint communication control approach. *2IEEE Wireless Communications and Networking Conference*, (pp. 1-6). Seoul , South Korea.

35. Transportation, U. S. (2017). *Volpe Center*. Retrieved from https://www.volpe.dot.gov: https://www.volpe.dot.gov/news/how-automated-car-platoon-works

36. University of Virginia. (2018, March 5). *IN DRIVERLESS CARS, COMMUNICATIONS FAILURES COULD BE DISASTROUS*. Retrieved from https://news.virginia.edu/content/driverless-cars-communications-failures-could-be-disastrous

37. Volpe Center. (2017). *How an Automated Car Platoon Works*. Retrieved from https://www.volpe.dot.gov/news/how-automated-car-platoon-works

38. Wamberto, J. ,., Danilo, B. T., Francisco, M., Waslon, Terllizzie, & Lopes, A. (2019). *Signal-to-noise ratio estimation for M-QAM signals for n-u and k-u fading channels* . EURASIP Journal on Advances in Signal Processing.

39. Wang, F. (2015). Big Challenges of Vehicle Communication and Application. *IEEE Asia-Pacific Conference on Antennas and Propagation (APCAP)*, (pp. 380-383). Kuta, Indonesia.

40. Xiong, F. (2006). *Digital Modulation Techniques.* Canton St.Norwood,MA,United States: Artech House Telecommunication Library.