EVALUATING THE PERFORMANCE OF THE PHY IEEE 802.11p PROTOCOL WITH VEHICLE TO VEHICLE COMMUNICATION WITHIN AN Ad HOC VEHICLE NETWORK

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ABSTRACT

Faced with the increasing number of road accidents of recent decades; Vehicular Ad hoc Networks (VANET) have become an essential technology in the realization of intelligent transport systems (ITS) to meet various demands in real time. In these networks being among the Mobile Ad hoc Networks (MANET), vehicles that tend to move in an organized manner communicate with each other, or even with roadside infrastructures that can also be characterized with a fairly high accuracy. To establish a communication in real time, the study is done on the performance evaluation of the transmission and reception protocol in a vehicular environment. In order to support ITS, the IEEE-1609 set of standards has made an amendment for Wireless Access to Vehicle Environment (WAVE) that specifies an architecture that includes new standards for vehicular communications. The IEEE 802.11p standard, which is the standard for Vehicle to Vehicle (V2V) and for Vehicle to Infrastructure (V2I) communication, constitutes the WAVE protocol stack for support and enhancement of physical (PHY) and medium access control (MAC) layers. In this article, we focus on the communication of vehicles with vehicles by evaluating after simulation that the new standard 802.11p is the optimization of the 802.11a in terms of transmitted information and packets error rate. However, there is always works which should be done to increase the execution time within that new standard.

Keyword : - *VANET, PHY, IEEE 802.11p, packet delivery, channel access.*

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1. INTRODUCTION

Many researchers have been focused in the fields of telecommunications and computer technology to manage intelligent transport systems. One of the achievements of this research is to ensure safety and efficiency, as well as reducing the number of accidents on board that continue to increase in recent decades. To do this, the concept of vehicular ad hoc networks (VANET) has given birth. It is a communication between vehicles or between vehicle and road infrastructure via a device installed on the edge of these vehicles. VANET is an example of an ad hoc network that uses cars by road to exchange information. Figure 1 shows the VANET architecture :

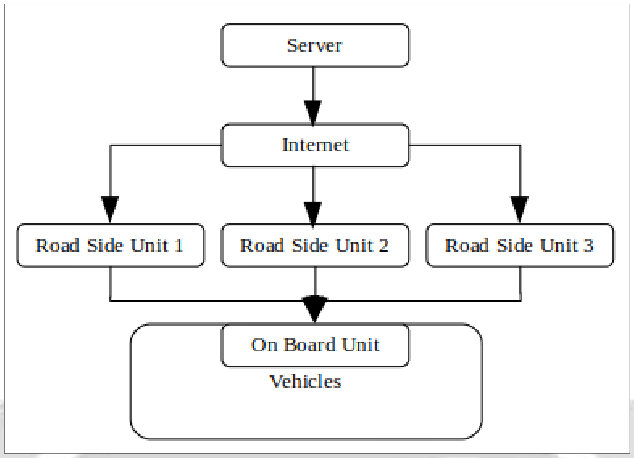

Fig -1 : Principle of VANET

The idea is to contribute to road safety by drivers and / or road users to deal with road accidents that are too frequent in recent years. It should be noted that the discussion of the routing protocol, the information security and the authentication of new vehicles on the network are major challenges for the development of these networks. Indeed, the distinctive properties of this network are that it has a very dynamic network, a topology that changes frequently and an ephemeral nature of network connectivity. In this network, there are three types of communication, namely Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Infrastructure-to-Infrastructure (I2I) which is the combination of these two modes hybrid. Concerning the V2V type, this type of communication follows a distributed architecture. In reality, two or more mobile nodes communicate with each other with a message transmitted inside or outside a cluster. In addition, for the V2I type, this type of communication follows a centralized architecture. In fact, this allows vehicles to communicate with road infrastructure to transmit their own information and / or incidents on the road to a central server. Currently, the problem within this network is that how to transmit information on time with a high rate of data transmission as well as to maintain communication reliability within a high mobility environment. In fact, warning message should be transmitted 5 seconds before an incident which would happen. Thus, we will focus on how to evaluate the performance of the PHY layer of the IEEE 802.11p standard.

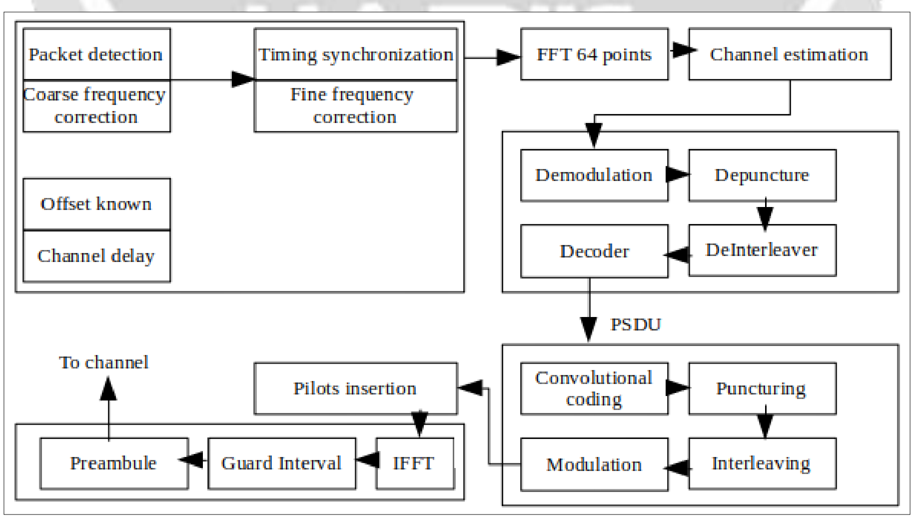

Fig -2 : Synoptic diagram of a transmitter and receiver within IEEE 802.11p

We will follow this article as follows: Section 2 will present standards including IEEE 802.11p based on DSRC (Dedicated Short Range Communication) following the models used for VANETs in Section 3. Besides, Section 4 will assess the performance of these standards in the context of V2V communication. We will conclude this article in section 4.

2. STANDARDS

The IEEE 802.11p standards which is derived from the IEEE 802.11 standard as amended by the IEEE-based DSRC (Dedicated Short Range Communications) working group for wireless access in the intelligent transport system will be seen in this section. Indeed, the IEEE 802.11p Wireless Access for the Vehicular Environment (WAVE) standardization process, which is a kind of mobile Wi-Fi, stems from the allocation of the DSRC spectrum band and the technology definition effort. This technology avoids collisions in which cars are mutually attentive to changing conditions and can significantly improve road safety. In addition, this technology supports over 200km / h of speed with a transmission range of up to 1000m. The DSRC spectrum is structured in seven channels with a width of 10 MHz. Channel 178 is the Control Channel (CCH), which is limited to security communications. The two channels at the ends of the spectrum band are reserved for special uses. The others are service channels (SCH) available for both secure and insecure use. Also, DSRC is considered the best candidate for vehicular communication in many cooperative systems of ITS given its advantages over other potential technologies, such as Bluetooth, Infrared, Zigbee, and 3G mobile communication.

During this article, we focus on the physical layer (PHY) of the IEEE 802.11p standards. Meanwhile, the PHY layer represents an interface between the MAC layer and the support which makes it possible to send and receive frames.

It is composed of 2 sub-layers :

- the physical layer convergence protocol (PLCP) which is not only responsible for the communication with the MAC layer but also for the convergence process which ensures the transformation of the packet data unit arrived from the MAC layer for compose Orthogonal Frequency Division Multiple Access (OFDM) and
- the physical media access protocol which is the interface with a physical transmission means such as radio channels and fiber links. Its task is to manage the coding of the data and to perform the modulation.

As appeared in work already carried out, the previous IEEE 802.11 had for bit rate of 54Mb / s while that of the IEEE 802.11p is at 27Mb / s because of the limits of the layer PHY, some characteristic of the network of vehicles is pose exactly on the high mobility as well as the instability of the network. Also, VANETs have emerged as a new technology to ensure road safety, user comfort and driver assistance.

The PHY is the key factor in achieving the objectives of the VANET network. We will evaluate it by this article aims to contribute the performance of technical communication in the PHY layer for this IEEE 802.11p standards by checking the transmission rates and by minimizing the error rate per bit with maximum bandwidth utilization. The following figure shows wireless access for the Vehicular Environment architecture.

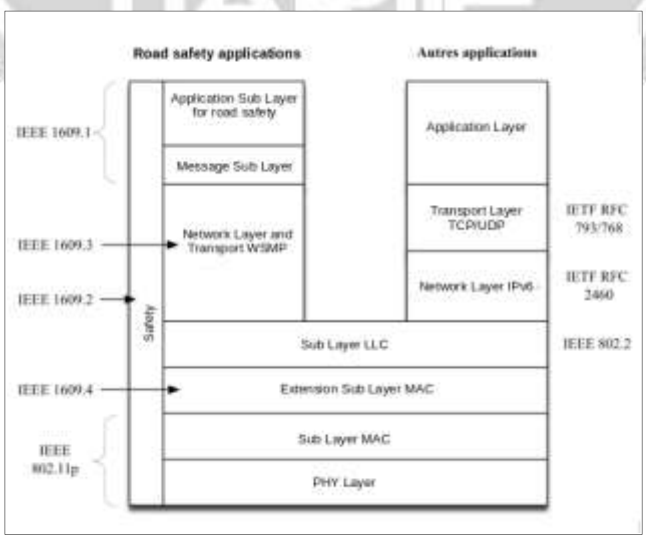

Fig -3 : Wireless Access for the Vehicular Environment architecture

Compared to the IEEE 802.11a, OFDM modulation which is enable to cope with the highly dynamic channel condition is selected but with some modifications. The following table illustrate the changes :

Tab -1 : Comparison between old and new DSRC

IEEE 802.11p		IEEE 802.11a
Throughput	3-27Mbps	0.5 Mbps
Mobility	>60 mph	-
Latency	< 50ms	-
Range	<1000m	<30m
Total Spectrum	75 MHz	
Modulation type	OFDM	-
Channel's number	07	01 without license
Supported communication	V2V and V2I	V2I

3. MODELS

We introduce the system models which were used to develop the communication performance of a vehicular networks.

3.1 Orthogonal Frequency Division Multiple (OFDM)

As we mentioned above, OFDM is used within this standard. In fact, OFDM is a multicarrier transmission technique, which divides the available spectrum into many carriers, each one being modulated by a low rate data stream. It can be viewed as a collection of transmission techniques. In addition, OFDM is generated by first choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on the modulation scheme (typically differential BPSK, QPSK, or QAM). The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform (IFFT) which performs the transformation very efficiently, and provides a simple way of ensuring the carrier signals produced are orthogonal.

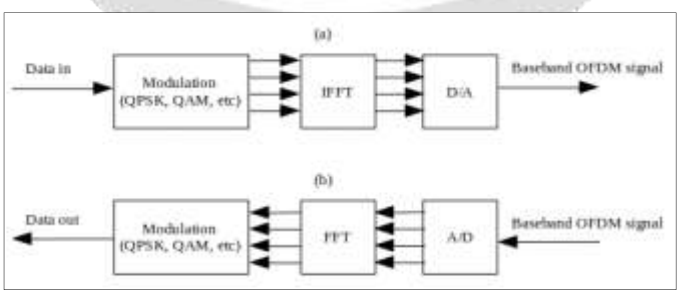

Fig -4 : OFDM transmitter (a) and receiver (b)

3.2 Probability of blockage

We consider that vehicles act as obstacles to the propagation of the signals. The probability $P_{bl}(l)$ of one or more vehicles with a distance *l* potentially obstructing the Line Of Sight between the transmitter and the receiver is given by :

$$P_{bl}(l) = 1 - min(1, max(0, al^2 + bl + c)) \qquad (1)$$

Where a, b and c are derived from geometry-based deterministic simulations and depend on the vehicle density.

3.3 Non Line Of Sight (NLOS)

Non-line-of-sight (NLOS) is a radio transmission across a path that is partially obstructed, usually by a physical object in the innermost Fresnel zone.

The probability $P_{NLOS}(l)$ of NLOS condition for a link that spans a distance *l* is given by :

$$P_{NLOS}(l) = P_{bl}(l).Q\left(\frac{h - \mu_h}{\sigma_h}\right) \qquad (2)$$

Where $P_{bl}(l)$, *Q*-function, μ_h and σ_h represent the blockage probability, the probability that at least one vehicle is within the Fresnel ellipsoid zone corresponding to 60% of the radius, the mean and the standard deviation of the obstacle height, respectively.

$$h = (h_i - h_j)\frac{l_{obs}}{l} + h_i - 0.6\left(\sqrt{\frac{\lambda l_{obs}(l - l_{obs})}{l}}\right) + l_{an} \qquad (3)$$

Where h_i, h_j, λ, l_{an} and l_{obs} are heights of the transmitting and the receiving vehicles, the wavelength, the physical length of antenna and the distance between the transmitter and the obstacle, respectively.

3.4 Probability of connection

Let us assume that vehicles are distributed on the road following a Poisson distribution. Let ρ be the traffic density in terms of vehicles per meter. Therefore, the probability that *n* vehicles are found in a distance of *x* meters is given by:

$$P_n(x) = \frac{(\rho x)^n e^{-\rho x}}{n!}, n \geq 0. \qquad (4)$$

Let $X_i (i = 1,2,...,N-1)$ represent the intervehicle distance between two consecutive vehicles and which obeys an exponential distribution. In our context, the network should be connected if there is a path connecting any pair of vehicles. In fact, the distance between any two consecutive vehicles must be smaller than the transmission range of the vehicles *R*.

It is assumed that there are formation of clusters on road. Let P_{con} be the connectivity probability of the networks given by :

$$P_{con} = P\{X_1 \leq R, X_2 \leq R, \ldots, X_{N-1} \leq R\} \qquad (5)$$

X is identically distributed, we get:

$$P_{con} = \prod_{i=1}^{N-1} P_r\{X_i \leq R\} \qquad (6)$$

Let P_r the probability that the distance between two vehicles is smaller than *x*, which also means the probability that there is at least one vehicle in an interval with length *x*, where :

$$P_r\{X \leq x\} = 1 - e^{-\rho x} \qquad (7)$$

Then, (6) can be given by:

$$P_{con} = [(1-p)(1-e^{-\rho R_1}) + p(1-e^{-\rho R_2})]^{N-1} \quad (8)$$

3.5 Path Loss in IEEE 802.11p

Path loss is the reduction in power density of an electromagnetic wave as it propagates through space. In IEEE 802.11p, the path loss expression is given by:

$$PL_{l_0 \to l}(dB) = A1_N + PL(l_0) - 10\vartheta_1 \log_{10}\left[\frac{l}{l_0}\right]_{0}^{l_c} - 10\vartheta_2 \log_{10}\left[\frac{l}{l_c}\right]^{\infty} + X_\sigma \quad (9)$$

Where ϑ_1 and ϑ_2 are the path loss exponents, $PL(l_0)$ is the path loss at a distance l_0 and l_c is the Fresnel distance:

$$l_c = \frac{4h_i h_j}{\lambda} \quad (10)$$

A is given by :

$$A = \begin{cases} 6.9 + 20\log_{10}\left[\sqrt{(v-0.1)^2+1} + v - 0.1\right], if\, v > -0.7 \\ 0\, otherwise \end{cases} \quad (11)$$

And

$$v = \sqrt{2}\,(h_i - h_j)\sqrt{\frac{l_{obs}(l - l_{obs})}{l}} \quad (12)$$

We have chosen those models because connectivity and the power of signal are crucial in VANET.

4. RESULTS AND EVALUATION

We considerate the V2V communication during this experimentation. In fact, to evaluate the performance of the PHY IEEE 802.11p standard, we have made simulation experiment in GNU Octave which is an Open Source tool for simulation running on Linux operating system (OS).
The following table outlines the parameters during the simulation:

Tab -2 : Simulation parameters

Parameters	802.11 a	802.11p
Bandwidth	20	10
Throughput (Mbps)	6, 9, 12, 18, 24, 36, 48, 54	3, 4.5, 6, 9, 12, 18, 24, 27
OFDM (µs)	4	8
Preamble duration	20	40
Space window	312.5	156.25

During this simulation, we will focus on the amount of data transmitted through data transmission with IEEE 802.11p technology that supports the environment vehicular. We have seen that since the IEEE 802.11a technology, there are changes in frequency up to half including 20 MHz at 10 MHz. We are visualizing the quantity of data transmitted during this operation, as well as the signal to noise ratio to packets error rate. We also viewed the look of the result for using the frequency at 5 MHz.

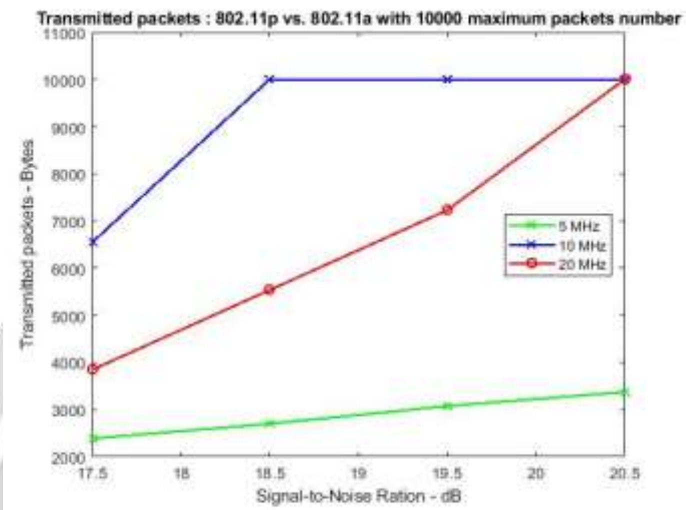

Fig -5 : Packets number transmitted with OFDM 5, 10 and 20 MHz

We can see according to this figure that the number of transmitted packets is better using IEEE 802.11p with the 10 MHz frequency. However, we also simulated the use of the frequency at 5 MHz and visualized that this number of transmitted packets is very low. Moreover, the old IEEE 802.11a standard experienced a lot of loss packets compared to the new technology so it is not very satisfactory but still it reaches the same level of packets transmitted as the new standard at the end of the transmission. The illustration of the packet error rate during transmission is shown in the following figure:

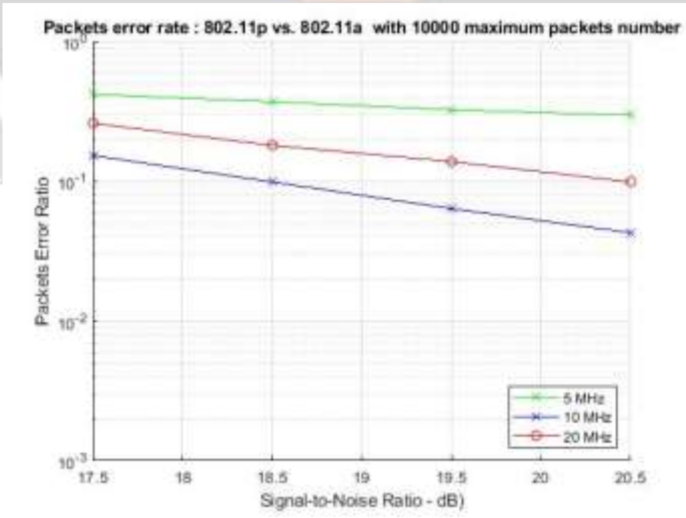

Fig -6 : Packets error rate with OFDM 5, 10 and 20 MHz

We can note from this figure that the packet error rate is lower for IEEE 802.11p technology given the 10 MHz frequency reduction compared to 20 MHz for IEEE 802.11a.

For the rest of this paper, we took other numbers of packets for this simulation as shown in the following table:

Tab -3 : Summary of data for the frequency at 5 MHz

SNR	Packets number : 200		Packets number : 10 000	
	Packets transmitted	PER	Packets transmitted	PER
17.5	44	0.47727	2384	0.41988
18.5	67	0.31343	2697	0.37115
19.5	53	0.39623	3073	0.32574
20.5	64	0.32813	3371	0.29694

Tab -4 : Summary of data for the frequency at 10 MHz

SNR	Packets number : 200		Packets number : 10 000	
	Packets transmitted	PER	Packets transmitted	PER
17.5	169	0.12426	6539	0.15308
18.5	200	0.084577	10000	0.09909
19.5	200	0.084577	10000	0.063794
20.5	200	0.039801	10000	0.042896

Tab -5 : Summary of data for the frequency at 20 MHz

SNR	Packets number : 200		Packets number : 10 000	
	Packets transmitted	PER	Packets transmitted	PER
17.5	79	0.26582	3841	0.26061
18.5	156	0.13462	5532	0.18095
19.5	143	0.14685	7227	0.13851
20.5	200	0.074627	10000	0.09909

Given these tables that represent the details of packets transmitted and packets error during transmission, we can say that all packets are transmitted using the IEEE 802.11p regardless of the number of packets to transmit. In addition to that, the following figure illustrates the data transfer run time based on their sizes using both the 10 MHz and 20 MHz frequencies.

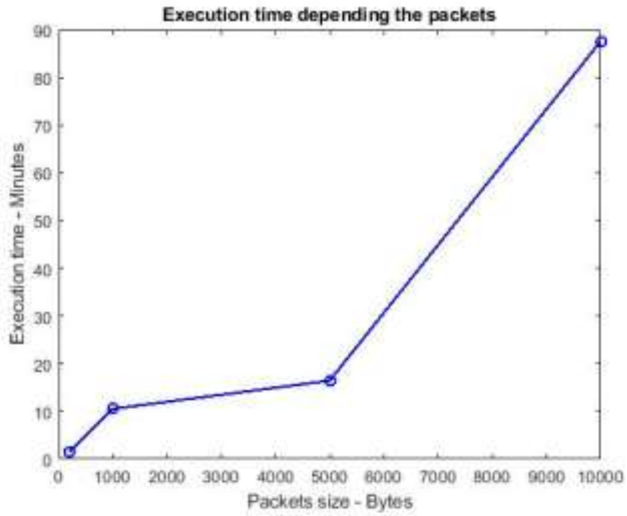

Fig -7 : Execution time during a data transfer

We find that the execution time increases according to the number of packets. But for the rest we will detail the execution time with each use of the two technologies.

We have taken the same parameters as Tab 2 for comparison of execution times between IEEE 802.11a and IEEE 802.11p.

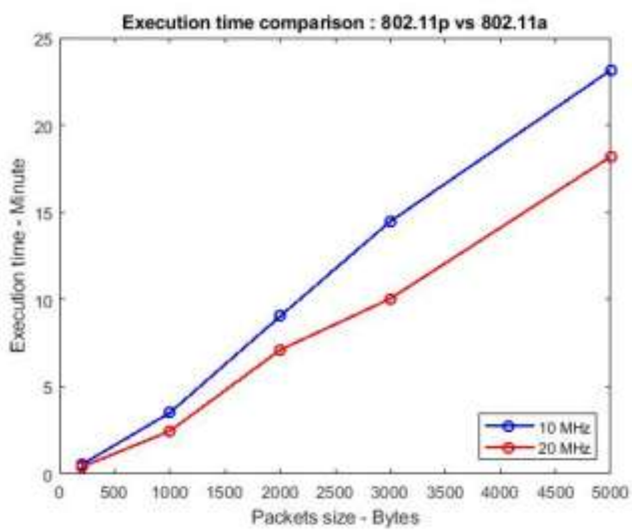

Fig -8 : Comparison of execution time when transferring data between 802.11p and 802.11a

We can say from this figure that the new IEEE 802.11p technology for transferring data over a vehicular environment took a lot of time compared to the old technology.

5. DISCUSSION

In this article, we were able to evaluate performance of the technology PHY IEEE 802.11p. In fact, we have compared it with the old version IEEE 802.11a so that we found the error rate and packets transfer rate are better for the new technology in a vehicular and dynamic context. However, the time required to transfer within the new technology is difficult. For our future work, we will focus more on execution time depending on the amount of information to be transmitted.

6. REFERENCES

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