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PERFORMANCE STUDY OF 802.11P STANDARD IN VEHICULAR NETWORKS

Oscar Eduardo Gualdrón[1], Nancy Yaneth Gelvez[2] and Danilo Alfonso López S [*3]
[1]Department of System Engineering, Pamplona University, Pamplona, Colombia, South America
[2]Department of System Engineering, Distrital "Francisco José de Caldas" University, Bogotá, Colombia, South America
[3]Department of Electronic Engineering, Distrital "Francisco José de Caldas" University, Bogotá, Colombia, South America
E-Mail: oscar.gualdron@unipamplona.edu.co

ABSTRACT

In this article we show a study on the functioning and performance of the 802.11p protocol which was designed for Ad-Hoc vehicular networks. The assessment scenario of the protocol is a stretch of avenue in Bogota, and simulation is performed on the omnet ++. network simulator. The parameters evaluated were the response of the connection venue, delays in data transfer, data loss and connection feasibility in a noisy environment. A mathematical operation was applied to the data obtained in order to achieve a correct interpretation of them. From the analysis it was concluded that the standard meets the requirements necessary to be implemented in a vehicular network, however a disadvantage is evident when traffic density is low, since each node fails to establish a connection, or if it succeeds the packet loss rate is high.

Keywords: VANET, mobile networks, ad-hoc networks, 802.11p.

1. INTRODUCTION

Vehicular networks increasingly hold more potential applications for the comfort and safety of drivers and passengers; for this reason protocols and studies have been developed in such networks [1, 2].

Vehicular wireless communications can be of the vehicle to vehicle type (V2V) or vehicle to infrastructure (V2I), and both are encompassed within the VANET (Vehicular Ad-hoc Networks). Through the VANET networks, information about traffic conditions can be transmitted and warnings about possible accidents, maps, internet access, etc. [3]. In these networks the vehicles make up the nodes, and in general, all are treated equally, and each one is also a point to forward information [4]. Unlike MANET networks, in VANET networks the nodes move along predefined paths (the streets of a city) and the velocities of these are limited by the speed limit of the routes, which makes it easier to design and manage them [5].

For proper access to the wireless medium and reliable transmission of information in VANET networks, the IEEE has developed the 802.11p protocol (known as WAVE, Wireless Access for the Vehicular Environment). This standard operates in the 5.9 GHz band in the US and 5.8 GHz in Europe and Japan; the average bandwidth required is 6 Mbps, but can it reach up to 100 Mbps, and the median coverage is 300 m, but can be up to 1000 m with a transmit power of up to 28.8 dBm [6].

This paper is divided into 5 sections. Section 2 gives an overview on the VANET networks and the IEEE 802.11p standard; in section 3 we show the simulation process for performance evaluation of the 802.11p protocol on a stretch of an avenue in Bogota, at an average speed of 6.3 m/s (22.67 km / h); section 4 shows the results of the network simulation; section 5 is the analysis of these results; and section in 6 we present the conclusions on this work.

2. AUTOMOTIVE AD-HOC NETWORKS

The development of VANET networks involves a lot of applications for road safety and driver comfort. Also, this has brought the need to develop new routing protocols, transmission control data, security, among others [7]. Topology models and therefore VANET network routing protocols have been developed based on the MANET network models since the former are a special case of these, where the mobility simply follows the pattern of vehicular roads, thus being less complex.

Here vehicles can form a network with multi-hop mesh topology, allowing the transmission of multimedia data between users. This transmission requires a transport protocol such as TCP, but studies have shown that this protocol is very inefficient in mobile environments, encouraging the development of other alternatives such as ATP, ELN or variants of TCP [8].

Due to the characteristics of an urban environment, various physical obstacles to direct transmission between two points are present, because of this it is usually necessary for the data sent to take alternative routes, which is why routing protocols are developed for VANET [5, 9]. Routing protocols for VANET fall into two groups, reactive and proactive protocols [5]. DSR is a reactive protocol example; it is a routing algorithm, where the intermediate nodes between sources are listed, and it sets the path only when required by the source; it quickly adapts to changing topologies, but has some weaknesses regarding the feasibility of delivering the totality of packets [9]. In the group of proactive protocols we can mention the B.A.T.M.A.N [10]. This protocol is based on the choosing the neighboring node reachable with a single bound, which is the most efficient to be used as a gateway to the destination node. This choice is done by proprietary protocol algorithm [11].

The previously mentioned protocols require a platform to operate properly, an access and physical medium control protocol (wireless). To this end, the IEEE

has developed a version of the 802.11 standard specialized for the VANET, the IEEE 802.11p standard. This standard is designed for quick communication, necessary for the constantly changing position of the nodes in a VANET network. The vehicular band standardized by the.11p is the 5.9 GHz and the channels are multiplexed OFDM with channel bandwidths of 10 MHz (OF3.3.16), 20 MHz (OF3.3.17) or 5 MHz (OF3.3.18), where the use of OF3. 3.16 is recommended to make the signal more robust against fading [12]. One of the characteristics of this standard is that it allows the transmission from stations that do not belong to a BSS, thus making authentication or associations unnecessary, being suitable for environments where connections vary rapidly [11]. As for adjacent channel rejection (ACM) in 802.11p, a more rigorous distribution was made. Table 1 shows the values of ACM for each modulation type [12].

Table-1. Rejection of adjacent and non-adjacent channel based on [12].

Modulation	Coding rate	Adjacent channel rejection	Non adjacent channel rejection
BPSK	1/2	28	42
BPSK	3/4	27	41
QPSK	1/2	25	39
QPSK	3/4	23	37
16QAM	1/2	20	34
16QAM	3/4	16	30
64QAM	2/3	12	26
64QAM	3/4	11	25

Furthermore four masks of spectrum are defined with their respective power classes (A, B, C, D), where class A has a maximum power output of 0 dBm; class B, 10 dBm; class C, 20 dBm; and class D, 28.8 dBm [12]. And in general, the bit rate is halved compared to 802.11 - 2007; the symbol duration, guard time, FFT period (Fast Fourier Transform) and preamble duration doubled in value; and the subcarrier space was halved [12]. The data packet transmission format is shown schematically in Figure-1, which matches the 802.11 - 2007 format [12].

3. DESCRIPTION OF THE TEST PERFORMED

The purpose of the test is to assess the performance of the 802.11 standard regarding responses to setting connections, delays in data transfer, loss of data, and connection feasibility in a noisy environment. The network topology comprises 4 vehicles (nodes) that flow through a stretch of 7th Avenue in Bogota, two from north to south, and two in the opposite direction; their speed is 6.3 m/s, which is the average speed in the city [13]. These four nodes are interconnected in a type V2V network and have implemented the 802.11p standard. The transmission parameters are listed below:

- 10 MHz BW channel bandwidth.
- QPSK modulation.
- 6Mbps transmission bit rate.
- ½ coding rate.
- 10dBm transmit power.
- 5.9 GHz carrier frequency.
- Thermal noise level -110 dBm.
- MTU 3000 Bytes.
- Equipment sensitivity -85 dBm.

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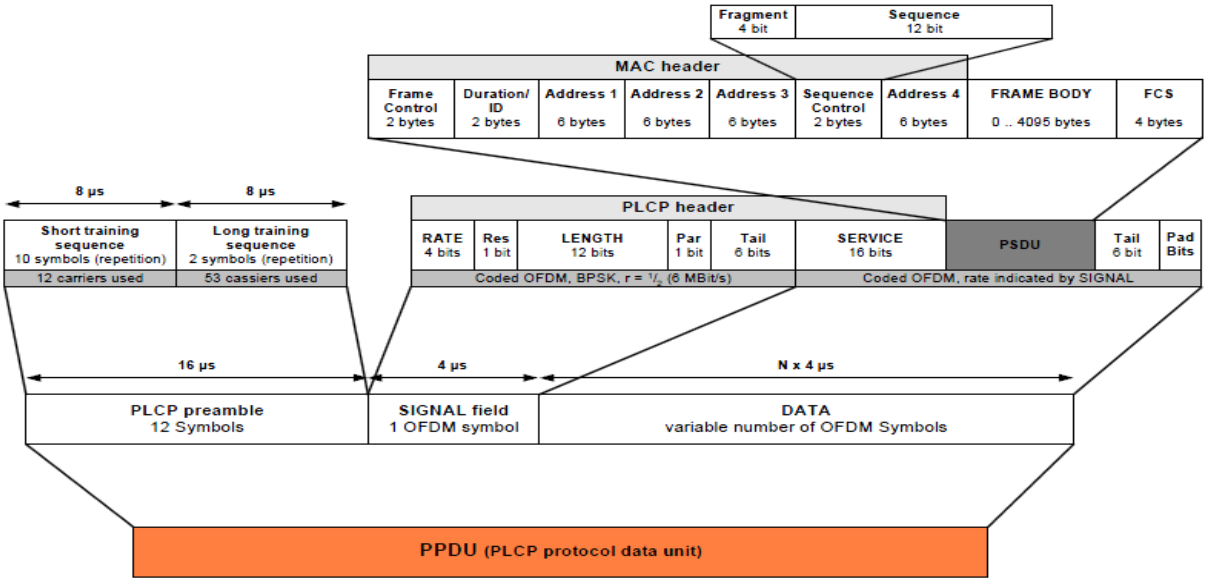

Figure-1. Schematic description of the packet transmission format [12].

This topology is proposed because it easily allows to appreciate the effect of the range scope of RF equipment installed in cars in order to establish a connection; they can also cause interference between different nodes by being aligned in line, thus simulating a noisy environment and in this way we can clearly assess the established parameters.

Figure-2. Location of the nodes and direction of movement on the map. Map taken from [14] Icons generated in omnet ++ 4.2.

Figure-2 shows the location and speed vector of the vehicles comprising the simulated VANET. It is important to note the location of the nodes in order to achieve proper interpretation of the results. Figure-3 shows a screenshot of the simulation model. Each node has a radio transmitter and receiver that are linked to the parameters listed above. The purpose of this radio is to illustrate the model behavior.

Figure-3. View of simulation running on Google earth. Socket management by OMNeT and Google earth plugin were used for dynamic display of layers.

When a vehicle is within the transmisson radius of another, a link is established and in this manner a vehicle network is set as can be observed in Figure-4.

4. RESULTS OBTAINED

In order to analyze the behavior of the standard on node 0, a differentiation was applied, as shown in equation 1; from this the graph in Figure-4 was obtained.

$$f'(kt_n) = \frac{f(kt_{n+1}) - f(kt_n)}{T} \quad (1)$$

Where *Ktn* is the current sample, *ktn + 1* is the next sample and *T* is the sampling period.

The same process was applied to radio data link nodes 1, 2 and 3, and the results were very similar to the response of node 0, except that the graph was moved along the x-axis (representing the number of the transmission performed), indicating that connections were established at different times.

The graph in Figure-4 shows great activity between transmissions number 15 and 58. This is because at that time the node was able to establish radio connection and the layer 1 device began receiving data. Something similar happened with the other three nodes. To evaluate packet loss and transmission delays, the ICMP protocol was implemented by sending an Echo Request (ping) between different nodes, thus traffic was generated in the network and these parameters could be assessed. The transmissions were carried out as detailed below.

- Node 0 to Node 3.
- Node 1 to Node 2.
- Node 2 to Node 0.
- Node 3 to Node 1.

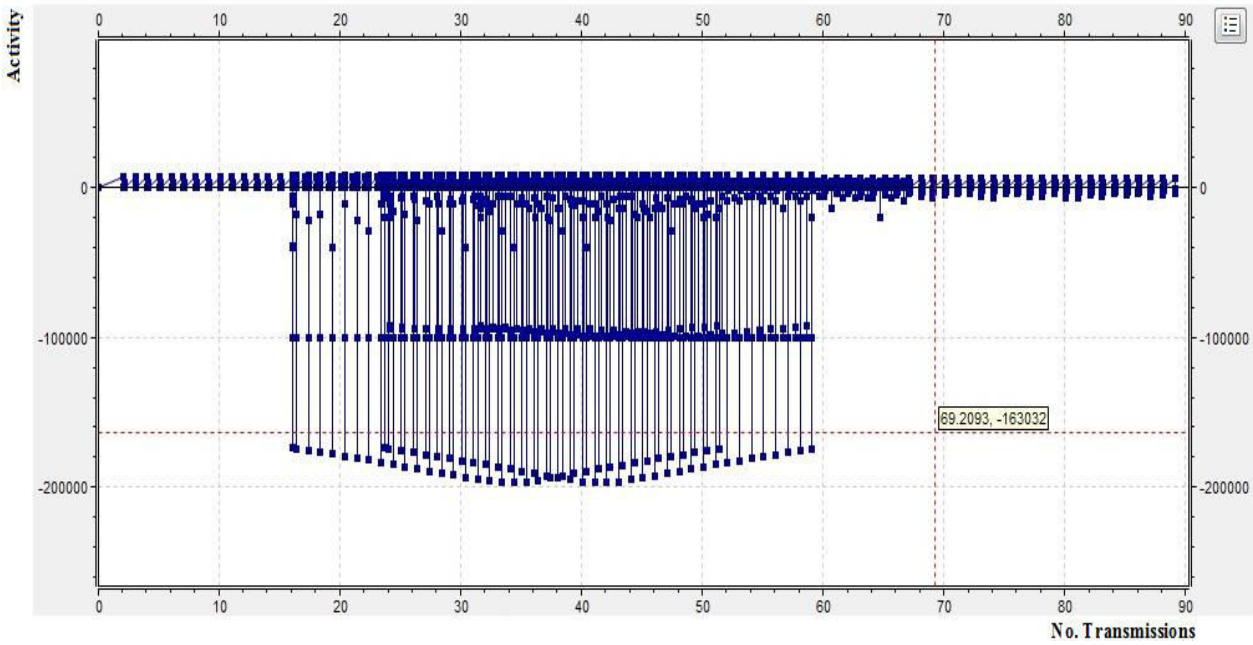

Figure-4. State of radio 0-node link. Differential coefficient.

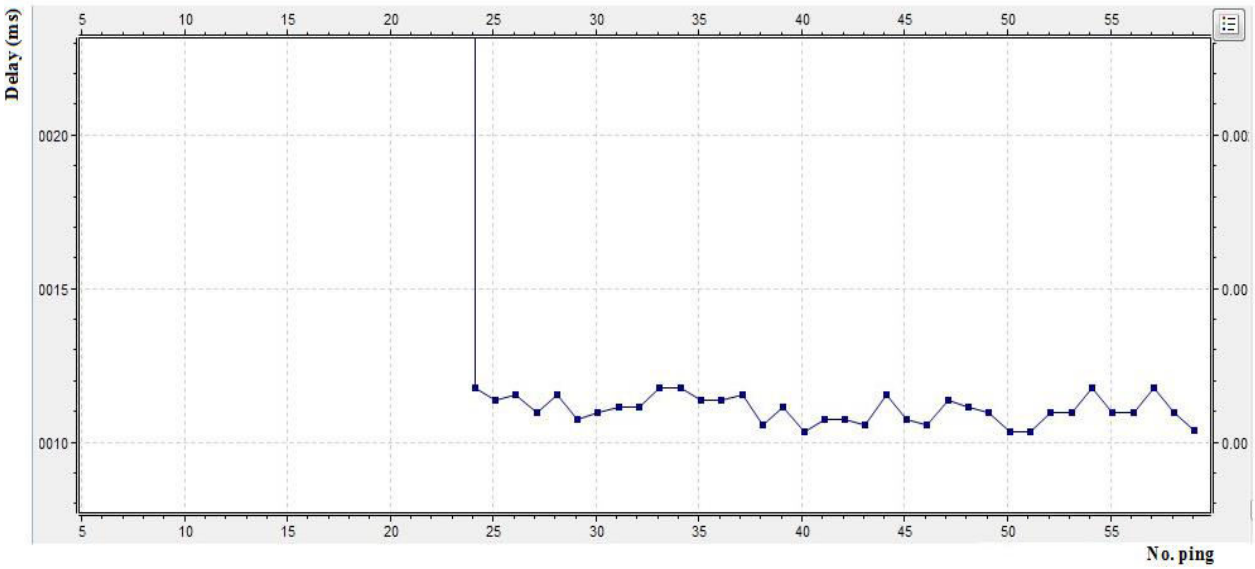

Figure-5. RTT (Round trip time) ping round-trip time from node 0 to node 3.

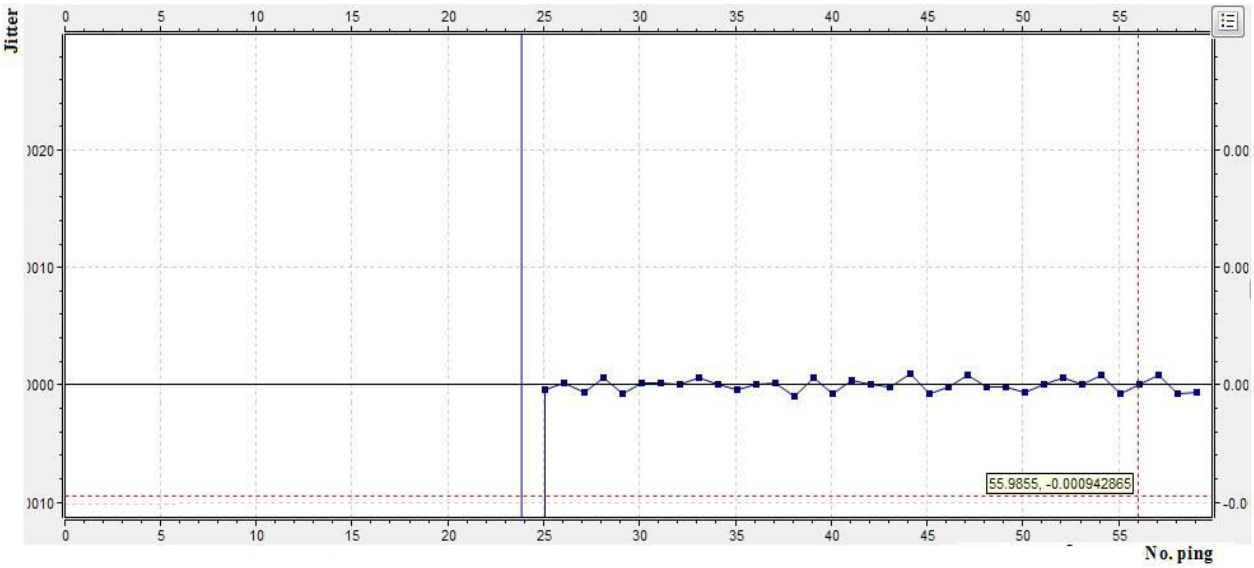

Figure-6. Jitter introduced in the transmission of node 0 to node 3.

Figure-5 shows the behavior of each sent ping delays. One can observe a peak in the first data sent, this delay is because the connection is not yet reliable, and the data is lost. The average delay was 1.1 ms, and the variation in delays was due to the movement of nodes and network variation. Figure 6 shows the jitter graph, obtained by applying equation 2. You can see that the jitter was very close to zero, so it can be inferred that the behavior of this transmission was stable.

$$\text{jitter} = \frac{(t_{received}(j) - t_{sent}(j)) - (t_{received}(i) - t_{sent}(i))}{j - i} \quad (2)$$

Figure-7 shows the behavior of Ping transmission delays from node 1 to node 2. We can observe a similar behavior to the transmission Node 0 - Node 3; in this case there was also an average delay of 1.1 ms and the previously mentioned peak also appeared. In Figure-8 we can also observe a low jitter for this transmission, showing the smooth functioning of the standard.

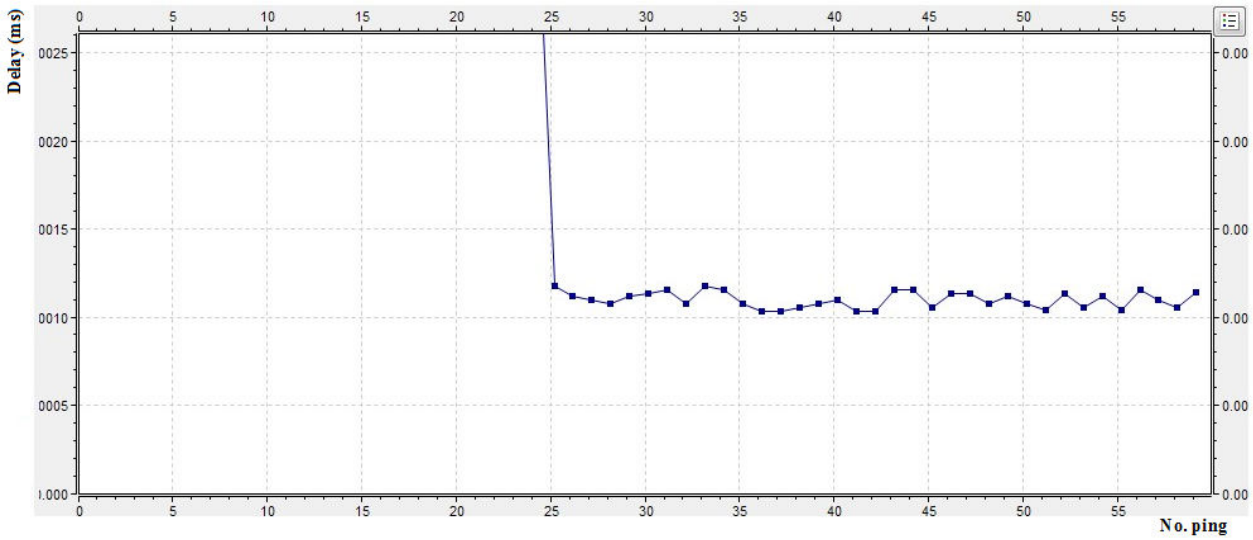

Figure-7. RTT (Round trip time) ping round-trip time from node 1 to node 2.

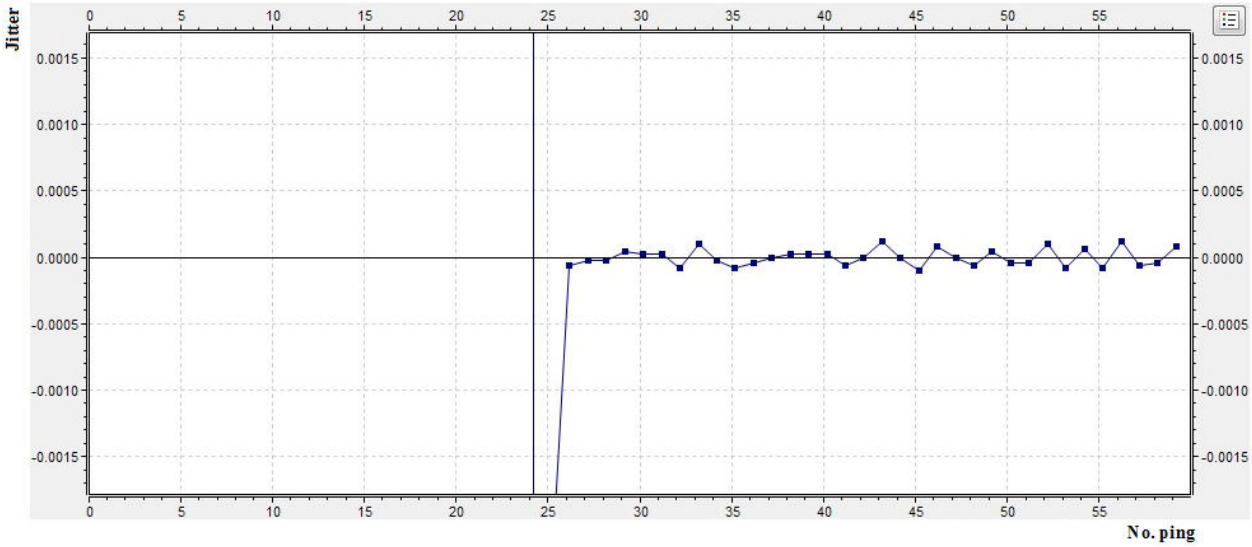

Figure-8. Jitter introduced in the transmission of node 1 to node 2.

The behaviors of Node 2 - Node 0 and Node 3 - Node 1 transmissions followed the same pattern already explained, therefore we do not delve into the explanation of these.

Table-2 shows the number of lost packets. We can see that it is high; this is due to low traffic density since the nodes have no possibility of establishing an alternative connection when a channel has a high noise level.

Table-2. Packets sent and lost in four preset routes.

	Pack. sent	Pack. lost	% Pack. lost
N0 - N3	59	24	40.68
N1 – N2	59	24	40.68
N2 – N0	59	30	50.85
N3 – N1	59	18	30.51

5. ANALYSIS OF RESULTS

Activity in radio devices present in the nodes increased in the time interval in which the nodes were close enough to make a connection. Once this connection was established and the nodes were within the range of scope, it did not have interruptions, indicating a good performance of the standard in terms of physical layer regarding establishing and maintaining the connection. The average delay obtained in the simulation is 1.1 ms, which is about half the average delay that occurs in wireless 802.11a/b/g: this occurs because the 802.11p protocol does not require a BSS to establish and maintain the connection. Due to the low traffic density with which the simulation was performed, the nodes were not able to establish an alternate route when the initial route had a high noise level; because of this the packet loss was high.

6. CONCLUSIONS

- The 802.11p standard had an effective behavior in establishing and maintaining the connection, which makes it a suitable standard for implementation in VANET type networks.
- The main feature of this standard, which consists in not requiring a BSS to establish and maintain the connection, enables mobile nodes to establish connections randomly and quickly, which is a determining factor in the proper functioning of vehicular networks.
- The fact that a BSS is not required significantly reduces transmission time delays, making the standard under study effective for implementation in vehicular networks.
- When traffic density is low, the capacity of the nodes to establish new routes decreases considerably, a factor that directly influences network performance, resulting in a high rate of packet loss. This may well be the only weakness found in this study. It is recommended to improve this in future versions of the standard.

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