Comparison Routing Protocols and Mobility Models for Vehicular Ad-Hoc Networks using Real Maps

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ABSTRACT

The mobile Ad-Hoc networks, specifically VANETs (Vehicular Ad-Hoc Networks), are studied since the last 10 years. The present work highlights comparisons between the routing protocols: AODV, DSDV and CBRP, on scenarios that describe the urban and road vehicular traffic, using real maps of the city of Loja (Ecuador). Likewise, mobility models from the CityMob for Roadmaps (C4R) traffic simulator are compared, also the protocols funcionality is analized, over the wireless cards benefits under the 802.11p and 802.11b standars; the same that are designed for vehicular environment use.

Keywords:

Ad-Hoc, C4R, routing protocols, VANET, metrics, mobility models, ns-2, 802.11p/b. ifx

1. INTRODUCTION

The wireless connectivity has experienced an extensive growth, and now with ubiquity it extends to diverse scenarios and in a totally independent way from the location [1], that is, environments that gather conditions of permanent mobility, as is the case of the vehicular ad-hoc networks.
Research on the issue derived mostly from Europe [2], North-America [3] and Japan [4], also it has deployed testbeds about real scenarios [5]. Although, most VANET studies and simulations found are on the basis of IEEE 802.11b standard, given the approval of IEEE 802.11p - WAVE, a comparative analysis of the routing protocols throughput is presented, on both communication technologies.
The paper is organized as follows. Section 2 exposes the main characteristics of routing protocols and a brief description of the mobility models applied to VANET simulations. Section 3 presents the materials and methods, like the preparation of the simulator, definition of scenarios with traffic and network parameters, metrics study for the VANET evaluation; and the methodology used for the outcome. Section 4 presents the simulation results, and finally Section 5 and 6 concludes the paper.

2. ROUTING PROTOCOLOS AND MOBILITY MODELS

It has taken in consideration 3 routing protocols: AODV, DSDV and CBRP, which belong to the group "based on topology" of the corresponding classification for VANETs [6]. The table 1 sums the main characteristics of thereof.

2.1 Krauss Model

It is a microscopic model for car tracking, proposed by Stefan Krau [10, 11]. It allows to represent the variations of the velocity, produced by the dependency corresponding to the minimun stopping distance, which has to be maintained by the drivers regard to the vehicle that precedes them in the way, with the aim of avoid shocks or collisions [12].

Table 2. Parameters of the IDM model to simulate the behavior of three classes of drivers and truck drivers [12]

IDM Parameters	*Normal*	*Shy*	*Aggressive*	*Truck*
Desired speed v_0 (Km/h)	120	100	140	85
Desired time spacial T (s)	1.5	1.8	1.0	2.0
Security length δ_0 (m)	2.0	4.0	1.0	4.0
Maximum acceleration a (m/s^2)	1.4	1.0	2.0	0.7
Deceleration b (m/s^2)	2.0	1.0	3.0	2.0

2.2 Wagner Model

Developed by Peter Wagner, with the purpose of introduce two main characteristics of the human driving: the first under the assumption that people usually plan the future event while they drive, the second refers to the type of control that people exercise over their vehicles, it's not continous but discrete in the time, it is, they just act in certain times that are named accion points, which are considered like random phenomen; they happen with more or less reason in function of the environment and the driver situation [13, 12].

2.3 Kerner Model

Known as theory of the phase traffic [14, 12], because it divides the vehicular traffic in 3 phases to model it: free flowing, synchronized flow and wide congestion. Following the explanation of each state:

2.3.1 Free flowing. in this state the vehicles can circulate without congestion problems.

2.3.2 Synchronized flow. the term "synchronized" means to the trend of synchronization of the vehicles velocity in the road; because of the low probability that exists in the congested traffic.

2.3.3 Wide congestion. is a case of congested traffic, given when traffic density is extremely high and the velocity that vehicles circulate is almost zero.

2.4 Intelligent Driving Model (IDM)

Deterministic model, in which the acceleration of the vehicle depends of: its own acceleration, the acceleration of the surrounding vehicles and the distance towards the precedent vehicle. With IDM is possible to simulate plus the aspects related with the vehicle and its environment, the drivers behavior, for implying 3 different types: aggressive, normal and shy. Likewise, it allows to differentiate between drivers of small vehicles and trucks, as shown in the table 2 [12].

Table 1. Comparison of routing protocols: AODV, DSDV and CBRP [7], [8], [9]

PARAMETERS	AODV	DSDV	CBRP
Protocol type	Reactive	Proactive	Hybrid
Control messages	RREQ, RREP, RRER	HELLO & Update	HELLO, RREQ, RREP, RRER
Central Administration	No	No	"clusterhead"
Route discovery	Each source node sends broadcast of RREQs on demand	It already possess information towards all the destinations	It already possess information of the neighbors inside the cluster, but sends broadcast on demand between clusters
Way to reconstruct the route	Each receiver of RREQs, manteins a bacwards pointer that is used by the RREPs messages for route trace towards the destination	The next hop is calculated by the routing table of neighbors until reach the destination	Through table of routing inside the cluster and under demand between clusters
Loop-free routing	Yes	Yes	Yes
Routing type	hop-by-hop	hop-by-hop	routing source
Support links	Symmetric	Symmetric	Symmetric, selective, asymmetric
Scalability	Yes, but vulnerable to network changes	No	Yes, but it can introduce too much overhead
Metric	Shortest path	Shortest path	Shortest path
Advantages	- Low overhead - Support of messages unicast, multicast and broadcast. - Low resource consumption	- Low probability of collisions - High throughput and low delay in small networks - Maintains only the best route towards the destination	- Low demand for the discovery of routes (clustering) - Repair of broken links locally - Optimization of routing by shorten path
Disadvantages	- High probability of collisions - Medium and high latency in the discovery of routes depending of the network size	- High overhead - Incremental delay in large scale networks - Waste of bandwidth - High resource consumption	- Because of the type of routing, the packet size increases in proportion to the length of the route navigation; which is proper for small clusters

However, the values in the table 2 serve only for reference, and they vary in accordance to the velocity limits established by the transport law and road safety of a country or region.

3. MATERIALS AND METHODS

3.1 Preparation of Simulators

For this study it has been used the tools of simulation of traffic and network: C4R[1]) and NS-2[2] respectively. The figure 1, represents the main scheme, in which is based from beginning to end the processes for the simulation and results analysis.

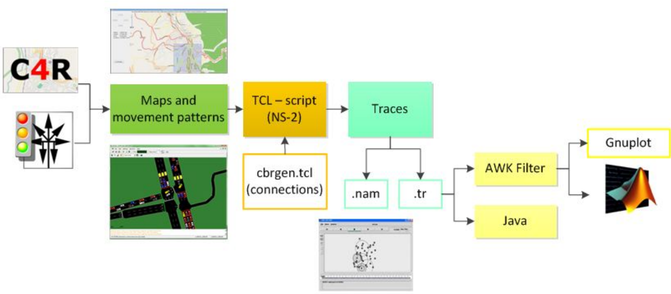


Fig. 1. Diagram of processes for the simulation and results analysis

Firstly in the software C4R, is generated the scenario of vehicular traffic from real maps in where can delimit the simulation area and the trace mobility generated (*.tcl). This trace is compatible with the network simulator NS-2, and is loaded together with the file of connections in the simulation scripts previously for each communication technology (802.11p and 802.11b). After running the simulations in NS-2, the traces *.tr and *.nam are generated, where the first trace allows to distinguish all the events produced during the simulation line by line for a comprehensive analysis of the network, and the second trace represents the events in a graphical interface, friendly for the user. In section D, the methodology used for the obtention of the results from the trace *.tr is explained, following the diagram of processes for the simulation.

[1]`http://www.grc.upv.es/Software/c4r.html`
[2]`http://www.isi.edu/nsnam/ns/`

3.2 Definition of Scenarios

With the aim to better evaluate the benefits of the wireless card selected as part of the OBU (On Board Unit) equipment, the next scenarios are set:

3.2.1 Scenario 1: Simulation of the urban vehicular traffic in the city of Loja. the figure 2 represents the simulation area on which unfolds the urban vehicular traffic in accordance to the configurations of the table 3.

Table 3. Parameter of traffic generation - Scenario 1

Parameters	Value
Simulation area	*1500m × 2000m*
Area in 'downtown'*	*550m × 350m*
Attraction in 'downtown'*	*0.5*
Number of vehicles	*50, 100, 150, 200, 250*
Maximum vehicle speed	13.89 $m/s \approx$ 50 Km/h
Vehicle speed in 'downtown'*	8.33 $m/s \approx$ 30 Km/h
Acceleration	1.4 m/s^2
Deceleration	2 m/s^2
Mobility models	*Krauss, Wagner, Kerner, IDM*
Simulation time	*250 s*

*Term used to refer to the zones in the map where the vehicles tend to concentrate or scatter by the probability of attraction assigned

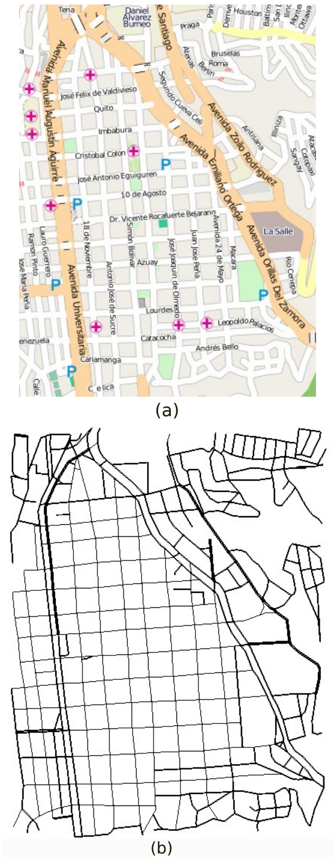


Fig. 2. Simulation area of the Scenario 1 – Center of the city of Loja; a) Representation in C4R; b) Representation in SUMO

The parameters of network simulation exposed in the table 4, are set based on the especifications in the 'datasheets' of the wireless interfaces: OBU-102 [15] under the standard 802.11p and WMIC Cisco 3201 [16] under the standard 802.11b.

Table 4. Parameters of network simulation - Scenario 1

Parameters	Value
Simulation area	*1500m* $\times$ *2000m*
MAC/PHY	*802.11b / 802.11p*
Propagation model	*Nakagami*
Transmission range	*250m*
Antenna model	*Onminidireccional 6dBi / 5dBi*
Transmission power	*20dBm / 30dBm (EIRP)*
Sensitivity	*-85dBm / -90dBm*
Transmission rate	*11Mbps / 6Mbps*
Number of nodes (vehicles)	*50, 100, 150, 200, 250*
Number of connections	*25, 50, 75, 100, 125*
Routing protocols	*AODV, CBRP, DSDV*
Transport protocols	*UDP*
Type of traffic	*CBR*
Packet size	*512 bytes*
Transmission rate	*150 pack/s*
Simulation time	*250s*

3.2.2 Scenario 2: Simulation of vehicular traffic over road (route Catamayo - Loja). the figure 3 represents the scenario generated based on the parameters exposed in the table 5, considering for the simulation the outflows at both ends of the track. The parameters of network simulation considered in the Scenario 1 (table 4), remain for this scenario, except to the simulation area, which is established with the value of 15000m $\times$ 7000m.

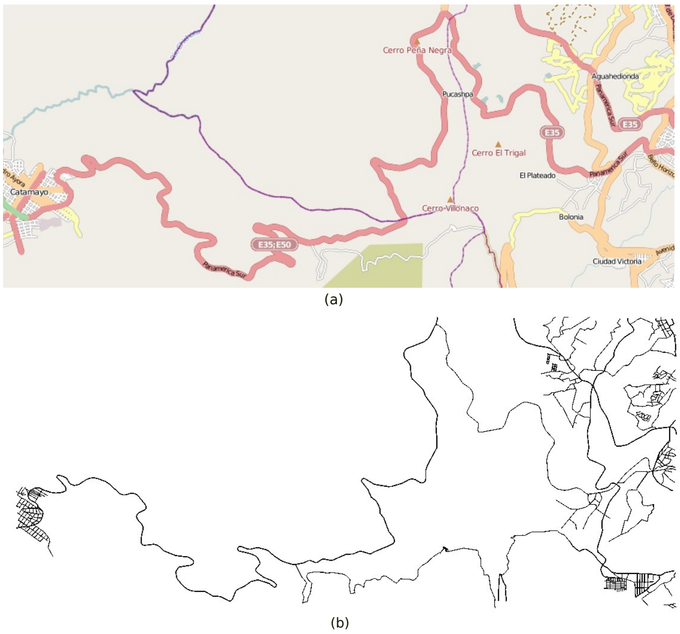


Fig. 3. Simulation area for the Scenario 2 – Route Catamayo - Loja: a)Representation in C4R; and, b)Representation in SUMO.

Table 5. Parameters of traffic generation - Scenario 2

Parameters	Valor
Simulation area	*17000m* $\times$ *7000m*
Number of vehicles	*50, 100, 150, 200, 250*
Maximum vehicle speed	*22.22* $m/s \approx$ *80* Km/h
Acceleration	*1.4* m/s^2
Deceleration	*2* m/s^2
Mobility models	*Krauss, Wagner, Kerner, IDM*
Simulation time	*250 s*

3.3 Metrics of Network Evaluation

RFC 2501[1] exposes some quantitative metrics commonly used to evaluate the performance of the routing protocols in ad-hoc mobile networks, determining whether the reliability and efficiency of the protocol (PDR, throughput, delay and jitter) or to obtain measures that help to optimize the resource allocation (energetic waste, routing overhead and NRL).

For this work it has considered the next metrics: throughput, average end to end delay, pdf and nrl, for being the most used [19], [20], [21], [22], [23] and sufficient to differentiate the behavior of the protocols over the different scenarios of mobility and maps. Then the description of the used metrics and the calculation of them.

3.3.1 Throughput. It is the total number of bits successfully delivered to destination during the simulation time. For this calculation has been used the equation 1.

$$TH = \frac{B_r \times 8}{Ts \times 1000} \quad [Kbps] \tag{1}$$

Where:

TH, Throughput
Br, Received bits

[1] `http://www.ietf.org/rfc/rfc2501.txt`

Ts, Simulation time

3.3.2 Packet Delivery Ratio. It is the relation between the data packets delivered to destination and the generated by the CBR sources [24]. It is calculated by the equation 2.

$$PDR = \frac{Pr}{Ps} \times 100\% \tag{2}$$

Where:

PDR, Packet Delivery Ratio
Pr, Received CBR Packets
Ps, Sent CBR Packets

3.3.3 Average end to end Delay. It is defined as the required time for a packet data set is transmitted through the network, since the source to destination [24]. The equation 3, is used to calculate the average delay from end to end [25].

$$D = \frac{1}{n}\sum_{i=1}^{n}(Tr_i - Ts_i) \times 1000 \quad [ms] \tag{3}$$

Where:

D, Average end to end delay
i, Packet identifier
n, Number of packets successfully delivered
Tr_i, Reception time
Ts_i, Send time

3.3.4 Normalized Routing Load. It is the charge of normalized routing, expressed by the relation between the number of packets of routing transmitted and the number of data packets delivered to its destination (equation 4) [24].

$$NRL = \frac{Pr_s}{Pd_r} \tag{4}$$

Where:

NRL, Normalized Routing Load
Pr_s, Routing packets transmitted
Pd_r, Data packets received

3.4 Metodhology for obtaining the results

After execution of simulation scripts for both technologies, depending on the scenario; the parameters mentioned in the figure 4 are varied, as follows.

—The simulation area is established according the scenario.
—The files of mobile scenario and the connections for each traffic density are loaded (number of nodes - blue color).
—The numbers in yellow color vary from 1 to 4 and indicate the mobility model applied: (1) Krauss, (2) Wagner, (3) Kerner and (4) IDM.
—The numbers in red color, indicate the maximum number of connections generated, corresponding to 40% of the number of nodes in the network.
—The prefix in red color, indicate the scenario: (e1) urban, (e2) on road.
—It simulates a protocol at a time with the scenario under consideration.
—It is verified to are enabled the parameters of the propagation model corresponding to each scenario.

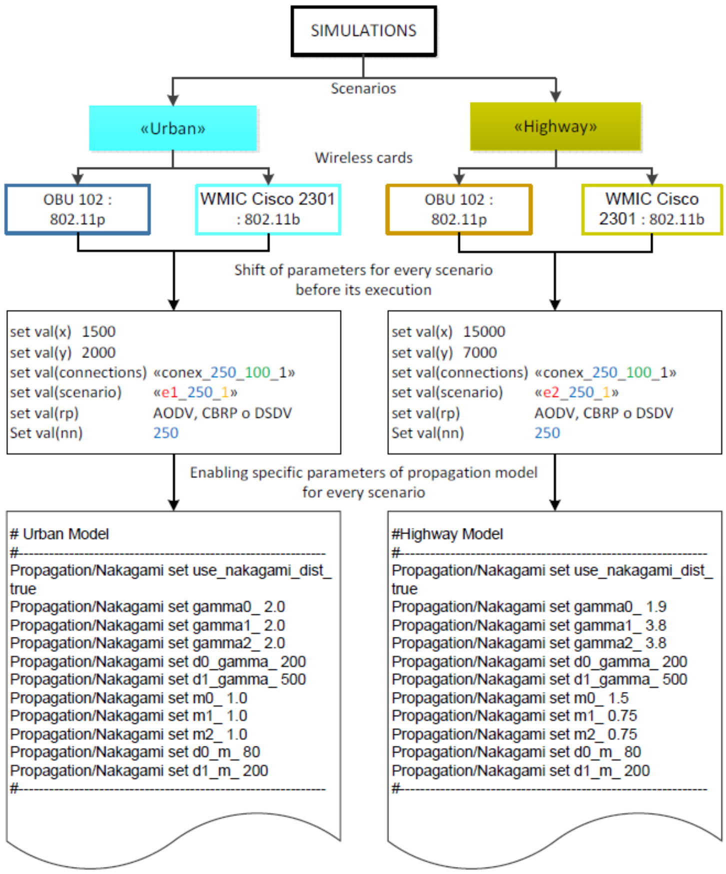


Fig. 4. Diagram of processes for obtaining the results

Each simulation realized with NS-2 delivers a trace, which is filtered with awk, it is shown in the figure 5. The graphical results were obtained with 'plottools' tool of MATLAB.

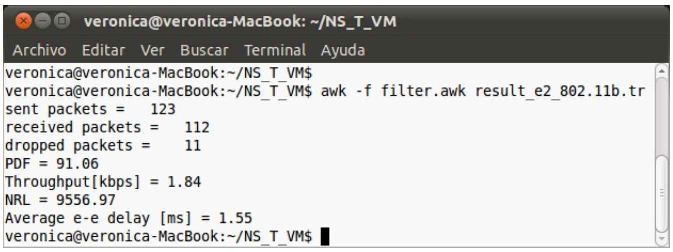


Fig. 5. Execution of AWK filtered

4. RESULTS

4.1 Comparison of routing protocols and mobility models in the "urban" scenario

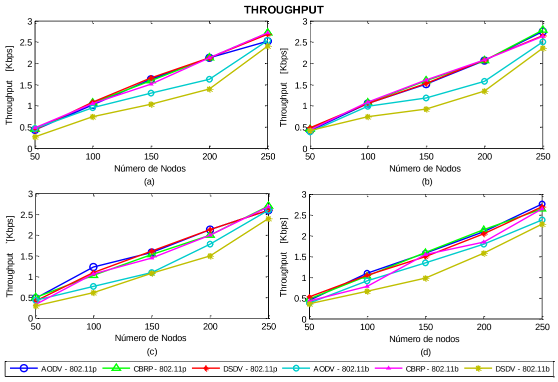


Fig. 6. Evaluation of routing protocols with the throughput metric over the "urban" scenario. Mobility models: a) Krauss, b) Wagner, c) Kerner and d) IDM

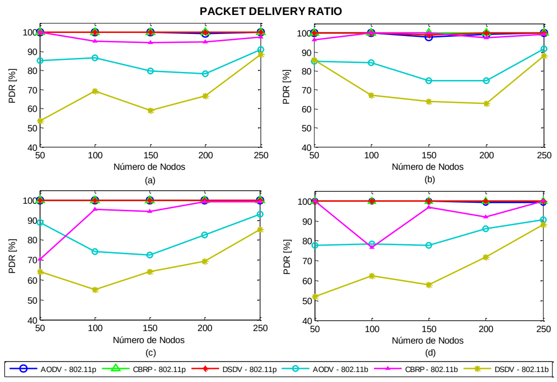


Fig. 7. Evaluation of routing protocols with the PDR metric over the "urban" scenario. Mobility models: a) Krauss, b) Wagner, c) Kerner and d) IDM

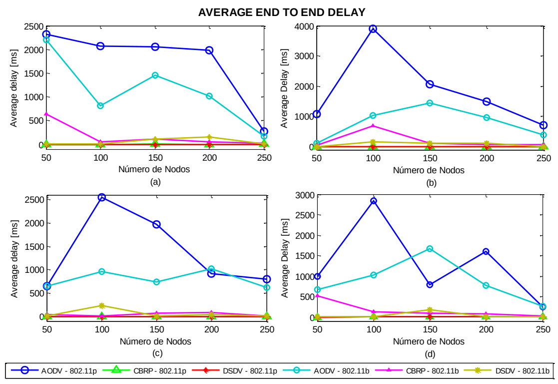


Fig. 8. Evaluation of routing protocols with the Average delay metric over the "urban" scenario. Mobility models: a) Krauss, b) Wagner, c) Kerner and d) IDM

4.2 Comparison of routing protocols and mobility models in the "on road" scenario

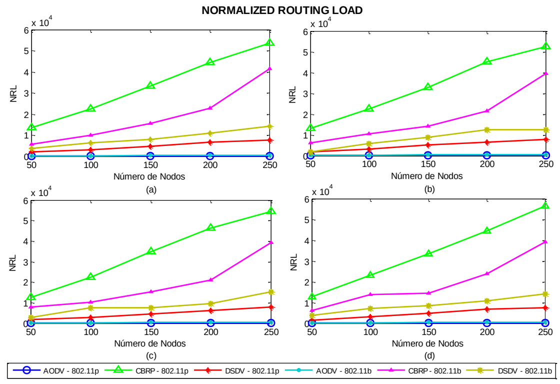


Fig. 9. Evaluation of routing protocols with the NRL metric over the "urban" scenario. Mobility models: a) Krauss, b) Wagner, c) Kerner and d) IDM

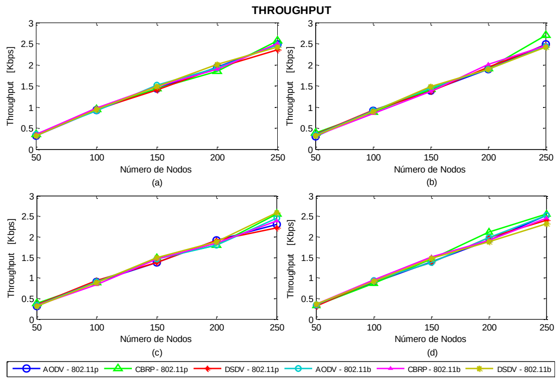


Fig. 10. Evaluation of routing protocols with the throughput metric over the "on road" scenario. Mobility models: a) Krauss, b) Wagner, c) Kerner and d) IDM

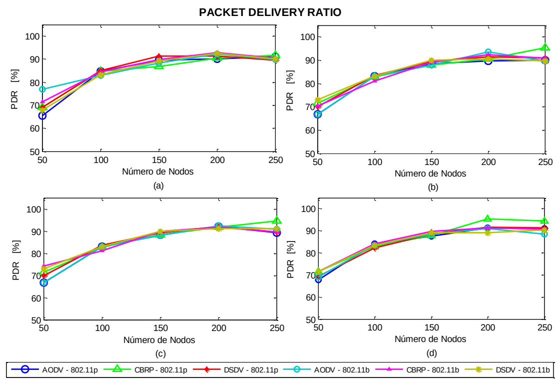


Fig. 11. Evaluation of routing protocols with the PDR metric over the "on road" scenario. Mobility models: a) Krauss, b) Wagner, c) Kerner and d) IDM

4.3 Comparison of scenarios

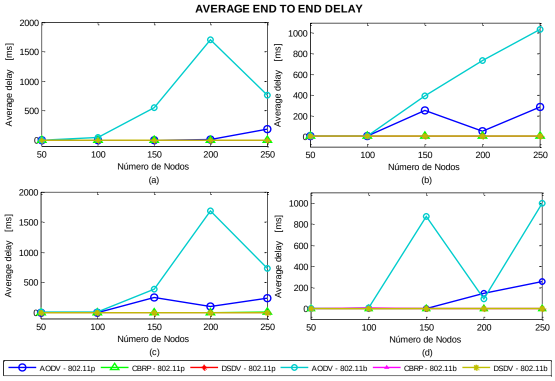


Fig. 12. Evaluation of routing protocols with the Average delay metric over the "on road" scenario. Mobility models: a) Krauss, b) Wagner, c) Kerner and d) IDM

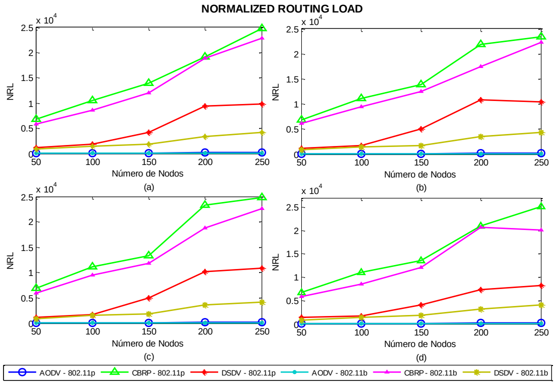
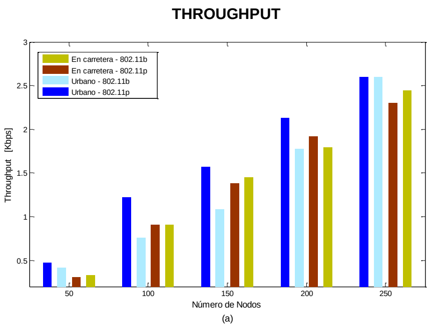


Fig. 13. Evaluation of routing protocols with the NRL metric over the "on road" scenario. Mobility models: a) Krauss, b) Wagner, c) Kerner and d) IDM

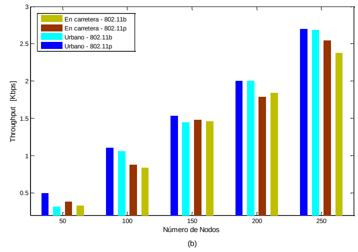


5. CONCLUSIONS

—The use of real maps and mobility models favored to the insertion of realism in the simulation, however, it remains uncertainty in the results; because it was not considered in the simulation of the urban the location of the semaphores in the intersections similarly to reality and the effect of obstacles characteristics of the environment; which introduce losses in the communication.

—From the comparison of scenarios (figures 14, 15, 16 and 17) were analyzed the benefits of the wireless cards selected, concluding generally that OBU-102 based on 802.11p standard is appropiate for urban VANET environments and that WMIC 2301 based on 802.11b, has better performance over VANET environments on road.

—In the on road scenario (figure 11) is clear that the protocol AODV has a better performance, independently of



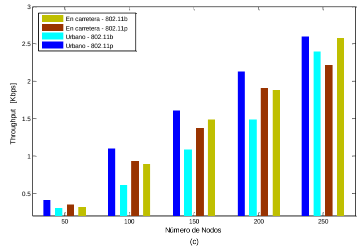


Fig. 14. Comparison of scenarios: "urban" and "on road" with the throughput metric. Routing protocols: a) AODV, b) CBRP and c) DSDV

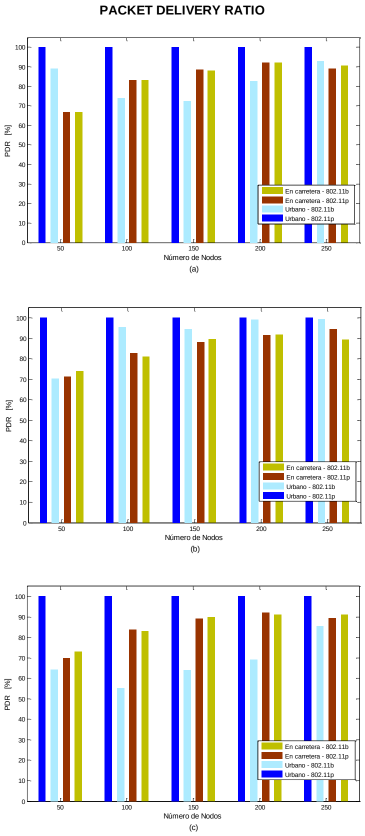


Fig. 15. Comparison of scenarios: "urban" and "on road" with the PDR metric. Routing protocols: a) AODV, b) CBRP and c) DSDV

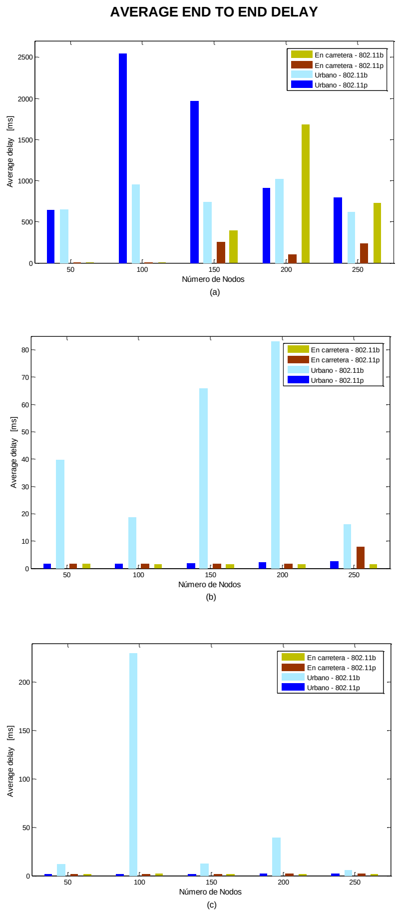


Fig. 16. Comparison of scenarios: "urban" and "on road" with the Average delay metric. Routing protocols: a) AODV, b) CBRP and c) DSDV

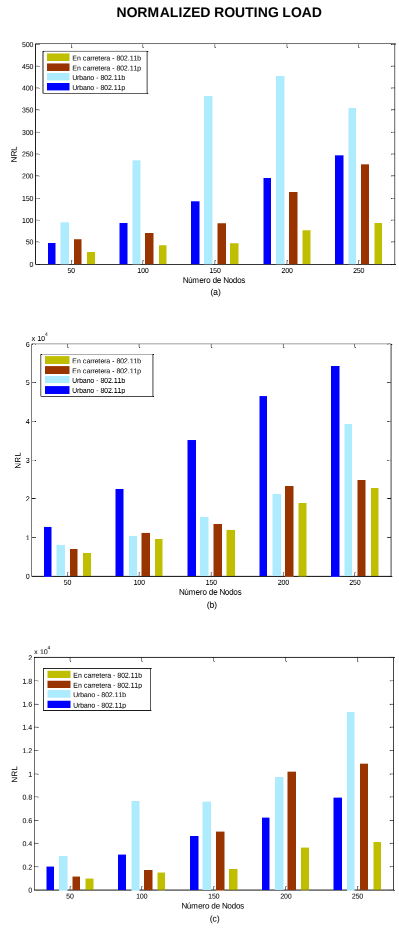


Fig. 17. Comparison of scenarios: "urban" and "on road" with the NRL metric. Routing protocols: a) AODV, b) CBRP and c) DSDV

the selected technology by the minimum NRL (figure 13). Although it has been said that about the 802.11b standard the three protocols have optimal performance, if AODV routing is considered, it will be preferably applied over 802.11p; because even if it means to increase the 'overhead', it will be possible to reduce the delay (figure 12) in the transmission and reception of data packets towards the destination.

—From the evaluation of the mobility models over the scenarios 'urban' and 'road', it was found that in the latter (figure 11) there is a difference between mobility models of approximately 5 to 10%, considering the metric of PDR with both communication technologies ((802.11p and 802.11b), which is tolerable or insignificant because the traffic on road is not affected by the intersections as in the urban case (figure 7); where a slightly higher loss is obtained (between 20 to 30%) with 802.11b technology, especially when it consists of 50 to 100 nodes, tending to be almost irrelevant (3 to 5%) in bigger scenarios. However, with 802.11p technology the difference between mobility models is almost null. Therefore, it concludes that the mobility models does not have significant impact in the vehicular traffic on road, but do have in vehicular traffic urban with 802.11b technology.

—In the urban environment, executing CBRP over the 802.11b standard, reduces the overhead level obtained with the same protocol 802.11p (figure 9), which is significant to safeguard the bandwidth, avoiding the waste in the protocol operation.

—DSDV can be a good replacement of CBRP, in the urban scenario, executing over the standard 802.11p; as insuring a delivery of reliable data packets (figure 7), this minimizes the routing charge significantly (figure 9).

—Comparing the amount of packets that the protocols are able to deliver to destination, concludes that AODV has better performance over the urban scenario with the 802.11p standard; mainly by its low overhead and high scalability (figure 7). It has an optimum performance, especially in networks with more nodes; since it reduces the average delay.

—CBRP may be ideal as source of routing in RSUs, because it presents extremely low delays; mainly in small networks. It may be optimal to indicate to semaphores when to change lights, according to the presence-absence of vehicles in the intersections.

—The results allow to distinguish that in the urban scenario there is greater fading and multipath, which can be seen in the values of NRL (figures 9, 13 and 17), which are higher to the on road scenario, they indicate that in the urban scenario the protocols have required the shipping of a big amount of control messages to the discovery and keeping of routes, unlike the on road scenario where to send the same amount of packets, it has been required lower routing load.

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