Routing Protocols in Vehicular Ad-Hoc Networks: A Performance Evaluation

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Abstract. The presented article evaluates the routing protocols in connected Vehicular Ad-Hoc Networks (VANET) through 802.11p considering synthetic mobility models and vehicular traffic generators, Manhattan and Intelligent Driver Mobility (IDM) models were selected respectively. The following programs were installed on a Linux-based system to simulate the scenarios: SUMO for the traffic management, NS-2 for simulating the data network and MOVE for exporting the information from SUMO to NS-2. Proactive and reactive routing protocols classification was considered, to subsequently apply the DSDV and AOMDV protocols that proved to have better performance. In the simulated scenarios, a low, medium and high number of connections were used with two communication types: Vehicle to vehicle (V2V) and Vehicle to infrastructure (V2I) for VANET networks. The indicators that were analyzed to determine the performance of the protocols were Throughput, Packet delivery ratio relationship (PDR), Average End to End Delay and Normalized routing load (NRL). The study was found that for V2V communications, regardless of the connections or the mobility model, AOMDV or DSDV can be used since the difference in performance is minimal. The results indicate that the best protocol is AOMDV with a superiority to DSDV in most cases. It is concluded that the model closest to reality is IDM since it is based on a traffic generator while the Manhattan model, based on mathematical formulas offers ambiguous results.

Keywords: Vanet · Routing · Mobility model · Vehicular traffic · Linux

1 Introduction

For several years, wireless networks have evolved to offer various services to users, satisfying their needs in different fields of application. The improvements in the existing technologies allow the operation of new types of wireless networks that work in different frequency ranges that are not congested, allowing a better performance in

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the sending of data, fact that also makes that the transmission speed is optimized and reduce implementation costs due to the offer that exists in the market.

The communication between vehicles has aroused interest among researchers and developers around the world [1], one of these technological improvements is being applied to transport field to organize the transit and save human lives through implementation of a Vehicular Ad-hoc Network (VANET), a special class of Mobile Ad Hoc Networks (MANETs) [2]. A VANET is an emerging technology where inter-vehicle communication occurs in a highly dynamic environment, in this wireless networks, vehicles moving at various speeds communicate with the help of a suitable data-forwarding strategy in VANET [3]. This task is possible thanks in part to routing protocols, which must have a fast and efficient adaptive capacity in the face of topological changes that they arise within the network, having at the same time, to use the minimum amount of memory, bandwidth (which can be a bottleneck [2]) and transmission's power.

In Valencia, Spain the research entitled "Optimal Configuration of the OLSR Routing Protocol for VANETs Through Differential Evolution", indicates that the routing in a VANET network must be efficient to guarantee the quality of service, in this context, that work seeks an efficient configuration of the Optimized Link State Routing protocol (OLSR) for VANET based on the packet sending rate, routing management load and point-to-point delay [4].

A similar work, carried out in South America, is the study conducted in [5], which is entitled "Simulation and performance analysis of unicast protocols for VANET Networks". In this publication, emphasis is placed on the technological challenges represented by routing in VANET networks, since routing protocols, and mobility models are required to offer solutions to the inconveniences that arise in this type of network infrastructures, in which, unlike the static network infrastructures, the nodes are in constant movement, which causes the constant change of the network topology [5].

In Ecuador, one of the latest researches published about VANET networks was conducted by students of the Escuela Superior Politécnica de Chimborazo with the title "Study of the VANET for the Control of Vehicles on Roads in Ecuador". This work presents a description and comparison of some reactive and proactive routing algorithms used in VANET networks, in addition, that work makes use of a mobility model based on traffic simulator [6].

The present work pretends to determine which of the routing protocols analyzed for VANET networks has a better and more efficient adaptive capacity against topological changes in a data network, analyzing parameters such as: Throughput, PDR, Average end to end Delay, and NRL for each protocol considering the synthetic mobility models and based on traffic simulators. To do this, computational simulations are used to obtain metrics to compare the performance of the most widely used routing protocols for VANET.

For the simulations, a representation of an urban environment will be used, specifically for an area of the downtown sector of the city of Riobamba, Ecuador, since it has an influx of considerable vehicular traffic. The analysis of the obtained values for each protocol and for each mobility model will allow determining which of the analyzed protocols present the best performance.

2 Methodology

The present work has simulated and analyzed the data of three VANET networks scenarios in vehicle-to-vehicle mode (V2V) and three scenarios in vehicle mode to infrastructure (V2I), with the aim of evaluating the routing protocols in VANET networks connected through 802.11p, The reason for the analysis of both types of communication is that in a full VANET infrastructure, vehicles need to communicate with each other (V2V, vehicle to vehicle, communication) and with road-side infrastructure (V2I, vehicle to infrastructure, communication) [2]. Researchers considered the synthetic mobility models Intelligent Driver Mobility (IDM) and Manhattan and vehicular traffic generators. To this end, the SUMO tools for vehicular traffic, NS-2 for the data network and MOVE for exporting information have been installed in an Ubuntu distribution. Figure 1 shows a diagram with the methodology applied to perform the simulation of the different scenarios.

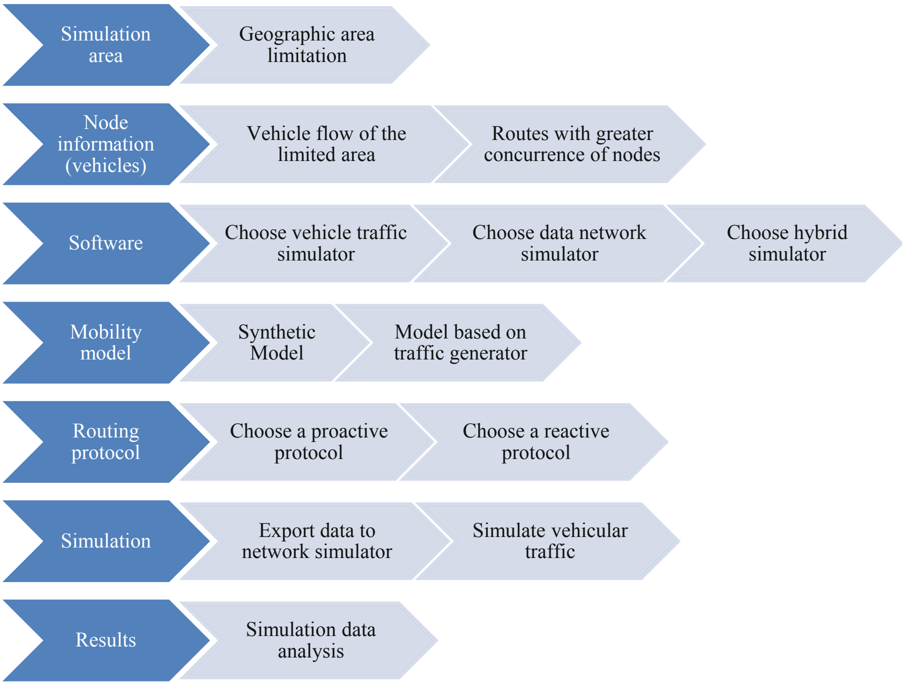


Fig. 1. Applied methodology for simulation

Table 1 details the specifications of the simulated scenarios for data collection that allowed the evaluation of routing protocols in connected VANET networks using 802.11p considering the synthetic mobility models and vehicle traffic generators.

Table 1. Simulated scenarios detail.

Scenario	Simulation time	Cars	Connections	Mobility model	Protocol
1 - V2V	500 s	10	5	IDM/Manhattan	AOMDV/DSDV
2 - V2V	500 s	50	30	IDM Manhattan	AOMDV/DSDV
3 - V2V	500 s	120	60	IDM Manhattan	AOMDV/DSDV
4 - V2I	500 s	10	5	IDM Manhattan	AOMDV/DSDV
5 - V2I	500 s	60	30	IDM Manhattan	AOMDV/DSDV
6 - V2I	500 s	120	60	IDM Manhattan	AOMDV/DSDV

3 Results

In this section, the results obtained in the different scenarios are analyzed, after executing the simulations and filtering the results to determine which routing protocol (AOMDV or DSDV) has a better performance according to the mobility model used in the scenario: Manhattan (synthetic model) and IDM (model based on a traffic generator). The presented study is the result of an experience in university education in which a computer's simulator was used to implement the test scenarios which generated the analyzed data was obtained. Researchers considered that the ability to perform simulations, without having to carry experiments in real scenarios, provide solutions that do not involve investments blindly, or the build new and costly infrastructures. In addition, the simulation used in the study allowed the capture of the interest metrics for the study and the possibility of manipulating these metrics and controlling the external variables. This fact would have been difficult to achieve in a real scenario.

3.1 Simulation Results Analysis

The results were analyzed based on the values obtained for the parameters: Throughput, PDR (Packet delivery ratio), Average End to End Delay and NRL (standardized routing load). When evaluating the results, the guidelines were obtained to determine which is the most efficient routing protocol for a VANET network simulation environment.

- *Throughput:* It refers to the efficient use of bandwidth, that is, the maximum speed at which a device does not discard any of the received packets [7].
- *PDR:* The packet delivery ratio is the quotient that results when dividing the number of packets sent for the received packets, it allows to know the packet loss rate.
- *Average end to end Delay:* Delay time that it takes the packages to arrive from their origin to their destination.
- *NRL:* The standardized routing load is equal to the relationship between the number of packets sent from the routing layer with respect to the packets received at the application layer.

Analysis of V2V Communication. In this subsection, the obtained values from the simulations of V2V communication are compared with different numbers of connections and simulation times.

Scenario 1. Scenario 1 consists of 5 V2V connections and 10 vehicles that interact for 500 s, using AOMDV reactive protocol and DSDV proactive protocol. The following results were obtained from the scenario simulations.

Table 2. Scenario 1 data.

V2V communication				
Simulation time	500 s			
Vehicles number	10			
Connections number	5			
Mobility model	IDM		MANHATTAN	
Protocol	AOMDV	DSDV	AOMDV	DSDV
PDR [%]	99,43	99,34	99,62	99,41
Throughput [Kbps]	1797,59	1728,54	1972,38	1925,83
NRL	0,06	0,09	0,06	0,08
Delay End to End [ms]	53	24,37	18,04	9,31

Data shown in Table 2, indicate that regardless of the use of the IDM or Manhattan model, the protocol with the best throughput is AOMDV, which exceeds the DSDV protocol in both cases.

Scenario 2. Scenario 2 consists of 30 V2V connections and 60 vehicles that interact for 500 s, using AOMDV reactive protocol and DSDV proactive protocol. The following results were obtained from the scenario simulations.

Table 3. Scenario 2 data.

V2V communication				
Simulation time	500 s			
Vehicles number	60			
Connections number	30			
Mobility model	IDM		MANHATTAN	
Protocol	AOMDV	DSDV	AOMDV	DSDV
PDR [%]	99,21	98,56	99,31	99,23
Throughput [Kbps]	1865,48	1686,55	2103,07	2002,54
NRL	0,4	2,77	0,38	2,46
Delay End to End [ms]	12,14	9,44	60,85	100,75

Data shown in Table 3, indicate that regardless of the use of the IDM or Manhattan model, the protocol with the best throughput is AOMDV, which exceeds the DSDV protocol in both cases.

Scenario 3. Scenario 3 consists of 60 V2V connections and 120 vehicles that interact for 500 s, using AOMDV reactive protocol and DSDV proactive protocol. The following results were obtained from the scenario simulations.

Table 4. Scenario 3 data.

V2V communication				
Simulation time	500 s			
Vehicles number	120			
Connections number	60			
Mobility model	IDM		MANHATTAN	
Protocol	AOMDV	DSDV	AOMDV	DSDV
PDR [%]	99,37	99,07	99,33	99,16
Throughput [Kbps]	1687,47	1560,89	1813,68	1701,49
NRL	0,87	16,25	0,79	16,58
Delay End to End [ms]	82,74	85,54	3,77	5,82

Data shown in Table 4, indicate that regardless of the use of the IDM or Manhattan model, the protocol with the best throughput is AOMDV, which exceeds the DSDV protocol in both cases.

Analysis of V2I Communication. In this subsection, the obtained values from the simulations of V2I communication are compared with different numbers of connections and simulation times (equal to the values used in the V2V communication).

Scenario 4. Scenario 4 consists of 5 V2I connections and 10 vehicles that interact for 500 s, using AOMDV reactive protocol and DSDV proactive protocol. The following results were obtained from the scenario simulations.

Table 5. Scenario 4 data.

V2V communication				
Simulation time	500 s			
Vehicles number	10			
Connections number	5			
Mobility model	IDM		MANHATTAN	
Protocol	AOMDV	DSDV	AOMDV	DSDV
PDR [%]	95,03	94,15	99,69	99,8
Throughput [Kbps]	632,96	534,07	1594,75	1557,31
NRL	0,27	0,34	0,1	0,11
Delay End to End [ms]	113,98	86,23	81,12	104,81

Data shown in Table 5, indicate that regardless of the use of the IDM or Manhattan model, the protocol with the best throughput is AOMDV, which exceeds the DSDV protocol in both cases.

Scenario 5. Scenario 5 consists of 30 V2I connections and 60 vehicles that interact for 500 s, using AOMDV reactive protocol and DSDV proactive protocol. The following results were obtained from the scenario simulations.

Table 6. Scenario 5 data.

V2V communication				
Simulation time	500 s			
Vehicles number	60			
Connections number	30			
Mobility model	IDM		MANHATTAN	
Protocol	AOMDV	DSDV	AOMDV	DSDV
PDR [%]	98,98	99,26	97,74	98,47
Throughput [Kbps]	1288,39	1199,77	321,42	388,34
NRL	0,69	3,98	2,79	14,91
Delay End to End [ms]	67,22	8,79	343,98	34,66

Data shown in Table 6, indicate that the protocol with the best throughput is AOMDV in relation to the DSDV protocol when using the IDM model. When applying the Manhattan model, the protocol with the best throughput is DSDV respect to AOMDV.

Scenario 6. Scenario 6 consists of 60 V2I connections and 120 vehicles that interact for 500 s, using AOMDV reactive protocol and DSDV proactive protocol. The following results were obtained from the scenario simulations.

Table 7. Scenario 6 data.

V2V communication				
Simulation time	500 s			
Vehicles number	120			
Connections number	60			
Mobility model	IDM		MANHATTAN	
Protocol	AOMDV	DSDV	AOMDV	DSDV
PDR [%]	98,06	98,79	99	99,02
Throughput [Kbps]	739,71	807,12	1065,73	1010,56
NRL	2,4	46	1,67	34,17
Delay End to End [ms]	10,37	107,94	113,92	125,97

Data shown in Table 7, indicate that the protocol with the best throughput is DSDV in relation to the AOMDV protocol when using the IDM model. When applying the Manhattan model, the protocol with the best throughput is AOMDV respect to DSDV.

3.2 Results Comparison

After collecting the data of the simulations under the established conditions, the values of the parameters mentioned in Sect. 3 are compared to determine the mobility model with the best performance in the simulated scenarios.

Communication V2V Comparison

PDR (Packet Delivery Ratio). Figure 2 shows the PDR values obtained from the simulations, with a value higher than 95% for both mobility models, independently of the routing protocol and the connections number. This high level of successful Packet delivery is due to the application of IEEE 802.11p technology in our scenarios.

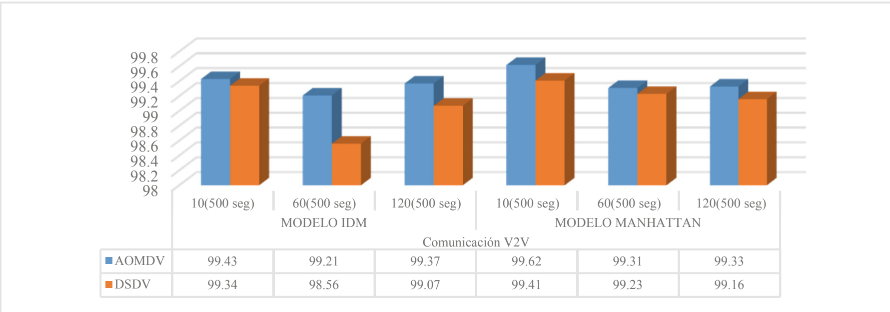


Fig. 2. PDR parameter (5, 10 and 30 V2V connections).

Throughput. Figure 3 presents the obtained results in the simulations corresponding to the Throughput metric, it is evident that the use of the bandwidth of the AOMDV protocol is better in all cases in comparison with the DSDV protocol, independently of the mobility model that was used. The speed of sending information with AOMDV in all cases is higher than DSDV.

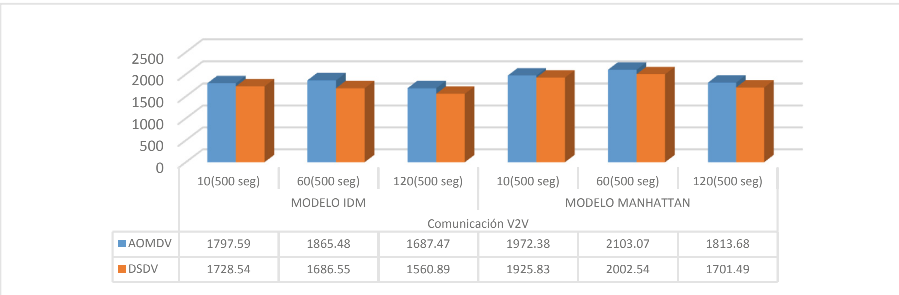


Fig. 3. Throughput parameter (5, 10 and 30 V2V connections).

NRL (Normalized Routing Load). Figure 4 shows the results for the Normalized Routing Load parameter, in this figure can observe that for this metric the AOMDV protocol generates a lower routing overhead, for that reason, this protocol is faster and more efficient than the DSVD protocol regardless of the mobility model used in the simulation scenario.

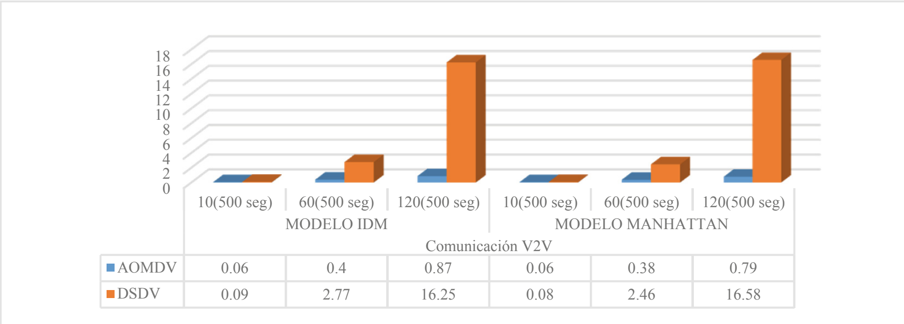


Fig. 4. NRL parameter (5, 10 and 30 V2V connections).

Average End to End Delay. Figure 5 shows the results for the Delay End to End parameter, it is observed that, with a small number of connections and long working times, the AOMDV protocol present greater delays than DSDV. However, for a high number of connections, the AOMDV protocol present lower delays than DSDV.

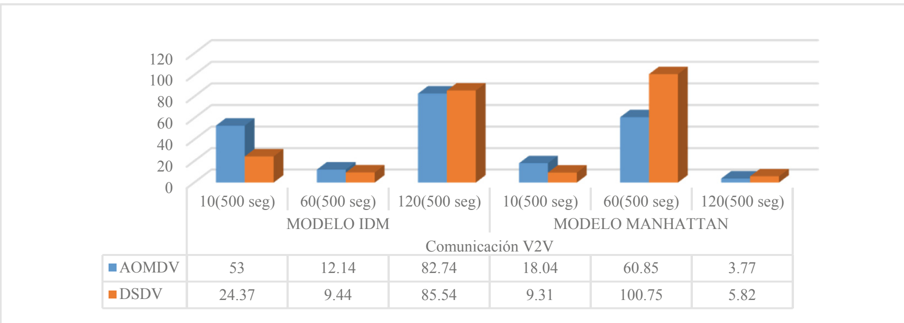
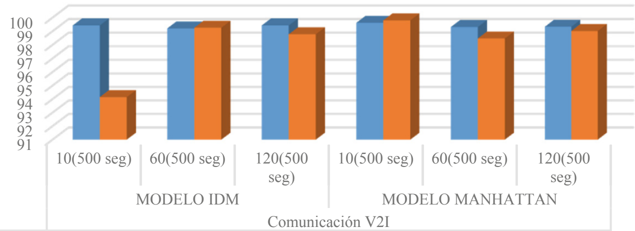


Fig. 5. Delay End to End parameter (5, 10 and 30 V2V connections).

Communication V2I Comparison

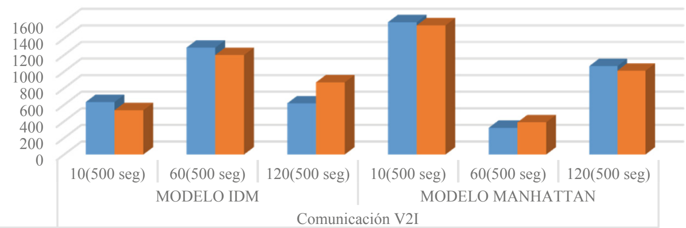
PDR (Packet Delivery Ratio). Figure 6 shows the values obtained in the simulations for the PDR parameter, a value greater than 99% is observed for both the IDM model and the Manhattan model independently of the routing protocol and the number of connections. This high level of successful Packet delivery is due to the application of IEEE 802.11p technology in the scenarios.



	10(500 seg)	60(500 seg)	120(500 seg)	10(500 seg)	60(500 seg)	120(500 seg)
AOMDV	99.43	99.21	99.43	99.62	99.31	99.33
DSDV	94.15	99.26	98.78	99.8	98.47	99.02

Fig. 6. PDR parameter (5, 10 and 30 V2I connections).

Throughput. Figure 7 shows the data for the Throughput parameter, in this is observed that for a small number of connections and long work times, the AOMDV protocol present better throughput than DSDV, independently of the mobility model used. With a value high of connections under the IDM model, The Throughput of the DSDV protocol is higher than the AOMDV protocol. When using the Manhattan model, the protocol with the best Throughput is AOMDV compared with DSDV protocol.



	10(500 seg)	60(500 seg)	120(500 seg)	10(500 seg)	60(500 seg)	120(500 seg)
AOMDV	632.96	1288.39	616.63	1594.75	321.42	1065.73
DSDV	534.07	1199.77	869.88	1557.31	388.34	1010.56

Fig. 7. Throughput parameter (5, 10 and 30 V2I connections).

NRL (Normalized Routing Load). Figure 8 shows the results for the Normalized Routing Load (NRL) parameter, it is observed that the AOMDV protocol generates a lower routing overhead for all cases, in cases with a high number of connections it is seen that the NRL generated by AOMDV is lower than that of DSDV with a high margin of difference.

Average End to End Delay. Figure 9 shows the results for the Delay End to End parameter, the AOMDV protocol registers greater delays than DSDV with the IDM mobility model. In contrast, for the Manhattan model, the AOMDV protocol presents minor delays than DSDV in most cases.

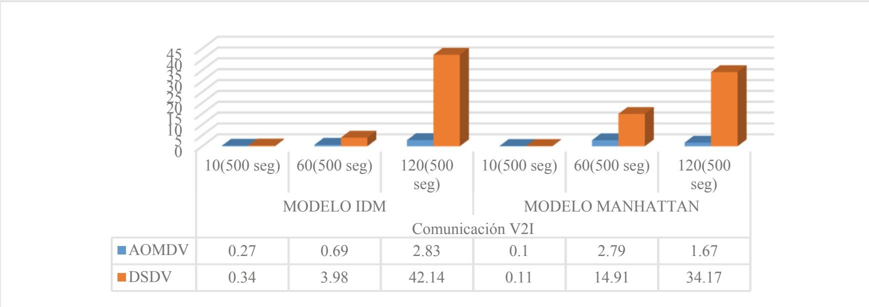


Fig. 8. NRL Parameter (5, 10 and 30 V2I connections).

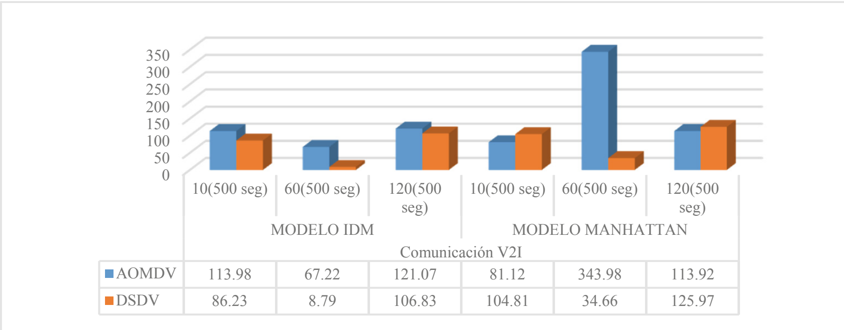


Fig. 9. Delay End to End parameter (5, 10 and 30 V2I connections).

4 Conclusions

- The most used protocols in VANET networks are reactive and proactive the most used in recent research are the DSDV and AODV protocols. Regarding the mobility models, the synthetic ones are the least reliable because they do not offer data close to reality, this is the case with models based on traffic generators.
- Manhattan synthetic mobility model was used since it is coupled to the topology of the simulated scenarios, while IDM was used as a traffic generating model since, in it, mobility not only depends on the predecessor car, it depends too on himself and the cars in the environment.
- When comparing the values of Throughput, PDR, Average End to End Delay and NRL, a better routing performance of the AOMDV protocol was observed compared to DSDV, but with a minimum difference, so it is concluded that for a V2V communication regardless of the model of Mobility and the number of connections can be used both the AOMDV reactive protocol and the proactive DSDV.
- For V2I communications the margin of difference between AOMDV and DSDV is more evident, in most cases the AOMDV protocol is more efficient, so it is

concluded that in V2I communication scenarios, AOMDV has a better performance in the routing of packages.

- In general, for both V2V and V2I communications, the protocol with the highest efficiency is AOMDV, regardless of the number of connections. Emphasizing that in V2V connections, AOMDV is superior with a relatively low margin while in a V2I communication the superiority of AOMDV over DSDV is more evident. This fact is since AOMDV, in addition to calculating routes at the request of the nodes, also offers backup routes to guarantee even more the delivery of packets to their destination.

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