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# Performance evaluation of AODV, DSR, GRP and OLSR for VANET with real-world trajectories

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**Abstract**—Vehicular communications can be achieved through the infrastructure (Vehicle-to-infrastructure network, V2I), as well as directly through vehicle-to-vehicle communication (V2V) via ad hoc networks. In V2V communications, the routing protocols are designed in order to optimize the dissemination of messages. This paper presents an evaluation of routing protocols such as the Optimized Link State Routing (OLSR), Ad hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Geographic Routing Protocol (GRP), while considering both vehicular safety application requirements and mobility models based on real-world traces of vehicular traffic. The results show that, though proactive routing protocols perform better in this context, the four routing protocols fail to fulfill the safety application requirements on the delay metric even for a reasonable number of vehicles.

**Index Terms**—OLSR, AODV, DSR, GRP, VANET

## I. INTRODUCTION

With the rapid development of wireless communication, Vehicular Ad hoc Networks (VANET) have become a very active topic in recent research literature. Applications using vehicular communications abound, and they allow vehicles to exchange road traffic events and traffic management information. Recent simulation evaluations of various applications are presented in [1].

In vehicle-to-vehicle communication (V2V) network, bandwidth and network management functions are shared by the vehicles, which locally reduces the available bandwidth for the transmission of application data. Also, the power of radio transmission is limited by the legislation. As a result, the maximum communication range is only up to 1 km with IEEE 802.11p technology. The communication between two vehicles that are out of the range of each other is performed through relaying vehicles, which selection is one of the two main tasks of ad hoc routing protocols. The other task consists in maintaining network topology.

The network topology can be optimized in several ways. For instance, a hierarchy can be created among vehicles of the network. Also, vehicles can be grouped into clusters according to common requirements [2]. In the literature, the route discovery is divided into three families [3] which are defined according to the moment where methods handle the route search. The family of proactive routing protocols periodically

performs local neighborhood discovery, and updates routing tables. The family of reactive protocols searches for relay nodes on-demand, when a vehicle node has data to transmit and no previous route is already known to the destination. The family of hybrid protocols is a mixture of the two others. Their nodes use either a proactive or a reactive approach, according to different network and application optimisation contexts.

Further, routing algorithms can take advantage of optimizations, sometimes assisted with context information such as the position of vehicles or their density in the network. Usually, the combination of one dissemination method with a set of optimisations leads to the proposal of a new routing protocol. In this way, the literature gives rise to plentiful new protocols [4] evaluated in various different contextual frameworks. Only a few protocol have actually proceeded in the standardization process such as DSR, OLSR, and AODV. Recent ad hoc routing protocols for VANET take advantage of location information to enhance the algorithms performance, such as the GRP protocol implemented in Riverbed OPNET Modeler. Only few studies have been published on this GRP protocol. We propose to compare it with OLSR, AODV, and DSR, which are the main representative of proactive and reactive protocols that proceed in the standardisation process.

Precisely, this paper deals with the evaluation of OLSR, AODV, DSR, and the GRP protocol of Riverbed OPNET Modeler considering road safety application requirements and real-world mobility based on real vehicle traces. The paper is organized as follows. Firstly, some work related to the evaluation of routing protocols are exposed. Secondly, the four studied routing protocols are presented. Next, the system used to evaluate the protocols is described. Then simulation results are analyzed and discussed, before the conclusion.

## II. RELATED WORK

Studies on the evaluation of routing protocols abound. They present a wide variety of evaluation frameworks as the choices for network size, density, data traffic, and mobility pattern differ.

In estimating delay, throughput, control overhead and packet delivery ratio in 10 to 50-node networks for the reactive AODV and DSR, and the proactive OLSR and Highly dynamic destination-sequenced distance-vector (DSDV), [5] shows that

DSR is the best protocol if the network is sparse, otherwise OLSR is better. Performances obtained for AODV and DSDV are lower. [6] states that OLSR is the best choice for a database application in terms of network load and throughput metrics, and GRP provides the best delay.

Observing routing traffic, delay, and throughput, [7] notices that OLSR optimizes the end-to-end delay for FTP application, but it generates a lot of control traffic at high vehicle speeds. GRP is cited as being a good protocol for dense vehicular networks. DSR is suitable in the case of sparse network, while AODV is useful for average speeds. Similar results are obtained by [8] where OLSR obtains the best performance in terms of throughput, delay, load, and data dropped if the network is dense. The paper shows that GRP is interesting for FTP applications in sparse networks since it obtains the lowest delay. AODV gets good performances in terms of throughput with HTTP applications, but performance decreases with the growing number of nodes.

Comparing geographic protocols, [9] notes that routing traffic overhead is lower with proactive protocol (GRP). Nevertheless, reactive protocols (the Location-Aided Routing, LAR, and the Geographical AODV, GeoAODV) are more interesting in high mobility contexts. The work in [10] shows that GRP is better for video conferencing applications than AODV in terms of end-to-end delay and throughput.

Rather than implementing a random mobility model such as in the other referenced studies of Table I, [11] uses VanetMobiSim with the Intelligent Driver Model (IDM) and lane change option. But, origins and destinations of vehicles are chosen randomly. The study shows that the delay and the number of packet losses increase with the number of vehicles. DSR has the best performance if the vehicle density is low comparing to AODV and OLSR which are the best in the context of high density. AODV generates higher end-to-end delays with low packet losses, inversely OLSR generates lower end-to-end delays with higher packet losses. Finally, performances of GRP are lower.

Using high speed nodes (up to 100 m/s) with a random mobility pattern and studying delay and throughput metrics, [12] shows that OLSR has the best performance, next AODV in the case of a 20-node network, then GRP for a higher density network (80 nodes).

In all these previous works, TORA has presented poor performances whatever the applications studied and the performance metrics used. DSR is suitable in sparse networks [5], [7], [11]. OLSR presents a good performance for dense networks [5], [11]. It optimizes load and throughput [6], [12], end-to-end delays [7], [11], [12], but with higher packet losses [11]. AODV induces lower packet losses [11] and higher delays than both GRP [10], [12] and OLSR [11]. Like OLSR, AODV is adapted for a high density (80 nodes in 2.5x2.5 km<sup>2</sup>) [11]. The authors of [8] demonstrate AODV is appropriate for HTTP applications and, those of [7], it is for FTP under random mobility model with a maximal speed value of 10 m/s. GRP causes higher delays than OLSR [6], but lower than AODV [10], [11]. It is adapted to applications with high

data load such as FTP [8] and video conferencing [10]. GRP provides less traffic routing than other geographic protocols (GeoAODV and LAR) [9]. Results concerning its ability to adapt to density does not converge: [7], [12] find it adapted to high density using a random mobility model whereas [11] obtains worse performance than with AODV and OLSR in using VanetMobisim mobility simulator.

To summarize, Table I shows that the previous studies give different results in terms of the best routing protocol according to the chosen performance metrics (load, delay, throughput, packet received, routing traffic, data dropped, route length) and the application context (mobility model, application data, number of nodes, network density...).

### III. PRESENTATION OF OLSR, AODV, DSR, AND GRP PROTOCOLS

In this paper, we examine and compare the performance of four routing protocols implemented in Riverbed OPNET Modeler software: two proactive protocols, OLSR and their GRP implementation, and two reactive protocols, AODV and DSR. Below, a brief description of these protocols is given.

#### A. OLSR

The Optimized Link State Protocol [13] is a proactive ad hoc routing protocol that computes shortest paths from a source node to all known destination nodes. It defines the Multipoint Relays (MPR), which are selected nodes enabled to generate the link state information used to build and update routing tables. Only MPRs forward broadcast control traffic during flooding [13], thus saving radio resources. Also, only MPR nodes are able to relay messages from a source node to its destination. Each network node selects the smallest subset of its symmetric one-hop neighbors that allows it to reach every node in its two-hop neighborhood. The OLSR parameter values recommended by the RFC 3626 are reported in Table II. Hello interval concerns the periodic Hello messages sent by every node to discover its one-hop neighbors. The Topology Control (TC) interval concerns the TC messages sent by every MPR, and are used by each node in order to build and update its routing table.

#### B. AODV

The Ad hoc On-demand Distance Vector [14] is a reactive protocol which does not require nodes to maintain routes to destinations that are not in active communication. Every Hello interval (Table III), each network node broadcasts a Hello message to collect the information of its one-hop neighbors. When a node has a message to send, it broadcasts a route request packet (RREQ) that is processed by its one-hop neighborhood. If a one-hop neighbor knows a route to the destination, it sends a Route Reply message (RREP) with a destination sequence number to the originating node. The destination sequence numbers are generated increasingly by the destination, and it allows the originating node to select the most recent route when there are several RREP. When a one-hop node has no knowledge of a path to the destination,

TABLE I  
SUMMARY OF RELATED WORKS

Ref	Type	Protocols	Software	Mobility	Number of nodes	Duration	Network size	Application	Node configuration	Performance metrics
[5]	MANET	AODV, DSDV, DSR, OLSR	NS2	Random	10, 20, 30, 40, 50	150 s	$0.04 \text{ km}^2$ - $1 \text{ km}^2$	500 bytes	802.11 MAC	delay, throughput, control, overhead, packet delivery ratio
[6]	MANET	GRP, OLSR, TORA	OPNET	Random (10 m/s)	15 to 150	900 s	$1 \text{ km}^2$	Database	1 Mb/s	load, delay, routing overhead, throughput
[7]	VANET	AODV, DSR, GRP, OLSR, TORA	OPNET	Random (10 m/s, 28 m/s)	5, 20, 40	3600 s	-	FTP	11 Mb/s	routing traffic, delay, throughput
[8]	MANET	AODV, DSR, GRP, OLSR, TORA	OPNET	Random (0-10 m/s)	30,60, 90	600 s	$1 \text{ km}^2$	FTP et HTTP	2 Mb/s, 11 Mb/s	throughput, delay, load, data dropped
[9]	MANET	GeoAODV, GRP, LAR	OPNET	Random	2, 5, 15, 30	300 s	$2.25 \text{ km}^2$	exp(1024) bytes	0.001 W, -95 dBm, 11 Mb/s	routing traffic, route length
[10]	VANET	AODV, GRP	OPNET	Random	19	-	$4 \text{ km}^2$	Voice + Videoconf (9 bits/pixel 10fps)	0.005 W, -95 dBm, 11 Mb/s	delay, data dropped, throughput
[11]	VANET	AODV, DSR, GRP, OLSR	OPNET	VanetMobisim (0.83-2 m/s)	20, 40, 60, 80	3600 s	$6.25 \text{ km}^2$	1024 bytes/s	1 Mb/s	delay, data dropped
[12]	MANET	AODV, DSR, GRP, OLSR	OPNET	Random (100 m/s)	20, 80	3600 s	$1 \text{ km}^2$	FTP	11 Mb/s	delay, throughput

TABLE II  
PARAMETERS OF OLSR

Attribute	Value
Hello interval	2 s
TC interval	5 s
Neighbor hold time	6 s (3*Hello interval)
Topology hold time	15 s (3*TC interval)
Duplicate message hold time	30 s

it forwards the request by sending a RREQ request to its one-hop neighbors if the Time To Live counter value (TTL) still enables it. The TTL is a counter which value is fixed by the source, and decremented by each node which retransmits the message. A node does not retransmit a message when the TTL is below 1. At first, a route request is initiated with a TTL set to 1 by the originating node, therefore the request message stops at the one-hop nodes. When the originating node does not receive any RREP replies after the duration of a timeout, it increments step by step the TTL value, up to a maximum threshold or until it receives at least one RREP. The timeout corresponds to the ring traversal time which is calculated by :  $RingTraversalTime = 2 * NodeTraversalTime * (TTL + Timeoutbuffer)$ .

The *Timeoutbuffer* value allows taking into account additional time in the event of packet congestion. When a relay node receives a RREP packet that it has already processed, it removes it; otherwise it transfers the RREP packet to the originating node. The originating node can then send its message after having taken note of the addresses of relay nodes to the destination node. Each relay node records in a cache system this path to the destination for the duration of the “active route timeout”.

### C. DSR

The Dynamic Source Routing [15] is a reactive source routing protocol. The route search system is closed to AODV except that each intermediate node relaying the RREP enriches the packet by adding its identifier. With this list, the destination node knows the intermediate relay nodes through which the source node can reach it, and it includes this list in the Route Reply packet to the source node.

TABLE III  
PARAMETERS OF AODV

Attribute	Value	Attribute	Value
Route request retries	5	TTL start	1
Route request rate limit	10 packets/s	TTL increment	2
Active route timeout	3 s	TTL threshold	7
Hello interval	(1,1.1 s)	Local repair	yes
Packet queue size	infinity	Hello loss	2 s
Net diameter	35 hops	Addressing mode	IPv4
Node traversal time	0.04 s	Timeout buffer	2
Route error rate limit	10 packets/s		

The prior request can be limited to one-hop neighbors with the “Non-propagating request” option. This request makes the one-hop neighbor look for the destination in its routing table. If there is no response after the “Non propagating request” timeout (Table IV), a classical route request is performed. The “Packet salvaging” option allows the intermediate node to choose another link without prompting, if it detects a broken link with the next relay node.

TABLE IV  
PARAMETERS OF DSR

Attribute	Value	Attribute	Value
<b>Route Discovery:</b>		<b>Route Maintenance:</b>	
Request table size	64 nodes	Max buffer size	50 packets
Req. table identifiers	16	Hold off time	0.25 s
Req. retransmission.	16	Maint. Retransmis.	2
Max. Req. period	10 s	Ack. timer	0.5 s
Non-propagating Req.	no	<b>Send Buffer:</b>	
GratuitousReply timer	1 s	Max. Buffer size	infinity
<b>Route Cache:</b>		Buffer timeout	30 s
Max Cached routes	infinity		
Route Cache timeout	300 s	Packet salvaging	yes
Route Cache export	no	Broadcast jitter	(0,0.01) s

### D. GRP

The GRP protocol that is considered on this paper is the one implemented in Riverbed OPNET Modeler. This GRP, described in [16], is a proactive geographic routing protocol. The protocol divides the network into several zones of different hierarchical levels. The first subdivision leads to two areas representing the hierarchical level 1. Each one is divided into four

areas corresponding to the hierarchical level 2, and so on (see Figure 1). This topology optimizes the spread of a message to the entire network by confining it to a geographically limited area. For the dissemination of a message, the protocol assumes that each node knows its position. This information is used to select the next relay node to reach the destination node of a message.

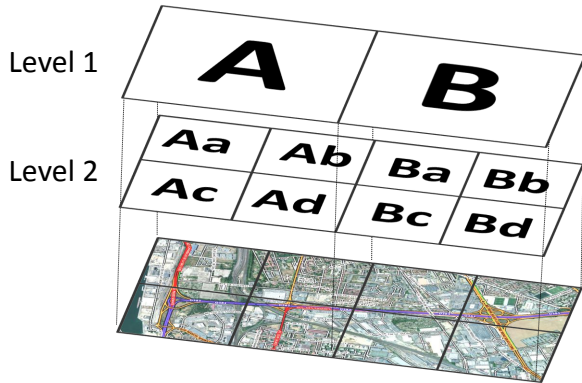


Fig. 1. Quadrant division in GRP [9] adapted to the road context.

As a proactive protocol, GRP uses routing tables. They include the exact position of the neighbors in a same area. For remote neighbors, out of this zone, GRP uses the fisheye extension [17], and only records the higher hierarchical level of the zone number. To build these routing tables, packets are periodically sent by the nodes to specify their location. Initially, every node sends its position as many times as the “Number of initial floods” value (Table V). Next, to reduce network congestion, a node sends its new position if:

- it travelled a certain distance (“Distance Moved” value);
- it changed zone;
- it did not send its position for a period of time (“Hello interval” time).

This process is the location-based service of this GRP protocol. According to the taxonomy about location-based service defined in [18], this process belongs to “flooding based” “proactive” location services. The geographical coverage of these messages is limited. In the first two cases, the message spreads to vehicles belonging to the area of higher level between the old and the new area. In the third case, the periodic transmission of the position is limited to the immediate neighbors. A maintenance of the routing tables is performed: a neighbor node which has not transmitted packets for the period of the “Neighbor expiry time” is removed from the routing table.

When a node has a message to be sent to a node from the same area and known in its routing table, it sends it to its neighbor in closest proximity to the destination node. However, if the destination node is in another area, it sends the message to its neighbors located in the higher hierarchy level area. When the message arrives in an empty area (i.e., no neighbor is closer enough to reach the destination node)

and the recipient is out of range of any relay node, the packet is returned to the preceding relay node (Backtrack option). This latter searches for another relay to reach the destination; if there is not any, it then returns the message to the sender and informs it that no path is available towards the destination node.

TABLE V  
PARAMETERS OF GRP

Attribute	Value	Attribute	Value
Hello interval	5 s	Backtrack	yes
Neighbor expiry time	10 s	Route export	no
Distance moved	1000 m	Number of initial floods	1
Position request timer	5 s	Quadrant size	2 km

Let’s note that because of the modelling of the traffic flow needed for the location-based service in the GRP routing protocol, we are able to compare this protocol to OLSR, AODV and DSR using the same performance metrics.

#### IV. SYSTEM CONFIGURATION AND METRICS

Our goal is to evaluate the behavior of the four routing protocols in the same conditions of traffic and mobility. The simulations have been performed with Riverbed OPNET Modeler. The simulated system is an ad hoc network of vehicles equipped with IEEE 802.11p cards configured as described in Table VI. The transmission power is set to 0.005 W and the receiver sensitivity to -95 dBm in order to obtain a communication range of 300 m and match the IEEE 802.11p dedicated short range communication. The implementation of 802.11p used is the one provided by the Riverbed OPNET Modeler software. The five following performance metrics are considered:

- The “load” metric represents the total number of bits forwarded from the wireless layer to higher layers. This metric measures the traffic received in all the network at a given time.
- The “throughput” metric represents the total number of bits submitted to wireless layer by all higher layers. Its upper value is restricted by the bandwidth, so it may give an idea of the local bandwidth obtained by each node with each protocol.
- The “end-to-end delay” metric concerns the time taken by a packet to reach its destination. It is measured as the difference between the arrival time of a packet at its destination and the creation time of this packet. This metric will help to evaluate the routing protocols in relation to the applications requirements.
- The “routing traffic” metric is defined as the total number of routing packets transmitted over the network (including Hello and Topology Control messages). This metric measures the resources consumed by the routing protocol to the detriment of data traffic, and gives an idea on its scalability.
- The “ratio of the routing traffic sent to the total traffic sent” metric highlights the resources consumed by the routing protocol.

TABLE VI  
NODE CONFIGURATION IN OPNET

Attribute	Value
Physical Characteristics	5.0 Ghz
Data Rate	13 Mb/s
Transmit power	0.005 W (i.e. 7 dBm)
Receiver sensitivity	-95 dBm
Transmission range	300 m
Routing protocols	OLSR, AODV, DSR, GRP
Protocol parameters	Tables II to V

### A. Application

This work focuses on future real-time VANET applications such as those related to the autonomous vehicle. In such safety applications, on-board functions (sensors, geo-localization, extended perception, *etc.*) will have to share variables periodically (speed, acceleration, positioning information, *etc.*) for their inner process. The chosen throughput is conformed to the IEEE data traffic settings [19]: a 300-byte packet length is sent with a 10-Hertz update rate. However, active safety applications need higher exchange frequencies. Keeping the same throughput, we model the traffic of safety applications as packets of 75 bytes sent every 25 ms.

### B. Scenarios

Five scenarios have been created to measure the impact of the number of transmitting nodes in the network. The first four scenarios concern a 20-node network and the last scenario concerns a 30-node network. The last scenario is chosen to test the scalability of the protocols and to match the studies mentioned in the related work.

In the first scenario, only one node (5%) sends its messages to the 20 other nodes; in the second, three nodes are sender of messages (15%); in the third, eight nodes (40%); and in the fourth, all vehicles send messages to the 20 other nodes, causing a full-mesh network traffic (100%). The fifth scenario constitutes a full-mesh 30-node network.

### C. Mobility model

In this paper, the mobility model is based on the real-world trajectories of the MOCoPo (Measuring and MOdelling Congestion and Pollution) research project. The MOCoPo database consists of vehicles close to each other recorded at the RN 87 (in the southern suburbs of Grenoble). A helicopter equipped with three high-definition cameras filmed the highway for several hours. Collected data are from a 500-meter-long express road with a speed limit of 70 km/h and with an access ramp.

In order to be transformed into trajectories, the MOCoPo videos were processed [20] using a new filtering approach based on polynomial fitting and polar coordinates. The result is a set of trajectory data of 619 vehicles distributed in a 60-minute time window. Each trajectory consists of a new location information every 0.1 s. This database is split [21] into three groups of different congestion levels (fluid, congested with stop and go wave and hybrid). We are interested in the vehicles

of the first group (fluid); these vehicles have an average speed of 51.3 km/h with a standard deviation of 8.5 km/h.

## V. SIMULATION RESULTS ANALYSIS

Each scenario is run several times with different seed values for the OPNET random generator in order to avoid that the related sequence favors a particular routing protocol. Figures 2 to 5 present the average results for each performance metric.

In Figure 2, AODV obtains the highest throughput for the five scenarios, while OLSR, DSR and GRP protocols report almost the same value. The throughput increases with the number of source nodes in the network, except with AODV. Indeed, it is lower in the 20-source scenario than in the 8-source one. Actually, there are more traffic, but the maximum available bandwidth, almost reached with 8-source nodes, imposes a lower throughput when shared by 20-source nodes.

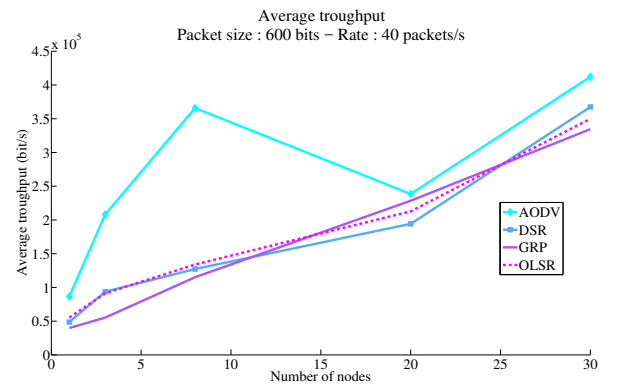


Fig. 2. Throughput in the network with 1, 3, 8, 20 and 30 sources

In Figure 3, the GRP protocol obtains the smallest load. OLSR and AODV present a higher load and their curves follow the same slope for the 1 to 20-source scenarios. AODV curve keeps the same slope between 20 and 30 nodes. But, the increase of the OLSR curve remains very low and the slope drops. DSR protocol gets the highest load, which shows a poorer scalability in comparison with the other protocols. The scalability is best for GRP and OLSR than AODV and DSR.

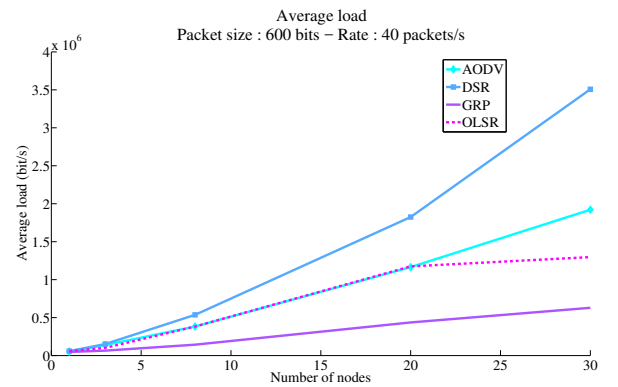


Fig. 3. Load in the network with 1, 3, 8, 20 and 30 sources

In Figure 4, the GRP and OLSR protocols produce the lowest amount of routing traffic in every scenario, followed by AODV and DSR. The homogenous mobility of the vehicles on the section of the road may favor a stable network topology, but it should be noticed that it is the most observed situation over roads when the traffic is dense. As a result, OLSR and GRP, that are proactive protocols, seem to be more relevant because they have already a route in their routing table at the moment of transmission requests. AODV and DSR suffer from a dramatic increase in their routing traffic. This observation emphasizes the problem of scalability of reactive routing protocols with the growing of both the density of the network and the number of traffic source nodes.

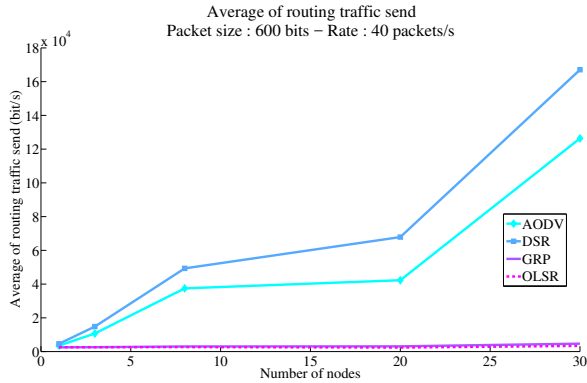


Fig. 4. Average routing traffic sent in the network with 1, 3, 8, 20 and 30 sources

In Figure 5, the worst delay values are obtained with DSR. AODV scales good until its throughput falls down, and then the delay increases significantly even more than for DSR. DSR and AODV delays decrease for the 30-node network. The results confirm the observations already made on reactive protocols about the throughput and the average routing traffic sent. GRP gets the lowest delay for every scenario, and it demonstrates a very good scalability even with the growing number of source nodes. Though the delay for OLSR increases, the delay increases between the 1-source and the 20-source scenarios, then it declines such as the delays of DSR and AODV. For instance, the average delays obtained with 3-source nodes are 0.12 ms (GRP), 3.2 ms (OLSR), 5.5 ms (AODV), and 48 ms (DSR). It can be observed that the more abundant are the sources within the 20-node network, the longer the end-to-end delay.

In Figure 6, the routing traffic generated by OLSR consumes the least resources, then GRP comes and shows the same shape. Firstly, few data are transmitted, therefore the routing protocol takes about 5% of the resources. Next, the more are the source nodes, the least is the ratio. In the 20-source scenario only one percent of the resources is used for the routing traffic. The results show a good scalability for the 30-source scenario: the ratio remains constant for both OLSR and GRP protocols. The routing traffic generated by AODV and DSR reactive protocols ranges from 6 to 10% for 1 to 8-node

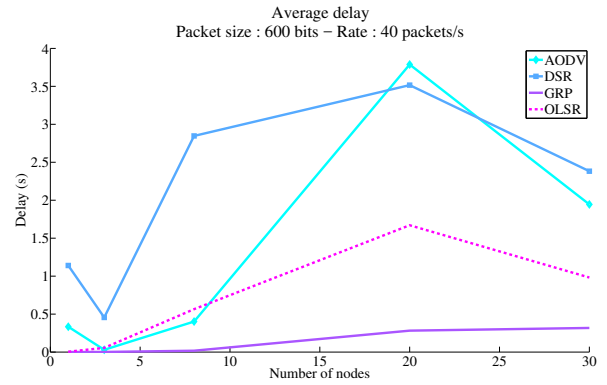


Fig. 5. Delay in the network with 1, 3, 8, 20 and 30 sources

sources. Then, in increasing the number of source nodes to 20, the data traffic grows and the ratio decreases. The results show a rather bad scalability for the 30-source scenario: the ratio rises for both AODV and DSR protocols.

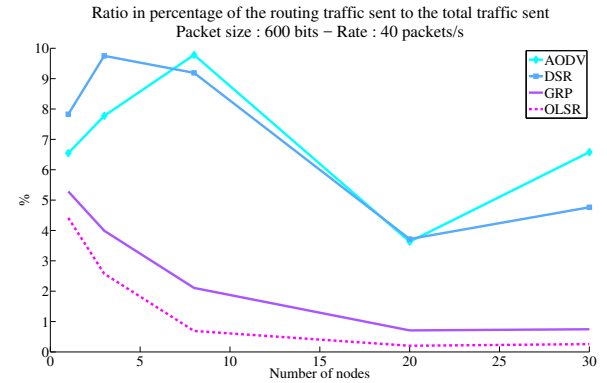


Fig. 6. Ratio in percentage of the routing traffic sent to the total traffic sent in the network with 1, 3, 8, 20 and 30 sources

## VI. CONCLUSION

In this work, we studied four routing protocols, namely GRP, OLSR, AODV, and DSR in considering a realistic road traffic scenario and real-world trajectory data of vehicles. The results show that reactive protocols obtain a good throughput when there are only few source nodes in the network. However, they quickly meet an increase in the delay once the network is dense and with the growing number of source nodes, due to the routing traffic generated. Thus, reactive routing protocols should be used in sparse ad hoc networks, or when applications require only few nodes emitting data traffic. Even in these conditions, AODV seems to be preferable to DSR which completely fails on the scalability criterion. The proactive protocols are more relevant in normal road traffic conditions with a relative density. It has been demonstrated in this work that OLSR and GRP can offer good performance in a 30-vehicle ad hoc network. Furthermore, these proactive protocols spend less communication network resources. They scale better with both the network size and the growing



number of sender. They optimize the flooding of routing traffic. And particularly, GRP keeps a reasonable delay while it faces an increasing traffic. However, safety application requirements in terms of maximum end-to-end delay is in the order of 100 ms and even 20 ms for cooperative vehicle highway automation systems or pre-crash sensing application [22]. Thus, the protocols presented in this paper are not satisfactory for this kind of application, and still need to be improved. In our future work, we will study and propose new mechanisms that could help to improve the performance of protocols such as OLSR and GRP for VANETs regarding road safety real-time applications.

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