Routing Mechanisms Analysis in Vehicular City Environment

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Abstract—**The VANET are mainly characterized by the high nodes velocity, high nodes density at road intersections and traffic jams and severe radio signals degradation caused by obstacles present in the external environment. This make the direct application of routing protocols defined for MANET not suitable for VANET. In this paper we consider a simulation environment representing a real city map with its terrain characteristics and urban infrastructures and analyze the most common protocols developed for MANETs. The objective is to identify the appropriate and inappropriate routing strategies for vehicular networks. So, we examine the behavior of each protocol varying the vehicular density and the data traffic rate to determine the mechanisms that enable them to have a good efficiency and those that cause their performance degradation. The results show that when the effect of obstacles on the radio signals is ignored the reactive protocols outperform the proactive protocols while when the impact of the obstacles is taken into account, the results are almost similar.**

Keywords-VANET; routing mechanisms; performance analysis; obstacles.

I. INTRODUCTION

The performances of routing protocols are directly related to the characteristics of the underlying environment. For example, at high nodes density, an on-demand protocol which diffuses requests on the entire network at each route discovery may cause an important control traffic that prevents sending data packets. With table driven protocols, high nodes mobility can make topology information kept at each node often obsolete. The VANET (Vehicular Ad hoc Network) are a special class of MANETs in which entities that compose the network are vehicles. They are characterized by high nodes density mainly in a city at road intersections and at traffic jams; high nodes mobility, particularly in highways, constraints on nodes mobility and radio signal degradation due to obstacles present in the environment. The works on performance study of routing protocols in VANET consider vehicles moving either on a highway or in a city environment. The authors of [1] evaluated the performance of AODV, DSR, FSR and TORA in typical freeway traffic scenarios. The results showed that TORA is not feasible for VANET and that AODV is the protocol that has the best performance, followed by FSR and DSR which presents good results only at low vehicular densities. The same authors considered in [2] the four protocols and evaluated their performance in city traffic scenarios. The results are similar to those found in [1]; they showed that TORA is inapplicable to vehicular networks and that AODV outperforms FSR and DSR. In [3], the authors have analyzed the problem of network disconnection in highway topology that they consider as important as the broadcast storm problem in dense network. They demonstrated how well the store-carry-forward mechanism performs in disconnected VANET. A comparative study of AODV and OLSR performance in urban environments is presented in [4]. The results showed that globally, OLSR outperforms AODV and that AODV delivers more data packets than OLSR after a certain nodes density and data traffic rate. In [5], the authors considered three geographic routing techniques and presented the problems that may be encountered in each technique. They found that by using greedy heuristics, the protocol chooses the farthest neighbor as next hop, which usually has low probability of reception. In case the protocol incorporates the store-carry-forward approach, the authors showed that temporary loops are created. They also found that a bad choice of a next relay in trajectory based routing can cause data message to get stuck or move away from the final destination.

In this paper we analyze the performances of three popular routing protocols in MANETs, namely AODV (Ad-hoc On-Demand Distance Vector) [6] and DSR (Dynamic Source Routing) [7] which are reactive protocols and OLSR (Optimized Link state Routing) [8] that is a proactive protocol, in the context of VANET. The considered simulation environment is a real city to which is added information describing, the degree of interest of areas for moving vehicles, terrain characteristics and urban infrastructures. This information is taken into account in vehicles movement and radio signal propagation modeling. We examine the behavior of each protocol at different vehicular densities and data traffic rates. Our objective is not to determine the best protocol for vehicular network but rather to identify, among the mechanisms used by each protocol, those that are suitable for VANET and those that cause performance degradation. We bring two novelties to the ongoing works on routing protocols performance analysis in VANET. First, to show the impact of obstacles on radio signal propagation, the presented results consider a flat unobstructed environment, and then a propagation model is used to take into account the obstacles effect. The second contribution involves the analysis of the behavior of each protocol by considering, in more detail, the employed mechanisms.

The remainder of this paper is organized as follows: Section 2 presents in brief the mobility and propagation models. Section 3 presents the simulation environment and the obtained results and finally Section 4 concludes this paper.

II. MOBILITY AND PROPAGATION MODELS

The mobility model we used is V-MBMM (V-MBMM: Vehicular Mask-based Mobility Model) [9], which simulates vehicles movements in an urban environment. The road topology is represented by a graph whose edges correspond to road segments and vertices to the connections between these segments. A vertex represents either a simple connection or an intersection. Each segment is assigned an attraction weight which represents its degree of interest for moving vehicles. The roads are bidirectional and the intersections are regulated by means of traffic lights. At each intersection, the vehicle chooses its next direction following a Markov chain whose probabilities are calculated based on road segments attraction weights. Two coefficients that take into account roads congestion and vehicle previous movements are defined in the model; they are applied to the Markov chain in order to make displacements more realistic. For vehicle speed regulation, V-MBMM uses the IDM model (Intelligent Driver Model) [10] which characterizes the behavior of each driver according to its preceding vehicles.

Two propagation models have been used: the first one is TwoRayGround which assumes a non-obstructed area and determines the received signal power according to the distance between the transmitting and receiving antennas; the second one [11] is an adaptation of the empirical model defined in [12] to vehicular networks. This model takes into account the terrain characteristics and defines three terrain categories according to the type and density of obstacles (building, forest, mountain…) present in the environment. Category A, that corresponds to a hilly terrain with moderate to-heavy trees densities; category B, characterized as either mostly flat terrain with moderate-to-heavy trees densities or hilly terrain with light tree densities; and category C that corresponds to mostly flat terrain with light tree densities. The received signal power is determined according to the category of terrain located between the transmitting and receiving antennas.

III. SIMULATION AND RESULTS

We realized our study using the application TM (Territoire Mobile) for mobility and signal propagation modeling and the simulator NS2 [13], version 33, for network modeling. TM is an application written in C++ which represents the territory of Belfort in the north eastern France. The area is 40km*20km. Several data have been used to reproduce the real environment including GIS shapefiles representing the map of the city, survey data and socio-economical information collected by professionals for regional planning needs. The environment is divided into cells of 25m*25m. Each one is assigned information describing its attraction weight and terrain characteristics (type of structures, altitude, etc.). The mobility model V-MBMM and the propagation model described in Section 2 were integrated into the application by considering only those cells that are roads. Traces describing vehicles displacements in the territory are generated in TM and used as movement scenario files in NS2. For signal propagation aspect, we calculated, in TM, for each road cell, the received signal power from all road cells located at distance less than a predefined maximum distance. All obstacles situated between transmitters and receivers, even outside the roads, are considered in path loss calculating. The generated file is used as input of NS2; it allows determining the coverage area of each vehicle as a function of its position. We chose NS2 because it is the most used simulator. AODV and DSR protocols are directly integrated into NS2, for OLSR, we used UM-OLSR version [14]. In our study, we consider the implementation details of the protocols in NS2 which has a significant impact on routing performance. These details relate to the priority assigned to different packets types, the mechanisms used to manage the packets waiting to be transmitted, etc.

A. *Simulation Parameters*

The simulations were performed considering an area of 1200m * 1200m from Belfort downtown. The duration of each scenario is 180s. All presented results are an average among five runs. Two series of tests were conducted where we varied the density of vehicles and the number of data traffic sources; the parameters are summarized in Table 1.

TABLE I. SIMULATION PARAMETERS

Simulations duration	180s
Area size	1200m*1200m
Number of vehicles	40, 60, 80, 100 and 120
Number of CBR sources	5%, 10%, 20% and 30% of nodes.
Inter packet arrival time	0.25s
Packets size	512 bytes
OLSR HELLO interval	2s
OLSR TC interval	5s
Transmission range	200m

B. *Results*

The first tests were realized in order to analyze the behavior of protocols at different nodes densities. The considered number of vehicles is 40, 60, 80, 100 and 120 with 20% of vehicles acting as CBR traffic sources. We assumed a non-obstructed environment. Figure 1 shows the rate of failed connections, which represents the number of sources for which no packet is received by the destination node. From the figure, three situations can be distinguished: sparse network (40 to 80 vehicles), in this case increasing the number of vehicles improves network connectivity and thus decreases the rate of connections failure, moderate network density (100 vehicles) where each protocol shows its best results and finally dense network (120 vehicles) where we observe a decrease in performance.

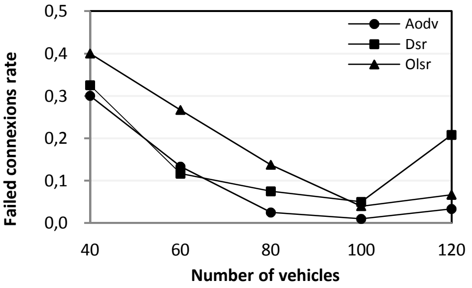
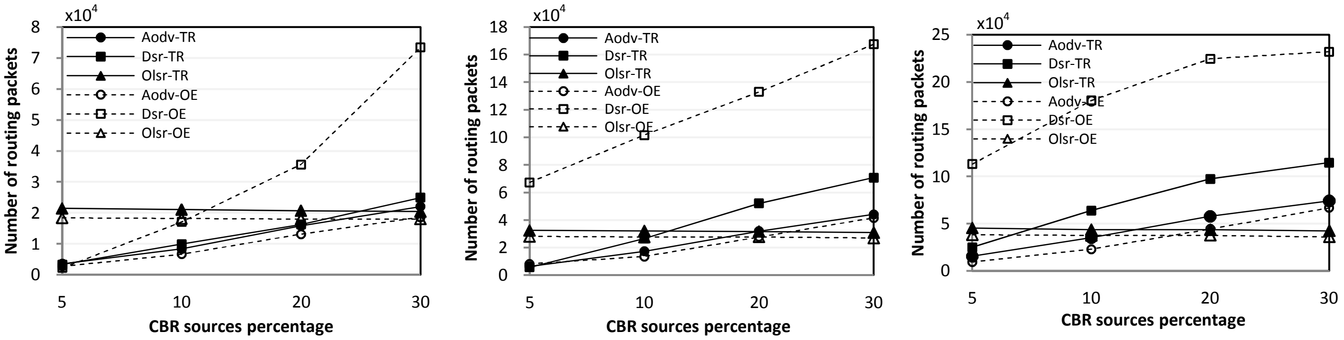


Figure 1. Connection failure rate vs. Vehicular density.

At sparse network, the difference in performance is due to the reactive or proactive nature of protocols. Indeed, DSR and AODV take advantage of the fact that route requests (RREQ) are broadcasted just before sending data packets, routes are thus calculated based on more recent information on network topology. AODV and DSR present almost the same rates of connection failures with a slight advantage of AODV when the number of vehicles is 80. The reason is that DSR produces more RREQ and gives more priority to routing packets than to data packets. At 80 vehicles, connectivity becomes better than at 40 or 60 vehicles; RREQ are more flooded in the network creating high control traffic which prevents sending data packets. With OLSR, network topology information are periodically exchanged, thus when sending data, route are determined based on information that may be obsolete. This depends on the values assigned to



(a) 80 vehicles (b) 100 vehicles (c) 120 vehicles

Figure 2. Routing overload vs. Percentage of CBR traffic sources

HELLO and TC (Topology Control) intervals. All protocols record the best results at 100 vehicles. With such a number of nodes, the network is dense enough to ensure connectivity and not too much to cause channel saturation. It can thus be seen as a threshold below which the network becomes disconnected and above which it becomes overloaded. Indeed, at 120 vehicles, the performances of the three protocols tend to decline due to channel saturation which is aggravated by vehicles queuing at road intersections. Due to the high number of generated RREQ, DSR presents the worst rate.

In the second series of tests, we considered the three cases identified above, sparse network with 80 vehicles, moderate density with 100 vehicles, and finally dense network with 120 vehicles. Three metrics are estimated that are:

Routing overload: it represents the number of transmitted control packets, packets forwarding are also included.

Packets delivery ratio: is the ratio between the number of data packets sent by the source and the number of data packets received by the destination.

Average end-to-end delay: it represents the difference between the time the data packet is generated by the source node and the time it is received by the destination node.

We performed the tests considering two propagation models. The first one assumes an unobstructed flat space and represents the transmission range of each node by a circle of 200m radius. We denote this model by *TR* for *Transmission Range*. The second is the model that considers obstacles effect on radio signals. We denote it *OE* for *Obstacles Effect.* For clarity, we separately analyze the performance obtained with the two models. However, for each metric we compare the results of OE with those of TR.

Routing overload-TR

Figure 2 shows the number of the control packets sent according to the percentage of nodes that act as CBR sources. In all protocols, routing load increases with density. This is obvious since the number of nodes increases, thus improving the network connectivity. This increases the number of nodes that generate control packets and especially the number of intermediates nodes that receive and rebroadcast these packets.

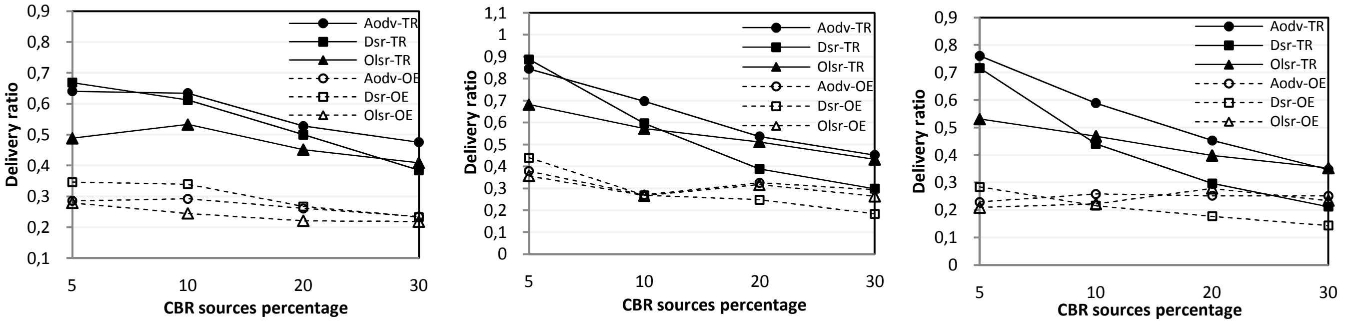
For each density, the routing overload in OLSR is almost constant whatever the percentage of sources; it is about $2x10^4$ packets at 80 vehicles, $3x10^4$ at 100 vehicles and $4x10^4$ at 120 vehicles. The reason is that control packets are periodically exchanged regardless of data traffic. When the number of vehicles is 80 (Figure 2(a)) and the percentage of sources is less than 25%, DSR and AODV have almost the same overload that is lower than OLSR. Since the number of data source is not high a few RREQ are generated. When the number of sources exceeds 25%, control traffic in DSR and AODV becomes higher than OLSR. DSR shows a slightly higher load than AODV because it produces more RREQ packets. The same behavior can be observed at 100 and 120 vehicles, Figure 2(b) and 2(c). Routing load in DSR increases dramatically with increasing nodes density (better connectivity) and number of sources. Control traffic also increases in AODV but less severely. From the same graphs, we can notice that AODV produces more control traffic than OLSR when the number of sources exceeds 20% with 100 vehicles and 13% with 120 vehicles. In DSR, the percentages are respectively 12% and 7.5%.

Routing overload-OE

With OE, the network is less stable. Due to the consideration of obstacles impact on radio signals, the connections appear and disappear more frequently [11]. Moreover, nodes coverage areas are smaller thus exacerbating the problem of network fragmentation and leads to multi-hop communications failures. The figures show that control traffic load in OLSR and AODV is almost the same as that obtained with TR with a slight decrease due to low network connectivity. In OLSR, the reason is that TC packets are less diffused in the network. In AODV, those are RREQ packets. However, given the low connectivity, control traffic generated in AODV is actually higher because of frequent topology changes and RREQ failures. Since DSR gives more priority to routing packets and generates more RREQ, control traffic load explodes.

Packets delivery ratio-TR

Figure 3 shows the delivery ratio of data packets. For all densities, with increasing number of sources, more packets compete for channel access which causes a decrease of the number of packets received by destination nodes. Whatever the percentage of CBR sources, AODV and OLSR have the best rate when the number of vehicles is 100. Indeed, as shown in Figure 1, with 100 nodes, the network is connected enough to ensure data delivery and the density is not too high to cause channel saturation. In DSR, the highest rate is recorded at 100 vehicles and 5% of CBR sources. For all



(a) 80 vehicles (b) 100 vehicles (c) 120 vehicles

Figure 3. Delivery data ratio vs. Percentage of CBR traffic sources.

other percentages of source nodes, the delivery rate decreases with increasing data traffic and nodes density. The reason still relates to the high number of route request and the priority given to routing packets which leads to control traffic growth that saturates the channel. The only scenario where DSR outperforms OLSR and AODV is at 80 and 100 vehicles and 5% of nodes acting as CBR source. Since routing overhead is not too high to cause channel saturation, DSR takes advantage of the fact that it produces more RREQ that allows nodes to better discover route. It also has the advantage of storing data packets in the buffer when route discovery fails. This gives more chance to packets being sent and increases the number of delivered data packets. Comparing AODV and OLSR, the results show that at low data traffic, AODV presents better results. Since AODV is an on-demand protocol it calculates routes based on more recent information than those used in OLSR. When the number of sources grows, 20% at 100 vehicles and 30% at 120 vehicles, the results of OLSR become close to those of AODV. The reason is that with a large number of sources, AODV produces a high control traffic load (Figure 2(a), 2(b)) which saturates the channel and degrades its performance.

Packets delivery ratio-OE

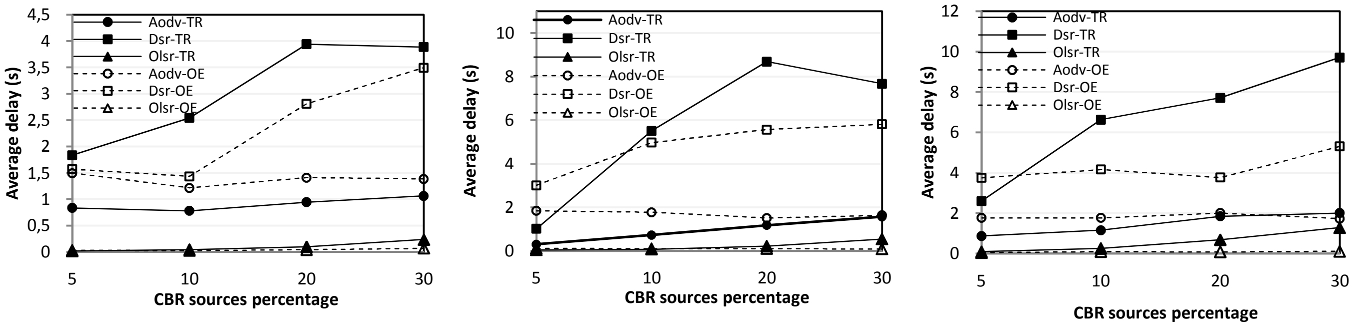
The interpretation of results in OE is less obvious than in TR due to network instability which dropped the delivery ratio at values ranging from 14.3% to 42%. However, from the different figures, some results can be explained. DSR presents the same behavior as with TR. For all vehicular traffic densities, the delivery ratio decreases with increasing number of sources caused by growing control traffic. The worst result is obtained at 120 vehicles when 30% of nodes act as CBR sources; it is 14.3%. At low data traffic, the results of DSR are better than those of AODV and OLSR. Indeed, despite of high control traffic rate, DSR benefits on one hand, from the priority it gives to the RREQ that allows nodes to have a better knowledge on network topology and on the other hand on its reaction to route discovery failure. When data traffic is higher, channel saturation caused by control traffic makes the performances of DSR lowest. At 80 vehicles, OLSR has the lowest results. As the network is disconnected, information topology carried by TC packets is not enough diffused which limits nodes view on network topology. At 100 and 120 vehicles, AODV begins to suffer from control traffic growth and OLSR takes advantage of the high connectivity that allows a better diffusion of TC. This makes delivery ratio almost similar in both protocols.

Average end-to-end delay-TR

Figure 4 presents the average end-to-end delay obtained with all nodes densities. With the three protocols, the delay increases with increasing vehicular density and data traffic. When the number of vehicles grows, the connectivity becomes better, making multi-hop communications possible. With increasing routes length, delays become higher; first, because many nodes must be traversed by data packets before reaching the final recipient, and secondly, link breakage and therefore local repairs (only for reactive protocols) are more frequent leading to longer delays. When the number of sources grows, data traffic in OLSR and both data and control traffic in AODV and DSR becomes higher. Several packets compete for medium access causing channel saturation and therefore high delays. Waiting time in nodes queue also increases. OLSR shows the lowest delays that are below 0.23s at 80 vehicles, 0.53s at 100 vehicles and 1.27s at 120 vehicles. Given the proactive nature of the protocol, routes are calculated in advance and not on demand as with AODV and DSR. When a node, the source or the intermediate node, has not a valid route to the destination of a packet, OLSR simply removes that packet. AODV and DSR store the packet in the buffer and initiate a route discovery process. DSR is a protocol that presents the greatest delays due to the high routing overload and to the fact that if no response is received for a route discovery, DSR does not delete the data packets but keeps them in the buffer for another attempt, which increases their delay. The greatest value is 9.7s; it is obtained at 120 vehicles when 30% of nodes generate data packets.

Average end-to-end delay-OE

For the same reasons as with TR, OLSR is the protocol that presents the lowest delays, followed by AODV then DSR. By comparing the end-to-end delays of OLSR and DSR obtained with EO to those obtained with TR, we can see that they are lower. Because of the low connectivity, in OLSR nodes have limited knowledge of the neighborhood two hops away, and in DSR high routing load prevents RREQ to be broadcasted far from the source node, in terms of number of hops. These reasons added to network disconnection prevent multi-hop communications. Thus only communications over a small number of hops succeed which makes delays low compared to TR. With AODV, the behavior is different because of the mechanism used by the protocol for RREQ generation. After sending a successive number of RREQ, if no response is received, originating node deletes, from the buffer, all data packets for the



(a) 80 vehicles (b) 100 vehicles (c) 120 vehicles

Figure 4. Average delay vs. Percentage of CBR traffic sources.

destination and retards sending the next RREQ for a fixed timeout (10s in NS2). During this timeout, the source node stores all generated packets in the send buffer. With OE, since connectivity is poor, RREQ failures are more frequent; therefore, more packets are queued in the buffer, which increases the average delay. The difference is more noticeable at low vehicular density and traffic data sources. When the number of vehicles increases the connectivity is better thus less RREQ failures occur.

IV. CONCLUSION

In this paper, we examined the performance of AODV, DSR and OLSR varying the nodes density and the number of data traffic sources in order to highlight their strengths and weaknesses in context of vehicular network. The realized study considered two propagation models, one optimistic that assumes an unobstructed flat environment and another which takes into account the impact of obstacles on radio waves. When this impact is ignored, the results show that AODV is the protocol that has the best delivery ratio. OLSR shows a low rate due to its proactive nature; routes are calculated based on less recent information than in AODV and DSR. Moreover, at low network connectivity, it presents the worst results since TC packets are not enough diffused in the network. This limits nodes knowledge of the topology. Despite the fact that DSR is a reactive protocol, it records low performance. The reason is that DSR gives more priority to control packets which saturate the channel and penalize data transmissions. This also prevents route discovery even when connectivity is well. This mechanism brings an advantage only when nodes density and data traffic are low, which is not common in VANET. When considering the effect of obstacles on radio signals, which is more realistic, the results are different. DSR shows the lowest performance owing to increasing routing traffic. OLSR and AODV have almost the same delivery ratio. Signals quality degradation caused by obstacles present in the environment make the network unstable. Thus to determine and maintain routes, AODV generates significant control traffic which cause channel saturation.

Having identified both suitable and inappropriate routing mechanisms for urban vehicular network at sparse and dense traffic, our next objective is to develop a new protocol that takes into account all found results. To overcome the problem of network instability which causes performance degradation due to obstacles effect on radio signal propagation, new techniques must be incorporated to the protocol.

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