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Comparative study of proactive and reactive routing protocols in vehicular ad-hoc network

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ABSTRACT

In recent years, the vehicular ad-hoc network (VANET), which is an ad-hoc network used by connected autonomous vehicles (CAV) for information processing, has attracted the interest of researchers in order to meet the needs created by the accelerating development of autonomous vehicle technology. The enormous amount of information and the high speed of the vehicles require us to have a very reliable communication protocol. The objective of this paper is to determine a topology-based routing protocol that improves network performance and guarantees information traffic over VANET. This comparative study was carried out using the simulation of urban mobility (SUMO) and network simulator (NS-3). Through the results obtained, we will show that the choice of the type of protocol to use depends on the size of the network and also on the metrics to be optimized.

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1. INTRODUCTION

Internet of things modules are embedded in all smart devices. The connecting networks between these devices such as smartphones and smart cars are called the internet of things (IoT) [1]. This wide implementation of IoT modules is accompanied by a very rapid evolution of communication technologies, namely the prevalence of the IEEE 802.11ac standard and the launch of the next generations of networks, such as five-generation (5G), with very high theoretical speeds, which can positively influence the communication between these smart devices [2]–[5] Despite all these technological advances, and as it's already introduced in [6], the practical implementation of multimedia applications in mobile ad-hoc network (MANET) faces many challenges due to the low performance of this type of network, while multimedia applications usually require strict quality of service (QoS) guarantees [7]. Among the dynamic characteristics of MANET are the ad-hoc connection, low capacity, and limited energy which make the network structure unstable.

MANET's data packet transmission process is a two-step process: optimal path calculation and data transmission. The first step is to find a route to the destination, then the next step is to transfer this data. In the first step we can mention two sub-steps, we can name them sub-step A and sub-step B. In sub-step A: The source node broadcasts routing request (RREQ) packets. In sub-step B the source node receives the routing response packets (RREP). After these two sub-steps (A and B) the source node starts transferring the data packets.

In this paper, we will discuss a special case of MANET where nodes are autonomous cars [8], the network topology is highly dynamic, the cars are very mobile [9], and the overhead is higher. This network is called a vehicular ad hoc network (VANET). In this type of network there are several types of communication [10]: vehicle to infrastructure (V2I), vehicle to vehicle (V2V), vehicle to X (V2X), and cloud and smart device. Figure 1 summarizes all these types, and the following lines define in detail each type of communication.

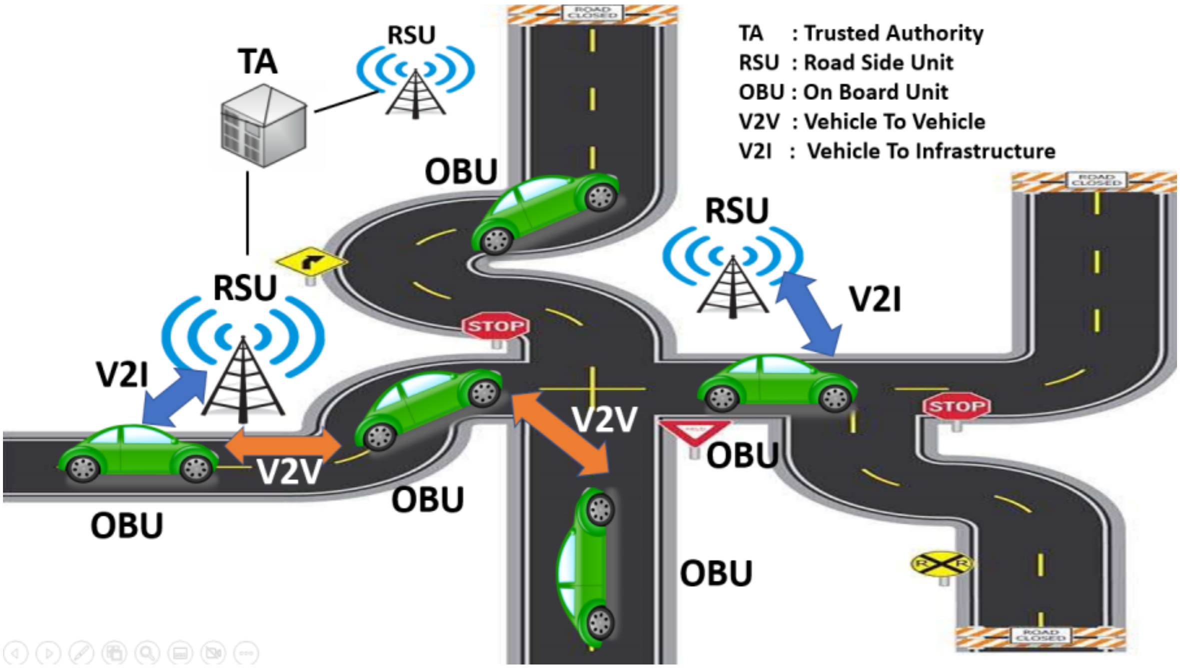

Figure 1. VANET model architecture

- V2I: this communication uses road side unit (RSU) and trusted authority (TA) to exchange data using the wireless network.
- V2V: this communication can be used to inform other vehicles if there are obstacles or accidents on the road.
- V2X: this communication includes vehicle-to-device (V2D), vehicle-to-home (V2H), and vehicle to pedestrians (V2P). This type of communication generally allows the vehicle to communicate with all devices connected to the network.
- Cloud and smart device: instead of using local data storage, the connected autonomous vehicle (CAV) uses cloud storage, where data is accessible via the Internet.

The VANET architecture is based on three main components: on-board unit (OBU), RSU and TA:

- On-board unit (OBU): is a tracking device based on the global position system (GPS). This device is installed in all vehicles. It is used to share vehicle information with RSUs and other OBUs.
- RSU: is a device that analyzes the data shared between vehicles. This device is fixed on the roadside (parking area and road intersections).
- TA: is the main component of the VANET architecture used to register devices such as vehicle users, RSUs, and OBUs. Their role is to control the security management of VANET.

In a vehicular network, autonomous vehicles communicate with each other using OBUs and with the infrastructure using RSUs. To guarantee this communication, the data transmission process in VANET is based on source tracking and data routing. The latter plays a very important role in routing the data to the destination using RREQ.

VANET is a challenge for researchers due to various difficult problems, such as the problem of high mobility of vehicles, especially on highways, the problem of overloading in the event of an accident on the road, the problem of security in the vehicular network, and the problem of data routing. The routing problem is one of the major problems to be solved to ensure the best functioning of this type of network. The objective of this paper is to determine an adequate routing protocol for routing problems in VANET. The determination of this protocol should be based on well-known metrics in the network domain. This paper will focus on V2V routing protocols and more precisely on topology-based routing protocols. This class of routing protocols uses link state to send a message to its destination. Topology-based routing protocols are classified as:

a. Proactive (table-driven) routing: These types of protocols have an overall idea of the network topology. They construct the routing tables before the request to transmit a packet. The implementation of proactive protocols in an ad-hoc network relies on two routing strategies: distance vector routing, as is the case of the destination-sequenced distance-vector (DSDV) protocol [11] and link state routing, which is the case of the optimized link state routing (OLSR) protocol [12]. In the literature, there are other proactive routing protocols such as wireless routing protocol (WRP) [13].
b. Reactive (on-demand) routing: These types of protocols do not use any prior information about the network topology. Routing table maintenance is performed after a node request. The most popular reactive routing protocols are: ad-hoc on-demand distance vector (AODV) [14], dynamic source routing (DSR) [15], and temporally ordered routing algorithm (TORA) [16].
c. Hybrid routing: These types of protocols combine two mechanisms: the mechanism of proactive and reactive routing protocols. The most popular hybrid routing protocols are the hybrid ad-hoc routing protocol (HARP) [17] and the zone routing protocol (ZRP) [18].

The objectives of this article are to:

– Present some comparative studies of routing protocols.
– Study three routing protocols based on topology: AODV, DSDV, and OLSR in a vehicular network.
– Simulate a vehicular network in the city of LARACHE-Morocco using a aimulation of urban mobility (SUMO) and network simulator (NS-3) simulators.
– Validate the simulation results with well-known performance measures in the network domain such as throughput, overhead, and packet loss rate (PLR).

The remainder of this paper is structured as follows: in section 2, we present the related work on implementing proactive, reactive, and hybrid routing protocols in VANET. In section 3, we present our comparative study. In section 4, we discuss the results of the simulation. Finally, section 5 concludes this article.

2. RELATED WORKS

Sharef *et al.* [19] have discussed several types of routing protocols used in VANET. They classified these protocols into two main families: V2I routing protocols and V2V routing protocols. The first includes the protocols used to exchange information with the RSU and TA infrastructure. The second category includes the communication protocols used between vehicles to share their speed, position, and many other information. The authors present a powerful study to the research community that examines routing metrics in VANET. They confirm that the most important metric is the method of establishing routes between vehicles. In brief, the authors of this paper confirm that position-based routing and geocasting are more efficient for VANET due to environmental limitations. Figure 2 presents the types of routing protocols.

Sharma and Lobiyal [20] studied the performance of some reactive routing protocols in a wireless sensor network. In the simulation the authors based on a set of standard metrics by varying the number of vehicles. The simulator used is NS2.34. The simulation results show that the TORA protocol is more efficient in terms of packet loss rate. On the contrary, the AODV and DSR protocols are more efficient than TORA in terms of throughput.

Praveen *et al.* [21] discussed a comparative analysis on the security part. The simulation was done using NS-2. The simulation results show that the OLSR protocol is the best when there is no attack and the number of source nodes is lower. And when the detection of the attack the AODV protocol is the best. In brief, we can say that the authors in this comparative analysis do not mention the simulation parameters such as the number of nodes, the topology, the mobility, and the pause time. These characteristics have a direct influence on the simulation results.

Mayada *et al.* [22] discussed the challenges of a transport system such as security, mobility and connectivity. The authors also confirm that intelligent diagnosis is recommended to test the performance of routing protocols. In this paper the performance test of some protocols based on topology using SUMO and virtual move simulator (VMS) show that DSDV protocol has low performance compared to other protocols, AODV protocol has maximum throughput value, and DSR protocol has minimum delay value.

Govindasamy and Punniakody [23] compared the robustness of some proactive and reactive routing protocols in case of attacks in wireless sensor networks. the standard measures are tested in this paper. The simulation is performed using the qualnet 5.0 simulator. The results show that ZRP has the highest throughput and OLSR has the lowest average E2ED. However, AODV has better overall performance than the other two routing protocols. The authors note that in the future, it is necessary to consider the design of a secure routing protocol.

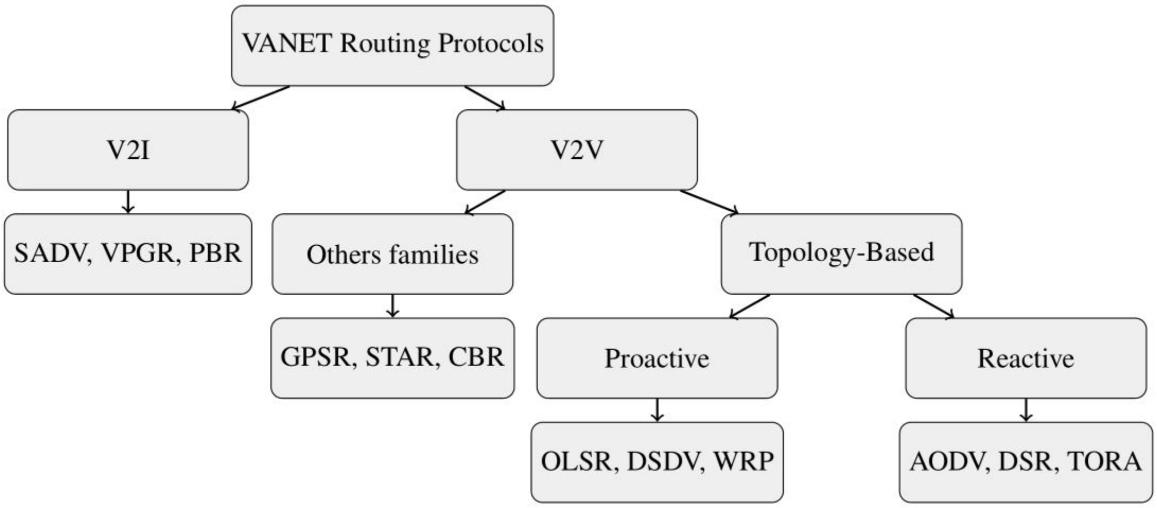

Figure 2. The main types of routing protocols in VANET

Malik and Sahu [24] proposed to analyze the AODV and DSR routing protocols in VANET. The simulation was performed using network simulator (NetSim) and SUMO. The metrics analyzed in this study are E2ED, PDR, PLR, and throughput. The authors propose a model that provides many key insights that can be used to improve the overall performance of the VANET system. The results show that the DSR protocol performs better than AODV in VANET although in a network containing a large number of vehicles. The advantages of the DSR protocol are higher throughput, enhanced delivery rate, and low PLR. However, the DSR protocol has a higher overhead rate. The proposed models, routing protocols, and simulation results can be used as guidelines for the design of modern traffic control mechanisms that follow the application of security and faster data packet delivery.

Deshpande *et al.* [25] performed a simulation-based study to analyze the performance of the VANET system using different routing protocols. The authors confirm that the quality of service in vehicular ad-hoc networks depends mainly on routing protocols. Maximum throughput, minimum packet loss, and controlled overhead are the essential things to verify the reliability of each proposed routing protocol. The result of this simulation shows that the AODV reactive protocol is the best using Opnet Modeler 14.5 simulator. The authors of this paper also discussed the advantages of the AODV protocol, such as the rapid processing of VANET link failures and the short delay in sending a packet. Even though the authors of this work prefer AODV over other routing protocols, AODV causes a lot of problems in VANET, namely bandwidth consumption in the generation phase of route response packets for a single path.

Dafalla *et al.* [26] proposed a topology control (TC) scheme based on OLSR. This study is validated by testing the network before and after running the OLSR protocol. The tests are focused on QoS parameters between two hops using the following software: ITU G.711 VoIP codec, OLSR Agent, and Wireshark. The results show positive values after running the OLSR protocol. Based on these results, the OLSR-based TC presented excellent performance. In Table 1 we summarized the related works cited in our paper, by listing the family, advantages, and limitations of each routing protocol. In the following section we present a comparative study of the three routing protocols AODV, DSDV and OLSR in VANET.

Table 1. Summary of related works

Reference and Year of publication	Routing protocol	Topology-Based	Advantage	Drawbacks
[20] 2015	TORA [16]	Reactive	- TORA generates efficient values when testing PLR in a sensor network.	- TORA is incapable of forwarding a large number of routing packets. -TORA is not considered for networks with high node density.
[22] 2017	DSDV [11]	Proactive	- DSDV has a global view on the network topology.	- DSDV performs poorly in a vehicular network.
[23] 2018	ZRP [18]	Hybrid	- ZRP aims to solve routing problems using both reactive and proactive approaches.	- The usage of the ZRP protocol in a network will result unstable in temporary routing. - The rate of overload in ZRP is high.
[24] 2019	DSR [15]	Reactive	- DSR performs better when a network contains a large number of vehicles. - DSR has higher throughput, enhanced delivery rate. - DSR has low packet loss rate.	- In a vehicular network with multiple idle vehicles, DSR will increase the overhead rate.
[25] 2021	AODV [14]	Reactive	- The AODV protocol rapidly handles VANET link failures. - The time to send a packet is low in the AODV protocol.	- AODV consumes bandwidth in the phase of producing packets for a route response single path.
[26] 2022	OLSR [12]	Proactive	- OLSR is more capable when studying VoIP applications in the VANET. - OLSR is based on the MultiPoint Relay (MPR) concept which minimizes the overload rate in ad-hoc network.	- There is not many works that compare the performance of OLSR with other routing protocols in VANET.

3. METHOD

3.1. Motivation research and study objectives

The goal of this paper is to deduce a robust and efficient topology-based routing protocol in VANET. Our study is based on the performance analysis of three topology-based routing protocols: two proactive protocols (DSDV and OLSR) and one reactive protocol AODV. The choice of these protocols is justified by the different algorithms that use these protocols for routing packets in a network. The OLSR protocol uses link-state routing, which is totally different from the algorithm used in the DSDV protocol, which is called distance vector routing. However, the AODV protocol belongs to the reactive family and is based on a different routing mechanism than the proactive family. The next part presents an overview of these routing protocols.

3.2. Overview on AODV, DSDV, and OLSR

3.2.1. AODV

AODV is a topology-based routing protocol that belongs to the reactive family and corrects the drawbacks of the DSR protocol. AODV does not need to have a global idea of the network topology. A route will be discovered by a node only when needed (on-demand fashion) and no routes to inactive nodes during the communication process will be recorded [27]. Figure 3 shows the process of RREQ and RREP packets. Algorithm 1 summarizes the working mechanism of AODV in the routing process in an ad-hoc network.

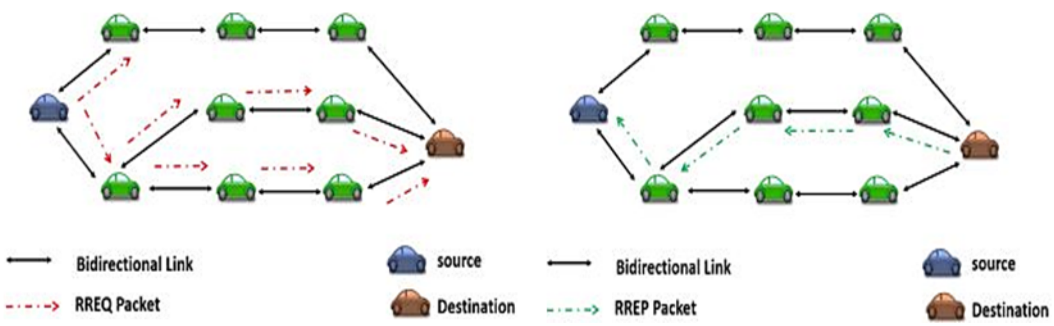

Figure 3. The process of routing RREQ and RREP packets in VANET

Algorithm 1. AODV working mechanism

```
The source address sends the RREQ packet,
The neighbor nodes receive RREQ,
if ( neighbor nodes contains RREQ packet ) then
    Neighbor nodes sends RREP to source node,
else
    Verification of the routing table,
end if
if (node address = destination address) then
    Activation of the route,
else
    ERROR message.
end if
```

3.2.2. DSDV

DSDV is a topology-based routing protocol that belongs to the proactive family. This protocol uses the Bellman-Ford algorithm [28] for routing packets in the Ad-hoc network. Each node must know all the other nodes connected to the network, and the routing tables are updated periodically. DSDV uses the principle of sequence numbers to solve the problem of routing loops and to determine the most recently used paths. Figure 4 shows the process of sending a packet using the DSDV protocol and algorithm 2 describes the function of the DSDV protocol.

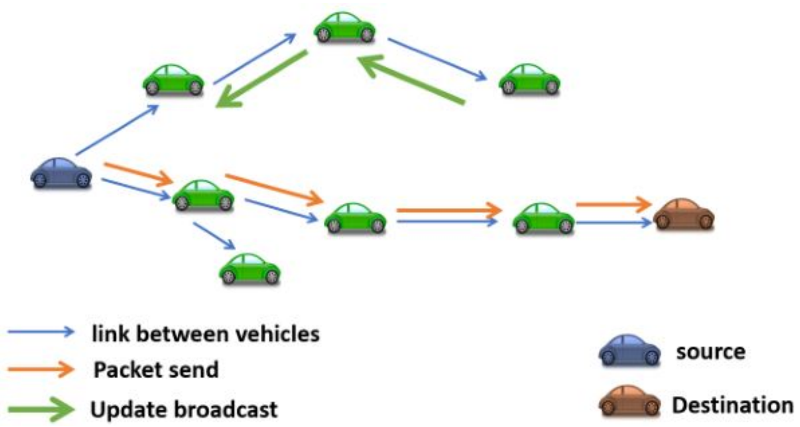

Figure 4. DSDV working process

Algorithm 2. DSDV working mechanism

```
Each node builds a “Cost” number,
if (Node, neighbors)=True then
    Cost = 1,
else
    Cost = ∞ ,
end if
Each node broadcast their table to it’s neighbours,
while (neighbors receive data from source node) do
    update routing tables,
end while
choose best route based on the sequence number,
```

3.2.3. OLSR

OLSR is a topology-based routing protocol that belongs to the proactive family. This protocol is an optimization of the link state algorithm. The concept is to broadcast two types of messages: HELLO messages for knowing the neighbors and topology control (TC) messages for knowing the network topology. There are many advantages of the OLSR protocol, we can cite :

– The use of the notion of MPR [29]: MPRs are nodes selected to retransmit TC messages with other MPRs whose objective is to minimize the overhead rate in an ad-hoc network. Figure 5 shows the MPR mechanism in OLSR.
– The use of the Dijkstra algorithm [30]: which chooses the shortest route between a source and a destination which speeds up the routing process. Algorithm 3 presents the working mechanism of the OLSR protocol [31]

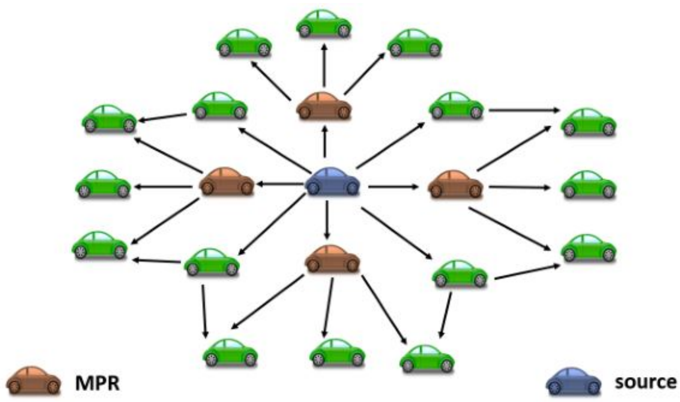

Figure 5. MPR mechanism in OLSR

Algorithm 3. OLSR working mechanism

Define source and destination nodes,
TTL = 225,
The source node broadcasts HELLO messages,
The source node receives all one-hop and two-hop neighbors,
define MPR nodes,
Broadcast TC message,
Forward TC messages to only MPR,
All nodes receive a partial topological graph of the network,
Application of Dijkstra's algorithm for determining the shortest path,
Each Node chooses the shortest path to send a packet to the destination,

In summary, routing protocols are characterized by a set of parameters that identify which protocol is compatible in certain situations in a network. Among these parameters we cite the chosen routing algorithm, the construction of the routing table, the topology based, and the types of packets sent to identify the routes. We present in Table 2 the most important characteristics to identify the features of the three ad hoc routing protocols chosen in our paper: AODV, DSDV, and OLSR.

Table 2. Summary of the characteristics

Protocol Property	AODV	DSDV	OLSR
Topology-based	reactive	proactive	proactive
Routing algorithm	Distance vector	Bellman- Ford	Dijkstra
Packets send	RREQ - RREP	–	HELLO - TC
Broadcasting periodicals	Yes	Yes	Yes
Multicast routes	No	No	Yes
Concept of the routing table	Yes	Yes	Yes

3.3. Simulator tools

The evaluation of scientific research on vehicular networks requires intelligent and robust tools. Simulators are developed for this objective. In general, in vehicular networks, two types of simulators are proposed: mobility simulators and network simulators. The first one is to determine the movements of vehicles. The second one is to simulate the communication between vehicles.

In the literature, there are several types of simulators. In this comparative study, we have chosen SUMO [32] to solve the high mobility problems of vehicles, and NS-3 [33] to evaluate the network performance. The choice of these two simulators is based on the great community of researchers who prefer these two simulators. In addition, SUMO allows the generation of a file that contains a set of information about the mobility of vehicles and NS-3 allows the use of this information and its manipulation.

3.4. Process validation

This section presents the validation process of this study. The simulation was realized in an urban environment by downloading the map of the city of LARACHE-Morocco using Open Street Map (OSM); it is the free wiki world map as shown in Figure 6. A road traffic scenario is generated in SUMO including low and high density of vehicles as shown in Figure 7.

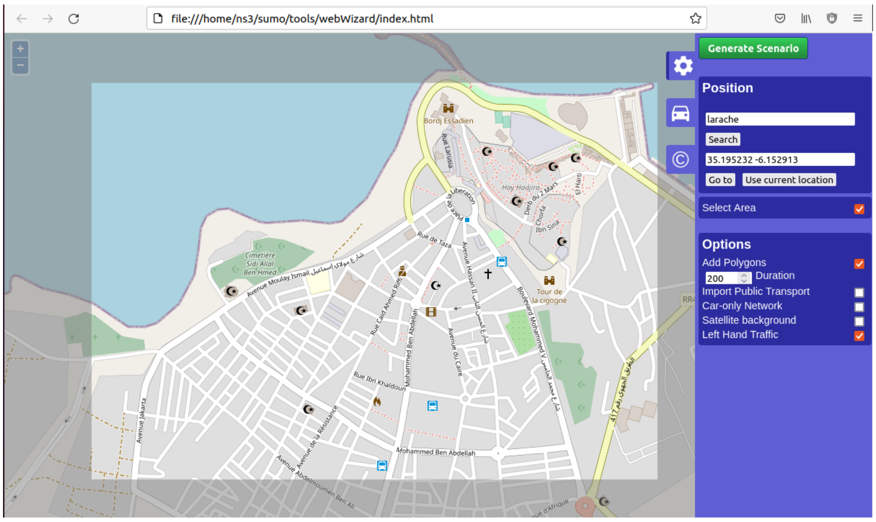

Figure 6. Scenario generated for LARACHE-Morocco

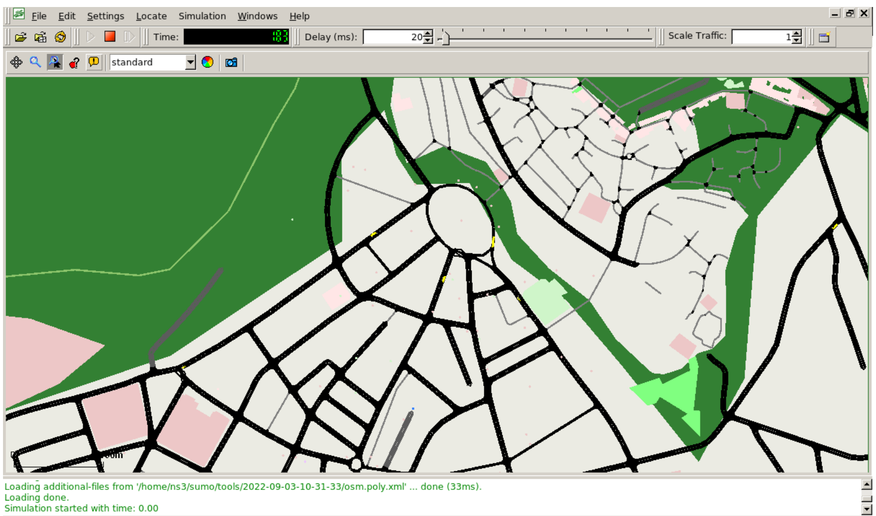

Figure 7. Simulation SUMO for LARACHE-Morocco

The routing protocols used are AODV (reactive) and DSDV, OLSR (proactive). The mobility data generated in SUMO trace is exported to NS3. Table 3 presents the characteristics of the machine used for the simulation, and the details of the simulation environment. The number of vehicles is incremented by 25 to move from a lower density to a higher density.

Table 3. Simulation setup

Platform	Ubuntu 20.04.3 LTS
OS Type	64-bit
GNOME Version	3.36.8
Windowing system	X11
Virtualization	VMware
Memory	3.7 GiB
Processor	11th Gen Intel® Core™ i5-1135G7 @ 2.40GHz × 3
Graphics	SVGA3D; build: RELEASE; LLVM
Disk capacity	80.5 GB
Network simulator	NS-3.33
Traffic simulators	SUMO
Map model	Region Tanger-Tetouan-Al Hoceima LARACHE-Morocco
Routing layer	IEEE 802.11p
Number of vehicles	25,50,75,100,125
Node speed	20 m/s
Node pause	0
Routing protocol	AODV, DSDV, OLSR
IEEE scenario	VANET (802.11p)
Mobility model	Urban Mobility
Simulation time SUMO	200 seconds
Simulation time NS-3.33	100 seconds

3.4.1. Performance metrics

The metrics for evaluating the performance of routing protocols in VANET are throughput, the overload rate, and PLR.

- Throughput: The number of bits that can be successfully transmitted. It is measured in bits per second (bps). A larger value of throughput indicates better performance. Mathematically:

$$Throughput = \frac{Total\ Packet\ Received}{Total\ Transmission\ Time} \tag{1}$$

- Overhead: This value characterizes the saturation level of the network. This is the relationship between the extra routing packets and the packets received by the target vehicles. The lower overhead shows the highest network performance. Mathematically:

$$overhead = \frac{Total\ number\ of\ overhead\ messages}{Total\ transmitted\ packets} \tag{2}$$

- PLR: The packet loss rate is defined as the ratio between the number of packets lost and the total number of packets sent. When the PLR values are lower, the network is considered to be more performant. Mathematically:

$$PLR(\%) = \frac{(Total\, transmitted\, packets - Total\, received\, packets)}{Total\ transmitted\ packets} \tag{3}$$

4. RESULT AND DISCUSSION

We measured the performance of some topology-based routing protocols: AODV, DSDV, and OLSR in VANET using robust simulation software such as NS3.33 and SUMO. The simulation metrics measured are throughput, overhead, and PLR. The speed of the vehicles is fixed at 20 m/s, and in each simulation, we varied the number of vehicles from 25, 50, 75, 100, and 125.

Figure 8 shows the throughput comparison. The simulation result shows high values for the OLSR protocol in a vehicular network with less than 60 vehicles. However, if a network contains more than 60 vehicles, the throughput obtained by the AODV protocol is greater than the other two protocols. The DSDV protocol has minimum values during all the simulation time.

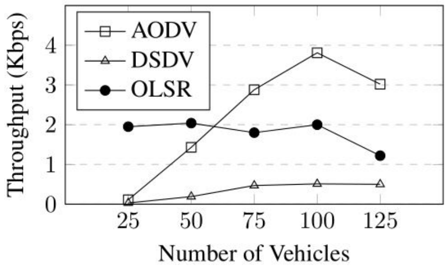

Figure 8. Throughput analysis of routing protocols by varying the number of vehicles in the VANET scenario

Figure 9 shows the comparison results of the overhead metric in VANET. When the network contains a large number of vehicles (in our simulation more than 75 vehicles) we observe minimum values in the case of the OLSR protocol and this means that the performance of OLSR protocol is better in terms of overhead. However, in the case of a vehicular network containing a minimum number of vehicles (less than 75 vehicles), it is the AODV protocol that works well. The DSDV protocol shows higher values especially in a VANET that exceeds 50 vehicles which means a higher overhead rate compared to the other protocols (AODV and OLSR).

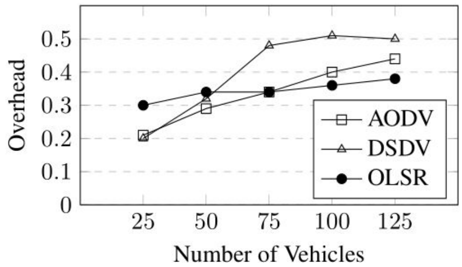

Figure 9. Overhead analysis of routing protocols by varying the number of vehicles in the VANET scenario

Figure 10 presents the results of the PLR metric comparison. In a vehicular network containing less than 120 vehicles, the OLSR protocol gives minimum values compared to the AODV and DSDV protocols. For this last protocol, the number of lost packets is maximum. The results obtained show that the OLSR protocol has the lowest PLR compared to the other protocols (DSDV and AODV) Figure 10. This packet loss rate decreases as the number of vehicles increases except for the last case where the number of vehicles is 125. To understand the cause behind this change, we have visualized the mobility of the vehicles (distribution vehicles on the map see Figures 11, 12, 13, 14, and 15) and we can clearly see in Figure 15 that the two vehicles 118 and 103 are away from other vehicles. Given the technology used at the physical layer (IEEE802.11p), these two nodes are hidden nodes (see Figure 16) and cannot receive or send data from and to other nodes. Consequently, all the packets transmitted from these nodes or sent towards these nodes will be lost and this will imply an increase in the rate of lost packets. the same remark applies to the figure relating to the AODV protocol. Knowing that during the simulation, communication takes place in broadcast mode and that a packet broadcast by a vehicle and not received by one of the network vehicles is considered lost, the number of packets lost at each transmission tower because of the Hidden Node issue related to the scenario in Figure 16 is: 2*123 (sent from these nodes to the rest of the network),123*2 (sent from other network nodes to nodes 103 and 118). This gives us a total of 492 packets lost per transmission tower which are not due to the routing issue. The same problem also appeared on Figures 11 and 12 except that the number of reduced vehicles does not have a great influence on the final results. In Figure 8, we can clearly see that this problem has also affected the transmission rate, whether for the OLSR or AODV protocol.

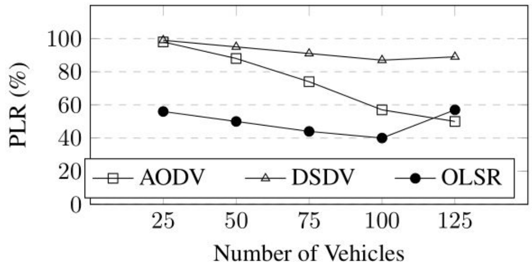

Figure 10. PLR analysis of routing protocols varying vehicles numbers for VANET scenario

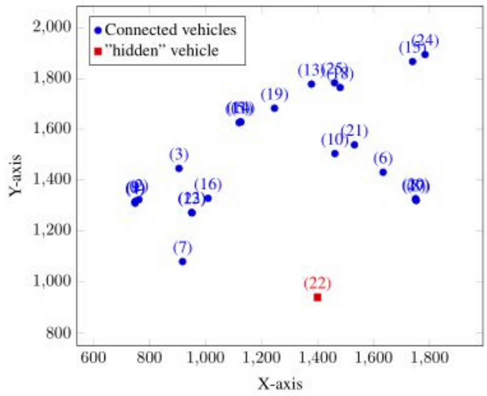

Figure 11. The mobility of 25 vehicles in the simulation scenario

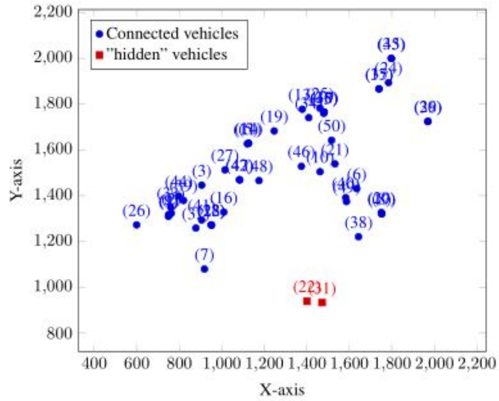

Figure 12. The mobility of 50 vehicles in the simulation scenario

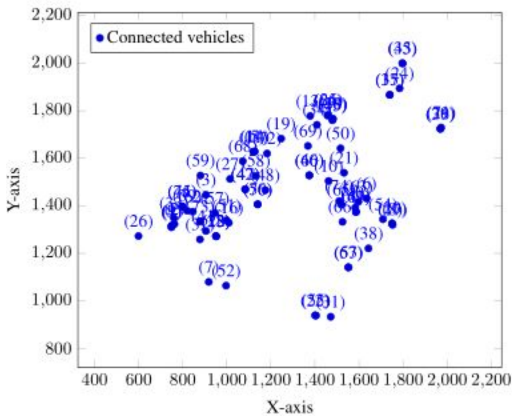

Figure 13. The mobility of 75 vehicles in the simulation scenario

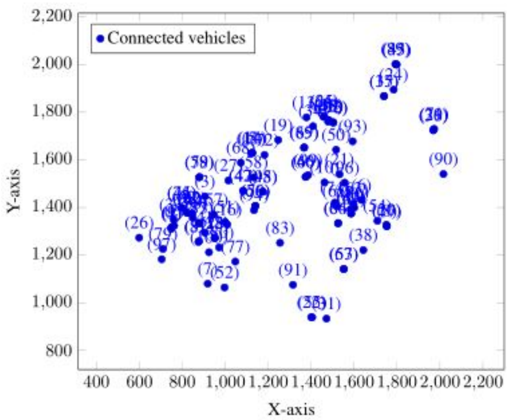

Figure 14. The mobility of 100 vehicles in the simulation scenario

The evaluation of topology-based routing protocols in a vehicular network requires a comparison of a set of metrics. In this paper, we have evaluated three essential metrics: throughput, overhead, and packet loss rate. For a protocol X to be efficient in a VANET, it must obtain maximum values in terms of throughput, and minimum values in terms of overhead and packet loss rate. For the different types of simulations performed, the results do not show a 100% efficient routing protocol. The OLSR protocol performs better in terms of PLR, throughput (in a vehicular network with a density lower than 50 vehicles) and overload (when the number of vehicles exceeds 75 vehicles). However, the AODV protocol performs better in terms of throughput especially in a VANET with more than 60 vehicles, and in terms of overhead when the number of vehicles is less than 50. The DSDV protocol is not recommended for vehicular networks because it shows poor results.

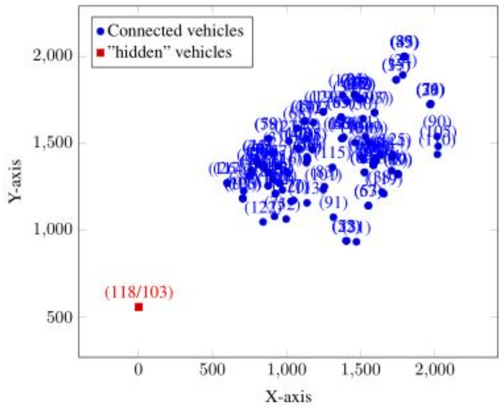

Figure 15. The mobility of 125 vehicles in the simulation scenario

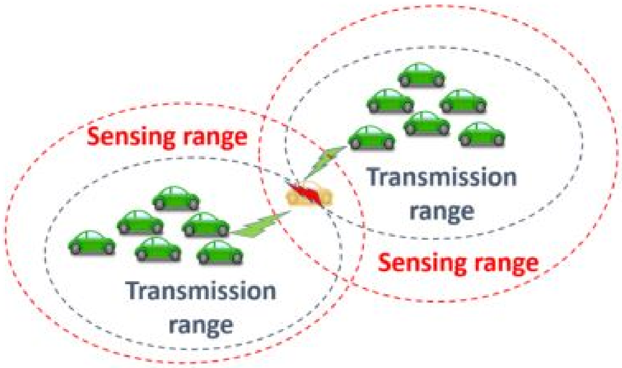

Figure 16. The hidden node problem

It remains to be noted that in the case of the OLSR protocol, the number of hops is limited to two, which will influence the connectivity of the nodes in the case of an extended (wide) network. Even in the case where there are no isolated nodes, the nodes can be considered isolated from each other in the case where the distance between them exceeds twice the maximum coverage distance of the er IEEE802.11p protocol. This may explain why the AODV protocol is suitable for large-scale networks while OLSR provides high performance in small-scale networks. The good performance of the OLSR protocol is due to the use of communication through the MPRs (one at most between each two communicating nodes) which reduces radio emissions in a network and consequently reduces interference. Based on this observation, we are going to try to propose an architecture for VANET networks which takes this remark into account and which allows the different vehicles to communicate with each other, based, if necessary, on the infrastructure made available to them.

5. CONCLUSION

This contribution presents a performance study of the three routing protocols: AODV, DSDV, and OLSR in VANET scenarios. We started by presenting the new classification of Ad-hoc networks. Subsequently, we presented the VANET architecture and discussed the use of some topology-based routing protocols used in MANET to enhance routing services in VANET. After that, we cited a set of related works, and finally, we presented the measured metrics and the process of comparing the performance of these three routing protocols in VANET scenarios using SUMO and NS-3 simulators. The simulation results indicate that the OLSR protocol is performing in terms of packet loss rate. However, the AODV protocol is efficient in terms of throughput especially when the number of vehicles exceeds 60. For the network overhead metric, OLSR is preferable in a vehicular network that exceeds 75 vehicles and AODV is better for a network lower than 75 vehicles. The DSDV protocol is not recommended for VANET. In future work, we will evaluate the performance of the vehicular networks in another city trying to deepen our study by studying each protocol in detail (for example the influence of the number of MPRs and the distance between vehicles for the case of OLSR) and also consider improving the OLSR protocol. In this sense, we will try to offer an intelligent solution using artificial intelligence, deep learning, and/or machine learning algorithms in the closest path determination part using estimation instead of exact calculation.

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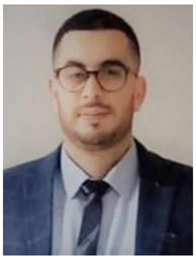

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