Performance evaluation of VANETs routing protocols using SUMO and NS3

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***Abstract*—Vehicular Ad-hoc network (VANET) is a self-organized ad hoc network, in which each vehicle, equipped with On Board Unit (OBU), participates in routing by forwarding data for other nodes. VANETs become a really hot topic and a challenging research field as it has several issues related to security, quality of service, routing protocols, etc. Although the big challenge in VANET is to design a routing protocols more suitable to route packets efficiently to their final destination, in spite of the high speed of vehicles, frequent disconnection and the highly changeable topology. This paper presents and analyses, the impact of vehicle density on the performance of the most well-known routing protocols. Quantitative metrics like overhead, packet delivery ratio, average throughput and average end to end delay are evaluated using the Network Simulator NS-3 and SUMO.**

***Keywords*-VANETs, routing protocols, NS3, SUMO;**

I. Introduction

Vehicular Ad Hoc Network (VANET) is a subclass of Mobile Ad-hoc Networks, which can be defined as a set of mobile nodes consisting of vehicles equipped with wireless transceivers, called OBUs (On Board Units), in order to collect, compute, receive and transmit information to other nodes. In VANETs each vehicle has the ability to communicate information either among each other through vehicle to vehicle communication (V2V) or directly to an external base station called Road Side Unit (RSU) through vehicle to infrastructure communication (V2I) [1][2].

VANET has its own unique characteristics [2] [3] [4] when compared with other types of Mobile Ad Hoc Networks (MANETs) that influence the design of the communication system and its routing protocols. The unique characteristics of VANET include:

High Dynamic Topology: The topology in VANET varies quickly depending on the speed of vehicles.

Different Communication Environment: The traffic condition differs from city to rural environment, which is simple in rural environment and complex in city due to obstacles like building trees and others.

Variable network density: The traffic density in VANET is not identical during the day and in all types of environments.

Frequently disconnected network: Due to the high speed of vehicles, VANETs will not have constant connectivity.

Hard delay constraints: Most of applications in VANET require the minimum delay than the high data rates.

At the last years, VANET has attracted a huge number of research in various area such as security, quality of service, Media Access Control and others, covering both V2V (vehicle-to-vehicle) and V2I (vehicle-to-Infrastructure) communications [1][2].

One particular area of VANET that still faces critical difficulties is the design of efficient and robust routing protocols for V2V communications [5], which could be divided into four groups [4] [6] as it is shown in the Fig. 1.

The main purpose of this paper is to analyze and compare five of common routing protocols over an urban scenario (Hay El qods Oujda-Morocco) in order to provide a better understanding of these protocols and their behaviors.

The remaining description of this paper is systematically arranged as follows: Related works are briefly discussed in section 2. Routing protocols for VANET are explained in section 3. In section 4, we describe the studied routing protocols. Then section 5 describes the simulation setups. The simulation experiment and results analysis are introduced in Section 6; finally, Section 7 concludes the paper and presents some future works.

II. Related works

There are some previous works in the literature that have compared and analyzed the performance of topology based routing protocols before. However, the research community feels the need of a systematic comparison and performance evaluation study that help to evaluate the performance of these protocols in VANET environment. There are few works that compare topology based and position based routing protocols in VANET environment.

In [7] authors analyzed the performance of OLSR and AODV protocols in a VANET crossroad simple scenario. They used CAVENET to generate the movement of the vehicles and NS3 to test the performance of routing protocols. Their results showed that OLSR performs better than AODV for high values of transmission rates.

In [8] authors have analyzed AODV, DSDV, AOMDV and DSR under NS2.34 by varying the velocity of vehicles. Their results showed that DSR is better in case of the end to end delay and throughput. Whereas in case of PDR (Packet Delivery Ratio) and packet loss, AOMDV and AODV showed better performance.

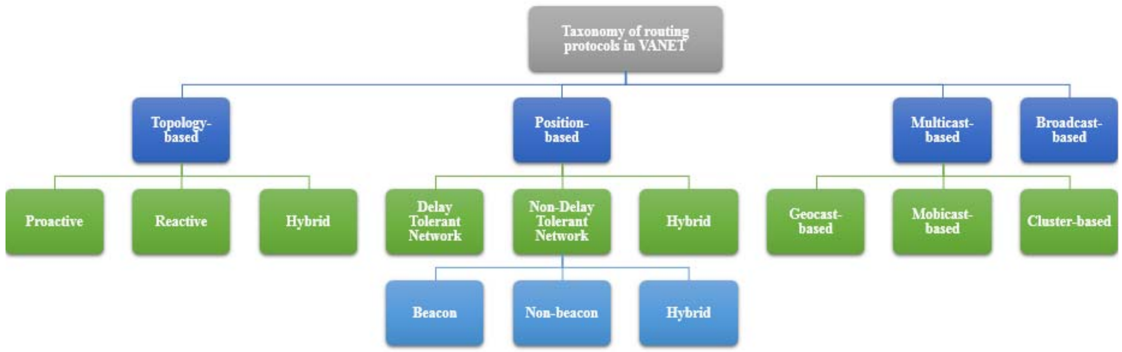

Figure 1. Taxonomy of routing protocols in VANET

Authors in [9], compared the performance of AODV, DSDV and OLSR on an urban environment by using NS-3 and VanetMobiSim as tools. The simulations showed that the OLSR protocol outperforms the other studied protocols in term of PDR, end to end delay and routing overhead.

In [10] authors have analyzed the performance of AODV and GPSR routing protocols in VANET under various scenarios, by using NS-2.35 in combination with VanetMobiSim, with respect to Packet Delivery Ratio (PDR) and average End-to-End Delay (E2ED). The simulation showed that AODV performs better with respect to PDR and GPSR outperforms AODV in case of E2ED. Also, the performance of AODV and GPSR is improved by the use of IEEE 802.11p instead of IEEE 802.11.

The work in [11] compared the performance of two position based routing protocols, namely, Greedy Perimeter Stateless Routing (GPSR) and Greedy Perimeter Coordinator Routing (GPCR). They used VanetMobiSim and NS-2 as simulation tools. The simulations showed that GPCR performs better than GPSR under varying the speed, the density and the transmission ranges of vehicles.

Our work in this paper is different from the previous works in many aspects. We focused on modeling a real VANETs mobility details to evaluate the performance of AODV, DSDV, OLSR, GPSP and GPCR. We extract a part of a real road map of Oujda city from Open Street Map, instead of considering a random map or grid map, then generate a mobility and traffic files from SUMO and taken it as input to NS3 for further analysis of network performance.

III. Routing protocols in VANETs

Routing protocols in VANETs govern the way in which the mobile nodes (vehicles) route packets to exchange desired information in considerable amount of time. They could be splitted into four major categories.

A. Topology-based routing protocols

In Topology-based routing protocols, to transmit data packet from source to destination, the link information that exists within the network is used. This category of routing protocols could be subdivided into three main types: Reactive or on demand protocol like AODV, Proactive such as OLSR and DSDV or table driven protocol and Hybrid protocol like ZRP.

1) Proactive routing protocols: In this routing protocols routes to destination are available immediately, because each node updates its routing table periodically and each time the network topology changes regardless of whether the paths are unused currently. This technique may occupy a significant part of the bandwidth and requires an important memory and processing.

2) Reactive routing protocols: The routes in reactive protocols are established only on demand and only those that are being used are kept up. In this case, an extra delay is required at the beginning of each session to look for the path to the destination.

3) Hybrid routing protocols: Hybrid routing protocols is a combination of reactive and proactive protocols which make them more effective.

B. Position-based routing protocols

Those protocols [12] [13] requires the availability of a location service like a GPS (Global Position System) that provide the physical position information of vehicles in the road. Those information are needed to make decision to route packets to their final destinations. The position-based routing can be splitted into three types, namely, Delay Tolerant Network (DTN), Non-Delay Tolerant Network (Non-DTN) and hybrid position-based routing.

1) Routing protocols for DTN: Based on many studies, researchers have been concluded that routing protocols for DTN overcome the problem of frequent disconnectivity, which results in a lack of instantaneous end-to-end paths. Thanks to the use of carry-and-forward technique, which means when any node loses the connection with other nodes it stores the packet and forward it when another vehicle moves into its vicinity.

2) Routing protocols for Non-DTN: The non-DTN routing protocols are based on the greedy approach, which means forwarding the packet to the neighbor nearest to the destination. However, the transmission could failed if a node does not discover any neighbors nearest to the destination than itself. The non-DTN protocols could be splitted into beacon, beaconless, and hybrid protocols.

3) Hybrid position-based Routing protocols: The hybrid position-based routing protocols combine both non-DTN and DTN to resolve the frequenlty disconnection problem in VANET.

C. Multicast-based routing protocols

In multicast-based routing protocols, the packet is transmitted from a single source to all multicast members by using multi-hop communication. Those protocols can be divided into three categories, namely, geocast-based, Mobicast-based and cluster-based protocols.

D. Broadcast-based routing protocols

In broadcast-based routing protocols the packet is forwarded from a single source to all vehicles in the network. Those protocols are generally used in VANET for sharing road conditions, traffic, weather and emergency event among vehicles.

IV. DESCRIPTION OF STUDIED ROUTING PROTOCOLS

This section reviews and describes the studied routing protocols which include: the Ad-hoc On-Demand Distance Vector (AODV) routing, the Destination-Sequenced Distance Vector (DSDV), the Optimized Link Stat Routing (OLSR) the Greedy Perimeter Coordinator Routing (GPCR) and the Greedy Perimeter Stateless Routing (GPSR) algorithms. We note that the OLSR and DSDV protocols can be categorized into the topology based under proactive routing whereas AODV protocol under reactive routing then the GPSR and GPCR protocols are the position based routing protocols.

A. DSDV (Destination-Sequenced Distance Vector)

DSDV [14] [15] is a proactive routing protocols, in which each node updates its routing table with a purpose to have a route for each destination in the network at all times even if the paths are unused currently.

In spite of the advantages of DSDV such as the simplicity, the loop free and no delay time caused by route discovery. The DSDV still suffer from the overhead due to the periodic updates caused by the highly changeable topology of the networks.

B. Optimized Link Stat Routing (OLSR)

In OLSR [16] each node periodically broadcasts its routing table. This allows each node to construct a global view of the network topology. OLSR uses the concept of Multi point Relays (MPR) for relaying control traffic, which reduce the overhead from flooding of control traffic by using only selected nodes, and optimize the broadcast procedure.

C. Ad-hoc On-demand Distance Vector (AODV)

In AODV [17], routes are established only on demand and only those that are in use are maintained. In this case, an additional delay is required at the beginning of each session to search for the path. In AODV, to find out the path to the destination, the source node will send to all its neighbors a route request packet RREQ, after that its neighbors broadcasts the RREQ to their neighbors and so on until it reaches the destination or any intermediate node that possesses a fresh information about route to the destination requested. In this case, the intermediate node will reply by unicasting a RREP.

AODV has the advantage of reducing the number of routing packets exchanged since the routes are created on demand and uses the principle of sequence number to avoid routing loops and keep the fresh route. However, the route discovery process causes significant delays before data transmission. Which is not convenient to VANET in the case of an urgent hazardous information.

D. Greedy Perimeter Stateless Routing (GPSR)

GPSR [18] requires the availability of the physical position information of the participating nodes by using a location service like a GPS (Global Position System). In GPSR, A node uses the greedy forwarding approach to transmit data. When the greedy forwarding approach fails, the perimeter forwarding approach is applied for selecting a node through which a packet will travel.

GPSR has many advantages, to forward a packet, a node needs to remember only one hop neighbors location. But for high mobility characteristics of node, stale information of neighbors position are often contained in the sending nodes neighbor table.

E. Greedy Perimeter Coordinator Routing (GPCR)

GPCR [19] uses a restricted greedy forwarding mechanism and repair strategy which is based on junctions where actual routing decisions are taken. Therefore packets must be transmitted to a node at a junction, then the junction node transmits packet to the neighbor which has the shortest distance to destination. The main advantage of GPCR is that it does not require any global or external information, it depends only on junction nodes. However, GPCR assumes that there is always a node at a junction, which does not always hold.

V. SIMULATION SETUPS

The simulation was carried out under the operating system Ubuntu 14.04 by using the NS3 [20] version 25 as network simulator, combining with SUMO 0.25 [21] as road traffic simulator. As shown in Fig. 2, we use a real-world urban map downloaded from the Open Street Map [22] for a part of Oujda (Hay al quds) city Morocco. The code used to evaluate

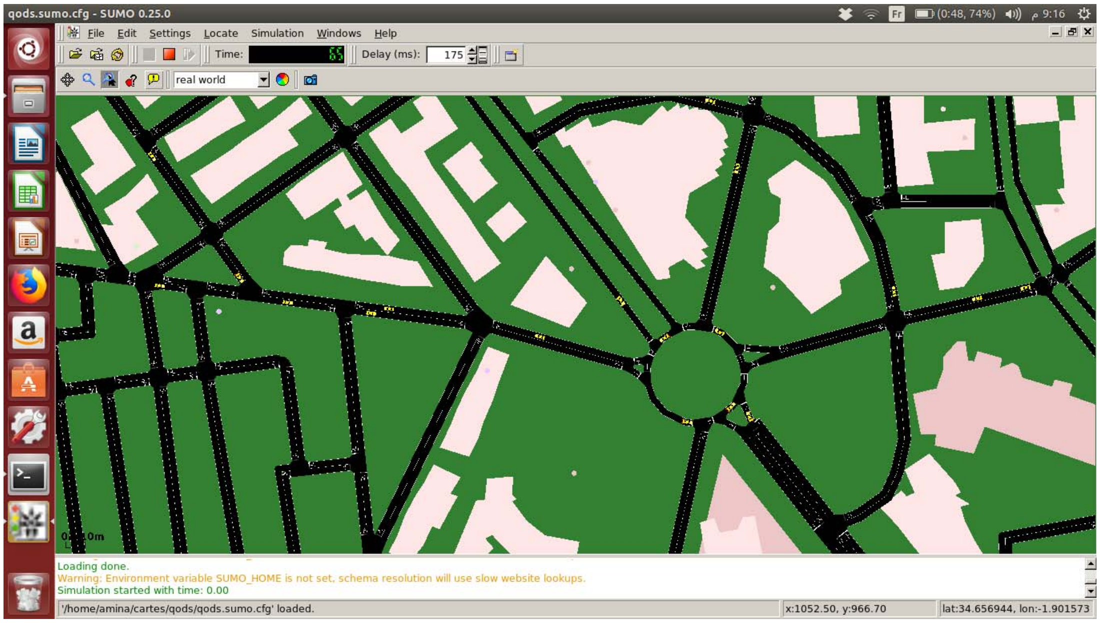

Figure 2. Hay-Alquds-Oujda-Morocco

the performance of routing protocols was implemented in C++ code and integrated into NS3.

The simulation was setup to evaluate the performance of the routing protocols (AODV, DSDV, OLSR, GPCR and GPSR) under varying node density (20,30,...,90). In the simulation, we use IEEE 802.11p as a model for the data link layer. We assume that the transmission power of all nodes in the network is 20 dBm and that the transmission range is 145m as it is shown in Table I.

Table I
SIMULATION CONFIGURATION

Parameters	Value
Simulator	NS3.25
Number of nodes	20, 30, 40, 50, 60, 70, 80, 90
Simulation time	100 s
Simulation area	1.7km *1.5 km
Packet size	512 bytes
Data type	CBR (Constant Bit Rate)
Transport protocol	UDP
Maximum Speed	20m/s
Propagation model	Two Ray Ground
Mac layer	IEEE 802.11p
Transmission range	145m
Transmission power	20 dBm

VI. RESULTS AND DISCUSSION

A. PDR

PDR represents the percentage of successful transmissions; it is the ratio of the total data bits received to total data bits sent from source to destination.

$$PDR = \frac{PacketsReceived}{PacketsTransmitted}$$

The first graph in Fig. 3, shows that when the density of nodes increases, PDR increased in both DSDV and OLSR routing protocols. Whereas, in the AODV routing protocol

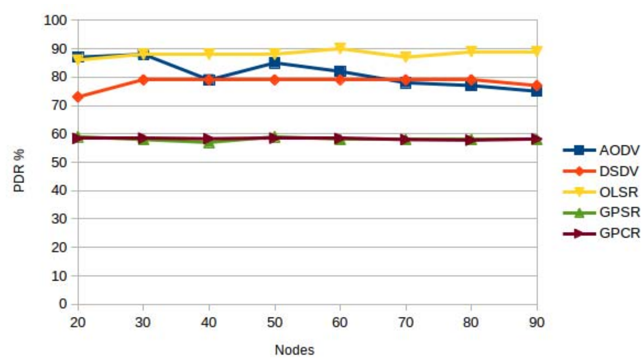

Figure 3. PDR Vs number of nodes

PDR decreases when density increased, and it stays stable in the case of GPCR and GPSR routing protocols. The results we have for GPSR and GPCR, could be justified by the involvement of a large number of radio obstacles in the urban scenario which increase the possibility of getting the problem of local maximum. In addition to that, the number of hops increases in perimeter mode which could affect negatively the PDR of GPSR and GPCR protocols. In case of OLSR, it could maintain its performance better than other routing protocols, because it uses the MPR mechanism which is helpful against larger and dense network.

B. Average End-to-end Delay

The average End-to-end Delay represents the required time needed to transmit data to the destination per the number of successfully delivered packets.

$$E2ED = \frac{\sum_1^n ReceptionTime - SendTime}{ReceivedPackets}$$

Based on the results in Fig. 4, it can be concluded that OLSR has the highest E2E delay. However, GPSR and GPCR have the lowest delay even if the node density increases, which could be explained by the use of the greedy technique that choose the closest neighbor to the destination. Therefore, the number of hops and the time taken to route packets efficiently to the final destination is reduced. It is also apparent that performance of AODV are better than DSDV and OLSR in low node density, but when the node density increase, DSDV performs better than AODV and OLSR. For AODV, the result could be explained by the fact that it makes a path request only when a node has something to send, which introduces extra delay that is showed when the number of nodes increase.

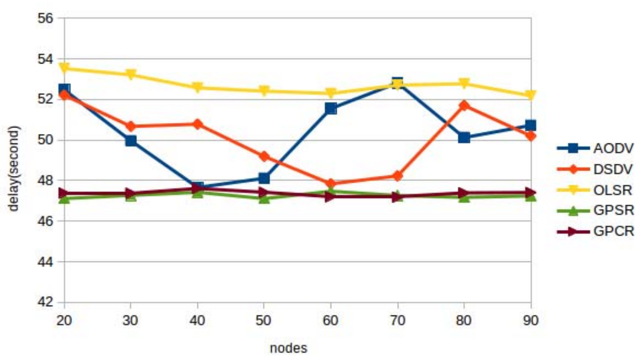

Figure 4. Delay Vs number of nodes

C. Throughput

Throughput, usually measured in kilobits per second, represents the total number of bytes successfully transmitted through the network. Routing protocols should maximize network throughput as this would represent more data successfully routed through the network.

$$Throughput = \frac{NumberOfReceivedPackets}{TotalSimulationTime} * PacketSize$$

In the graph of Fig. 5, we can observe that throughput of OLSR is better than DSDV and AODV which, decrease when the density increase. This could be explained by the fact that DSDV broadcasts the entire routing table after fixed interval of time which introduce extra overhead and that affect its throughput. The result given in case of OLSR, which reach 18kbps, could be thanks to the use of MPR mechanism that reduces routing overhead. Whereas GPSR and GPCR have the lowest throughput in comparison with other three protocols.

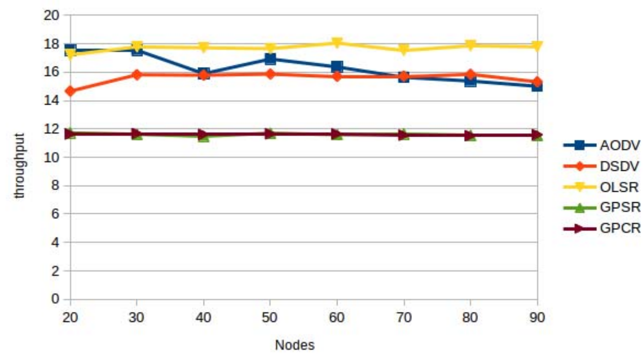

Figure 5. Throughput Vs number of nodes

D. Overhead

Overhead refers to additional bits added in the packet with the actual message at MAC and physical layer so that the message will be understable by the receiver. If the overhead is low, less number of bits is required for information other than the actual data, which clearly means more data bits can be sent in a packet.

$$Overhead = \frac{totalPhyBytes - totalAppBytes}{totalPhyBytes}$$

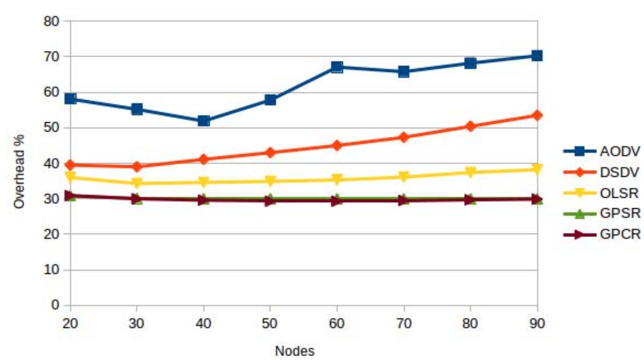

Figure 6. Overhead Vs number of nodes

In terms of control overhead the GPSR and GPCR protocol have less control overhead in comparison with other protocols as shown in the graph of Fig. 6. Indeed, GPSR is based on the location of the destination which is carried in the packet so that the retransmitting nodes do not need to use the location service again and that reduce the overhead. The AODV has highest control overhead, because it broadcasts a large number of control message packets to maintain the route.

VII. Conclusion

The article evaluates and compares the most well-known routing protocols for VANETs, using SUMO and NS-3 simulators, to determine the benefits and challenges of each algorithm. From the above research work, performance of OLSR could be considered as the best one for this scenario in terms of PDR and throughput. Whereas GPSR and GPCR are the best two routing in case of overhead and E2E delay. Indeed, GPSR and GPCR are based on the location of the destination which is carried in the packet so that the retransmitting nodes do not need to use the location service again and that reduce the overhead.

The field of routing protocols in VANET is a hot research topic, many related open issues still need to be resolved. As a future work, we will consider more metrics that affect network performance, such as the model of propagation, the size of the map, and so on. We trust that the instrument presented in this paper to be useful and pleasing to students and researchers in the field.

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