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Comparative Study of Ad Hoc Routing Protocols in Vehicular Ad-Hoc Networks for Smart City

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***Abstract*—**In this paper, we perform the investigation of some routing protocols in Vehicular Ad-Hoc Network (VANET) context. Indeed, we study the efficiency of protocols like Dynamic Source Routing (DSR), Ad hoc On-demand Distance Vector Routing (AODV), Destination Sequenced Distance Vector (DSDV), Optimized Link State Routing convention (OLSR) and Vehicular Multi-hop algorithm for Stable Clustering (VMASC) in terms of packet delivery ratio (PDR) and throughput. The performance evaluation and comparison between the studied protocols shows that the VMASC is the best protocols regarding fast data transmission and link stability in VANETs. The validation of all results is done by the NS3 simulator.

***Keywords*—**VANET, smart city, AODV, OLSR, DSR, OLSR, VMASC, routing protocols, NS3.

I. Introduction

RESEARCH on vehicle networks or inter-vehicular communications [1] began in Japan in the early 1980s with the Association of Electronic Technology for Automotive Traffic and Driving. Indeed, with the rapid development of wireless technologies, the number of publications in the field of vehicle networks has increased rapidly.

Vehicle networks are an emerging technology integrating the latest communication techniques. Each node of the network is a vehicle equipped with one or more wireless radio interfaces. Vehicles communicate with one another thanks to this equipment. A network of vehicles provides, along the route, connectivity to the outside world via gateways to other networks and inter-vehicle communication for intelligent vehicles.

The objective of the VANET networks [2] is to provide drivers and transport users with information on the state of road traffic, improving the efficiency of transport systems and ensuring the comfort and safety of users. Vehicle networks are a projection of Intelligent Transportation Systems (ITS) [3]. They have witnessed a great growth since their appearance. A lot of standard applications and routing mechanisms have been developed to contribute to the improvement of this new class of networks. In these networks, the collection of information can be done through different categories of sensors that can be fixed in a car, which offers the driver a lot of information and a better visibility of the road scene. A VANET provides communication between vehicles and road side units [4]. A new concept has recently appeared as smart cities [5], [6] that include intelligent traffic management, where VANETs play an important role.

Our simulation is based on the use of a Network Simulation (NS3) [7] tool utilizing realistic mobility traces of a Simulation of Urban Mobility (SUMO) [8] tool in order to compare the performance of vehicular routing protocols with node density effects for smart cities [9].

The rest of the paper is organized as follows. Section II includes the VANET characteristics. The classification and descriptions of routing protocols are presented in Section III. Section IV gives comparative details as regards the throughput and the PDR as well as the results of the analysis part of our work. Section V concludes the paper.

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II. VANET Characteristics

As a subclass of Mobile Ad hoc Networks (MANETs) [10], vehicular networks represent specific characteristics. Moreover, vehicular networks are characterized by the high mobility of nodes linked to the high speed of cars, which makes the links between the vehicles too dynamic and unstable. This explains the hugely variant topology of vehicular networks. In this section, we present some properties and constraints concerning this type of network.

A. Topology and Connectivity

Like the MANETs, the VANETs are characterized by sporadic connectivity [11], [12], because a vehicle can join or leave a group of vehicles in a very short time due to high node mobility and speed, which leads to having a very dynamic topology.

B. High Mobility

Several factors can affect mobility in such networks [13] as road infrastructure, for example roads and highways. In addition, mobility in VANETs is directly related to the behavior of drivers and their responses to different and complex encountered obstacles or situations like accidents and traffic jams.

C. Predictable Mobility

A vehicle is forced to follow the path of the road. This predictable mobility makes it possible to predict the position and the displacement of a vehicle in the future [14].

D. Frequent Disconnected Network

The density of a vehicle network varies greatly. A high density of vehicles allows the network to be connected, and therefore there is always a path between two nodes that wish to communicate. Conversely, a low density of vehicles results in a high rate of communication disruptions, a longer delivery time if the vehicle keeps the packet, or even the impossibility for two vehicles to communicate.

E. Energy and Storage Capacity

Contrary to the context of MANETs, where energy constraints represent a challenge for researchers, the elements of the VANET have enough energy that can power the various electronic equipment of a smart car [15]. Thus, the nodes are supposed to have a large capacity for data processing and storage.

III. Routing Protocols for VANETS

The objective of a routing protocol is to establish routes between groups of nodes in order to ensure a continuous and efficient exchange of packets [16]. This protocol must take into account changes in the network topology, as well as other characteristics such as the bandwidth, the number of links, the energy limitation, the PDR and the throughput. With the emergence of these latter, a great deal of research has been carried out, especially in the field of routing. This research has developed several routing protocols.

There are several criteria for designing and classifying routing protocols in ad-hoc networks: How is routing information exchanged? When and how are routes computed?

In order to present the main routing protocols in VANETs, we have chosen to start by classifying the different protocols existing in the literature into two main families, as illustrated in Fig. 1.

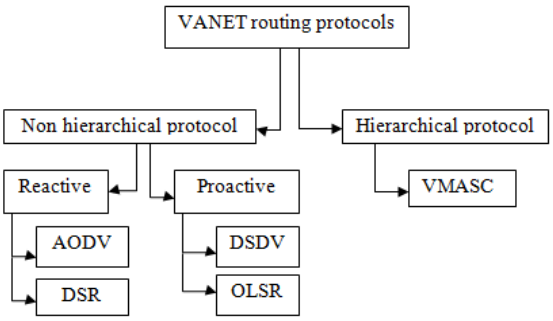

Fig. 1 General classification for routing protocols

A. Non-Hierarchical Protocols

Non-hierarchical protocols are broadly categorized into two types: reactive routing protocols and proactive routing ones.

1. Reactive Routing Protocols

On-demand driven protocols [17], the path is calculated only on demand, and the routing operation involves two steps: the route discovery of data routing toward a destination and the maintenance of existing routes for a changing network topology. We give in what follows two examples of reactive routing protocols:

DSR: It [18] is based on the use of the source routing technique and it allows the network to be managed and configured an infrastructure. In this technique, the source determines the complete sequence of nodes through which the data packets will be sent.

Before sending a data packet to another node, the sender broadcasts a Route Request (RREQ) packet. If the route discovery operation is successful, the transmitter will receive a Route Reply (RREP) packet that contains a sequence of nodes through which the destination can be reached.

AODV: It [19] is a reactive protocol that essentially represents an improvement of the DSR algorithm. It reduces the number of message broadcasts by creating routes when needed. It maintains these routes as long as they are necessary for the source nodes. This protocol uses a sequence number in order to consider the different roads to have update roads and it builds roads by utilizing a RREQ/RREP cycle. When a source node wishes to establish a route to a destination for which it has not had a route yet, it sends an RREQ packet through the network. The nodes receiving this packet update their source information and establish pointers back to the source in the routing tables. A node receiving an RREQ packet will then issue an RREP packet if it is the destination or if it has a route to the destination with a sequence number greater than or equal to that taken from the RREQ packet.

2. Proactive Routing Protocols

In table-driven protocols, each node maintains one or more tables that contain routing information for all destinations [20]. This category of protocols requires a periodic exchange of control packets between the different nodes to maintain the routing tables.

DSDV: It [21] is a table-driven routing scheme based on the classic idea of Bellman-Ford's distributed algorithm which has been modified to adapt to ad hoc networks. As it is a proactive protocol, each node has, at every moment, a complete view of the network. To do this, each node retrieves the distances separating it from every other node of the network and keeps only the shortest path. This is done through periodic exchanges of information on their respective routing tables. These exchanges are classified into two types:

- Incremental updates for which only data that have had changes since the last update are sent.
- Full dump for which the entire routing table is sent.

OLSR: It [22] is a proactive protocol with a link state. The OLSR makes some improvements on the basic principle of the link state in order to achieve better performances in an ad hoc context: it minimizes the flooding of the network by reducing redundant retransmissions in the same region of the network and it reduces the size of packets being exchanged. To do this, the OLSR relies essentially on the notion of a Multi-Point Relay (MPR), which is a subset of one-jump neighbors. This MPR allows reaching all neighbors with two jumps. Thus, during a broadcast, all neighbors receive and process the message, but only the nodes chosen as MPRs retransmit it, hence considerably reducing the number of messages sent in a network.

B. Hierarchical Protocol

The ad hoc vehicle network suffers from discontinuous connectivity and limited capacity. The VANET hierarchy provides solutions to these problems. This approach is well suited to the VANETs because the dynamics of vehicular traffic leads to the formation of groups at intersections or convoys on a highway.

In the VANETs, the grouping criteria must take into account the particular dynamics of vehicle mobility like the VMASC [23] in VANETs. This protocol is based on the clustering technique. It calculates the least mobility between the current node and their neighbors based on the average of the relative speed of all vehicles in the same direction. It uses the notion of aggregated mobility to choose Cluster Heads (CHs) that select other CHs to forward packets.

All nodes in a cluster can communicate with the CHs in a number of hops. By creating clusters of vehicles, the VMASC can maintain the link stability and ensure rapid data transmission, so we can control management functions and resource sharing in VANETs which are highly dynamic.

In the following section, we will evaluate the performance of the representative protocols of these classes through simulations.

IV. Comparative Study of VANET Routing Protocols

A. Parameter Settings

As an initial evaluation, we implement all related modules under the NS3 simulator in order to test their performance. To simulate reality as much as possible, we use a model with several node densities for a smart city scenario.

TABLE I
SIMULATION SETUP

Platform	Ubuntu14.04 LTS
NS version	NS-allinone-3.26
SUMO version	Sumo-0.19
Simulation time	300 s
Topology size	3000 x 4000 m
Routing protocols	AODV, OLSR, DSR, DSDV, VMASC
Data type	CDR (Constant Data Rate)
Data packet size	512 bytes
MAC protocol	IEEE 802.11 p
Transmit power (dB)	7.5

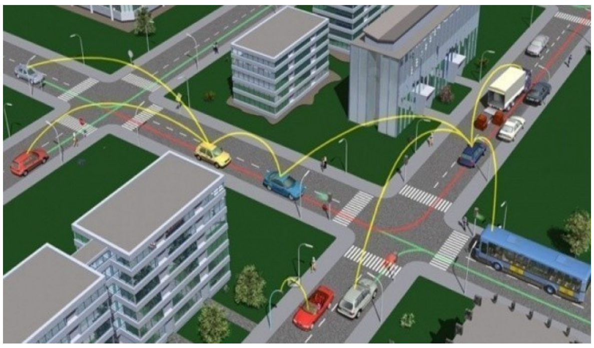

Fig. 2 Representative figure of geographical area and some cars [24]

As depicted in Fig. 2, N vehicles move at a speed of 44 mph and communicate in an area of 3000 x 4000 m in a suburban section of Ariana, Tunisia. Table I lists the details of the simulation setup used in this comparative study.

We evaluate the PDR and the throughput using these settings in three different densities: Case 1: Low density using 20 vehicles Case 2: Medium density using 40 vehicles Case 3: High density using 80 vehicles.

For each of the above cases, five routing protocols are investigated, which are the AODV, the OLSR, the DSR, the DSDV and the VMASC.

B. Simulation Scenarios

Our comparison aims to analyze the performance of the PDR parameter, which is the fraction of successfully received data packets by the total number of sent data packets. It represents the network ability for transporting the network packet load. It is one of the most important parameters of the quality of service.

The usual calculation of this measurement system is in percentage (%) of the relative amount. A high rate identifies the improved reliability of the routing protocol as follows:

$$PDR = Received\ Pkts / Sent\ Pkts$$

The throughput is measured as bytes or kbytes per sec (byte/s | kbp/sec) and defines the rate at which information is sent through the network; i.e. it is a measure of how fast a protocol can actually send data through a network. Consequently, it shows successful deliveries of a protocol as a function of time. Thus, the protocol with the highest throughput is better. It can be calculated as follows:

$$Throughput\ (kbps) = Size\ of\ received\ packets / (simulation\ start\ time - simulation\ end\ time)$$

1. First Case (20 Vehicles)

The performance of the AODV, DSR, OLSR, DSDV and VMASC routing protocols shows some differences in low, medium and high node densities. In a low density (20 nodes), we see in Fig. 3 (a) that the VMASC possesses a higher throughput with pause times. It reaches 650 kbps during 300s higher by 50 kbps compared to OLSR. The values for the AODV, the DSDV and the DSR are under 250 kbps.

However, the VMASC high value is caused by intra-cluster and inter-cluster communication. For the same scenario, the DSDV, the DSR and the AODV have a lower PDR since they perform poorly when mobility is high, and it is caused by the use of different approaches for route maintaining compared to VMASC and OLSR as presented in Fig. 3 (b).

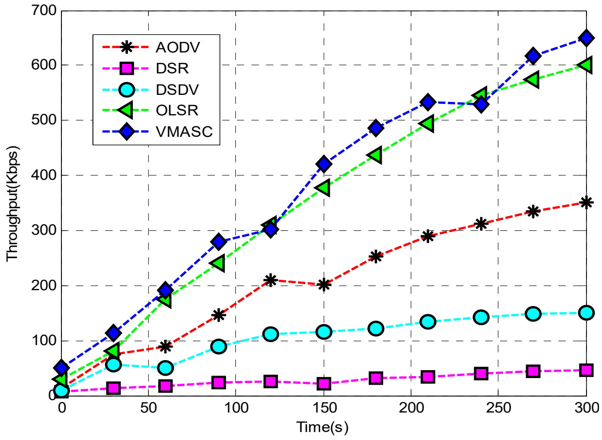

Fig. 3 (a) Throughput vs time for low node traffic (20 vehicles)

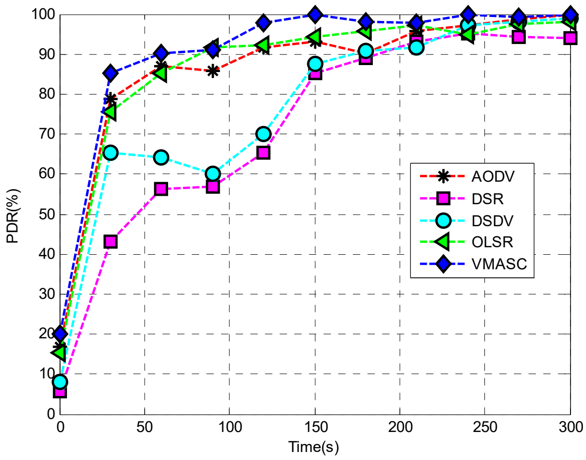

Fig. 3 (b) PDR vs time for low node traffic (20 vehicles)

2. Second Case (40 Vehicles)

The simulation results are provided in Figs. 4 (a) and (b), which represents the PDR and the throughput of different protocols. In fact, the throughput of the hierarchical protocol is more efficient than the non-hierarchical protocols because clustering organizes vehicular wireless ad hoc networks to make the communication between vehicles more organized and rapid.

Practically, in our scenarios, we increase the number of nodes, and so the VMASC performs better thanks to the CHs duration, the multi-hop communication and the link stability.

3. Third Case (80 Vehicles)

When the network size becomes larger and the mobility is high, its management becomes more difficult. Non-hierarchical protocols work well when the network does not include a large number of nodes, unlike hierarchical protocols such as VMASC.

The latter is used to partition the network into subsets to facilitate network management, especially routing in large networks, and to maintain link stability.

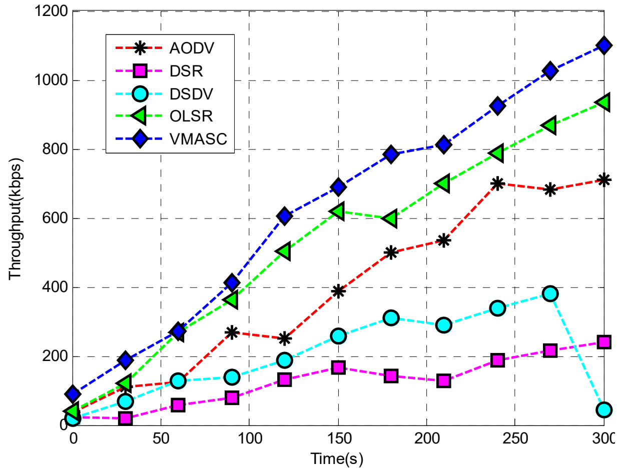

Fig. 4 (a) Throughput vs time for medium node traffic (40 vehicles)

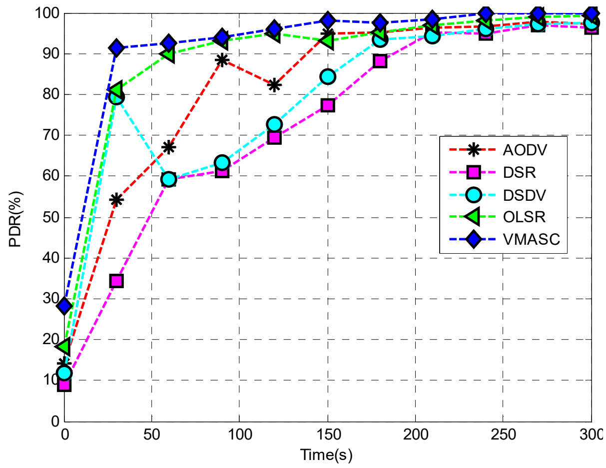

Fig. 4 (b) PDR vs time for medium node traffic (40 vehicles)

The graphs in Figs. 5 (a) and (b) demonstrate that the throughput and the PDR for VMASC are higher than other protocols. This is due to the CHs which are more powerful. VMASC experiences more traffic, reduces collision in wireless networks and transmits data rapidly compared to OLSR. Furthermore, this latter performs a better PDR and throughput in comparison with AODV and DSDV, whereas the DSR gives lower values for a high node density.

The decline of some curves in the graphs is due to high node mobility and more traffic.

To better show the performance of these routing protocols, we summarize in Figs. 6 (a) and (b) respectively, the PDR average and the throughput average for five routing protocols as a function of the number of nodes.

The VMASC is a very efficient approach for improving the throughput and the PDR in realistic urban scenarios with high density and mobility. This is because it increases the multi-hop clusters stability and decreasing the number of CH changes in VANET.

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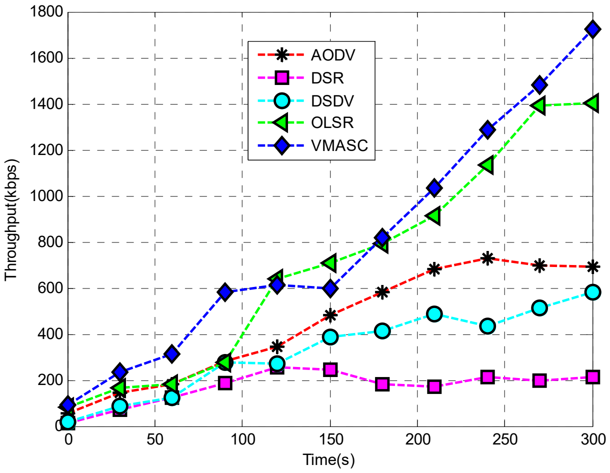

Fig. 5 (a) Throughput vs time for high node traffic (80 vehicles)

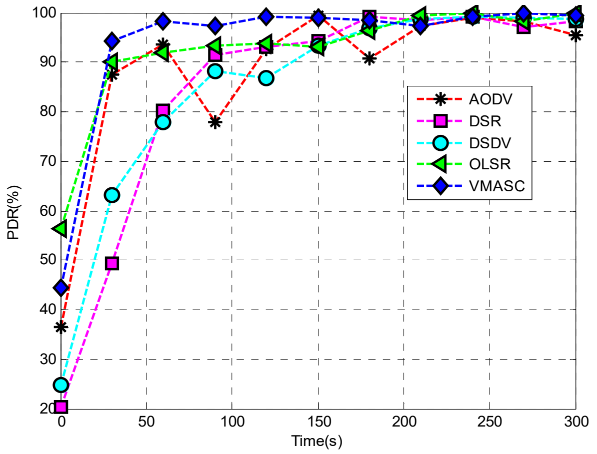

Fig. 5 (b) PDR vs time for high node traffic (80 vehicles)

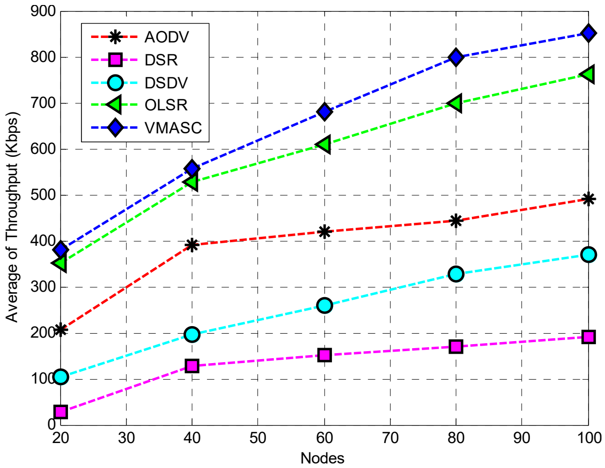

Fig. 6 (a) Average throughput vs nodes

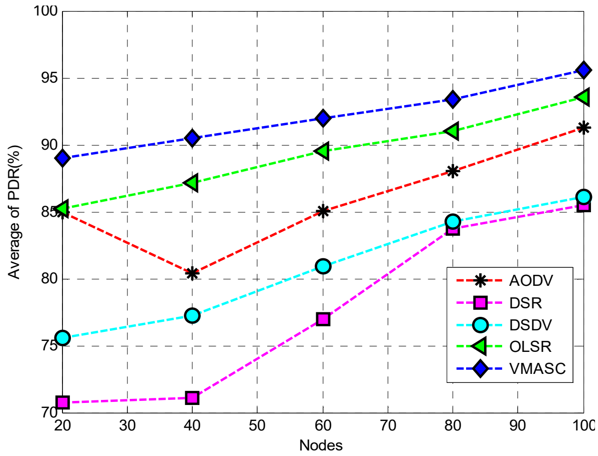

Fig. 6 (b) Average PDR vs nodes

V. Conclusion

In this paper, we have evaluated hierarchical and non-hierarchical routing protocols in VANET scenarios. We have first generated mobility scenarios using the SUMO tool, then the NS3 to evaluate the performance of all routing protocol were measured with respect to metrics like PDR and throughput in three cases: low, medium, and high traffic.

The results indicate that the performance of the VMASC is better thanks to the CHs duration, the multi-hop communication and the link stability than AODV, OLSR, DSR and DSDV especially when the number of nodes in the network is higher.

Finally, we have concluded in this comparative study that the hierarchical architecture is more advantageous than others in what relates to a well-structured network, a rapid data transmission, an easy network management and collision reduction in wireless networks.

References

[1] Stadler, Christina, Flamm, Xenia, Gruber, Thomas, et al. Communication Characteristics of VANETs. 5th GI/ITG KuVSFachgespräch Inter-Vehicle Communication, 2017, p. 33.

[2] Milne, James R., Carlsson, Gregory Peter, et Zustak, Frederick J. Vehicle ad hoc network (vanet). U.S. Patent Application No 15/149,562, 9 mai 2016.

[3] Menouar, Hamid, Guvenc, Ismail, Akkaya, Kemal, et al. UAV-Enabled Intelligent Transportation Systems for the Smart City: Applications and Challenges. IEEE Communications Magazine, 2017, vol. 55, no 3, p. 22-28.

[4] Alexander, W., Hong, X., et Hainen, A. V2I Communication-Enabled Real-Time Intersection Traffic Signal Scheduling. In: Proceedings of the SouthEast Conference. ACM, 2017. p. 26-33.

[5] Solano, Sandra Escamilla, Casado, Paola Plaza, et Ureba, Sandra Flores. Smart Cities and Sustainable Development. A Case Study. In: Sustainable Smart Cities. Springer International Publishing, 2017. p. 65-77.

[6] Khatoun, Rida et Zeadally, Sherali. Smart cities: concepts, architectures, research opportunities. Communications of the ACM, 2016, vol. 59, no 8, p. 46-57.

[7] A. Afanasyev, I. Moiseenko, and L. Zhang, Developing NS-3 based NDN simulator, CCNx Community Meeting held at PARC, September 2011. (Online). Available: http://www.ccnx.org/ccnxcon2011program.

[8] Liu, Weiwei, Wang, Xichen, Zhang, Wenli, et al. Coordinative simulation with SUMO and NS3 for Vehicular Ad Hoc Networks. In: Communications (APCC), 2016 22nd Asia-Pacific Confewwrence on.

ISSN: 2517-9942
Vol:12, No:3, 2018

IEEE, 2016. p. 337-341.
[9] Laouiti, Anis, Qayyum, Amir, et Saad, Mohamad Naufal Mohamad. Vehicular Ad-HOC Networks for Smart Cities. Springer Verlag, Singapor, 2016.
[10] Purohit, Kamlesh Chandra, Dimri, Sushil Chandra, et Jasola, Sanjay. Performance evaluation of various MANET routing protocols for adaptability in VANET environment. International Journal of System Assurance Engineering and Management, 2016, p. 1-13.
[11] Dong, Baihong, Deng, Jian, Wu, Weigang, et al. Topology Analysis System for Vehicular Ad Hoc Network. In: Parallel and Distributed Computing, Applications and Technologies (PDCAT), 2016 17th International Conference on. IEEE, 2016. p. 299-302.
[12] Yang, Liu, Xiang, Weidong, et Zheng, Guoxin. A Study on Vehicle Connectivity for VANETs Adopting Beamforming Antenna Array. Mathematical Problems in Engineering, 2017, vol. 2017.
[13] Dixit, Mayank, Kumar, Rajesh, et Sagar, Anil Kumar. VANET: Architectures, research issues, routing protocols, and its applications. In: Computing, Communication and Automation (ICCCA), 2016 International Conference on. IEEE, 2016. p. 555-561.
[14] Pandagre, Karuna Nidhi, Joshi, Apoorva, et Jharia, Jayanti. Vehicular Ad-HOC Network: VANET. International Journal of Research in Computer Application and Robotics, 2016, vol. 4, no 2, p. 29-32.
[15] Al-Sultan, Saif, AL-DOORI, Moath M., AL-BAYATTI, Ali H., et al. A comprehensive survey on vehicular ad hoc network. Journal of network and computer applications, 2014, vol. 37, p. 380-392.
[16] Rashvand, Habib F. et Chao, Han-Cheh. Dynamic ad hoc networks. Institution of Engineering and Technology, 2013.
[17] Marzak, Bouchra, Toumi, Hicham, Benlahmar, Elhabib, et al. Performance analysis of routing protocols in vehicular ad hoc network. In: Advances in Ubiquitous Networking 2. Springer Singapore, 2017. p. 31-42.
[18] Maratha, Barakat Pravin, Sheltami, Tarek R., et Shakshuki, Elhadi M. Performance Evaluation of Topology based Routing Protocols in a VANET Highway Scenario. International Journal of Distributed Systems and Technologies (IJDST), 2017, vol. 8, no 1, p. 34-45.
[19] Kumar, Vimlesh et BAGHEL, Anurag Singh. Comparison between AODV protocol and LSGR protocol in VANET. In: Computing for Sustainable Global Development (INDIACom), 2016 3rd International Conference on. IEEE, 2016. p. 3026-3030.
[20] Varshney, Pankaj Kumar, Agrawal, G. S., et Sharma, Sudhir Kumar. Relative Performance Analysis of Proactive Routing Protocols in Wireless Ad hoc Networks using Varying Node Density. Invertis Journal of Science & Technology, 2016, vol. 9, no 3, p. 161-169.
[21] Singh, Lalit et SAROIA, Ashish. Performance Comparison of Two MANET Routing Protocols (AODV and DSDV). Journal of Network Communications and Emerging Technologies (JNCET) www. jncet. org, 2017, vol. 7, no 5.
[22] Gupta, Kanika et Kohli, Asst Prof Saurabh. Optimizing OLSR Protocol for VANET. Asian Journal of Technology and Management Research (AJTMR) Volume, 2016, vol. 6, no 02.
[23] Ucar, Seyhan, Ergen, SinemColeri, et Ozkasap, Oznur. VMaSC: Vehicular multi-hop algorithm for stable clustering in vehicular ad hoc networks. In: Wireless Communications and Networking Conference (WCNC), 2013 IEEE. IEEE, 2013. p. 2381-2386.
[24] http://www.manutencionyalmacenaje.com/es/img2/2013/12/671_its_mlt_euskadi-7563.jpg.

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