UNSYS digital
Journal of Unmanned System Technology

A Comparative Study of Various Topology-based Routing Protocols in VANET

Noussaiba Melaouene, Rahal Romadi

Team of Information Research and Indexing Documents, Texts and Multimedia. ENSIAS, Mohammad V University, Morocco.

Abstract— In the last decade, the vehicle flow raises faster than road infrastructure in urban areas. Consequently, traffic problems are increasing affecting people's safety and comfort. Considering this literature, a various number of solutions is considered to deal with traffic problems using VANET. The most important issues in this field concern providing VANET routing protocols in a high speed environment. In this paper, the topology-based protocols were considered for the study. As known, the topology-based category is divided into three subcategories: reactive, proactive and hybrid. First, the principal characteristics are described and research challenges in VANET environment are discussed. Then, the performance of each topology-based routing protocol is evaluated and described in details. A comparative table of all protocols cited is, also, drawn up comparing protocols to each other. Finally, challenges and issues in topology-based routing protocols were discussed.

***Keywords*—** Vehicular ad hoc network, topology-based routing protocols, proactive, reactive, hybrid.

DOI: 10.21535/just.v8i1.1041

I. Introduction

Commonly, vehicular ad-hoc networks are self-organizing communication networks[1] that do not rely on any fixed network infrastructure. VANET were designed to avoid road accident, traffic jams and provide speed control in urban environment[2]. This network becomes a communication paradigm where vehicles can communicate directly with each other or via the infrastructure. However, direct vehicle to vehicle communication faces many problems in communication. Therefore, the different vehicles speeds and connectivity between RSUs and vehicles conduce to many challenging research issues and to the implementation of new approaches, which explains why many researchers are highly interested in this area of wireless and mobile communication. VANET routing protocols are broadly categorized into vehicle-to-vehicle-based (V2V) and vehicle-to-infrastructure-based (V2I) on the basis of VANET architecture[3]. Various touring protocols are implemented in VANET with a variety of designed goals. Literature further categorizes topology-based routing protocols as being either proactive, reactive or hybrid. These protocols are needed to maintain routes with features of mobility support, bandwidth limitations and power constraint.

The rest of the paper is organized as follows: Section II presents an overview of VANET by describing the system characteristics, challenges and limitations. Section III classifies the VANET routing protocols, Section IV discusses the issues and the limitations in topology-based routing protocols, while Section V concludes the paper.

Corresponding author: Noussaiba Melaouene (e-mail: melaouene.n@gmail.com)
This paper was submitted on April 11, 2020; and accepted on April 11, 2020.

II. VANET: An Overview

A. *VANET characteristics*

Vehicular communication systems include many features that allow communication among moving vehicles and the roadside infrastructure. Communication architectures are divided into two categories: vehicle-to-vehicle communication and vehicle-to-infrastructure. Modern vehicles are equipped with computing devices, event data recorders, digital maps, antennas and GPS receivers making VANETs realizable[4]. The exchange of information between vehicles and the routing protocols facilitate communication and the propagation of information to other vehicles.

B. *Trafficmatics*

The trafficmatics is a new concept of intelligent transportation systems (ITS) where every vehicle acts as a node in a network[5]. In VANET network, vehicles act as wireless nodes that have the ability to communicate with each other and with the infrastructure while in motion. These nodes are responsible for sending, receiving, routing and broadcasting data packets in VANET[6]. In ITS, a radio device and onboard units are installed on vehicles[7] thus, communication between nodes and road side units is established. Furthermore, vehicles are equipped with a digital map to get details on their geographical position.

C. *VANET limitations and challenges*

There are various research and studies performed in the field of VANET. However, challenges in Vehicular Ad-hoc Networks still exist. Due to the dynamic nature of network topologies, routing in VANET is the most attentive area of research to increase the robustness of the networks[5]. The high dynamic topology makes the topologies of VANET irregular and difficult to manage. It also makes the communication link lifetime brief[8]. The high speed between vehicles causes an unpredictable density of nodes. The unique characteristics of VANET, based on their high mobility and dynamic topology, present more challenges than other types of Ad-hoc networks[5].

The impact of traffic conditions, in urban and in highways, decreases the transmission signal. In cities, the traffic conditions are very complex contrary to highways. Indeed, obstacles in towns are one of the challenges that can affect the efficiency of VANET[9]. As a result, networking challenges in VANET is a main area of work for routing security efficiency and collision avoidance. In the end, in a strict applications requirement, the delay constraints are quite challenging.

III. Classification of Topology-based Routing Protocols

VANET routing protocols could be classified on the basis of four different categories: topology-based, position-based, quality of service (QoS) based and ant colony optimization (Ant) based. This paper focuses on topology-based routing protocols that usually use link information stored in the routing table forward packets from source to destination. These protocols fall into three groups: Reactive or on-demand protocol, Proactive or table driven protocol and Hybrid protocol. Figure 1 illustrates the taxonomy of VANET routing protocols.

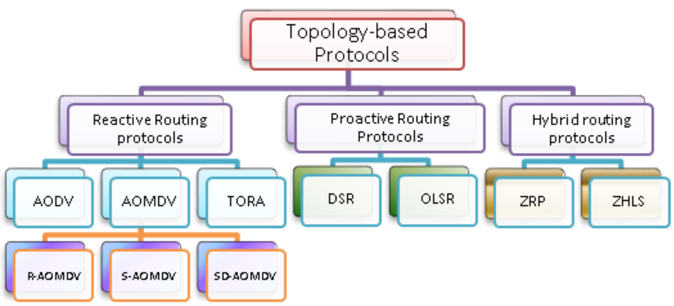

Figure 1 Taxonomy of Topology-based routing protocols

A. *Reactive (on-demand) protocols*

Reactive protocols provide a route on-demand[10]. To reach the desired destination, a query-reply exchange is made to discover the reactive route. Routing, in this case, needs some exchange of control traffic. However, if the route information is not available, reactive scheme may produce a significant delay to determine a route.

1) *Ad-Hoc On-demand Distance Vector (AODV)*

AODV is a well-known reactive routing protocol that enables routes only on demand. The algorithm enables dynamic, self-starting, multi-hop routing between participating vehicles wishing to establish and maintain an ad-hoc network[2]. Initially, AODV starts by looking for an available route to destination node from its local routing table. If the response is negative, it then broadcasts route request (RREQs) message to its neighborhood[11]. Every neighbor node iterates the process in order to find a path to destination node and to set up a path leading to RREQs originating node. Node that has received a RREQs packet transmits a route reply (RREPs) message, if the node is either a destination or having a destination route[5]. Finally, an end to end path is established when the source node receives the RREPs message. AODV selects the routing path from source to destination through route request (RREQs) message types; route replies (RREPs) and route error (RRER), by using user datagram protocol (UDP) packets.

2) *Ad-Hoc On-Demand Multi-path Distance Vector (AOMDV)*

AOMDV is defined as a multi-path on-demand protocol which is an improvement of AODV routing protocol. The main idea of this algorithm is to determine different and multiple paths during route establishment. AOMDV takes advantage from the same control messages used in the previous algorithm, but just adds extra fields to reduce the overhead occurring during the discovery of multiple paths process[12]. The algorithm retains all available paths in the routing table, so that the source chooses the first established route as the preferred one. Unlike the AODV, the AOMDV is designed primarily to highly dynamic ad-hoc network where link failures and route breaks occur frequently[13].To maintains the multiple paths in the AOMDV, there are two main components: a route update to establish and maintain multiple loop-free paths at each node and a distributed protocol to find link-disjoint paths. Compared to single-path based routing protocols, the performance of AOMDV is better in reducing route discovery retransmission, improving robustness and decreasing transmission delay.

In addition to that, the cross-layer AOMDV routing protocol (R-AOMDV)[14] is an extension of AOMDV routing protocol. The path discovery process of R-AOMDV is similar to AOMDV depending on route request (RREQ) and route reply (RREP) control packets. The difference is reflected in adding two fields to route reply (RREP) message in order to enhance the quality of the whole path. Therefore, R-AOMDV maximizes retransmission count at MAC layer and total hop count at network layer. Acquiring all good properties from AOMDV, the performance of R-AOMDV in both rural and urban vehicular networks is better compared to the two previous algorithms[15].

Furthermore, there are many other extensions of AOMDV with some new features such as S-AOMDV and SD-AOMDV; the first makes a speed of routing decision and combines the routing metrics hops while the second combines the routing metrics and speed to make routing decision and add mobility parameters, speed and direction to hop count[8].

3) *Temporarilly-ordered Routing Algorithm (TORA)*

TORA (temporally ordered routing algorithm) is also a reactive protocol based on three basic functions: creating, maintaining and erasing routes[9]. The first function consists on creating a route or establishing a sequence of links from a given node (source node) to the destination. This action is made on demand. First, TORA assigns directions to links in an undirected network or portion of the network. A directed graph is constructed regarding the source node as the tree root. This tree is called directed acyclic graph (DAG) and rooted to the destination. Maintaining routes refers to reacting to topological changes in the network in such a manner that routes to the destination are re-established within a finite time[16]. In the tree root, packets are forwarded from the top node to lower nodes in the tree. Once a node broadcasts a packet to a particular destination, its neighbor needs to broadcast a route reply to check if it has a downward link to the destination; if not, it just drops the packet[12]. A multi path loop free routing is ensured since the forwarding packets follow a downward direction to destination and do not flow upward back to source node. When invalid routes are detected, the third function takes place and erases all network partitions. In fact, TORA has many advantages such as offering a route to every node in the network and minimizing the control messages broadcast.

B. Proactive (table-driven) protocols

Contrary to reactive protocols, the proactive scheme provides route information when needed, resulting in a little delay prior to data transmission. It consists on continuously evaluating the routes within the network, so that when a packet needs to be forwarded, the route is already known and can be used immediately.

1) Dynamic source Routing protocol (DSR)

The routing of the source is a basic principle of DSR that makes it simple and efficient to use in wireless ad hoc networks. Overall, the protocol is divided into two distinctively routing techniques: Route discovery regards locating the routes (on-demand) and Route maintenance concerns controlling the progressive routing communication; in order to give a source route node to a random destination in the ad hoc network. Taking notice of this mechanism, the network becomes self-organizing and self-configuring. The source route is discovered dynamically across multiple network hops. Then, each date packet sent carries in its header the complete, ordered list of nodes through which the packet must pass; allowing packet routing to be trivially loop-free and avoiding the need for up-to-date routing information in the intermediate nodes through which the packet is forwarded[17]. Consequently, this routing information can be used by other forwarding nodes in future. However, the DSR protocol is not able to repair a damaged link locally which decreases its performance.

2) Optimized Link State Routing protocol

Thanks to its proactive nature, OLSR gives immediately available routes when needed[18]. To start, OLSR selects a few nodes as Multipoint Relays (MPRs) to broadcast the control traffic messages during the flooding process. This technique minimizes the number of retransmissions to all nodes in the network and reduces the redundant ones in the same region. Therefore, only a partial link state is flooded while giving the optimal path routes. Furthermore, this protocol is suitable for urban areas because of its reactivity to topological changes. It contains the routes of all nodes in the network even if it is dense and large. Moreover, many protocol extensions can be allowed by OLSR such as sleep mode operation, multicast-routing etc.

C. Hybrid protocols

The route determination is given only on-demand with a limited search cost, in proactive and reactive schemes/natures. While the hybrid (reactive/proactive) scheme has many advantages such as reducing the scope of proactive procedure and minimizing the search throughout the network like in the reactive procedure.

1) Zone Routing Protocol ZRP

ZRP is a hybrid protocol taking advantage of reactive and proactive protocols. The main goal of this protocol is to provide a flexible solution to the challenge of discovering and maintaining routes in a wide variety of ad hoc network environments. ZRP combines two radically different methods: Interzone and Intrazone routings. The first method relies on dividing the search area in multiple zones called ‘routing zone’. To search the whole network efficiently, few nodes are selected to be queried instead of querying all the network nodes. A routing zone is maintained for each of these nodes. More precisely, a node’s routing zone is a set of nodes whose minimum distance is in hops from the node in question[19]. Secondly, the Intrazone routing uses proactive protocol in order to update the routing information to nodes in the network. Consequently, this query control scheme enhances detection and prevention of overlapping queries. Accordingly, ZRP can provide routes to all accessible network nodes, with less control traffic than purely proactive link state or purely reactive route discovery, and with less delay than conventional flood searching.

2) Zone-based Hierarchical Link State (ZHLS)

The ZHLS follows the same concept as ZRP. The network is divided into non-overlapping zones identified by an ID, similar to the nodes. Only this time, an ID nomination (node ID and zone ID) is provided by GPS which offers the network topology two levels: node level topology and zone level topology. On one hand, this protocol minimizes the communication overhead unlike reactive protocols. Henceforth, the routing path is adaptable to the changing topology only for the node ID and zone ID as long as the destination is not migrating to another routing zone. On the other hand, all nodes should be re-programmed to the map of static zone which is not suitable to highly dynamic topologies[20].

IV. Discussion

Traditional topology-based routing protocols still need to be improved to deal with the VANETs environment[21]. Because of the non deterministic mobility behavior and high velocity of automobiles, the topology is unpredictable. The system characteristics such as multi-hop paths, node mobility, huge network, device heterogeneity, congestion and bandwidth are the main constraints in designing the routing protocols for VANET. Topology-based routing protocols, as shown previously, are divided into two categories: reactive and proactive protocols. Topology-based routing protocols still have issues such as the delay of transmission, non-suitability with rural scenarios, high overhead routing, more dropped packets, and frequent broken routes.

On one hand, communication in reactive protocols is based on the exchange of messages between vehicles in order to discover the route on-demand. Consequently, a problem in VANET may occur due to the highly dynamic topology. According to experimental results[22], the reactive process makes unnecessary route[23]. Furthermore, the delay of the reactive procedure is more than proactive for large networks. Also, the reactive process does not use the minimum path and cannot route properly in long distance. On the other hand, the proactive protocol provides route information when needed, but takes more time to update its table in long distance. The proactive routing protocols do not have initial route discovery delay but consume much of bandwidth for periodic updates of routes[2][24][25]. It performs better than reactive system in short and long distance but, considering the congestion, the reactive performs better than the proactive. The main constraint of proactive protocol is that the method of route maintenance is not able to repair a damaged link domestically[17]. With the high mobility of vehicles in VANETs environment, the protocol performance decreases. Both categories are not suitable for moving objects.

Finally, the hybrid system combines the proactive and the reactive protocols characteristics. It provides a flexible solution to the challenge of discovering maintenance routes in a wide variety of ad hoc network environments[19]. It takes the advantages of both categories. It performs in highly dynamic changes which make it more suitable for VANETs environment. Hybrid structure of routing events is widely deployed in ITS development[26].

Table 1 illustrates a comparison of various topology-based routing protocols.

V. Conclusions and Future Work

This literature presents a survey of various topology-based routing protocols in Vehicular Ad Hoc Network. Initially, characteristics, trafficmatics and issues in VANETs were discussed. The different types of routing protocols in VANETs were classified, starting with topology-based then position-based and finally the Ant colony optimization based. The paper highlights different topology-based protocols in details along with their routing issues. A further discussion illustrated a comparison between the three subcategories in topology-based which are: reactive, proactive and hybrid protocols. A table was described to give an overview of the comparison between the multiple protocols previously presented. Furthermore, the performance of the protocols presented above will be investigated in the future.

Acknowledgements

This paper was fully supported by the team of Information Research and Indexing Documents Texts and Multimedia at National School of Computer Science and Systems Analysis of Mohammed V University, Rabat, Morocco.

Table 1 Comparison of some popular topology-based protocols

Protocol	Type	Routing structure	Routing metric	Frequent and updates	Approach	Recovery strategy	Advantages	Disadvantages
AODV	Reactive	Flat Freeway	Shortest path	Unicast and Multicast	Distance vector (DV)	Multi hop forwarding	– Up-to-date path information – Reduce excessive memory requirement – Use in large scale network	– More time needed for connection setup – inconsistency in the route – Use extra bandwidth
AOMDV	Reactive	Flat Freeway	Shortest path	Multicast	Distance vector (DV)	Multi hop forwarding		
TORA	Reactive	Flat Freeway	Shortest path	Unicast and Multicast	Directed acyclic graph (DAG)	Multi hop forwarding	– DAG creates – Reduce network overhead – Performance is good in dense Networks	– not scalable
DSR	Proactive	Flat Freeway	Shortest path	Unicast	Distance vector (DV)	Carry and Forward	– Beacon less – Use caching which reduce load on the network – Periodical update is not required	– Unnecessary flooding burden – Performance is worse in high mobility pattern – Unable to repair broken links locally
OLSR	Proactive	Flat Freeway	Shortest path	Periodic	LS and multi point Relay	Carry and Forward	– Improve the QoS – Reducing Network Load – Reduce Contention	– Optimization Problem – Calculating the optimal node
ZRP	Hybrid	Flat Freeway	Shortest path	Multicast	Zoning	Carry and Forward	– Limit the scope of proactive procedure – minimize the waste – search in the network efficiently	– possible flooding search
ZHLS	Hybrid	Hierarchical	Shortest path		Zoning	Carry and Forward	– Reduce the communication overhead	– not suitable in highly dynamic topologies

REFERENCES

[1] U. Nagaraj, M. Kharat and P. Dhamal, "Study of various routing protocols in VANET", in IJCIST Vol. 2, Issue 4, pp. 45-52, October-December 2011.

[2] F. Ali, F. K. Shaikh, A. Q. Ansari, N. A. Mahoto and E. Felemban, "Comparative Analysis of VANET Routing Protocols: on Road Side Unit Placement Strategies", wireless Pers Commun, Springer Science Business Media. New York, May 2015.

[3] I. wahid, A. Ikram, M. Ahmad, S. Ali and A. Ali, "State of the art routing protocols in VANETs: A Review", the 9th international conference on Ambient Systems, Networks and Technologies, 2018.

[4] A. Husain, R. Raw, B. Kumar and A. Doegar, "Performance comparison of different routing protocols in vehicular network environments" Advances in computing and information Technology. ACITY 2011: Communications in computer and information science, Vol. 198, Springer, Berlin, 2011.

[5] G. D. Singh, R. Tomar, H. G. Sasty and M. Prateek, "A review on VANET routing protocols and wireless standards", Smart Computing and informatics, Smart innovation, Systems and technologies, 2018

[6] B. Pazand and C. McDonald, "A critique of mobility Models for wireless Network Simulation", In: 6th IEEE/ACS International Conference on Computer and Information Science (ICIS), 2007.

[7] Checkers and C. Perkins, "Dynamic MANET On-demand Routing Protocol", Internet Draft, March 2006.

[8] K. N. Qureshi, A. H. Abdullah, « Topology based routing protocols for VANET and their comparison with MANET" Journal of Theoretical and Applied Information Technology, vol. 58, No. 3, December 2013.

[9] K. Bayad, H. Boughim, M. Rziza and M. Oumsis, "Comparative Study of topology-based routing protocols in Vehicular ad hoc network using IEEE802.11p", 2nd international conference on electrical and information technologies, 2016.

[10] R. Kumar and M. Dave, "A comparative study of Various Routing Protocols in VANET", International Journal of Computer Science Issues, Vol. 8, Issue 4, No 1, July 2011.

[11] R. S. Shukla and N. Tyagi, "Performance of VANET Routing protocols Using realistic mobility Model", proceeding of the international conference on SocProS, AISC 130, pp. 549-555, 2011.

[12] G. Li, "Adaptive and Opportunistic QoS-based Routing protocols in VANETs", Final Report. France, Paris: University Paris-sud, July 2015.

[13] M. K. Marina, S. R. Das, "On-demand Multipath Distance Vector Routing in Ad Hoc Networks", proceedings ninth international conference on Network protocols, ICNP, USA, 2001.

[14] Y. Chen, Z. Xiang, W. Jian and W. Jiang, "A Cross-layer AOMDV Routing Protocols for V2V Communication in Urban VANET", Fifth international conference on mobile ad-hoc and sensor networks, 2009.

[15] B. Jarupan and E. Ekici, "A survey of Cross-Layer design for VANETs", Ad-Hoc networks, pp. 966-983, 2011.

[16] V. D. Park and M. S. Corson, "A Highly adaptive Distributed Routing Algorithm for Mobile Wireless Networks", Proceedings of INFOCOM, 1997.

[17] D. B. Johnson, D. A. Maltz, J. Broch, "DSR: The Dynamic Source Routing Protocol for Multi-Hop Wireless Ad Hoc Networks", Computer science Department Carnegie, 2001.

[18] T. Clausen and P. Jacquet, "Optimised Link State Routing Protocol (OLSR)", Network Working Group, October 2003.

[19] Z. J. Haas and R. Pearlman, "The performance of query Control Schemes for the Zone Routing Protocol", IEE/ACM Transactions on networking, Vol. 9, No. 4, August 2001.

[20] [20] M. Joa-Ng and I. Lu, "A peer-to-Peer zone-based two-level link state routing for mobile ad hoc networks", IEEE Journal on selected areas in communication, Vol. 17, No 8, August 1999.

[21] S. Cha and K. Lee, "Mobility information and road topology based inter-vehicle routing protocol in urban" Convergence and hybrid information technology. ICHIT 2011: communications in computer and information science, Vol. 206, Springer, Berlin, 2011.

[22] A. B. M. Moniruzzaman and M. S. Rahmann, "Analysis of topology based routing protocols for Vehicular Ad-hoc network (VANET)", International journal of computer applications, pp. 0975-8887, 2014.

[23] B. R. Umashankar and R. K Purnima, "A comparative study of Topology and Position based Routing protocols in Mobile Ad Hoc Networks", international journal of advanced research in computer science and technology, Vol. 2, Issue 2, Ver. 1, April-June 2014.

[24] M. Altayeb and I. Mahgoub, "A survey of vehicular ad hoc networks routing protocols", International Journal of innovation and Applied Studies, Vol. 3, No 3, pp. 829-846, 2013.

[25] K. C. Lee, U. Lee and M. Gerla, "A survey of routing protocols in vehicular ad hoc networks", Advances in vehicular ad-hoc networks: Development and challenges, pp. 149-170, 2010.

[26] M. Al-Rabayah and R. Malaney, "A new scalable Hybrid routing protocol for VANETs", Vehicular Technology, IEEE Transactions on, Vol. 61, No. 6, pp. 2625-2635, 2012.