Comparative Study of Topology based Routing Protocols in VANET

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***Abstract*— the recent advancement in wireless technology and car industry has created wireless communication between vehicles which is known as VANET (Vehicular Ad Hoc Network). VANET provides mobility to vehicles as smart vehicles can communicate with one another and prevent many accidents. Multihop wireless connectivity and frequently changing network topology in VANET are the factors that motivate to design efficient dynamic routing protocols. In this paper, various routing protocols are discussed and comparison based on various parameters such as loop free path, multicast capability, multiple route possibility, routes maintained, table expiration timers, route reconfiguration methodology and periodic routing advertisement has been presented.**

Keywords- VANET; DSR; AODV; TORA

I. INTRODUCTION

With the recent development in electronic devices and advancement in mobility, wireless networks are preferred over wired networks. The need of access to internet services motivates new wireless network known as ad hoc network. There are no central management units in ad hoc network, nodes or mobile nodes can directly communicate to each other. Multi-hop communication is formed between two end users.

VANET can be viewed as a subset of MANET; vehicles are used as mobile nodes in VANET. In VANET, each vehicle is considered as a node. In VANET, vehicles are connected to each other or to roadside units through wireless media which creates a wide range network. These vehicles act as mobile nodes that enable handoffs i.e. vehicles can drop out of the network by move out of the signal range. Similarly, the vehicles outside the range can connect to other vehicles of the network while on move to form an ad hoc network is created between them. It uses DSRC (Dedicated Short Range Communication) with band between 5.8 to 5.9 GHz [1] and data rate between 6 to 27 mbps [2].

Types of communication in VANET are V2V (Vehicle to Vehicle) communication and V2R (Vehicle to Roadside Unit) communication. The applications of VANET are basically divided into two broad categories:

1. **Safety related**: Applications like deceleration warning, road conditions warning, collision alert, merge assistance etc. which lays stress on timely distribution of safety critical alert to nearby vehicles [3][4].
2. **Internet connectivity related**: video streaming, audio, web browsing and accessing emails are some of the connectivity related applications, where the focus is on the availability of stable internet connectivity and high bandwidth [5][6].

The main challenges in the adoption of VANET architecture for future vehicular applications can be [7]:

1. For safety applications, low latency required.
2. Wide growth in multimedia and interactive applications.
3. Increasing concern about privacy and security.

This paper discusses topology based routing protocols with the aim to identify suitable routing protocol for VANET. This paper is further divided into three sections: In section 1, various routing protocol in VANET are discussed. In section 2, comparison among various routing protocols is done and Section 3 concludes the review of routing protocols.

II. ROUTING PROTOCOL IN VANET

There are various research issues in VANET related to system design and implementation which includes security, routing, connectivity and quality of service [8]. Focus of routing protocol is to provide an optimal path from source to destination with minimum overhead. Broad categories of routing protocol in VANET are given in fig. 1. The categories are: Position based, topology based, broadcast based, cluster based and geo cast based routing protocols [9]. Communications in VANET are: unicast, multicast and broadcast [8]. There are three types of network topologies in VANET: flat routing, position routing and Hierarchical routing [8].

Topology-based routing protocols are traditional MANET routing protocols. Topology-based routing protocol is further categorized into three categories: Proactive (periodic), Reactive (on-demand) and Hybrid [8].

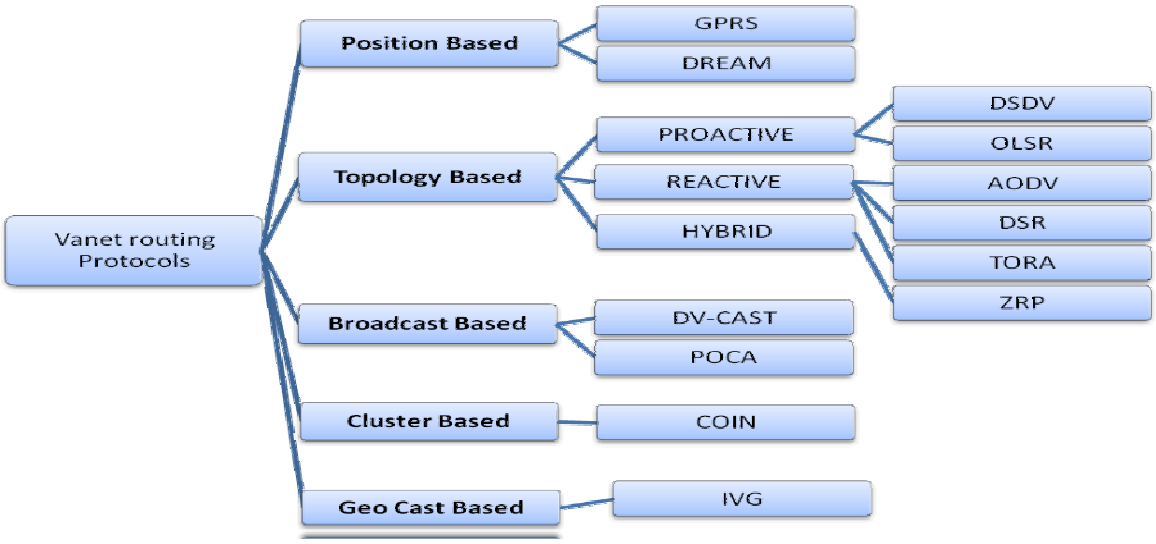

Figure 1: Routing Protocols in VANET

A. *Position Based routing Protocols [9]*

In this, geographical position information of node is used to send packets from source node to destination node. GPS (geographic position system) helps node and its neighbors to decide their location. Nodes within the radio range of node are known as neighbor nodes. Whenever source node needs to send packet to destination node, it just has to add the position of destination in the header of the packet. In this protocol, no information regarding route discovery, route maintenance or topology is needed. There are basically two parts for forwarding packets, first find the location and another is packet forwarding. Few position based routing protocols are DREAM (Distance Routing Effect Algorithm for Mobility) [10] and GPSR (Greedy Perimeter Stateless Routing) [11] etc.

The protocols in this category provide good performance in highway environment because of high mobility of vehicles and less number of obstacles. No routing tables need to be maintained, network topology does not matter and overall overhead is less. But there are some limitations also. GPS is always needed; if it does not work due to any technical mishap then protocol will not work.

B. *Topology based routing protocols*

In topology based routing protocols, the available information of link in the network is used for packet forwarding. Dynamic routing decisions are made in network. Proper route is needed for packet forwarding in a network. It sends unicast, multicast and broadcast type of messages. Route discovery is done when needed or a routing table is always maintained at node. These routing tables keep on refreshing themselves with a period of time. Further topology based routing protocols are divided into three categories, they are: Proactive, reactive and hybrid routing protocol.

1) *Proactive routing protocols*

Proactive routing protocols are also acknowledged as table driven routing protocol. As topology is represented by table so these table are regularly updated and node sends information to its neighbors for update. If the number of nodes increases in network then size of routing table also increases which leads to greater load on network. Proactive protocols are not preferred for large network due to their overhead. DSDV (Destination Sequenced Distance Vector) [12] routing protocol comes under proactive routing protocol.

a) *DSDV(Destination Sequenced Distance Vector) [12]*

It is table driven protocol; optimal path to each node is stored at the routing table at each node. It does not provide multiple paths to destination. Its routing scheme is based on Bellman-Ford algorithm. Routing table contains information regarding next hop, number of hops destination, and sequence number. Next hop is the first node towards the destination, number of hops means total number of nodes between source and destination. Sequence number is even if destination is active, odd if it is not active. It also provides loop free routes. Repeated update of routing table is done even if there is no change in the node from all neighbors. Routing table increases the network overhead and storage of route to each node also leads to increase in size of routing table.

2) *Reactive routing protocols*

Reactive routing protocol is also recognized as on-demand routing protocol. In this protocol, route is only discovered while it is needed and it maintains only those routes which are being used. Thereby reactive routing protocol has an advantage over proactive routing protocol i.e network overhead is reduced. Reactive routing protocol is useful in highly dynamic network. Reactive routing protocol has a disadvantage that it takes long time for route discovery Process. Few routing

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protocols under this category are DSR (Dynamic Source Routing) [13], AODV (Ad hoc On-demand Distance Vector Routing) [14] and TORA (Temporally Ordered Routing Protocol) [15].

a) AODV (Ad hoc On-demand Distance Vector Routing) [14]

AODV is an improved version of DSDV (Destination sequenced Distance Vector). In this, it executes the route-finding process and exchange of routing information happens only when a route is required by a node to communicate with destination. There are three phases: 1) Route discovery phase: A RREQ (Route request) packet is broadcast via flooding to all neighbors, broadcast ID gets incremented each time when a source uses RREQ packet. Broadcast ID and Source IP address form a unique identifier for the RREQ. Each node receiving RREQ forwards RREQ to its neighbors if it is not the destination node. If it is destination node or node which knows recent path to destination, it sends back RREP to sender. Sequence number helps to avoid the chances of circulating the same packet more than once**.** 2) Data Transmission phase: After getting the route information from source to destination it starts forwarding data to the route with the least number of hop count.3) Route maintenance phase: If data transmission fails due to breakage of link then Route maintenance comes into place. The last node of link breakage will process route discovery phase.

b) DSR (Dynamic Source Routing) [13]

In this protocol, route is discovered when needed, it is an on demand routing protocol. It is called source routing because it does not update routing table of nodes, instead it stores the route in nodes cache. Destination sequence number ensures loop free route to destination. It is multi-hop protocol. There are two phases: 1) Route Discovery phase: when route is needed, it broadcast route request and nodes who receives these packets rebroadcast further and so on. If Destination or the node which has route to destination, gets route request then it saves the path in cache for further use and send back the route reply along with the path to source. 2) Route maintenance phase: if source gets route error messages then it delete that particular route from its route cache and use any alternative route to destination. If no alternate path is available, then it run route discovery phase. It works best in low mobility network due to less overhead.

c) TORA (Temporally Ordered Routing Protocol) [15]

TORA is on-demand routing protocol. This protocol does not implement a shortest path algorithm. TORA creates a directed acyclic graph (DAG) which contains nodes between the source and the destination. In DAG, as no two nodes can be at the same height, so data flow will be from higher to lower nodes. TORA is loop free multipath routing protocol and data cannot flow back. Route information of adjacent nodes is collected by performing three phases 1) Route creation: formation of DAG 2) Route maintenance: if link broken then this phase come into action and create new DAG 3) Route Erase: to erase the invalid routes, broadcast clear packet (CLR) throughout the network.

3) Hybrid routing Protocols

Hybrid protocols exhibit the functioning of both proactive and reactive protocols. In this protocol, network is divided into zones so that it can reduce the overhead incurred by proactive protocols and reduce the time taken for route discovery in Reactive Protocol. Inside the zones it uses Proactive routing Protocol and outside the zones it uses Reactive Protocol for zone to zone communication. ZRP (Zone Routing Protocol) [16] falls under hybrid routing protocol.

a) ZRP (Zone Routing Protocol) [16]

ZRP is a hybrid wireless protocol which divides the network into zones based on factors like: signal strength, speed, power of transmission and many other factors. The area inside the zone is in range area for the particular node which lies in the zone and vice versa. For destinations outside the zone, ZRP uses the reactive routing schemes while proactive routing schemes are used inside the zone. Within the zone, node uses proactive protocol so that delay before sending a packet is minimal. For outside region of zone it uses reactive protocol to discover route and transmit data to border node which pass the packets to destination node. This packet consists of a unique sequence number, the source address and the destination address. As soon as the border node receives a route request packet, it searches for the destination within its zone. When the packet reaches the destination, it sends a route reply back to the source node by reversing the sequence of addresses and copying to route reply packet. Otherwise the border node adds its address to the route request packet and forwards it to its own border nodes. When the source node receives a reply, it stores the path and transmits data to the destination. ZRP targets larger zones, performs like a pure proactive protocol while for smaller zones it performs similar to a reactive protocol.

C. Broadcast Based routing protocols

As the name suggests it broadcast the packet in the network. These packets are available to all the vehicular nodes which are in the range of broadcast domain. This protocol is mostly used for safety or emergency information related announcement to all Vehicles like road block, accidents etc. Such types of protocols have limitations problems such as duplication of packets and large bandwidth consumption. Few routing protocols which fall under this category are POCA (Position Aware Reliable Broadcasting Protocol) [17], DV-CAST (Distributed Vehicular Broadcast Protocol) [18] and DECA (Density Aware Reliable Broadcasting Protocol) [19].

D. Cluster Based routing protocols

In this, cluster of vehicle are created based on different characteristics like direction, speed etc. A cluster head is elected to provide communication between different clusters. Communication inside the cluster is done through the direct route but for outside cluster it creates a virtual network infrastructure. Cluster heads of different clusters communicate with each other. Limitation of this is that high delay may occur

in case of large no of clusters so the overhead also increases. COIN (Clustering for Open Inter Vehicular Communication Network) [20] falls under cluster based routing protocol.

E. Geo Cast routing protocols

In these types of protocols multicast packet forwarding is done. One source can send packet to a group of nodes which act as destination. In this protocol, one vehicle can send a message to a group of vehicles in particular geographical area, this area is also referred as zone of relevance (ZOR). Membership is defined for every particular ZOR. Packet delivered from different geographic zone to another ZOR is called as ZOF (Zone of Forwarding). In highly dynamic topology, ZOF aims to achieve a reliable PDR (Packet Delivery Ratio). There is a periodic retransmission which handles network change. Delay caused by network disconnections is a major issue in this category of routing protocol. IVG (Inter-Vehicular Geocast) [21] and DG-CASTOR (Direction-based GeoCast Routing Protocol) [22] falls under this protocol.

III. COMPARATIVE ANALYSIS

In this section, Comparison of various topology based routing protocols are presented. In Table 1, the comparison between reactive routing protocols and proactive routing protocols is given on the basis of parameters such as routing information availability, topology distribution, periodic route updates, routing information and delay. In on demand routing protocols, routing information is available when needed whereas, in table-driven routing protocols it is always available (irrespective of need). Topology is formed when needed in Reactive protocols but in Proactive protocols topology changes periodically. Periodic route update is not required in case of reactive protocols but it is needed in case of proactive protocols. In proactive protocols, routing information is always stored in routing table but in reactive protocols routing information is not stored. End-to-end delay is higher in most of the reactive protocols than proactive protocols. Traffic control is low in reactive protocol and high in proactive protocol.

Table1. Comparison of On-Demand (Reactive) and Table-Driven (Proactive) routing Protocols

Parameters	**On-Demand(Reactive)**	**Table-Driven(Proactive)**
Routing information availability	when needed	Always (regardless of need)
Topology distribution	On-demand	Periodical
Periodic route updates	Not required	Required
Routing information	Does not stored	Stored in routing table
Delay	High	Low
Traffic control	Low	High

Table 2 presents the comparison between on-demand routing protocols (AODV,DSR and TORA) on the basis of parameters such as loop free path, multicast capability, multiple route possibility, routes maintained, table expiration timers, route reconfiguration methodology and periodic routing advertisement. AODV, DSR and TORA provide loop free route from source to destination. AODV has multicast capability whereas, DSR and TORA do not. TORA and DSR provide multiple routes from source to destination but AODV provides single path to destination. AODV and TORA maintain routes in routing table but DSR stores routes in nodes cache. When a link in a route is broken, the source will look for another route in its cache. If there is no route in the cache then the source node initiates route rediscovery whereas, in AODV and TORA the broken link route is erased and notified to the source node. Source node will start route discovery phase again in AODV and TORA. DSR and TORA does not make use of periodic routing advertisement, therefore, it incurs low overhead than AODV.

Table2. Comparison of reactive routing protocols (AODV, DSR and TORA)

Performance Parameter	**AODV**	**DSR**	**TORA**
Loop free path	Yes	Yes	Yes
Multicast capability	Yes	No	No
Multiple route possibilities	No	Yes	Yes
Routes maintained	In routing table	In node cache	In routing table
Table expiration timers	Yes	No	No
Route reconfiguration methodology	Erase route; Notify source	Erase route; Notify source	Link reversal; Route repair
Periodic routing advertisement	Yes	No	No

IV. CONCLUSION AND FUTURE WORK

Over the years, the motivation towards research on various issues in VANET has increased due to increased technical enhancement in the telecommunication and vehicular industry. Routing is one of the main issues in VANET. In this paper, various routing protocols have been explained and comparison of topology-based proactive routing protocols (AODV, DSR, and TORA) is presented. The process of finding and maintaining the routes between source and destination nodes are the factors which differentiates these routing protocols. Based on this comparison, AODV seems to be most promising routing protocol for VANET. In future, the performance of reactive routing protocols (AODV, DSR, AOMDV etc.) can be quantitatively analyzed. Also, the increased end-to-end delay of AOMDV routing protocol can be minimized by proposing some enhancements in the existing protocol.

ACKNOWLEDGMENT

I am also grateful to my guide, friends, in the Department of PEC University of Technology. I am extremely thankful and indebted to my mentor for sharing expertise, and sincere and valuable guidance and encouragement to me.

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