

A Comparative Study Of Various Routing Protocol For VANETs

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Abstract—Vehicular Ad hoc Network (VANET) is most active research area that provides wireless communication between vehicles moving at high speeds. These networks are self-organized in nature and a key component for future intelligent transportation system (ITS). It is a subclass of mobile ad hoc networks (MANET) but with some different characteristics like high mobility of vehicles, constrained mobility, highly dynamic topologies, frequent disconnections of networks, bandwidth limitation, no power constraints, sufficient storage and unpredictable node density. It is difficult to develop an efficient routing protocol for VANETs. In this research paper, we have discussed some existing ad hoc routing protocols AODV, DYMO and OLSR. Also, we have presented the comparative study of these routing protocols along with their advantages and disadvantages.

Keywords— Vehicular Ad hoc Network (VANET), Ad hoc routing protocols, AODV, DYMO, OLSR

I. INTRODUCTION

Vehicular Ad hoc Network (VANET) is an emerging technology that provides wireless communication between vehicles and road side units (RSUs). VANET is a subclass of mobile ad hoc network (MANET) and a key component for intelligent transportation system (ITS). These communication networks are distributed, self-organizing and infrastructure less where vehicles and road side infrastructure units communicate with each other, on highways or urban areas without using any infrastructure.

VANET helps the vehicles by providing the road traffic information and increases the safety of vehicles by exchanging safety relevant information with each other. Some applications [2] of VANETs are traffic information system, weather information, emergency warning system, traffic sign/signal violation warning, road-condition warning, and interactive communication such as Internet access.

Vehicles form a wireless network interface and communicate with each other by passing message. In VANET Wi-Fi technologies are used and vehicles use IEEE 802.11b or IEEE802.11g standards for access media but due to high dynamic in nature of VANET these standards do not meet complete requirements. IEEE802.11p and IEEE1609 standards are used in currently proposed short range communication service DSRC (Dedicated Short Range Communication) which provides high data rates and very low latency.

Some unique characteristics of VANETs include, high mobility of vehicles, highly dynamic topologies, frequent disconnections of networks, mobility modelling for varying environments for communication, bandwidth limitation, no power constraints, and stringent delay constraint [5]. One important challenge of VANET is to decide the efficient routing protocol. In VANET vehicles can only move along roads according to well established vehicular traffic models. VANET is a kind of MANET but in order to transfer information, the routing protocols of MANET are not appropriate for VANET. So it is required to develop mobility management solutions specifically for vehicular networks.

Infrastructure networks and Infrastructure less networks are two ways for communication between mobile nodes. In Infrastructure networks e.g. GSM and WLAN, the communication is done through a central node like RSU which acts as a communication agent to which all nodes are connected. In Infrastructure less networks or wireless ad hoc networks e.g. VANET, there is no fixed topology and no physical connection between nodes.

In VANET the communication is done among nearby vehicles or nodes and road side units. Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) are two categories of communication in VANET. In V2V communication vehicles can communicate with another vehicle directly [5]. It provides hop to hop or multi hop communication among nodes or vehicles. This communication is efficient and cost effective and it is based on dedicated short range communication (DSRC) [1]. In V2I communication a vehicle can communicate with infrastructure such as Road Side Unit (RSU). It is based on GPRS/3G, Wi-Fi or Wi-Max and can be used for internet access [1].

Some problems in VANET routing protocols are uneven slopes, unstructured and sharp curved roads, difference in the size of the intersections in a certain area and obstacles such as trees, large buildings, traffic lights, and sign boards. Some challenges areas are Quality of Service (QoS), efficient routing algorithm design which is required to timely and properly send data packets, Scalability and robustness, Cooperative communication, and Network security. It is a challenging task to provide data delivery with minimum delay, less retransmission and high connectivity time. It is also a challenge to design proper authentication mechanism and a security protocol.

Two mobility models for VANET are Macro mobility model and Micro mobility model. Macro mobility discusses the vehicular traffic which includes road topology, traffic flows, traffic density and initial vehicle distribution and motion constraint which includes streets, roads, crossroads, number of lanes, speed limits, traffic light and traffic signs. The road structure means unidirectional or bidirectional, single lane or multi-lane. Micro mobility focuses on the behaviour of a driver based on the driver's personal aspect like age, gender, and mood while driving, when interacting with other drivers or with road infrastructure.

The aim of this research paper is to provide a survey of routing protocols in vehicular ad hoc networks highlighting the advantages and disadvantages of these routing protocols so as to make comparison among them. The rest of the

paper is categorized into subsections as follows, the second section describes the vehicular ad hoc networks routing protocols. The third section is the comparative study of VANET routing protocols along with their advantages and disadvantages. The fourth section is the conclusion of this paper.

II. VEHICULAR AD HOC NETWORKS (VANETs) ROUTING PROTOCOLS

This section describes the routing protocols in vehicular ad hoc networks. VANET is a subclass of Mobile Ad hoc Networks (MANETs) [4] and both are similar in many ways. Some similarities of VANETs and MANETs are as both are multi-hop networks, have dynamic topology, use no central entity, and have no need of infrastructure. But there are some distinguishing characteristics too [11]. Both VANET and MANET are mobile networks but VANETs can move on specific paths [5]. The mobility pattern of vehicles in VANET is predictable. VANETs have sufficient storage capacity, enough battery power and high processing power. MANETs, on the other hand, have limited storage capacity, low battery power and low processing power. In VANET vehicles may move at high velocity with highly dynamic topology [3], [4], which makes the short lifetime of communication links between vehicles because links between vehicles connect and disconnect very often [4]. The density of vehicles in VANET is not predictable. The traffic on one road is different from other roads and on a single road the number of vehicles may vary with time. The solutions proposed for MANETs can be used for VANETs but it need to be tested and evaluated carefully first and then adapted in order to be used in VANET environment [3].

Routing protocols are used to find an optimal way of communication between vehicles or nodes [5]. One of the major challenges in VANET is to design the dynamic routing protocol. Routing protocols developed for MANETs are used by the VANETs due to many similar characteristics between them. Some routing protocols are Ad hoc on demand Distance Vector (AODV), Dynamic MANET on demand (DYMO) and Optimized Link

State Routing (OLSR). Two variants of OLSR are OLSR-DEF and OLSR-MOD.

A. *Ad hoc Routing Protocols*

Ad hoc or topology driven routing protocols are classified into two categories. One category of Ad hoc routing protocols is proactive routing protocols and another is reactive routing protocols. In proactive routing protocols, the routing table of nodes are continuously updated. It updates the routing tables when new routes are available within the network or there is any change in the routes. Proactive routing generates substantial routing overhead [5]. The advantages of Proactive routing are, it does not require the route discovery process and low latency for real time applications [7]. But in Proactive routing the maintenance of unused paths causes the reduction in the available bandwidth [6]. Examples of proactive routing protocols are OLSR, TBRPF and FSR. In Reactive routing or on demand routing [7] protocols, nodes do not continuously update their routing table. Instead, they initiate route discovery process through sending certain type of message, only when there is a need to send data. Discovering the route to send the information is the overhead in reactive routing protocols [5]. Reactive routing protocols need high initial latency for the route discovery process and these protocols are unsuitable for safety related applications [7]. These Protocols save the bandwidth and the routes which are currently in use are maintained by it. It also reduces the burden on the network [3]. Some examples of reactive routing protocols are AODV, DYMO, BRP and DSR [5]. Reactive routing protocols perform better under high mobility environment than proactive routing protocols [8].

B. *Ad-hoc On Demand Distance Vector (AODV) Routing Protocol*

AODV [13] is a distance vector routing protocol and uses broadcast route discovery mechanism. AODV protocol supports both unicast and multicast routing [12], [13]. In AODV every node maintains a routing table [10]. The routing table contains a next hop node, a sequence number and a hop count. All the packets are sent to the next hop node in

source to destination delivery of packets. The sequence number is used to find the latest path for communication. It determines the freshness of a route. The hop count is the distance between the source and destination node.

As AODV is a reactive routing protocol, when a source node wants to communicate with the destination node, it starts the route discovery process. The route discovery process [9] use route request (RREQ) and route reply (RREP) messages [12]. The RREQ message contains the source address, source sequence number, broadcast id, destination address, destination sequence number and hop count. The RREP message contains source address, destination address, destination sequence number, hop count and lifetime. In this process, the source node which wants to start communication with another node or destination node, checks in its routing table for an available path from source to destination node. If the path is available, the source node use this path for communication [8]. Otherwise, the source node broadcasts a RREQ message to its neighbourhood nodes. The node which receives a RREQ message, it also checks in its routing table for a path to the destination. If no path is available, then it re-broadcast this RREQ message and establish a path leading to the source node. This process of broadcasting the RREQ message continues until this RREQ message reaches to the node leading to the destination node or to the destination node. Intermediate nodes update their routing table when they receive the RREQ message. When the destination node or the node leading to destination node receives the RREQ message, it will reply with the RREP message to the source node which originally broadcasted the RREQ message. The route discovery process ends with a path created between source and destination node and this path is stored for further communication.

Then, route maintenance process is performed after route discovery process. In route maintenance, the Hello message is used to detect the link breakage. A node issues a route error (RERR) message when it loses connectivity to its neighbour or there is no path exit to the destination node. A

node issues this RERR message to the nodes that received its RREP message. The RERR message helps to recalculate or update the path when an intermediate node leaves a network or loses its next hop neighbour.

No routing overhead is introduced by the AODV, until a RREQ is made. The overhead for AODV is only to find the best path for communication. In this protocol the bandwidth is not wasted unnecessarily. In this protocol a source node has to discover a path from source to destination first and then it can start communication with the destination. This introduces an initial latency and which can be unsuitable for safety related emergency applications.

C. Dynamic MANET On Demand (DYMO) Routing Protocol

We have discussed about the AODV, now discuss about its successor DYMO [8] which is also a reactive routing protocol. It works in multi hop wireless networks. It is currently in the focus of Internet Engineering Task Force (IETF)'s MANET working group and is still work in progress [15]. Its predecessor AODV achieved the RFC status. But DYMO is expected to reach the RFC status in near future. DYMO is similar to AODV and it also use route discovery and route maintenance process as AODV. It also use RREQ, RREP messages in route discovery and RERR message in route maintenance.

When a source node wants to communicate to a destination node, it initiate the route discovery process [16]. The source node broadcast the RREQ message to the network. When a node receives the RREQ message, it checks for a path leading to destination. If path exists it replies with RREP message, otherwise re broadcast the RREQ message. While broadcasting the RREQ message, each intermediate node attaches its address to the message. Every intermediate node participates in hop by hop circulation of the RREQ message and records a backward path to the originator node. When the RREQ message reaches to the destination node, it replies with RREP message unicast towards the source node. Every intermediate node receiving this RREP message adds its entry to the message and creates a route to the destination node. This RREP message arrives at the originator of the RREQ message. At the end a forward path between

source and destination is created and every intermediate node knows a route to every other node along the path. The node may resend the RREQ message if source does not receive RREP within a specified TTL value.

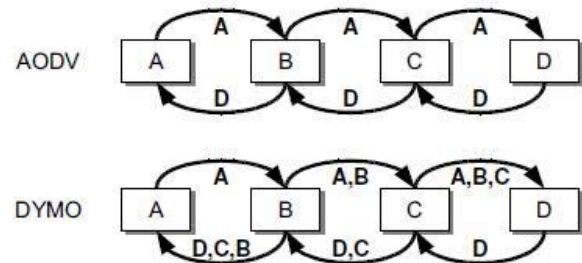


Fig. 1 DYMO vs. AODV (From C. Sommer & F. Dressler, 2007)

The major difference between DYMO and AODV is that AODV only contains entries about the destination node and the next hop in the routing tables, while DYMO stores routes for each intermediate hop [15]. In DYMO when an intermediate node receives a RREQ it generates routes entries for each intermediate node [8]. Figure 2.1 above shows this difference; In AODV, when node A initiated a route discovery process to communicate with the node D, it only learned about routes to its next hop neighbour node B and the destination node D after route discovery process is finished. While in DYMO for the same scenario, node A additionally learned about the route to node C and B. This is referred to as path accumulation feature of DYMO [15].

The next process route maintenance is to preserve the existing path and to find the link breakage. The lifetime of the route is extended upon successful forwarding of a packet to preserve the existing routes in use. Whenever a packet is successfully forwarded, the lifetime of the route is extended automatically. It is to use the route for further communication. When a route to a destination is lost or a route to a destination is not known, then a RERR message is generated by a node. This RERR message is multicast towards the packet source node, to only those nodes which are concerned with the route failure, to notify it about a particular route

being invalid or missing. Upon receiving RERR message the source node updates the routing table and deletes the route. If the source node has another packet to send to the same destination node, it will again initiate a route discovery process.

DYMO is to handle variety of mobility and traffic patterns. It has somewhat simpler design and easy to implement. It helps to reduce the system requirements of participating nodes [15]. In DYMO every node maintains a unique sequence number to avoid loops in the route [16].

D. Optimized Link State Routing (OLSR) Protocol

OLSR is an optimization of link state routing protocol. It is proactive protocol and it has been achieved RFC status in 2003 (T. Clausen (Ed.), and P. Jacquet (Ed.) Oct. 2003). In Link state routing protocol Link State (LS) advertisements are flooded. Flooding cause reception of multiple copies of same LS advertisement. The main aim of OLSR is to avoid this unnecessary transmission of LS packets.

In OLSR HELLO and TC messages are exchanged. Link sensing and neighbourhood detection is done by using HELLO messages. These messages help to find one hop neighbours and two hop neighbours [20]. In OLSR some nodes are chosen as Multi Point Relays (MPRs). This selected MPR helps in reducing the number of duplicate retransmission while forwarding packets. A node selects its MPR as a set of one hop neighbours by which it can reaches to all its two-hop neighbours. During the flooding process only nodes which are in the MPR can retransmit the broadcast messages, reducing the control overhead [17] and nodes which are not in the MRP will not retransmit the broadcast message. OLSR is different from the classical link state routing because in classical link state routing every node broadcasts the messages which generates large overhead traffic.

Topology Control (TC) packets contain the link state information. These packets are flooded in the network so that every node can have enough link state information and can calculate routes [18]. A node sends its TC message to advertise a set of links. A set of link includes the links to all nodes of its MPR selector set [20]. The nodes which are

selected as MPR can broadcast the TC messages in the network [20] and it offers flooding of the topology information in the whole network in a controlled manner.

OLSR minimizes routing overhead of link state routing because it reduces duplicated retransmissions of the routing information in the same region. OLSR is suitable for large and dense ad-hoc networks and also for high mobility ad hoc networks with highly dynamic topology, like in VANETs. It is different from reactive protocols as it does not need control traffic or route discovery process and a new route is readily available once the topology changes. This protocol is suitable for time critical or safety related applications where data needs to be delivered with minimum delay.

OLSR generates overhead traffic because it is proactive in nature. It is helpful in avoiding initial latency involved with route discovery, but it uses high network bandwidth for its control traffic. TC messages increase the network resource consumption because these messages are exchanged more frequently throughout the entire network [20]. Both reactive and proactive routing protocols are used to provide communication in wireless ad hoc networks. Each approach has its own pros and cons.

III. COMPARATIVE ANALYSIS OF VANET ROUTING PROTOCOLS

In this section the comparison of various ad hoc routing protocols in VANET context has been carried out. We also described the advantages and disadvantages of these VANET routing protocols.

DYMO is expected to achieve the RFC status in the near future. But both AODV and OLSR achieved this status. In [14], the throughput of AODV is low than DYMO and DYMO is recommended protocol for a highway scenario. DYMO has low end to end delay than AODV but little bit higher than OLSR. But DYMO shows the worst packet delivery ratio [8]. The route maintenance mechanism of DYMO is better than OLSR and AODV for VANETs [9]. DYMO have better performance than OLSR and AODV protocols [10].

TABLE I
ADVANTAGES AND DISADVANTAGES OF ROUTING PROTOCOLS

VANET Routing Protocol	Advantages	Disadvantages
Ad hoc on Demand Distance Vector (AODV)	• An up-to-date path to the destination by use of the destination sequence number [7]. • It reduces excessive memory requirements [7]. • It reduces the route redundancy [7]. • Bandwidth is not wasted unnecessarily. • It quickly responses to link breakage in active routes [13]. • Loop-free routes maintained because of using destination sequence numbers [13]. • It can be applied to large populations of nodes [13].	• It has longer latency for route establishment [13]. • It needs more time for connection setup & initial communication to establish a route [7]. • It can leads to inconsistency in the route, if intermediate nodes contain old entries [7]. • Because of periodic beaconing it consume extra bandwidth [7].
Dynamic MANET On Demand (DYMO)	• It is energy efficient in large and high mobility network [16]. • Its routing table is less memory consuming than AODV even with path accumulation feature [16]. • Less overhead with increased network sizes and high mobility [16]. • It is simple and easy to implement. • It maintains a unique sequence number to avoid loops in the route. • It has better performance and better route maintenance mechanism.	• It does not perform well with low mobility [16]. • High and unnecessary overhead in low mobility scenarios [16]. • It shows worst packet delivery ratio [8].
Optimized Link State Routing (OLSR)	• Optimization over pure link state routing. • Reduce duplicate retransmission while forwarding broadcast packets. • It is most suitable for large and dense ad-hoc networks. • It is also suitable for ad hoc networks with nodes of high mobility with rapid topological changes. • This is useful for time critical or safety related applications. • It avoids initial latency involved with route discovery.	• It generates overhead traffic. • It uses high network bandwidth for its control traffic. • It increases network resource consumption.

IV. CONCLUSIONS

VANET is an emerging technology in wireless communication. It is useful to provide safety related applications for vehicles moving at high velocity on the road. Various routing protocols have been proposed for VANET. This paper deals with the study of various ad hoc routing protocols in VANET environment. In this paper review of AODV, DYMO and OLSR on demand routing protocols has been done. Each protocol has its pros and cons. This paper also discusses the comparison among these routing protocols based on their advantages and disadvantages.

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