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RESEARCH ARTICLE

Performance Analysis of Topology based Routing Protocols in VANET

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Abstract— ***Vehicular Ad Hoc Network is an emerging field in wireless technology. Data Dissemination in VANET is complicated due to high mobility and continuous change in the topology of the network. In this study we have analyzed the performance of topology based routing protocols with two different traffic scenarios in VANET. In order to analyze the performance of these protocols, we considered some of the QOS parameters like Average Throughput, End-to-End Delay, Packet Delivery Ratio and Average Jitter. This paper considered the different topology based routing protocols including OLSR, IARP, AODV, DYMO and ZRP. Here OLSR, IARP are proactive protocols, AODV, DYMO are reactive protocols, and ZRP is a hybrid protocol. The performance of these protocols has been analyzed and presented using QualNet Simulator 5.0.2.***

Keywords — VANET; Protocols; Throughput; End-to-End delay; Packet Delivery Ratio and Jitter

I. INTRODUCTION

Vehicular Ad Hoc Network is one of the concrete applications of MANET. VANETs are the core of Intelligent Transportation System (ITS). It is a wireless communication technology where communication takes place due to the presence of On Board Unit (OBU) and Road Side Unit (RSU) [1].The routing algorithm embedded in the OBU will find the route for the packets to reach its destination. Vehicles can directly communicate with the moving vehicles or with the fixed RSU. The RSU's work like an access point continuously transmitting signal if a particular vehicle comes near its transmission range and the packets will be forwarded to that vehicle. The main motto of VANET is the transfer of safety information as it is one of the most important applications to prevent vehicles crashes. If vehicles involved in an accident are equipped with short-range communication, they can send out a warning message through multiple hops to the desired destination to avoid mass collisions [9].

Many routing protocols have been developed for VANETs environment which can be classified in many ways according to different aspects; such as: protocols characteristics, techniques used, routing information, quality of services, network structures, routing algorithms, and so on.

The following list shows the different types of routing protocols:

- Routing protocols characteristics and techniques based: Topology, Position, Geocast, Broadcast, and Cluster-based routing protocols.
- Network Structures based Routing Protocols: Hierarchical, Flat and Position-based routing protocols.

- Routing Information used in Packet Forwarding: Geographic and Topology-based protocols.
- Quality of Services based: it is divided into three categories: (i) Network Topology (Hierarchical, Flat, and Position Aware), (ii) Route Discovery (Reactive, Proactive, Hybrid and Predictive), (iii) based on the MAC layer interaction.

However all previous classifications did not concern by transmission strategies classification (such as unicast, broadcast, and multicast) [12].

In wireless networks, the basic MANET routing algorithms such as Dynamic Source Routing (DSR) and Ad-Hoc On-demand Distance Vector (AODV) routing were designed to control traffic on the network. But, these basic routing algorithms applied directly on VANET could lead to some issues such as large area of flooding, empty set of neighbours, flat addressing, widely-distributed information, large power consumption, interference, and load-balancing problems. Therefore, a number of routing algorithms have been proposed to enhance their performance in wireless networks [11]. As each algorithm has got its own merits and demerits, the objective of this paper is to analyse the performance of the various topology based routing protocols in VANET using Qualnet Simulator.

II. RELATED WORK

Several papers have already done the quantitative and qualitative analysis of various routing protocols like in Ad Hoc Networks. In paper [7], Performance evaluation of AODV and ADV protocols in VANETs are compared on the basis of throughput, packet drop and time taken for simulation. In [6], Prabhakar Ranjan et al. discussed the comparative study of VANET and MANET routing protocols. In [4], they compare AODV, DSR and ZRP routing protocols in MANET and the performance metrics is based on average jitter, end-to-end delay, throughputs and hop-count. In [8] Reena Dadhich et al., compared the following reactive routing protocols AODV, DSR and TORA, using a variety of highway scenarios, characterized by the mobility, load, and size of the networks. They indicate that reactive routing protocols performance is suitable for VANET scenarios in terms of packet delivery ratio, routing load, and end-to-end delay. Among the three reactive protocols, the performance of DSR is best in all cases. TORA performs better at maximum number of nodes or high mobility.

Paper [11] shows that proactive protocols are good at low complication of implementation and high stability but it may not be a good choice when applied in a high mobility environment such as VANETs. A storm of control messages can be needed to maintain an accurate view of the network topology. It can automatically give rise to heavy traffic contention, collisions of packets due to mass flooding broadcasts between neighboring nodes. Consequently, waste of all-too-scarce wireless bandwidth happens. From these points, proactive protocols are more suitable for environment where mobility is relatively static.

The drawbacks of topology-based and geography based routing protocols are discussed in [3]. The hybrid routing protocol called Hybrid Bee swarm Routing (HyBR) protocol for VANET has been designed in [3]. HyBr is a unicast and a multipath routing protocol which guarantees requirements of VANET safety applications. It combines two fundamental routing methods namely topology-based and the geography-based routing protocols. HyBR is a hybrid protocol which applies a topology-based routing approach when the network density is high (e.g., city-based VANET) and applies a geography-based routing approach when the network is not dense (e.g., highways). Using GPS devices, outdoors or through other means, each node saves the position information of all VANET nodes in a table called a positions table which is updated whenever the network topology changes.

III. **TOPOLOGY BASED ROUTING PROTOCOLS**

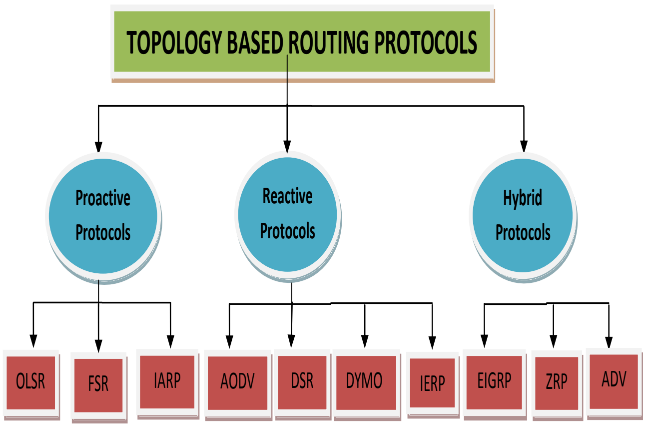

Fig.1 Taxonomy of Various VANET Routing Protocols

Fig.1. illustrates the taxonomy of VANET routing protocols [5], [6] which can be classified as Proactive, Reactive and Hybrid Routing Protocols. Topology-based routing uses the information about links that exist in the network to perform packet forwarding. Every node has to maintain the routing table and topology-based protocols developed for mobile ad-hoc networks may not directly be applied to vehicular environments, due to the unique vehicular network characteristics. One good way is to modify the MANET protocols and make it suitable for vehicular environment [10]. Since link information changes in vehicular environment, the topology-based routing suffers from route breaks or route failure.

A. Proactive Protocols

In proactive routing protocols or table-driven routing protocols, every node maintains one or more tables representing the entire topology of the network. These tables are updated regularly in order to maintain up-to-date routing information from each node to every other node. To maintain the up-to-date routing information, topology information needs to be exchanged between the nodes on a regular basis and in VANET, the topology change very quickly leading to relatively high overhead on the network [5].

As per Prabhakar Ranjan et al. in [6], each node in a proactive routing protocol sends a broadcast message to the entire network if there is a change in the network topology. It leads to additional overhead due to maintaining up-to-date information. Also throughput of the network may be affected but it provides the actual information to the availability of the network. The examples of Proactive protocols discussed here are:

- Optimized Link State Routing Protocol(OLSR)
- Intra-Zone Routing Protocol (IARP)

In [11] a Proactive routing protocol is discussed, getting the path information is fast and the maintenance of the up-to-date network information requires high overhead traffic and needs some significant amount of bandwidth. The process of maintaining the routes to the reachable nodes is continuous even if there is no data traffic flowing on these routes.

1) Optimized Link State Routing Protocol (OLSR): OLSR is based on a link state algorithm and it is proactive in nature. It employs periodic exchange of messages to maintain topology information of the network at each node. OLSR is an optimization over a pure link state protocol as it compacts the size of information sent in the messages and reduces the number of retransmissions to flood these messages in entire network. For this purpose, the protocol uses multipoint relaying technique to efficiently and economically flood its control messages. It provides optimal routes in terms of number of hops, which are immediately available when needed. This protocol is best suitable for large and dense ad hoc networks [15].

The advantages of OLSR optimization protocol are:

- It reduces the size of control packets, instead of all links; it declares only a subset of links with its neighbors who are its multipoint relay selectors.
- It minimizes flooding of this control traffic by using only the selected nodes called multipoint relays, to diffuse its messages in the network.
- Only this multipoint relays in the node retransmits its broadcast messages. This technique significantly reduces the number of retransmissions in a flooding or broadcast procedure.

2) Intra-Zone Routing Protocol (IARP): Intra-zone Routing protocol (IARP) is a component of the Zone Routing Protocol (ZRP). It is a proactive routing protocol used inside a zone. It can also be used as a standalone mode. IARP maintains routing information for nodes that are within the routing zone of the node. The Intra-zone Routing Protocol (IARP) proactively maintains routes to destinations within a local neighbourhood, which is referred to as a routing zone. More precisely, a node's routing zone is defined as a collection of nodes whose minimum distance in hops from the node in question is no greater than a parameter referred to as the zone radius. Note that each node maintains its own routing zone. An important consequence is that the routing zones of neighbouring nodes overlap.

In IARP each node monitors the changes that occur in R hop neighbourhood and avoids the global route discovery to local destination. IARP's routing provides enhanced, route maintenance after routes have been discovered.

B. Reactive Protocols

Reactive routing protocols also known as on-Demand routing protocols. It does not maintain records of available routes in a network. When route is needed it will flood the system with route request packet. These are sent out to immediately connected routers that pass on the request for a path to a given destination. Reactive Routing can cause overhead on a network by clogging up channels with route requests. The system is appropriate for constantly changing networks such as Ad Hoc Mobile Networks eg.VANET [5]. Eiman Alotaibi et al. in [11] each node in reactive protocol has no pre-built routing table (or global information), due to the node's mobility in a vehicular network maintaining the existing route is an important process.

In a Reactive routing the route discovery process happens more often but this process requires low control overhead compared to the Proactive routing. Therefore, the Reactive routing is considered to be more scalable than the Proactive routing. In addition, using a Reactive routing the node has to wait for the discovery process each time the node attempts to send a message; this increases the overall delay.

1) Ad Hoc On-Demand Distance Vector (AODV): AODV is a reactive routing protocol for dynamic wireless network. It is an on demand protocol, start route discovery operation only when a source node wants to send packet to the destination node. The route discovery operation is performed by broadcasting Route Request packet (RREQ) to its neighbors [4]. In [12], the primary objectives of this protocol are:

- To broadcast discovery packets only when necessary.
- To distinguish between local connectivity management (neighborhood detection) and general topology maintenance.
- To disseminate information about changes in local connectivity to neighboring nodes.

AODV has the following features

- Nodes store only the routes that are needed
- Need for broadcast is minimized
- Reduces memory requirements and needless duplications
- Quick response to link breakage in active routes
- Loop free routes maintained by use of destination sequence numbers
- Scalable to large populations of nodes

2) Dynamic MANET On-Demand Routing Protocol (DYMO): DYMO is a reactive routing protocol used by mobile nodes in wireless multi-hop networks. It is a successor to the Ad Hoc On-Demand Distance Vector (AODV) routing protocol.

The prime operation of DYMO protocol is Route Discovery and Route Maintenance. When a source wants to communicate with the destination node about which it does not have any routing information, source node will flood the network with RREQ message to get the target node. During flooding each intermediate node records a route to the originating node by adding the routing information into this routing table.

In [15], DYMO has implemented the concept of path accumulation, removes gratuitous RREP and determines routes in a unicast way among DYMO nodes. In addition, the Internet connectivity is also defined in the DYMO Internet-Draft.

DYMO work much like the AODV routing protocol, but in AODV, only information about destination node and the next hop is maintained, while in DYMO, path to every other intermediate node is also known. A major difference between DYMO and AODV is the latter of which only generates Route table entries for the destination node and the next hop, while DYMO stores routes for each intermediate hop [17]. Hence its performance in IEEE 802.11 Medium access control (MAC) and Distributed Coordination Function (DCF) is least considerable.

C. Hybrid Protocols

Hybrid routing combines the characteristics of both Reactive and Proactive routing protocols to make routing more scalable and efficient. Mostly hybrid routing protocols are zone based (i.e. the message transmission takes place between different zones (Intra-Zone and Inter-Zone) to make route discovery and route maintenance more reliable for MANETs or VANETs [5]. Proactive protocols can be used to implement intra-zone routing while reactive can be used for inter-zone routing case. Hybrid routing protocol in a large- scale fading environment, there are still a number of key issues remain unsolved [10].

In [14], the network scalability is increased by forming a near zone by the close nodes which work together to reduce the route discovery overheads by proactively maintaining routes to nearby nodes, and using a reactive strategy to determine routes to far away nodes. In hybrid protocols, the network is partitioned or seen as a number of zones by each node. The protocols belonging to this category, each given node partitions the area of the network into two distinct regions. The nodes in near distance from the node, or inside a particular geographical region form the routing zone of the given node. A proactive (table-driven) approach is used in the routing zone and on-demand routing approach is used for nodes located in the area beyond the routing zone.
The most typical hybrid routing protocol is:

- Zone Routing Protocol (ZRP)

1) Zone Routing Protocol (ZRP)

ZRP was proposed to reduce the control overhead of proactive routing protocols and decrease the latency caused by routing discover in reactive routing protocols. ZRP defines a zone around each node consisting of its k-neighborhood (e. g. k=3). In ZRP, the distance and a node, all nodes within –hop distance from node belongs to the routing zone of node. ZRP is formed by two sub-protocols, a proactive routing protocol: Intra-zone Routing Protocol (IARP) [9] is used inside routing zones and a reactive routing protocol: Inter-zone Routing Protocol (IERP) is used between routing zones, respectively. A route to a destination within the local zone can be established from the proactively cached routing table of the source by IARP; therefore, if the source and destination is in the same zone, the packet can be delivered immediately. Most of the existing proactive routing algorithms can be used as the IARP for ZRP.

For routes beyond the local zone, route discovery happens reactively. The source node sends a route requests to its border nodes, containing its own address, the destination address and a unique sequence number. Border nodes are nodes which are exactly the maximum number of hops to the defined local zone away from the source. The border nodes check their local zone for the destination. If the requested node is not a member of this local zone, the node adds its own address to the route request packet and forwards the packet to its border nodes. If the destination is a member of the local zone of the node, it sends a route reply on the reverse path back to the source. The source node uses the path saved in the route reply packet to send data packets to the destination.

IV. SIMULATION PLATFORM

A. QualNet

QualNet (Quality Network) is a network simulation tool that simulates both wired and wireless modes of communication networks. QualNet Developer is a discrete event simulator used in the simulation of MANET, WiMax networks, satellite networks and sensor networks, among others. QualNet has models for common network protocols that are provided in source form and are organized around the OSI Stack.

There are plenty of network simulators available like NS2, OMNET++ etc. but we opted for QualNet because it provides user friendly support with various protocols, environment factors, different terrains and analysing capabilities [2]. A study done by Hsu et al. compared performance results from a real world ad hoc wireless network deployment to the results obtained from a model of the network in QualNet and concluded that QualNet modelled the deployment scenario with remarkable accuracy, thus validating the ability of QualNet to model realistic wireless environmental effects. The QualNet simulation engine is extremely scalable and can accommodate high fidelity models of networks of thousands of nodes. It makes good use of computational resources and models large scale networks with heavy traffic and mobility in reasonable simulation times.

B. Wireless Technology

The QualNet 802.11 MAC model is based on the IEEE Standard 802.11 - 1999 standard. The IEEE 802.11 standard defines a set of MAC and PHY specifications for wireless LAN, also known as Wi-Fi. It was developed by the IEEE 802.11 working group and wireless station STA's are associated with access point. All communication takes place through access point. DSRC provides a communication link between vehicles and roadside beacons for road transport and traffic telematics applications. In [18], DSRC is a set of technologies dedicated to vehicular communications. In DSRC, each vehicle has an embedded communication terminal which named OBE (On Board Equipment) and some fixed terminals named RSE (Road Side Equipment) constitute the infrastructure along the routes. OBEs and RSEs are used as entry points for each type of application in vehicular networks, rather than using a specific tag. It is also known as IEEE 802.11p or WAVE (Wireless Access for Vehicular Environments) standard occupying 75 MHz of bandwidth (5.850 GHz-5.925 GHz). The DSRC protocol mainly consists of three layers: The physical layer (Ll), the data link layer (L2), the application layer (L7).

C. Performance Metrics

For analysis and evaluation of the different routing protocols, the performance metric chosen is of utmost importance. Different metrics can be chosen and for each the performance can be evaluated and compared to other results, however not all metrics are suitable in all cases. For example, one could measure delay, however if the scenario is delay tolerant, delay might not be the performance metric of choice.

This study uses Average Throughput, Packet Delivery Ratio, Average Jitter and Average End-to-End delay as performance metrics to evaluate the simulation results. These performance metrics are explained in detail in the following subsections.

1) *Average Throughput:* The throughput is the amount of data packets per unit time is delivered from one node to another node in the network through a communication link. It is measured in Packets per unit TIL or bits per TIL. TIL is Time Interval Length.

$$\text{Throughput} = \frac{\text{Total no. of Received Packets at Destination} \times \text{Packet Size}}{\text{Total Simulation Time}}$$

2) *Average Packet Delivery Ratio:* The ratio of the number of delivered data packet to the destination. This illustrates the level of delivered data to the destination. The greater value of packet delivery ratio means the better performance.

$$\text{PDR} = \frac{\sum \text{Number of Packets Received}}{\sum \text{Number of Packets Sent}}$$

3) *Average Jitter:* It is defined as the difference between transmit time of the packet and the arrival time of the packet divided by total number of packets arrived. It is measured in seconds.

$$\text{Jitter} = \frac{\text{Transmit Delay}}{\text{Total Number of Packets Arrived}}$$

4) *End-to-End Delay*: It refers to the time taken for a packet to be transmitted across a network from source to destination. It is measured in seconds. Delay is inversely proportional to the efficiency and reliability of the protocol.

$$\text{Average Delay} = \frac{\sum (\text{Packet Arrival Time} - \text{Send Time})}{\text{Number of Packets Received}}$$

D. Parameters for Simulation Set Up

TABLE I
PARAMETERS

Parameters	**Specifications**
Network Simulator	QualNet
Terrain	1500*1500
Routing Protocols	OLSR,IARP,AODV,DYMO,ZRP
Traffic Source	CBR
Source/Destination	Fixed
Data rate	2 Mbps
MAC Protocol	802.11
Antenna Model	Omni directional
Number of vehicles	10/20
Simulation Time	150 sec
Channel frequency	2.4 Ghz
Battery Model	Linear model
Pathloss model	Two-ray
Shadowing model	Lognormal

V. DIFFERENT TRAFFIC SCENARIOS IN VANET

Here we have considered two types of VANET scenarios: Dense and Sparse for a four-way lane road and is based on Intelligent Transportation System (ITS). At one side accident happens and to avoid mass collision, emergency messages are passed to the other vehicles. The results of these scenarios are analysed with different topology based routing protocols. For fair comparison, the same numbers of CBR (Constant Bit Rate) channels are used in all types of communication.

A. Sparse Traffic Regime

In this scenario the number of vehicles on the road is limited, as in late night hours, the traffic is sparse and hence dissemination from source to destination becomes difficult due to out of transmission range of the source and destination node [8]. In this scenario the vehicles are moving in four directions and communicating with the neighbouring vehicles. We have analysed the performance of this scenario with the above mentioned metrics with different topology based protocols. The vehicles are communicated using the CBR (Constant Bit Rate) application. While simulation, using the CBR application all the vehicles are communicated in order to send beacon messages from source to destination node.

1) Throughput (bits/s):

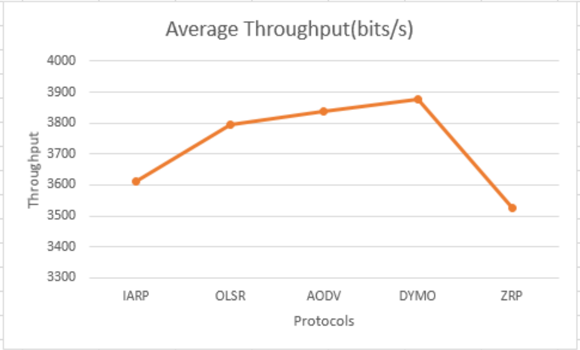

Fig.2. Average Throughput (bits/s)

Fig.2 shows the average throughput in seconds. More is the throughput of sending and receiving packets better is the performance. Lesser is the throughput of dropping packets better is the performance. The reactive protocols AODV and DYMO have highest throughput.

2) Average Packet Delivery Ratio (bits/s):

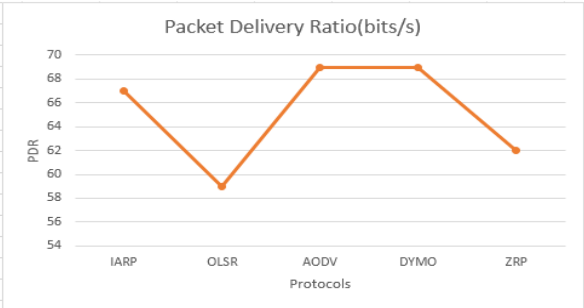

Fig.3. Average Packet Delivery Ratio (bits/s)

Fig.3 shows the average packet delivery ratio. The greater value of packet delivery ratio means the better performance. In this case AODV and DYMO have highest PDR.

3) Average Jitter in Seconds:

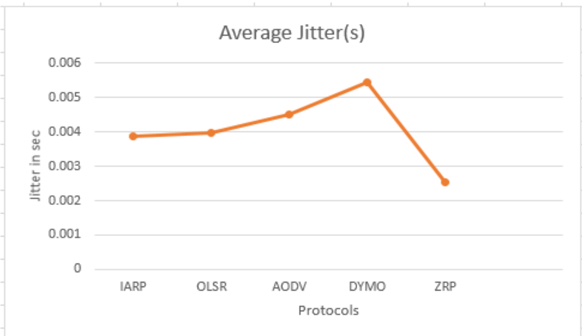

Fig.4. Average Jitter in Seconds

Fig.4 shows the average jitter in seconds. If the average jitter value is more, the quality of service becomes less. The reactive protocol DYMO has highest jitter.

4) Average End-to-End Delay

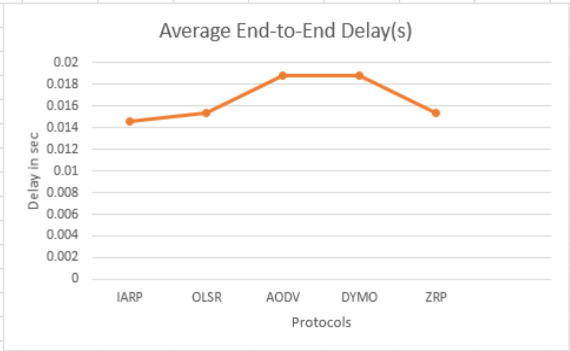

Fig.5. Average End-to-End Delay(s)

Fig.5 shows the average in seconds. If the average delay value is more, the quality of service becomes less. The reactive protocol DYMO and AODV have highest delay.

B. Dense Traffic Regime

Every vehicle is surrounded by more number of vehicles, since maximum number of vehicles will be on the same transmission range [8] which makes data dissemination quick and efficient but one of the drawbacks of this scenario is flooding which cause wastage of bandwidth and creates overhead on the network. Vehicles are moving in 4 directions communicating either with the nearby vehicles.

1) Throughput in seconds:

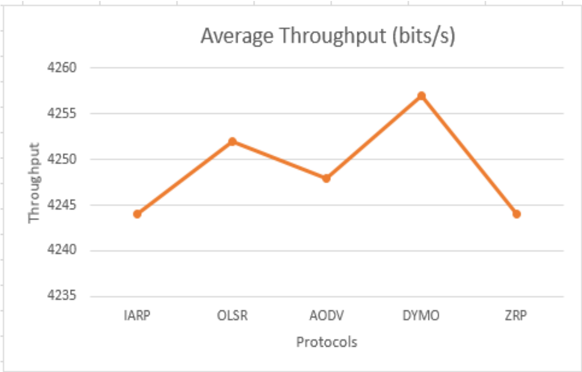

Fig.6. Average Throughput (bits/s)

Fig.6 shows the average throughput in seconds. The protocols OLSR and DYMO have highest throughput in dense scenario.

2) Average Packet Delivery Ratio:

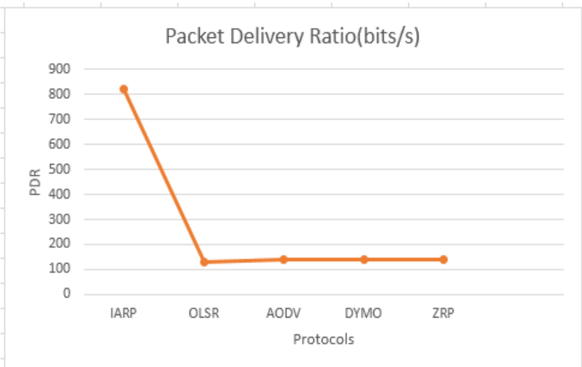

Fig.7. Average Packet Delivery Ratio (bits/s):

Fig.7 shows the average packet delivery ratio. The greater value of packet delivery ratio means the better performance. In this case IARP has highest PDR.

3) Average Jitter in Seconds:

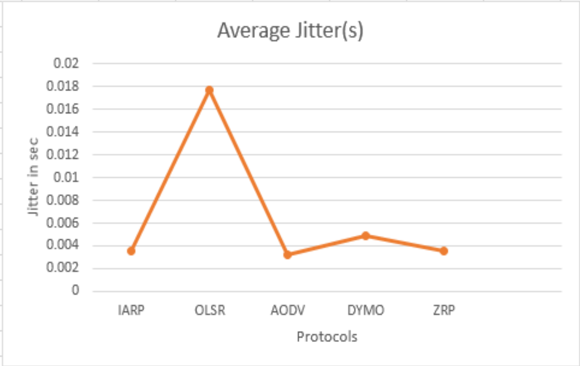

Fig.8. Average Jitter in Seconds

Fig.8 shows the average jitter in seconds. The proactive protocol OLSR has highest jitter.

4) End-to-End Delay:

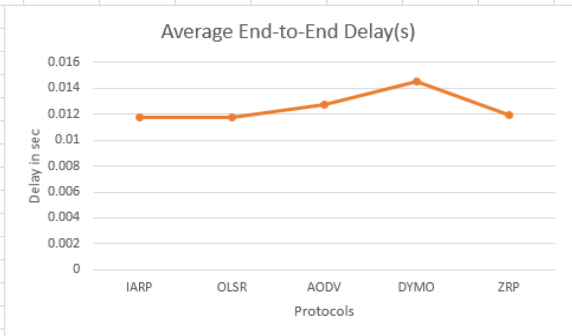

Fig.9. Average End-to-End Delay(s)

Fig.9 shows the average delay in seconds. The reactive protocol DYMO has highest delay.

VI. CONCLUSION

This article compared the different topology based routing protocols in two different types of traffic scenarios in VANET. The performance of Proactive, Reactive and Hybrid routing protocols with different QOS metrics has been analysed. The simulation result presented here shows that there is need for new routing protocols for the specific characteristics of vehicular networks. It shows that the important characteristics differences between the routing protocols. In both scenarios, OLSR, IARP, AODV, DYMO and ZRP provides high throughput. But AODV and DYMO have high delay and jitter. Because both are reactive protocols and DYMO work much like the AODV routing protocol, but in AODV, only information about destination node and the next hop is maintained, while in DYMO, path to every other intermediate node is also known. A major difference between DYMO and AODV is the latter of which only generates Route table entries for the destination node and the next hop, while DYMO stores routes for each intermediate hop. Hence its performance in IEEE 802.11 Medium access control (MAC) and Distributed Coordination Function (DCF) is least considerable.

From the graph it is very much clear that the appropriate routing protocol for emergency data dissemination in sparse and dense scenario are ZRP, OLSR and IARP compared to AODV and DYMO.

This is because OLSR and IARP are a proactive protocols and it pre determines the route in well-defined manner. OLSR uses destination sequence numbers to ensure loop freedom at all times and it offers quick convergence when the network topology changes. ZRP is a combination of both reactive and proactive protocol. From the above scenario, highest delay in sparse traffic is 100 sec and highest delay in dense traffic is 45 sec which is not efficient for Vehicular Ad Hoc Networks. But in VANET information has to be passed in nano-seconds because of high mobility and continuous change in the topology of the vehicles.

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