Simulation of Vehicular Ad-hoc Network Routing Protocols with a Performance Analysis

Thangakumar Jeyaprakash, and Rajeswari Mukesh

***Abstract*— Vehicular Ad-hoc Network (VANET), a subset of Mobile Ad-hoc networks (MANETs), is one of the emerging technologies of Road Transportation system. In recent years, the aspect of Vehicular Ad-hoc Network (VANET) is becoming an interesting research area as it is characterized as self-configured wireless network. The design of routing protocols in VANETs is play a vital role and necessary issue for the Vehicle to Vehicle Communication Technology. The existing routing protocols of MANETs are suitable for VANET with changes in configuration of protocol. The routing protocols fall into two major categories of topology-based and position-based routing. We discussed different kinds of existing routing protocols with two major categories, the advantages and limitations of each which will helps to enhance the existing routing protocols for the suitability of Vehicular Ad-hoc Networks. We implemented three existing routing protocols and the testing results stated that the performance of each in aspects of various parameters such as Packet Delivery Ratio, Throughput and End-End Delay using Network Simulator.**

Keywords - Routing Protocol, Vehicular Ad-hoc Network, Topology Based, and Position based

I. INTRODUCTION

Vehicles communicate with each other with a special communication device to form a structure of wireless networks, known as vehicular ad hoc networks or VANETs [1]. VANET differentiates the wireless communication between vehicles (V2V), and between vehicles and infrastructure access point (V2I). Vehicle to vehicle communication technology (V2V) has two types of communication: one hop communication (direct vehicle to vehicle communication), and multi hop communication). Apart from Mobile Ad-hoc networks, The special characteristics of VANET are self-organization, [24] high mobility of nodes, restrictions in road pattern and there is no restrictions in the size of the network.[2]. The Wireless communication of Vehicular Ad-hoc Networks has been achieved by wireless access called Wireless Access for Vehicular Environment (WAVE) dedicated to vehicle-to-vehicle and vehicle-to-roadside communications [3], [4]. The major objective of the VANET has clearly been to improve the road user's safety, providing traffic management solutions and on-board value added applications are also expected.

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The main aim of Routing Protocol is to provide an optimized path selection to disseminate the message between the nodes among the networks. The Routing protocols adopted for Vehicular Ad-hoc Networks can be classified with the characteristics, Routing Techniques used, Routing tables, Routing algorithms used and the structure of the networks. VANET routing protocols can be classified into two main categories: Topology based and Position based [2]. Moreover, the Topology - based can be categorized into two classes according to routing strategies: proactive and reactive [5].

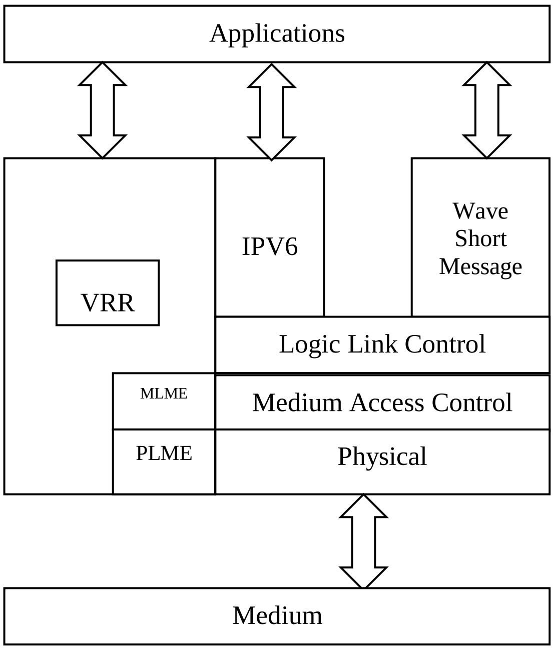

Figure 1. WAVE Protocol Stack

Fig 1. shows the WAVE protocol which is known as Wireless Access for vehicular Environments [3][23] designed for Vehicular Reacting routing (VRR). This Protocol [23] will helps in efficient route discovery [24], Route Maintenance, and the data delivery process. Table 1 represents the acronyms of Routing Protocols. In Fig 2, the Routing is classified into two major categories: Topology – based and Position Based Routing. Routing based on the layout of the network and the packets transmitted using the routing table information is known as Topology Based Routing. Routing based upon the location of the nodes in the network is known as Location Based Routing.

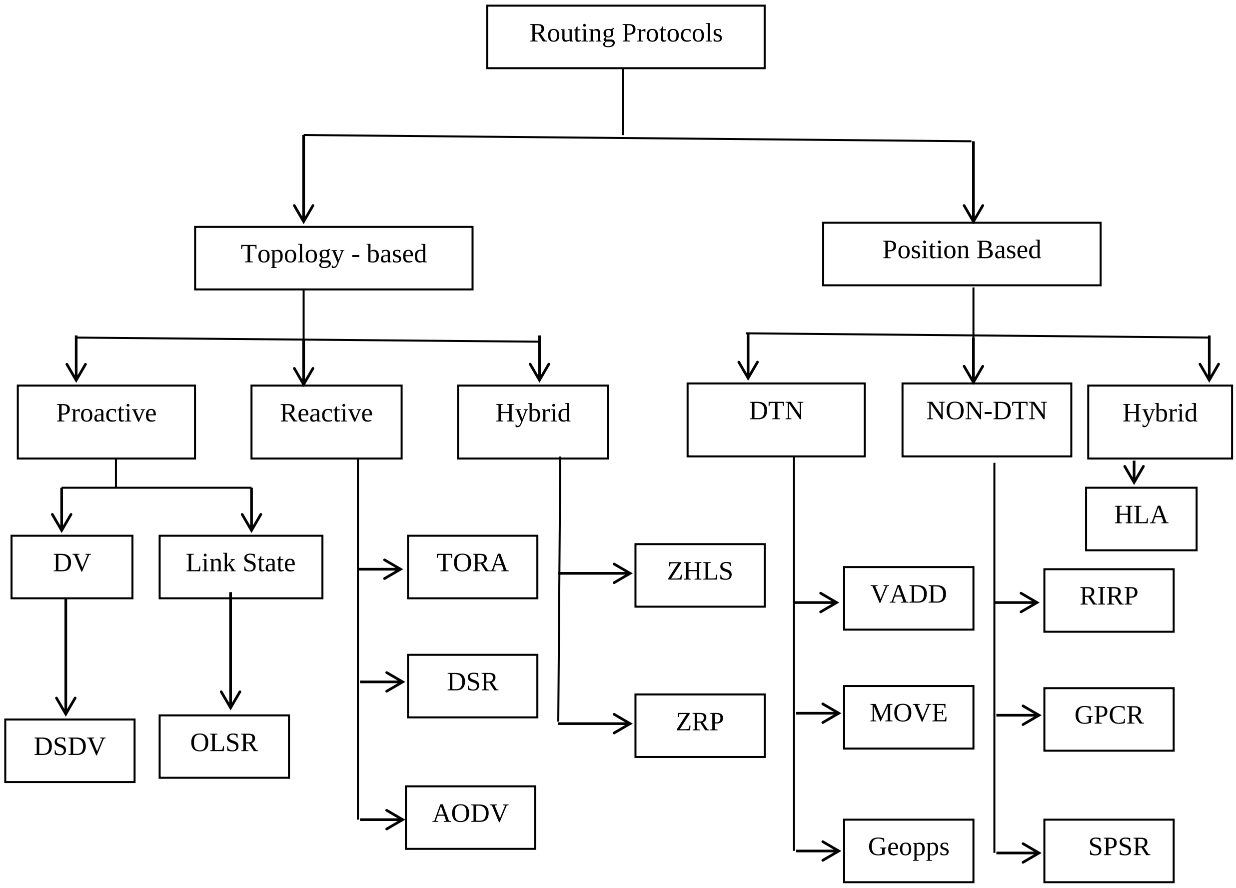

Figure 2. Classification of Routing Protocols [5][6]

In forthcoming chapters we discussed deeply about the advantages and limitations of existing routing protocols for the usability of VANET. Section II describes the Topology based routing protocols such as proactive, reactive and hybrid. The advantages and limitations of topology routing protocols are discussed deeply in section II and also we have mentioned the acronyms of all routing protocols in Table I. The section III focuses the various locations based routing protocols such as Delay Tolerant Network (DTN) and Non-Delay Tolerant Network. This section focuses more about the location based routing and provides the importance of each protocol. In Section IV, we have implemented the existing routing protocols such as Modified Ad-hoc on-demand Distance Vector Routing protocol (AODV), Destination Sequence Distance Vector Routing Protocol and Greedy Perimeter Coordinator Routing Protocol (GPCR).

II. TOPOLOGY-BASED ROUTING

James Bernsen et al [7] classifies the Topology based routing protocol into Proactive, Reactive and Hybrid [7]. Each subclass is classified into different types of routing protocols. The location Based routing is classified into Delay Tolerant Network (DTN), Non - Delay Tolerant Network (Non-DTN) and Hybrid. The routing is proactive (periodic), if the node frequently broadcasts its routing information to the neighbour node for the packet forwarding. The routing information includes the next hop node used to reach the destination and the hop count. Communication overhead may be caused by this routing protocol especially in the high mobility network. The Routing is reactive, if the node transmits its routing information on - demand to the neighbour node for the packet forwarding. The main advantage of the reactive routing protocols is to reduce the network overhead by transmitting the routing information only when needed [8]. Raphael Frank et al [9] mentioned the high mobility networks and change in frequent topology networks are suitable for reactive routing protocols. The combination of proactive and reactive routing protocol is known as Hybrid Routing Protocol. The objective of hybrid routing protocol is to minimize the proactive routing protocol overhead and reduce the delay of the route discovery process in reactive routing. The Proactive routing is based on the shortest path algorithms which uses the distance vector and link state routing aspects.

TABLE I
ACRONYMS

Acronyms	Expansion
WAVE	Wireless Access Vehicular Environments

PLME	Physical layer Management Entity
MLME	MAC layer Management Entity
IPV6	Internet Protocol Ver.6
VRR	Vehicular Reacting Routing Protocol
WME	WAVE Management Entity
DV	Distance Vector
DSDV	Destination Sequence Distance Vector Routing
OLSR	Optimized link state routing Protocol
TORA	Temporally Ordered Routing Algorithm
DSR	Dynamic Source Routing
AODV	Ad-hoc on demand Distance Vector Routing
ZHLS	Zone-Based Hierarchical Link State
ZRP	Zone Routing Protocol
DTN	Delay Tolerant Network
VADD	Vehicle-Assisted Data Delivery In VANET
MOVE	Motion Vector Routing Algorithm
GEOPPS	Geographical Opportunistic Routing
RIRP	Reliability-Improving Position-Based Routing
GPCR	Greedy Perimeter Coordinator Routing
HLAR	Hybrid Location-Based

A. *Destination Sequence Distance Vector Routing (DSDV)*

Destination-Sequenced Distance-Vector Routing protocol [10] is a periodic routing protocol. Each node broadcasts its routing table frequently to the neighbour nodes for the packet forwarding. It is a proactive table driven algorithm based on Bellman-Ford routing. In DSDV protocol each node maintains routing table for all the known destinations and broadcast the routing information periodically. Each routing table contains the next node to reach the destination, total no of hop to reach the destination and the sequence number. The destination node assigns a sequence number to each entry updated in the routing table. Every time, the network overhead increases due to the frequent updation of entries in the routing tables.

B. *Optimized link state routing Protocol (OLSR)*

The Optimized Link State Routing Protocol (OLSR) is a Link state routing protocol optimized for mobile ad-hoc networks which can also be used on other wireless ad-hoc networks. Jamal Toutouh et al stated the OLSR uses hello and topology control (TC) messages to discover the status of the link and then disseminate the link state information throughout the mobile Ad-hoc network. The other nodes use this link state information to compute the next hop destinations for all nodes in the network for forwarding the packets. The frequent control packets sent to handle topology changes causes network congestion [11].

C. *Temporally Ordered Routing Algorithm (TORA)*

TORA [12] is a single-hop knowledge algorithm which only maintains the information about the adjacent nodes. It is a reactive routing protocol that transmits the routing information on demand. It provides more than one route for any source to the destination pair. It creates a set of routes to a given destination once the source is initiated the transmission only when needed. It builds a directed acyclic graph which contains the source node as the tree root. It transmits the packets from the higher nodes to the lower nodes in the tree. i.e., it broadcasts the packets only if it has a downward link to the destination otherwise, it just drops the packets. During the change in the topology, this protocol quickly re-establishes the valid route via temporally- ordered sequence computations. Finally, the protocol notices the divider and erases all worthless routes within a finite time. V. Park et al [12] the benefits of TORA are that it provides a route to every node in the network, and reduces the control messages broadcast. However, it causes communication overhead in maintaining paths to all network nodes, especially in highly dynamic Vehicular Ad-hoc Network.

D. *Dynamic Source Routing (DSR)*

Dynamic source routing (DSR) is known as of source routing [13]. In Fig 3, the source node broadcasts a route request (R_REQ) to the neighbour node to transmit the packet the destination. If the neighbour node does not know the route to the destination, it appends its address to the route request packet and propagates it to its neighbours, when the destination receives the ROUTE_REQ; it transmits the R_RPLY to the source containing the route appended in the R_REQ. The R_REPLY unicasted in the reverse direction of the new route discovered by the destination. On receiving the R_REPLY, the source node will buffer the route in its route cache. If the neighbour node knows the route to the destination, the intermediate node returns the R_REPLY to the source node if it is fresh enough than the route in its route cache. It simple concatenates the new address to the route request and in the route cache and send the R_REPLY and send it to the source node. The DSR protocol is suitable for the network which has low mobility as it has alternative routes before start a new route discovery. The multi routes may lead to additional routing overheads as a result; the network performance will be low [14].

E. *Ad-hoc on demand Distance Vector Routing Protocol (AODV)*

Ad-hoc on demand Distance Vector Routing Protocol [15] is a reactive routing protocol. Each source node initiates the route discovery process to communicate with the destination node. The node broadcasts a route request (RREQ) packet to all its neighbours to find the destination node. The RREQ packet includes source address, source sequence number, broadcast

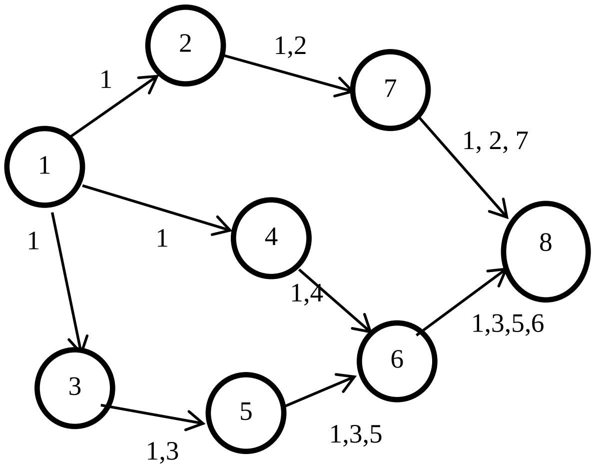

Figure 3. Route Request of Dynamic Source Routing – (R_REQ)

ID, destination address, destination sequence number and hop count. If a neighbour node knows the route to reach the destination node, it replies with the route reply (RRPLY) packet to the source node. The RRPLY contains source address, source sequence number, broadcast ID, destination address, destination sequence number and hop count. The source sequence number specifies the freshness of the information about the reverse route to the source. The destination sequence number specifies the freshness of the route to reach the destination from the source. Otherwise, the neighbour node will forwarded the RREQ until an active route is found to reach the destination. AODV causes large delays [16] in a frequent route discovery due to frequent route failure may require a new route discovery. This may decreases the data transmission rate and increase the network overhead.

F. Zone Routing Protocol (ZRP)

Zone Routing Protocol divides the networks into number of zones [16] based on the factors like power transmission, speed, received signal strength index. Inside the zone, it follows the proactive routing scheme and follows the reactive routing scheme for the outside area of the network. Inside the zone, the source node uses a proactive cached routing table to reach the destination without any network delay. For the nodes outside, ZRP initiates the route discovering process to reach the destination with the RREQ packet. The packet contains a unique sequence number, the source address and the destination address. When a border node receives the route request packet, it checks the destination node within its zone. If found, it replies the source node with the route reply (RPLY) packet on reverse path to the source node. If the border node not found any destination node inside the zone, it broadcasts the RREQ to the other border nodes until to find an active route to reach the destination node. After the source node received a route reply, it stores the route included in the route reply packet to use it for data transmission to the destination. The limitations of ZRP protocol is that it performs like a pure proactive protocol and it is not applicable for VANET due to high mobility [16].

G. Zone-based hierarchical link state (ZHLS)

Zone-based hierarchical link state (ZHLS) divides the networks into number of non-overlapping zones [16] which has no position administrator or cluster head are used to manage the transmission of data. For a data transmission, ZHLS requires only the node ID and the ZONE ID to reduce the transmission overhead. Each zone has a zone ID which is measured by Global Positioning System (GPS). As it needs a zone map into each node, and this may not be sufficient for a dynamic network with dynamic zone edges. it is not suitable for highly dynamic topologies [16].

III. POSITION BASED ROUTING

Position or geographic routing protocol is based on the location information of the nodes; where the source transmits a packet to the destination using its geographic position using GPS rather than using the network address [2].The position routing protocols are considered to be more stable and suitable for VANET with a high mobility environment. It is classified into Delay Tolerant Network (DTN) Protocols, Non Delay Tolerant Network (Non DTN) Protocols and hybrid protocols. DTN is a wireless network node avoids frequent disconnection communication and end to end delays [17]. In this network each nodes help each other to forward packets (store and forward scheme) with a limited transmission range which results in larger delays. The non-DTN protocols are geographic routing protocols which transmits the packet to the nearest neighbour to achieve the data communication. If there is no closest neighbour, this approach may be unsuccessful [2][17].

A. Vehicle-Assisted Data Delivery in Vehicular Ad-Hoc Networks (VADD)

Vehicle-Assisted Data Delivery in Vehicular Ad-Hoc Networks [17] (VADD) is a DTN protocol designed to handle vehicular Ad-Hoc networks to solve high mobility issues and frequently change environment. When a node broadcasts the packet to reach the destination, the intermediate node stores the packet and then forwards the stored packet to a new node once a new node arrives to its coverage area. It uses the available wireless network to deliver the packet to the higher speed nodes available in the route to reach the destination. Routing loops may occur due to the transmission of packet to the closest node in the network [17]

B. Greedy Perimeter Coordinator Routing (GPCR)

B. Karp et al [18] proposed GPCR (Greedy Perimeter Coordinator Routing) which uses the closest location of node for the data communication on the basis of distance. The packets are transmitted on a greedy basis by selecting the node closest to the destination. This process repeats until the destination is reached. In some cases the best path may be determined [18]. In such cases, it resumes the greedy process by selecting the best path to reach the destination.

C. Motion Vector Routing Algorithm (MOVE)

Chao Song et al [19] states the MOVE algorithm is developed for light networks and especially for road side vehicle communication. When a source node initiates the data communication to the destination nodes, each source node assumes that each node in the network has global position information. From this information, the source node can find the closest neighbour to the destination. Using the HELLO/RESPONSE messages [18], each node will know its neighbours and their locations. By the location information, the source node can find the shortest path to the destination and forward the messages. MOVE protocol is a NON – DTN position based routing protocol and it will be useful in light environments of VANET. If the routes are stable and consistent, then it could have better performances.

D. Reliability-Improving Position-Based Routing (RIRP)

M. W. Ryu et al [20] proposed the Reliability-Improving Position-Based Routing (RIRP) algorithm predicts location of vehicles by transmitting beacon messages, and estimates information of the characteristics of road to select the relay node. RIPR protocol a greedy mode and perimeter mode as well as the road characteristics consideration, and the position of the nodes. RIPR can solve the link failure problem [21] but not the routing loop occurs between the nodes.

E. Geographical Opportunistic Routing (Geopps)

To collect the geographical information such as position, a navigation system is used by Geographical Opportunistic Routing [22] to select the vehicles closest to a certain destination. This protocol uses store and forward technique. This protocol has some restrictions like it has to depend upon the navigation system measurement to calculate the route [22].

F. Hybrid Location – Based Routing Protocol (HLR)

Mohammad Al-Rabayah et al [6] the hybrid position - based routing protocol is a combination of any protocols of to avoid network overhead, Communication delay, and to increase the throughput and efficiency. The protocol may be combined with Topology based also. Hybrid Location Based Routing protocol (HLAR) is an example of hybrid position – based routing protocol [6].

IV. RESULTS

Experimental Simulation has been done using Network Simulator 2 to evaluate the performance of Ad-hoc on demand Distance Vector Routing Protocol AODV), Destination Sequence Distance Vector (DSDV) Routing protocol and Greedy Perimeter coordinator routing (GPCR). Fig 4 -6 shows the performance of routing protocols with respect to Packet Delivery Ratio. Fig 7-9 shows the results of End-End delay transmission of data packets. Fig 10-12 shows the performance criteria of Throughput of each protocol. Table 2 represents the simulation parameters.

TABLE II

SIMULATION PARAMETERS

Parameter	Values
Simulation time	2000 seconds
Simulation area	1000 m x 1000 m
Data pay load	512 bytes/packet
Bandwidth	2 Mbps
Routing protocols	AODV, DSDV, GPCR
Packet rate	8 Packets/sec
Node pause time	60
Channel Type	Wireless Channel
Antenna type	Omni Directional

The performance metrics such as Delay, Throughput and Packet Delivery ratio for the node density up to 100 has been implemented for the existing protocols in the presence of link failures using Network Simulator. The rate of packet transmission is 8 per seconds.

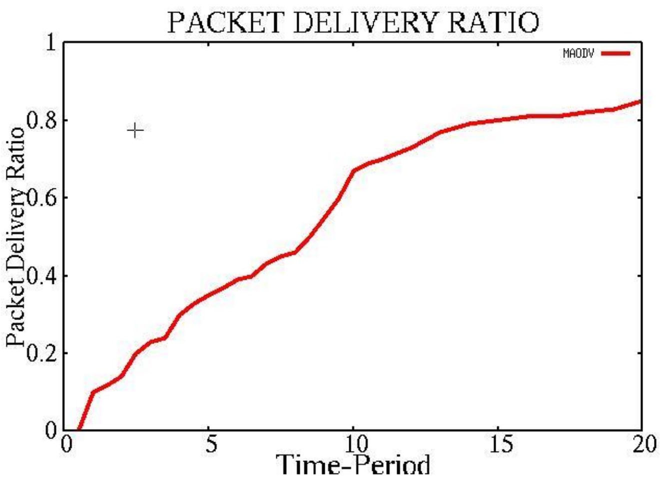

Figure 4. Packet Delivery Ratio of Modified AODV

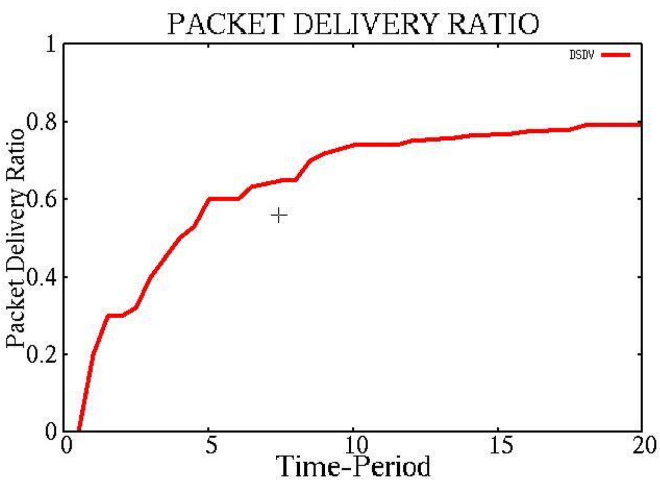

Figure 5. Packet Delivery Ratio of DSDV

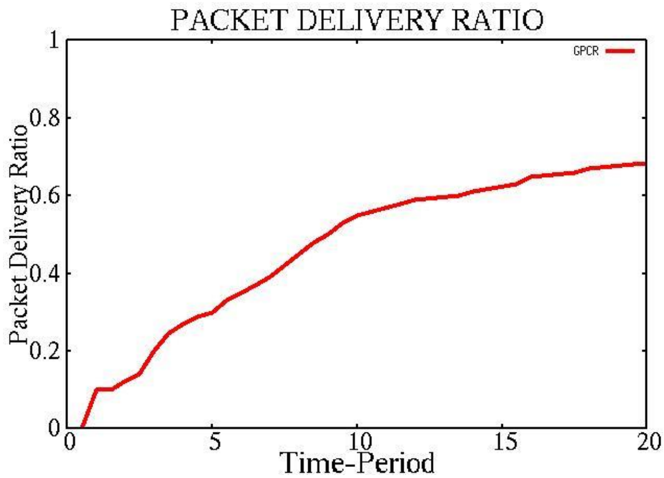

Figure 6. Packet Delivery Ratio of GPCR

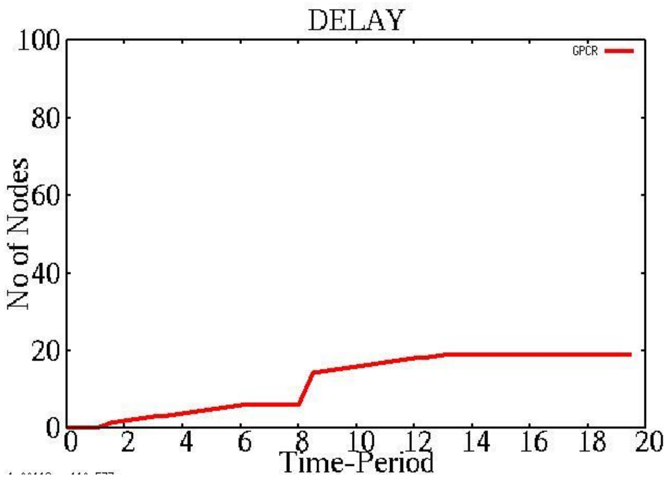

Figure 9. Delay of GPCR

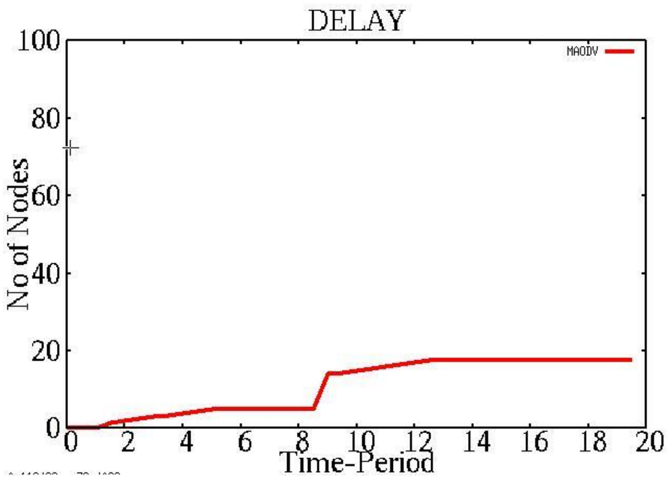

Figure 7. Delay of Modified AODV

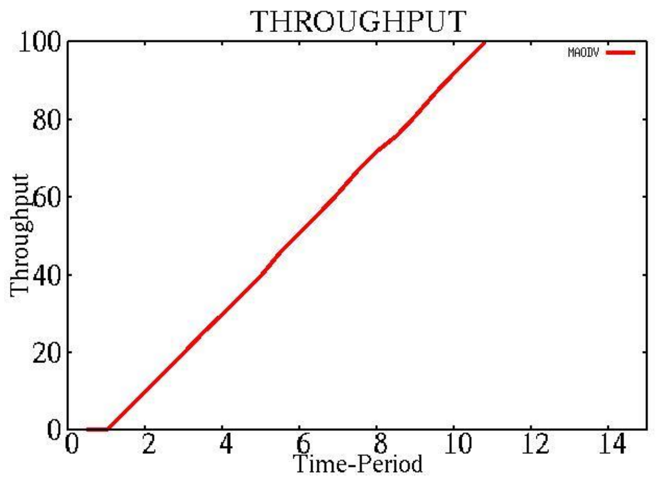

Figure 10. Throughput of Modified AODV

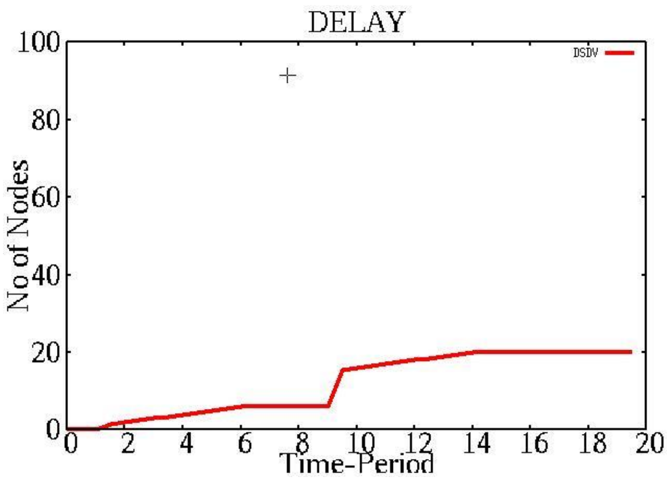

Figure 8. Delay of DSDV

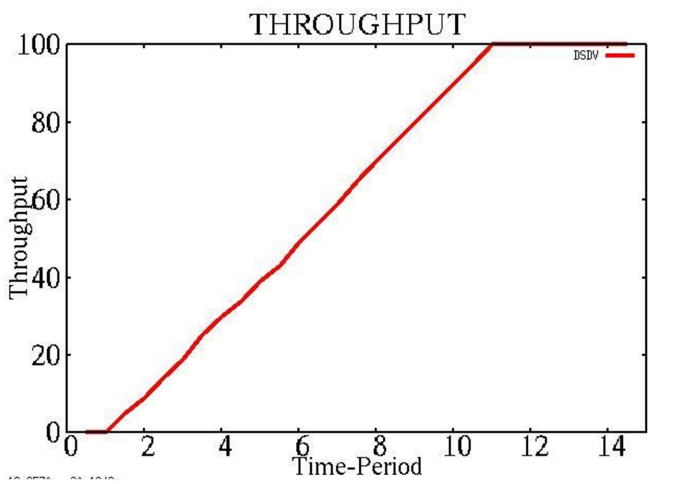

Figure 11. Throughput of DSDV

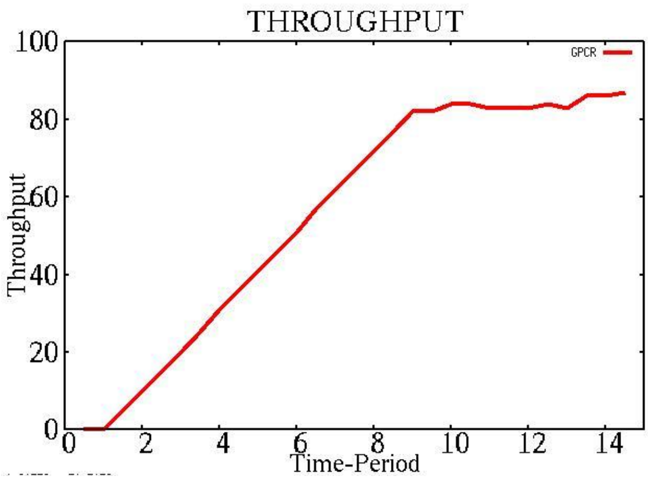

Figure 12. Throughput GPCR

V. Conclusions and Future Work

We discussed the two major categories of ad-hoc routing protocols and reviewed the different types of existing routing protocols of Topology-based and Position Based. The reviewed routing protocols are differs in architecture but the goal is to reduce the Communication overhead, maximize the throughput and end to end delay. Experimental results show the performance of existing routing protocols of major categories with the parameter metrics packet delivery ratio, throughput and end to end delay. We planned to extend our work with the discovery of new hybrid routing protocol which outperforms both Topology- based and Position-Based routing protocols.

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