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Performance Evaluation of Hybrid Routing Protocols in Mobile Ad Hoc Network

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Abstract*— *Mobile Ad hoc Network (MANET) is a self configuring infrastructure-less wireless network in which mobile nodes are free to move anywhere independently in any direction There is no central administration in MANET. Each mobile node acts as a router. In the absence of fixed infrastructure, wireless mobile nodes dynamically establish the network. Routing Protocols in MANET helps to communicate a mobile node with the other nodes in the network by sending or receiving the data packets. Routing Protocols must be capable of handling large number of nodes with minimum energy resources. Various numbers of routing protocols are developed in this field but it is not easy to decide which one is better. Establishing and maintaining the ad hoc network through the use of routing protocols is an important research area. In this paper, the performance of three hybrid routing protocols ZRP(Zone Routing Protocol), SHARP (Sharp Hybrid Adaptive Routing Protocol) and ZHLS (Zone Hierarchical Link State) is analysed and compared on the basis of parameters Throughput, Load, Data Dropped and Delay using simulator OPNET 14.0.

Keywords*— *MANET, Routing Protocols, ZRP, SHARP, ZHLS

I. INTRODUCTION

Wireless networks play a very prominent role in day to day communication. It is widely used in military & civilian applications, search and rescue, temporary meeting rooms & airports, industrial applications and even in personal area networks. There are two types of wireless networks [5]: Infrastructured Network and Infrastructure-less Network. Infrastructured network contains fixed and wired gateways whereas infrastructure-less network contains multi hop wireless nodes and it has no fixed infrastructure. MANET comes under the second type. MANET [1] [2] is a temporary wireless network in which no fixed infrastructure is used. So in MANET, topology changes frequently as mobile nodes moves independently and changes their links to the other nodes very quickly. Each mobile node acts a router and forwards the traffic to the other nodes in the network. If two mobile nodes are within each other's transmission range, they can communicate directly, otherwise the nodes in between have to forward the packets for them [4].

A mobile ad hoc network may consist of only two nodes or hundred nodes or thousand nodes as well. The entire collection of nodes is interconnected in many different ways. As shown in Fig. 1 there is more than one path from one node to another node. To forward a data packet from source to destination, every node in the hope must be willing to participate in the process of delivering the data packet. A single file is split it into a number of data packets and then these data packets are transmitted through the different paths. At the destination node, all these packets are combined in sequence to generate the original file.

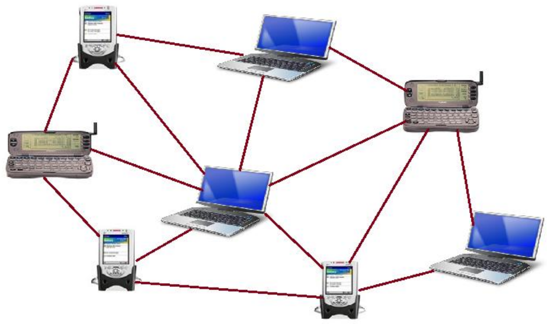

Fig. 1 Mobile Ad hoc Network

II. ROUTING PROTOCOLS IN MANET

Routing [4] is the process of transferring a packet from source to its destination. In the routing process, a mobile node will search for a path or route to communicate with the other node in the network. Protocols are the set of rules through which two or more devices communicate with each other. In MANET, routing tables are used for routing purpose. Routing tables contain the information of routes to all the mobile nodes.

The routing protocols in MANET are broadly classified into three categories [2] [4] [6]:

- Proactive or Table Driven Routing Protocols
- Reactive or On-Demand Routing Protocols
- Hybrid Routing Protocols

A. Proactive or Table Driven Routing Protocols

In Proactive or Table-Driven [8] Routing Protocols, there are routing tables which contains the information of routes to all the nodes. Routes are predefined in the routing tables and the packets are transferred to the routes. As route is already specified in the table so packet forwarding is faster and as the routes have to be defined first before transferring the packets so overhead is more. All routes are maintained at all the times so latency is low. Some highly used proactive routing protocols are Destination Sequenced Distance Vector (DSDV), Optimized Link State Routing (OLSR), Wireless Routing Protocol (WRP).

B. Reactive or On-demand Routing Protocols

In Reactive or On-Demand [1] [15] Routing Protocols, routes are not predefined. For packet transmission, a source node calls for route discovery phase to determine the route. The route discovery mechanism is based on flooding algorithm which employs on technique that a node just broadcasts the packet to all its neighbours and intermediate nodes forwards the packets to their neighbours [4]. Overhead is smaller in reactive protocols but latency is higher. Some reactive protocols are Dynamic Source Routing (DSR), Ad hoc On-Demand Distance Vector (AODV), Temporally Ordered Routing Algorithm (TORA).

C. Hybrid Routing Protocols

Hybrid Protocols [6] [7] are the combination of both i.e. Table-Driven and On-Demand protocols. These protocols take the advantage of best features of both the above mentioned protocols. These protocols exploit the hierarchical network architecture and allow the nodes with close proximity to work together to form some sort of backbone, thus increasing scalability and reducing route discovery [3]. Nodes within a particular geographical area are said to be within the routing zone of the given node. For routing within this zone, Proactive i.e. table-driven approach is used. For nodes that are located outside this zone, Reactive i.e. an on demand approach is used. So in Hybrid Routing Protocols, the route is established with proactive routes and uses reactive flooding for new mobile nodes [2]. In Hybrid Routing protocols, some of the characteristics of proactive and some of the characteristics of reactive protocols are combined, by maintaining intra-zone information proactively and inter-zone information reactively, into one to get better solution for mobile ad hoc networks [3].

III. OVERVIEW OF HYBRID ROUTING PROTOCOLS

A. Zone Routing Protocol

The Zone Routing Protocol was the first Hybrid routing protocol [9] [11]. It was proposed to reduce the control overhead of Proactive routing protocol and to decrease the latency of Reactive routing protocol. It is suitable for the networks with large span and diverse mobility patterns. For each node a routing zone is defined separately. Within the routing zone, routes are available immediately but for outside the zone, ZRP employs route discovery procedure.

For each node, a separate routing zone is defined. The routing zones of neighboring nodes overlap with each other's zone. Each routing zone has a radius ρ expressed in hops [9]. The zone includes the nodes whose distance from the source node is at most ρ hops.

In Fig. 2, routing zone of radius 2 hops for node A is shown. Routing zone includes nodes all the nodes except node L, because it lies outside the routing zone node A. The routing zone is not defined as physical distance, it is defined in hops. There are two types of nodes for a routing zone in ZRP [9]:

- Peripheral Nodes
- Interior Nodes

The nodes whose minimum distance to central node is exactly equal to the zone radius ρ are Peripheral Nodes while the nodes whose minimum distance is less than the zone radius ρ are Interior Nodes. In Fig. 2, Peripheral nodes are E, F, G, K, M and Interior Nodes are B, C, D, H, I, J. The node L is outside the routing zone of node A.

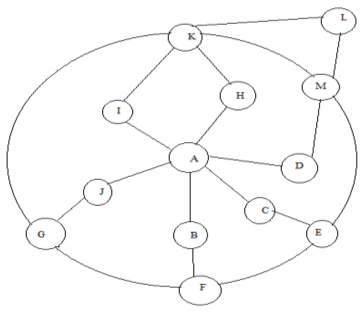

Fig. 2 Routing Zone of Node A with Radius ρ=2 hop

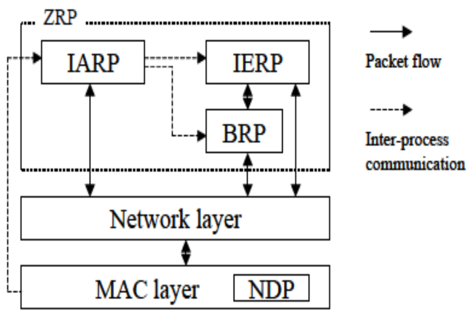

Fig. 3 ZRP Architecture [10]

The source node sends a route request to the peripheral nodes of its zone. Route request contains source address, the destination address and a unique sequence number. Each peripheral node checks its local zone for the destination. If the destination is not a member of this local zone, the peripheral node adds its own address to the route request packet and forwards the packet to its own peripheral nodes. If the destination is a member of its local zone, 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. By adjusting the transmission power of nodes, numbers of nodes in the routing zone can be regulated. Lowering the power reduces the number of nodes within direct reach and vice versa [10].

ZRP uses both the strategies i.e. Proactive and Reactive routing. Within a routing zone, Proactive strategy is used. Between the routing zones, Reactive strategy is used. ZRP refers to locally proactive routing component as IntrA-zone Routing Protocol (IARP). The globally reactive routing component is named as IntEr-zone Routing Protocol [9]. Its architecture is shown in Fig. 3. IARP maintains routing information of the nodes which are within the routing zone of a node. Route discovery and route maintenance is offered by IERP. When global discovery is needed, if the topology of local zone is known, it can be used to reduce the traffic. Instead of broadcasting a packet, ZRP uses the concept of Bordercasting [10]. Bordercasting packet service delivery is provided by the Bordercasting Resolution Protocol (BRP). The BRP [11] uses a map of an extended routing zone, provided by the local IARP, to construct Bordercast trees along which query packets are directed. The BRP uses very special query control mechanisms to steer route request away from areas of the network that have already covered by the query [11].

B. Sharp Hybrid Adaptive Routing Protocol

The Sharp Hybrid Adaptive Routing Protocol (SHARP) [3] [13] adapts efficiently and seamlessly between proactive and reactive routing strategies by varying the amount of routing information shared proactively. Around some nodes, it defines a proactive zone. Around the node, zone radius is specified which determines the number of nodes within a proactive zone. A node will be the member of the proactive zone if it has distance less than or equal to the zone radius.

Nodes outside the proactive zone of a given destination use reactive routing protocols to establish the routes to that node. Within a proactive zone, node specified proactive routing is employed. SHARP creates proactive zones automatically around hot destinations that receive data from many sources. The proactive zones act as collectors of packets, forwarding the packets efficiently to the destination, once the packets reach any node at the zone periphery [13].

Fig. 4 shows the SHARP topology, in which it maintains proactive zones around the destinations A, B and C. The vertices represent the nodes and directed edges represent route table entries. The size of proactive zone is adjusted by each node independently. The nodes with little or no load like nodes D, E and F will have no proactive zone and will rely on reactive routing.

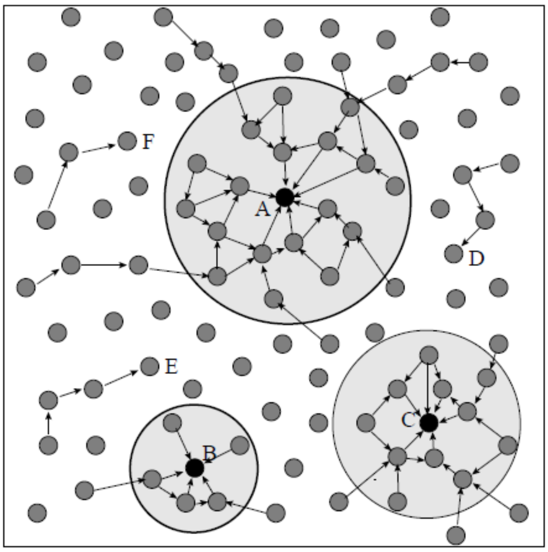

Fig. 4 Proactive zones of node A, B, C in SHARP [13]

C. Zone Hierarchical Link State

ZHLS [4] [14] is a Hierarchical protocol in which the network is divided into non-overlapping zones. Each node only knows the node connectivity within its zone and the zone connectivity of the whole network. In ZHLS, nodes are assumed to know their physical locations with assistance from a locating system like GPS. Based on geographical information, the network is divided into non-overlapping zones. ZHLS uses a hierarchical addressing scheme that contains zone ID and node ID [14]. A node determines its zone ID according to its location and the pre-defined zone map is well known to all nodes in the network. A two-level network topology structure is defined in ZHLS, the node level topology and the zone level topology. Node level topology tells how nodes are connected to each other physically. Zone level topology tells how zones are connected together. A virtual link between two zones exists, if at least one node of a zone is physically connected to some node of other zone [4]. This incurs a large communication overhead in the network. The Fig. 5 shows both node and zone level network topology. Since ZHLS divides an area into zones which can be further divided into sub-zones, it is considered as an appropriate topology for large scale MANET.

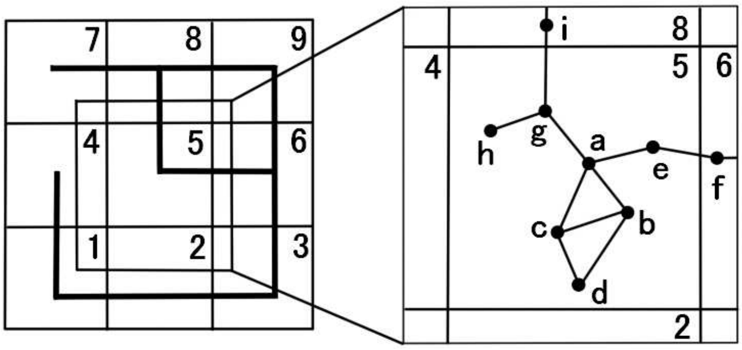

Fig. 5 Zone and Node Topology in ZHLS [15]

There are two kinds of link state updates, the node level LSP (Link State Packet) and the zone level LSP [14] [15]. A node level LSP contains the node IDs of its neighbours in the same zone and the zone IDs of all other zones. A node periodically broadcast its node level LSP to all other nodes in the same zone. Therefore, through periodic node level LSP exchanges, all nodes in a zone keep identical node level link state information. In ZHLS, gateway nodes broadcast the zone LSP throughout the network whenever a virtual link is broken or created. Consequently, every node knows the current zone level topology of the network. Before sending the data packets, a source node checks its intra-zone routing table. The routing information is already there if the destination node is in the same zone as the source node. Otherwise, the source node sends a location request to all other zones through gateway nodes. After a gateway node of the zone, in which the destination node resides, receives the location request, it replies with a location response containing the zone ID of the destination. The zone ID and the node ID of the destination node will be specified in the header of the data packets originated from the source node. During the packet forwarding procedure, intermediate nodes except nodes in the destination zone will use inter-zone routing table and when the packet arrives at the destination zone, an intra-zone routing table will be used.

IV. SIMULATION SETUP

A. *Simulation Scenario*

The OPNET 14.0 simulator is used to analyse the parametric performance of ZRP, SHARP and ZHLS. The IEEE 802.11 for wireless LAN is used as MAC layer protocol. The 60 mobile nodes are placed uniformly over the simulation area of 1000 m ×1000 m with the constant traffic load and constant pause time. Simulation scenario of ZRP protocol with 60 mobile nodes is shown in Fig. 6. Simulation parameters used for the implementation of three protocols are listed in Table I.

TABLE I SIMULATION PARAMETERS

Parameters	Values
Simulator	OPNET 14.0
Protocols	ZRP,SHARP,ZHLS
Simulation Time	300 seconds
Simulation Area	1000m×1000m
Pause Time	10 sec
Buffer Size (bits)	256000
Data Rate (bps)	11 Mbps
Mobility Model	Random way point
Mobile Nodes	60 Nodes

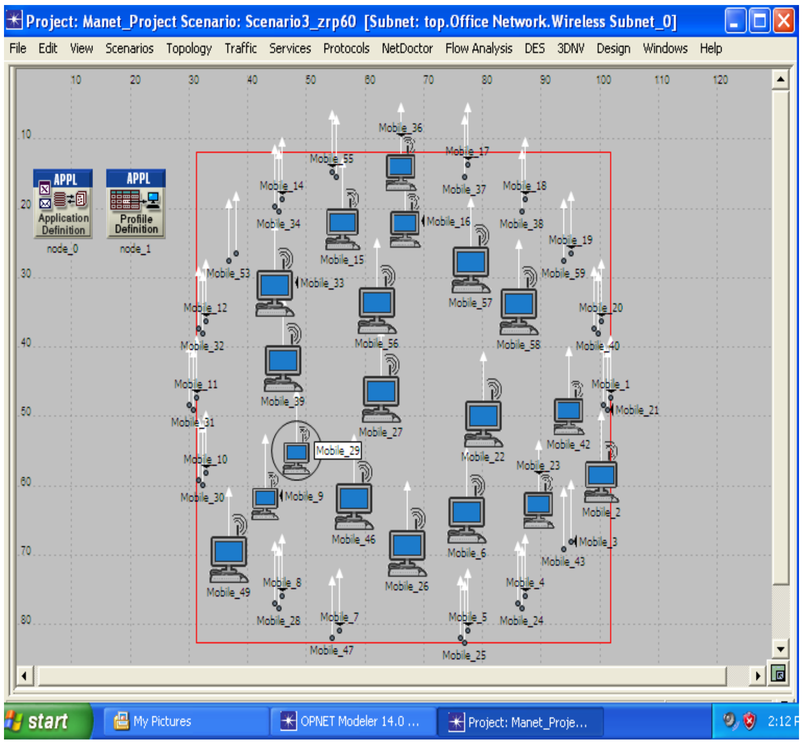

Fig. 6 Simulation Scenario for MANET protocols

B. *Performance Metrics*

OPNET simulator supports different parameters for different networks for the evaluation of different protocols. Some parameters are in built in OPNET, from which the parameters can be selected according to the requirement. The parameters used are Throughput, Load, Data Dropped and Delay [6] [7] [14].

1) Throughput: Throughput is the average rate of successful data packets received at the destination [2]. It is the measure of how fast we can actually send the packets through the network. It is measured in bits per second (bits/sec or bps) or data packets per second.
2) Load: Load in the wireless LAN is the number of packets sent to the network greater than the capacity of the network. When the load is less than the capacity of the network, the delay in packets is minimum. The delay increases when the load reaches the network capacity.
3) Data Dropped: Data dropped is the count of number of bits per second which are dropped during the travelling of signals from source to destination. Data can be dropped due to unavailability of access to medium.
4) Delay: The packet end-to-end delay refers to the time taken for a packet to be transmitted across the network from source to destination. In other words, it is the time a data packet is received by the destination minus the time a data packet is generated by the source. It is measured in seconds. End-to-end delay has a critical importance when a packet arrives too late at the destination node as a consequence the packet can be effectively lost. Lost packets due to delay have a negative effect on received quality.

V. RESULTS & DISCUSSION

A. *Throughput*

It is observed from the Fig. 7 that the throughput of ZRP, SHARP and ZHLS is 0 bits per second from the beginning of the simulation till 1 minute 45 second. After that the throughput of SHARP and ZRP gradually increases to 3,000,000 bits per second and 4,200,000 bits per second respectively. Then their throughput value gradually increases and then fluctuating between 5,000,000 bits per second to10,000,000 bits per second. At 1 minute 45 second the throughput of ZHLS increases from 0 bits per second to 1,000,000 and then it is showing constant value till the end of the simulation. In this scenario the maximum throughput observed is 10,010,955 bits per second for ZRP.

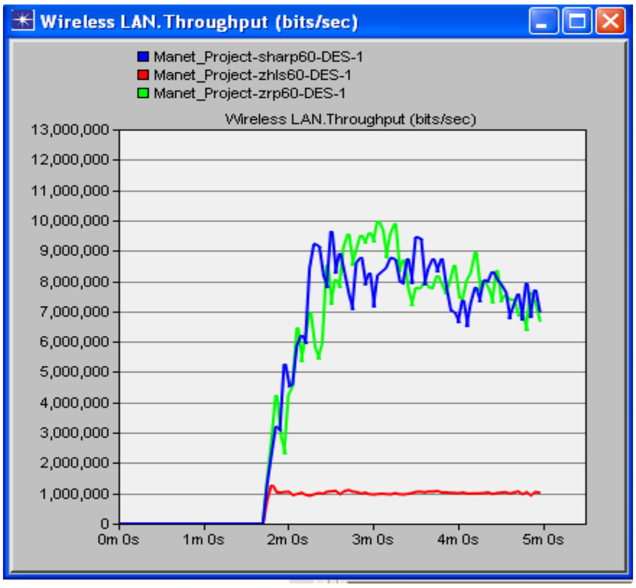

Fig. 7 Throughput

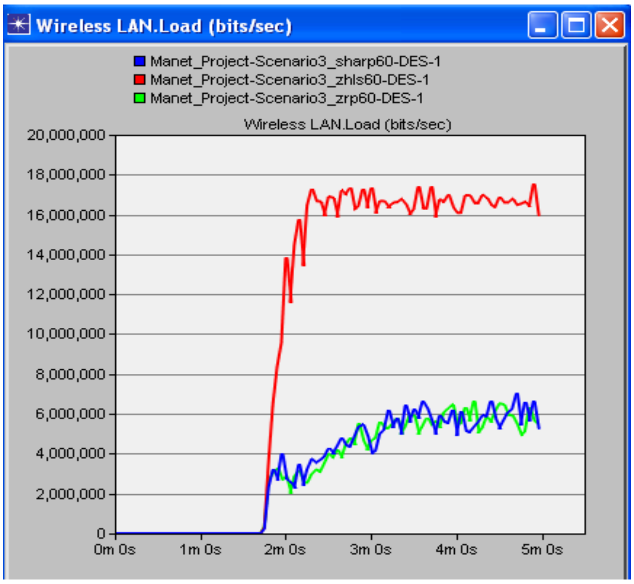

Fig. 8 Load

B. *Load*

From the Fig. 8, very high load is observed for ZHLS. For 60 nodes, ZRP shows low load as compared to SHARP and ZHLS. The maximum value of load for ZRP is 6,674,453 bits/sec. It is observed from the Figure 5.11 that with the increase in network size, ZHLS performs poorly and gives a very high load. The maximum load is 17,554,219 bits per second for ZHLS which is double than the ZRP and SHARP. SHARP gives high load than ZRP but very low than ZHLS. For SHARP, maximum load observed is 7,031,669 bits per second.

C. *Data Dropped*

From the Fig. 9, it is observed that the highest data is dropped in ZHLS. From the beginning of the simulation till 1 minute 50 second, no data is dropped. After that data dropped rate is highly increased from 0 bits per second to 12, 200,000 bits per second for ZHLS. Then it decreases to 10,450,000 bits per second and then it again increases to 14,300,000 bits per second. After 2 minute the data dropped rate in ZHLS lies between14,000,000 bits per second to 17,000,000 bits per second. The maximum data dropped value observed in ZHLS is 16,663,253 bits per second. The data dropped rate is less in ZRP and SHARP. It is observed that the data dropped rate of ZRP and SHARP is almost same from 2 minute o second till the end of the simulation. The maximum data dropped in ZRP is 5,811,253 bits per second at 4 minute 10 second. The maximum data dropped observed in SHARP is 6,218,901 bits per second at 4 minute 45 second.

D. *Delay*
From the Fig. 10, it is observed that the delay is maximum in SHARP as compared to ZRP and ZHLS. No delay is observed till 1 minute 45 second. After that there is high increase in delay in ZHLS and it reaches to its peak value which is about 19.158 second. The maximum delay is observed in SHARP which is about 19.541 second. There is less delay in ZRP as compared to SHARP. ZRP shows maximum delay of 19.353 second.

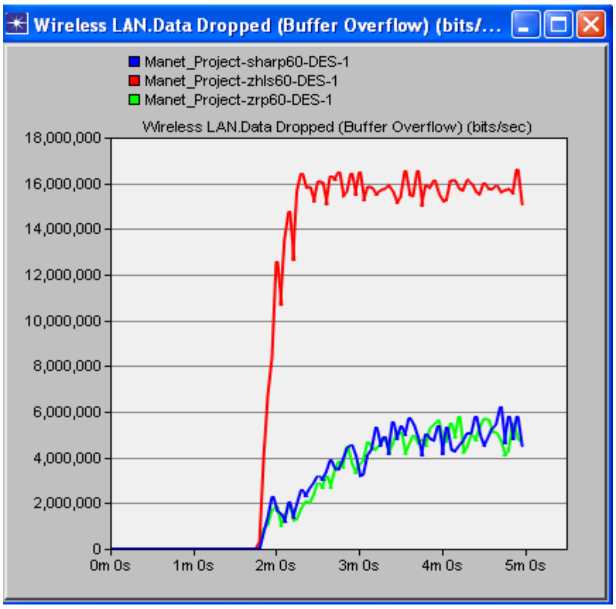

Fig. 9 Data Dropped

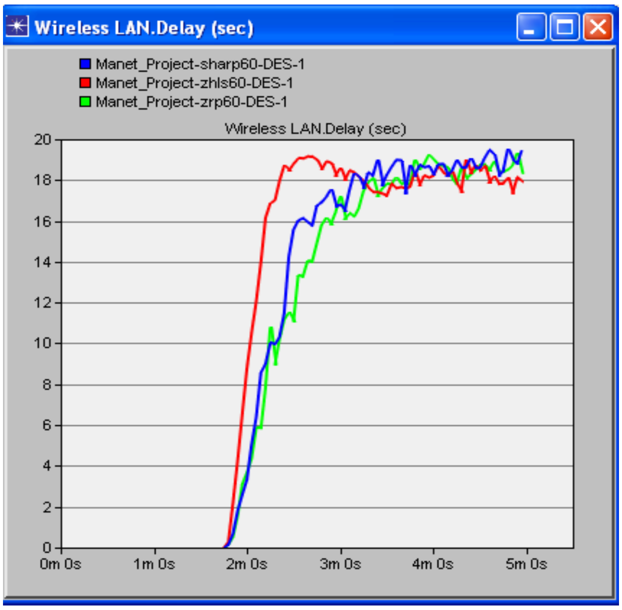

Fig. 10 Delay

VI. CONCLUSIONS
With 60 mobile nodes, a very high throughput is observed in ZRP. The throughput of SHARP is less than ZRP but very high than ZHLS. Minimum throughput is observed for ZHLS. A very high load is observed in ZHLS. Load in SHARP is less than ZHLS but more than ZRP. With the increase in load, delay also increases. Maximum delay is in SHARP and the delay in ZHLS is low. A very high amount of data is dropped in ZHLS. Minimum data is dropped in ZRP. So from the results it is concluded that the performance of ZRP is better than the other two protocols.

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