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A Simulation Based Performance Comparison of Routing Protocol on Mobile Ad-hoc Network (*Proactive, Reactive and Hybrid*)

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Abstract— **Mobile Ad-hoc Network (MANET) is a collection of wireless mobile nodes which dynamically forms a temporary network without the use of any existing network infrastructure or centralized administration. Recently, there has been a tremendous growth in the sales of laptops, handheld computers, PDA and portable computers. These smaller computers nevertheless can be equipped with megabytes/gigabytes of disk storage, high-resolution color displays, pointing devices and wireless communications adapters. Moreover, since many of these small computers operate for hours with battery power, users are free to move without being constrained by wires. To support such type of scenario MANET has been designed. MANET has several characteristics such as, dynamic topologies, bandwidth-constrained, variable capacity links, energy-constrained operation and limited physical security. There are three types of routing protocols in MANET such as Proactive, Reactive, and Hybrid. In this paper, a detailed simulation based performance study and analysis is performed on these types of routing protocols over MANET. Ad Hoc On-Demand Distance Vector (AODV), and Dynamic MANET On-demand (DYMO) routing protocol (reactive), Optimized Link State Routing protocol (OLSR) (proactive) and Zone Routing Protocol (ZRP) is (hybrid) have been considered in this paper for the investigation and their relative performance is reported.**

Keywords- Mobile Ad-hoc network (MANET), Qualnet 4.5 Developer, AODV, DYMO, ZRP, OLSR.

I. INTRODUCTION

For the past few years there has been a tremendous growth in the usage of notebook or laptop computers and PDAs while their prices are steadily decreasing. Being battery operated and with increasing processing capability, these devices are allowing people to get internet access while on the move using wired or wireless network. Though traditionally wired Network was the only solution to get network or internet access the use of wireless technology has become a more popular technique currently to access the Internet or connect to the local network for a corporate, educational, or private Users. It is much easier and less expensive to organize a wireless network compared to a conventional wired network, as the required effort and cost of running cables are negligible. Moreover, additional devices can be added to the wireless network at no extra cost and wireless network have many more advantages. Wireless equipped devices are called Nodes and every node has a fixed transmission range to communicate with each other. If the desired node (receiver) is out of range from the transmitter then intermediate nodes must function as routers and forward the packets towards the destination node thus the communication can be established by multiple hops. In this type of networking nodes might be moving arbitrarily which result in multi-hop networks with dynamic topology. This sort of network is called Mobile Ad-hoc Network (MANET). MANET is a collection of wireless mobile nodes which dynamically forms a temporary network without the use of any existing network infrastructure or centralized administration. For this purpose different types of protocols for MANET have been designed such as DSDV, AODV, TORA, DYMO, ZRP, and OLSR. These protocols can handle different situation of MANET. Performance comparison among some set of MANET routing protocols (Proactive, Reactive and Hybrid) is already done by the researchers such as among PAODV, AODV, CBRP, DSR, and DSDV [1], among DSDV, DSR, AODV, and TORA [2], among SPF, EXBF, DSDV, TORA, DSR, and AODV [3], among DSR and AODV [4], among STAR, AODV and DSR [5] and among AM Route, ODMRP, AMRIS and CAMP [6]. This paper presents the performance comparison of OLSR, AODV, ZRP and DYMO routing protocols where OLSR, AODV and ZRP are the prominent protocols of Proactive, Reactive and Hybrid nature respectively and DYMO is reactive routing protocol which has been especially designed for MANET. To the best of the authors' knowledge no reported study has been found yet representing the relative merits and demerits among the above mentioned protocol.

The rest of the paper is organized as follows. Descriptions of routing protocols are given in Section II. Section III describes simulation environment. Results are discussed and analyzed in section IV. Finally, conclusion is drawn in section V.

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II. DESCRIPTION OF THE PROTOCOLS

A. OLSR

Optimized Link State Routing protocol (OLSR) [3, 8] is based on link state algorithm and it is proactive in nature. OLSR is an optimization over a pure link state protocol [1] as it squeezes the size of information send in the messages, and reduces the number of retransmissions. It provides optimal routes in terms of number of hops. For this purpose, the protocol uses multipoint relaying technique to efficiently flood its control messages [3]. Unlike DSDV and AODV, OLSR reduces the size of control packet by declaring only a subset of links with its neighbors who are its multipoint relay selectors and only the multipoint relays of a node retransmit its broadcast messages. Hence, the protocol does not generate extra control traffic in response to link failures and node join/leave events. OLSR is particularly suitable for large and dense networks [3]. In OLSR, each node uses the most recent information to route a packet. Each node in the network selects a set of nodes in its neighborhood, which retransmits its packets. This set of selected neighbor nodes is called the multipoint relays (MPR) of that node. The neighbors that do not belong to MPR set, read and process the packet but do not retransmit the broadcast packet received form node. For this purpose each node maintains a set of its neighbors, which are called the MPR Selectors of that node. This set can change over time, which is indicated by the selectors in their HELLO messages. The smaller set of multipoint relay provides more optimal routes. The path to the destination consists of a sequence of hops through the multipoint relays from source to destination. In OLSR, a HELLO message is broadcasted to all of its neighbors containing information about its neighbors and their link status and received by the node which are one hop away but they are not relayed to further nodes. On reception of HELLO messages, each node would construct its MPR Selector table. Multipoint relays of a given node are declared in the subsequent HELLO messages transmitted by this node.

B. AODV

Ad-hoc On-demand distance vector (AODV) [9] is another variant of classical distance vector routing algorithm. Like DSDV, AODV provides loop free routes in case of link breakage but unlike DSDV, it doesn't require global periodic routing advertisement. AODV experiences unacceptably long waits frequently before transmitting urgent information because of its on demand fashion of route discovery [9]. In AODV, each host maintains a traditional routing table, one entry per destination. Each entry records the next hop to that destination and a sequence number generated by the destination, which indicates the freshness of this information. AODV uses a broadcast route discovery mechanism where source node initiate route discovery method by broadcasting a route request (RREQ) packet to its neighbor. The RREQ packet contains a sequence number and a broadcast id. Each neighbor satisfied with the RREQ replies with the route reply (RREP) packet adding one in the hop count field. Unlike DSDV, in AODV if a node cannot satisfy the RREQ, it keeps track of the necessary information in order to implement the reverse and forward path setup that will accompany the transmission of the RREP. The source sequence number is used to maintain freshness information about the reverse route to the source and the destination sequence number specifies how fresh a route to the destination must be before it can be accepted by the source. The source node can begin data transmission as soon as the first RREP is received. Hence, the first sending of data packet to the destination is delayed due to route discovery process.

C. DYMO

The Dynamic MANET On-demand (DYMO) [10] routing protocol is a simple and fast routing protocol for multihop networks. It determines unicast routes among DYMO routers within the network in an on-demand fashion, offering improved convergence in dynamic topologies. To ensure the correctness of this protocol, Digital signatures and hash chains are used. The basic operations of the DYMO protocol are route discovery and route management. Firstly, route discovery is the process of creating a route to a destination when a node needs a route to it. When a source node wishes to communicate with a destination node, it initiates a Route Request (RREQ) message. In the RREQ message, the source node includes its own address and its sequence number, which is incremented before it is added to the RREQ. It can also include prefix value and gateway information if the node is an Internet gateway capable of forwarding packets to and from the Internet. Finally, a hop count for the originator is added with the value 1. Then information about the destination node is added. The most important part is the address of the destination node. If the originating node knows a sequence number and hop count for the target, these values are also included. Upon sending the RREQ, the originating node will await the reception of an RREP message from the target. If no RREP is received within RREQ waiting time the node may again try to discover a route by issuing another RREQ. When the RREQ reaches the destination node, an RREP message is created as a response to the RREQ, containing information about destination node, i.e., address, sequence number, prefix, and gateway information, and the RREP message is sent back along the reverse path using unicast. Similar to the RREQ dissemination, every node forwarding the RREP adds its own address to the RREP and installs routes to destination node. Secondly, route maintenance is the process of responding to changes in topology that happens after a route has initially been created. To maintain paths, nodes continuously monitor the active links and update the Valid Timeout field of entries in its routing table when receiving and sending data packets. If a node receives a data packet for a destination it does not have a valid route for, it must respond with a Route Error (RERR) message. When creating the RERR message, the node makes a list containing the address and sequence number of the unreachable node. In addition, the node adds all entries in the routing table that is dependent on the unreachable destination as next hop entry. The purpose is to notify about additional routes that are no longer available. The node sends the list in the RERR packet. The RERR message is broadcasted.

D. ZRP

Zone Routing Protocol (ZRP) [11] is a hybrid protocol which combines the advantages of both proactive and reactive schemes. It was designed to mitigate the problems of those two schemes. Proactive routing protocol uses excess bandwidth to maintain routing information, while reactive protocols suffers from long route request delays and inefficient flooding the entire network for route determination. ZRP addresses these problems by combining the best properties of both approaches. Each node in ZRP, proactively maintains routes to destinations within a local neighborhood, which is referred as a routing zone. However, size of a routing zone depends on a parameter known as zone radius. In ZRP, each node maintains the routing information of all nodes within its routing zone. Nodes learn the topology of its routing zone through a localized proactive scheme, referred as an Intra-zone Routing Protocol (IARP). No protocol is defined to serve as an IARP and can include any proactive routing protocol, such as distance vector or link state routing. Different zone may operate with different proactive routing protocols as long as the protocols are restricted within the zone. A change in topology only affects the nodes inside the zone, even though the network is quite large. The Inter-zone Routing Protocol (IERP) is responsible for reactively discovering routes to the destination beyond a node's routing zone. This is used if the destination is not found within the routing zone. The route request packets are transmitted to all border nodes, which in turn forward the request if the destination node is not found within their routing zone. IERP distinguish itself from standard flood search by implementing the concept, called border-casting. The border-casting packet delivery service is provided by the Border-cast Resolution Protocol (BRP) [12]. For detecting link failure and new neighbor nodes, ZRP relies on a protocol provided by the Media Access Control (MAC) layer, known as Neighbor Discovery Protocol (NDP). If MAC level NDP is not supported, the functionality must be provided by IARP. NDP transmits HELLO beacons at regular intervals to advertise their presence. After receiving a beacon, neighbor table is updated. If no beacon is received from a neighbor within a specified time, the neighbor is considered as lost.

III. Simulation Environment

The overall goal of this simulation study is to analyze the performance of reactive, proactive and hybrid routing protocols in Mobile Ad-hoc environment. The simulation has been performed using QualNet version 4.5[13], a software that provides scalable simulations of Ad hoc Networks and a commercial version of GloMoSim. Here the traffic and mobility model is different from the common traffic and mobility model used in. This traffic model is designed for dense area of mobile nodes and used reasonable mobility/traffic speed in any metropolitan city. Traffic sources are Constant Bit Rate (CBR). By changing the total number of traffic sources, we get scenarios with traffic loads 30 sources, the packet rate at the source node is 4 packets/sec. The source destination pairs spread randomly over the network. Only 512 byte data packets are used. The number of source destination pairs and the packet sending rate in each pair is varied to change the offered load in the network. The mobility model uses the random waypoint model in a rectangular field. In our simulation, we consider a network of 120 nodes that are placed randomly within a 1500m X 1500m and operating over 200 seconds. Here each packet starts its journey from a random source location to a random destination. The simulation is run with mobility patterns generated for 11 different pause times.

A two-ray propagation path loss model is used in our experiments with lognormal shadowing model. The MAC 802.11 is chosen as the medium access control protocol. The specific access scheme is CSMA/CA with acknowledgements. In order to fully guarantee the service types, we configure 8 queues at the network layer. Unsolicited grant service (UGS) service type is considered to support real-time data streams consisting of fixed-size data packets issued at periodic intervals.

To evaluate the performance of routing protocols, we use four different quantitative metrics to compare the performance of the selected protocols. They are

- Packet Delivery Fraction: The fraction of packets sent by the application that are received by the receivers [14].
- Average End-to-end delay: End-to-end delay indicates how long it took for a packet to travel from the source to the application layer of the destination [15].
- Jitter: Jitter is the variation in the time between packets arriving, caused by network congestion, timing drift, or route changes.
- Throughput: The throughput is defined as the total amount of data a receiver receives from the sender divided by the time it takes for the receiver to get the last packet [16].

IV. Simulation Result and Discussions

In this section simulation results for the selected protocols in term of packet delivery fraction, average end-to-end delay, jitter and throughput are elaborated.

A. *Simulation result for packet delivery fraction*

Figure 1 shows the simulation results of packet delivery fraction verses pause time for 30 nodes. DYMO has the highest packet delivery fraction (33%). In MANET AODV is purely on-demand routing protocol and DYMO is Dynamically on-demand routing protocol that means DYMO can be adjusted dynamically and send data better than AODV. In case of the link breakage and route error or route discovery failure AODV sends two times RREQ for getting destination route whereas DYMO sends three times RREQ thus leading to better performance for DYMO than AODV. Packet delivery fraction of ZRP and AODV are similar but better than OLSR. This is because, Zone Routing Protocol has both proactive and reactive nature. OLSR has proactive nature and it can not form routing table proficiently with the dynamically changing network. During link breakage OLSR fails to resend data. Moreover, it is efficient for cluster and close network nodes. So OLSR has lower performance than other protocols.

B. *Simulation result for Average end-to-end delay*

In figure 2 average end-to-end delay verses pause times are plotted. It shows the average time it took for a packet to travel from the source to destination's application layer. OLSR and ZRP demonstrate lower delay than other two protocols due to their operation which is table driven in nature. The presence of routing information in advance leads to lower average end-to-end delay. But DYMO shows worst performance in the case of average end-to-end delay. DYMO often uses stale routes due to the large route cache, which leads to frequent packet retransmission thus leading to extremely high average end-to-end delay. AODV shows an average performance with respect to DYMO, ZRP, and OLSR protocols. As shown in figure 2 average end-end delay of AODV is more than ZRP and OLSR. AODV broadcast messages through entire network to find its destination because of its reactive nature. AODV needs more time in route discovery. Hence it leads to greater end-to-end delay. So as compared to other protocols average end-end delay of ZRP and OLSR offers better performance.

C. Simulation result for jitter

Figure 3 shows value of pause time verses jitter. DYMO uses multi path routing so that more probability of collision of packet leading to higher jitter value (more than 2.5s). DYMO has greater chance to packet loss between transmission packets. AODV shows average good performance in terms of jitter though it is still higher than ZRP and OLSR protocols. AODV uses a broadcast route discovery mechanism where source node initiate route discovery method by broadcasting a route request (RREQ) packet to its neighbors so there is more scope for jitter. OLSR is proactive in nature and it provides optimal routes in terms of number of hops. For this purpose, the protocol uses multipoint relaying technique to efficiently flood its control messages. So that OLSR has less jittering than other protocol. ZRP is Hybrid type protocol that also shows better performance in terms of jitter due to reduced message flooding.

D. Simulation result for Throughput

In figure 4 the throughput result for 30 source nodes are shown. The graph shows ZRP has highest throughput value than other protocols. ZRP delivers data packets at higher rate because of proactive and reactive characteristics. In ZRP, while sending in INTRA zone routing protocol if it fails to send data or link breakdown occurs then INTER zone routing protocol will be activated. Henceforth data transfer will continue. OLSR has worst performance in throughput than other protocols because most of the nodes can not participate in data transfer. Another reason is link breakage since OLSR cannot repair route of breakage path. AODV and DYMO show good throughput performance than OLSR but less than ZRP. DYMO shows better performance than AODV because it can adjust dynamically in case of the change in the network topology and can do better route repair function than AODV.

V. CONCLUSION

In this paper, the performance of OLSR, AODV, DYMO and ZRP is compared with respect to four performance metrics. DYMO shows best performance than AODV, OLSR, and ZRP in term of packet delivery fraction. Where ZRP and AODV show close value in the graph while OLSR performed the worst. But in terms of average end-to-end delay and jitter DYMO performed the worst. OLSR and ZRP performed the best in terms of the average end-to-end delay and jitter compared to AODV and DYMO. ZRP shows the best performance in terms of throughput compared to DYMO, AODV and OLSR The overall performance considering the metrics packet delivery ratio, average end-to-end delay, jitter and throughput, ZRP demonstrates the best performance than the remaining three routing protocols

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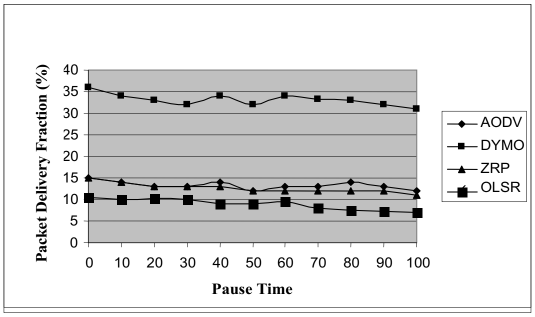

Figure 1: Packet Delivery Fraction for 30 Nodes

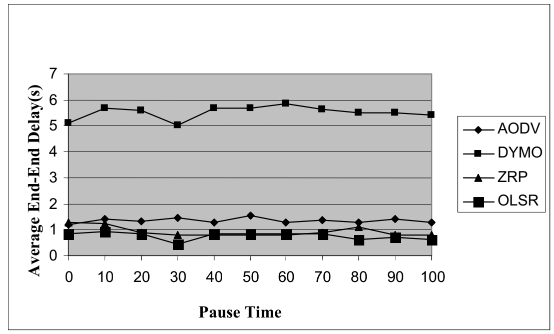

Figure 2: Average End-to-End Delay for 30 Nodes

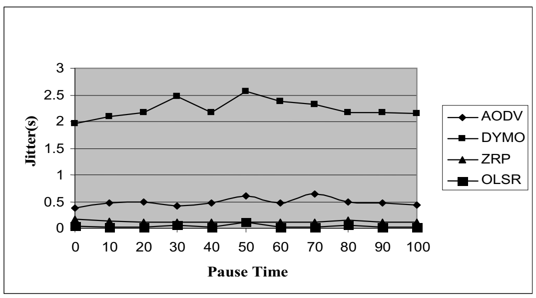

Figure 3: Jitter for 30 Nodes

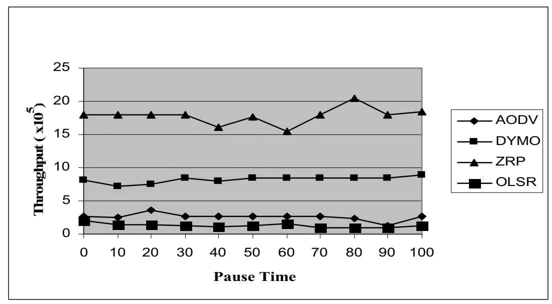

Figure 4: Throughput for 30 Nodes