Mobile Ad Hoc Network Routing Protocols – Using OPNET Simulator

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Abstract- Mobile Ad Hoc Networks have evolved rapidly and are finding numerous applications in the areas of self-creating, self-organizing and self-administering wireless networks. The present paper describes use of and comparison of three routing protocols. The parameters used for comparison are throughput and delay in response by varying the number of mobile nodes. A random waypoint mobility model was used for fixing the mobile nodes. The simulation study is carried out using OPNET modeler 14.5. Simulation result shows that for increasing number of mobile nodes OLSR offers better throughput and minimum delay than AODV and GRP routing protocols.

Index Terms--MANET, OPNET, Routing Protocols, throughput, delay.

I. INTRODUCTION

MANET

Mobile Ad hoc network [1] is a way to communicate different mobile device without any central administration or infrastructure. This property of MANET makes it unique and different among all other networks. The major challenges of Mobile Ad hoc networks are dynamic topology, radio communicating for multi-hop communication, bandwidth limitation, frequently breakage of links [2], power and resource constraint [3], physical security, network control without centralised access etc [4].

As MANET networks forms autonomous and communicating in an infrastructure less environment, they are gaining importance with huge number of applications in the commercial, military and private sectors.

Various routing protocols have been designed to exchange the information between different MANET nodes. Efficient routing protocols are key components of successful, reliable and proficient communications. These protocols are classified into three categories. Proactive or Table-driven routing protocols, Reactive or On-demand routing protocols and Hybrid (both proactive and reactive) routing protocols.

In reactive routing approach, a routing protocol does not take the initiative for finding a route to a destination, until it is required, resulting less overhead of control traffic [5]. E.g. AODV [6], DSR [7]. On the other hand, Proactive protocols mainly concern to provide route immediately as and when needed and are based on timely exchange of control messages for route discovery and maintenance. To send frequent updates of topology proactive routing protocol uses most of the bandwidth of the network. [8]. The examples of this kind of protocols are OLSR [9], DSDV [10] etc. Hybrid MANET protocols combine the features of both the classes i.e table driven and on demand. These category protocols keep route available for some destination all the time as like proactive feature and discovers the route for other destination only when it is required as like reactive protocol feature. ZRP [11], GRP [12] and TORA are the examples of hybrid protocols. To better understanding and utilization of the routing protocols it important to study and compared various routing protocols from different category.

OPNET

OPNET is one of the general-purpose simulator tool, build to check the performance of networking projects. It has some unique features like it provides Graphical User Interface for analysing, debugging and to simplify many tasks of simulation process. OPNET is a discrete event, object oriented commercial simulator. Though it is commercial, free licence tool is available for educational purpose [13]. OPNET simulator also allows the features like personalised presentation during runtime, addition of new models that are specific to the infrastructure to simulate etc, [14].

There are many reports in on using NS2 simulator for evaluating the performance of variety of routing protocols for MANET. However very few works have been done to evaluate the performance of routing protocols for MANET using OPNET modeler which provides very good GUI interface and programming tools which are very helpful to the researcher to do the simulation.

This paper discussed the most widely used three routing protocols of MANET and compared the performance using varying number of mobile nodes (25, 50, 75 and 100) using end to end delay and throughput performance matrices.

The rest of the paper is organized as follows: Overview of Mobile Ad hoc network routing protocols discussed in Section 2. Section 3 describes the Simulation Environment studied. Section 4 gives the analysis of results and discussion. Section 5 concludes this paper.

II OVERVIEW OF ROUTING PROTOCOLS

Routing protocols in MANET are categories into three types – Table Driven, On-Demand and Hybrid. In this paper we have considered the most popular protocols among these three types.

This section briefly describes the algorithms AODV, OLSR and GRP protocols.

AODV Routing Protocol

AODV falls under category of on-demand routing protocol. AODV starts building of the route from source to destination only if it required by source node. This strategy comparatively reduces the control overhead. Types of messages or packets for routing in AODV are – RREQ (Route Request Packet), RREP (Route Response Packet), RERR (Route Error Packet) and Hello message packet [15]. As per an RFC document [16], the AODV uses two phases for routing purpose – Route Discovery Phase and Route Maintenance phase. In the route discovery phase the path from source to destination will be discovered and transmission begins. In the maintenance the algorithm takes care of the route repair [17, 18]. The same has been described in algorithmic steps Figure 1.

Fig.1 –AODV Protocol

```
Input: S Node, D Node, RREQ
Output: RREP, Route from S to D
1: Start
2: if DestAddressAvial (D Node) ==1 then
3:    UpdateRT (); //Synchronising bet nodes
4:    TransferMsg (RT.NextNode) ;
5:    if IsNodeReady (NextNode)==1 then
6:          if IsDestNode (D Node) ==1 then
7:                TransferFlag=1; Goto Step 40
8:          else
9:                Goto Step 4;
10          end if;
11:   else
12:         if RouteRepair () ==1 then//Send RERR pkt to S
13:               Goto Step 4;
14:         else
15:               if TTL > 0 then
16:                     TTL=TTL-1; Goto Step 12;
17:               else
18:                     Goto Step 35;
19:               end if;
20:         end if;
21:   end if;
22: else
23:   if RouteDiscovery (D Node) ==1 then
24:         ReveserPathSetup (RREP pkt);
25:         Goto step 4;
26:   else
27:         if TTL > 0 then
28:               TTL=TTL-1; Goto step 23;
29:         else
30                Goto step 35;
32          end if;
33:   end if;
34: end if;
35: if TransferFlag=1 then
36:         Print "Transfer Successful";
37: else
38:         DropPacket ();
39: end if;
40: Stop;
```

The algorithm exhibits a loop free processing and ensures freshness of route through the use of sequence number [17]. AODV can also support both multicasting and unicasting within unchanging framework. AODV protocol provides the facility of timer to expire the life time of route to maintain only fresh route in the table. AODV also has a challenge in Route discovery process might hamper optimal path discovery due to traffic overhead. Also congestion control and avoidance methods are not present in AODV to balance the traffic load [19.]. The delivery ratio of AODV can drop dramatically as number of connection increases [20].

OLSR protocol:

OLSR routing protocol of MANET is proactive in nature, i.e. it provides the route to the nodes in the network as and when needed [21]. OLSR inherits its basic properties from Link State Routing (LSR) protocol. It provides optimization to this LSR through a concept known as MPR (MutiPoint Relay). MPR are the nodes choose to flood the link state information to all other nodes within the network [22]. Use of MPR considerably reduces the control overhead compared to classical flooding mechanism. As OLSR is periodic in nature Route Construction process continuously going on to available routes as and when needed to every node. [23][24].

OLSR routing protocol can be described in three stages.
Figure 2(a), 2(b) and 2(c) describes these steps. In Fig.2(a) each node discovers the path from every other node in the network. While it discovers the path MPR helps the nodes to flood the link state information to all other nodes within the network. Fig 2(b). Fib 2(c) will takes care of message transmission in case required.
Types of messages/packets used in OLSR are – Hello packets, Topology control Packets and MID packets.
Algorithmic steps for OLSR are as follows.

Fig.2 (a) OLSR Protocol

```
Input: Hello pkts, Topology Control Pkts, MID pkts
Output: Generate Hello, TC and MID pkts, Route for each node
1: Start
2: for each node N in network
3:    Broadcast Hello msg-received by all neighbour nodes 'n'
4:    if node 'n' receives Hello msg then
5:          Process Link Sensing;
6:          Construct/update MPR Selector table;
7:          if MPR set available then
8:                Generate TC_msg;
9:                if change encounter then
10:                     Increment seq. no.;
11:                     Generate TC_msg;
12:                     Broadcast TC_msg through MPR;
13:                     if TC_msg covers entire network then
14:                           if node receives TC_msg then
14:                                 if new info received then
15:                                       Update RT;
16:                                 else
17:                                       Update time;
18:                                 end if;
19:                           else
21:                                 Delete stale entry;
22:                           end if;
23:                     else
24:                           Generate TC_msg;
25:                           Goto step 13;
26:                     end if;
27:               else
28:                     Update RT;
29:                     Advertise the new entry if any;
30:                     Keep sending "Hello Pkts" periodically;
32:               end if;
33:         else
34:               Stop forwarding TC-msg;
```

```
35:             Goto step 2:
36:         end if;
37:     end if;
38: Stop.
```

Fig. 2(b) - MPR Nodes selection Algorithm

```
Input:  Node N of OLSR Protocol
Output: MPR selection set for Node n
1: Start
2: Identify all nodes set as N1 : neighbours of node N;
3: Identify all nodes set as N2 : Strict 2-hop neighbours of N;
4 : Add rows to the MPR set for those nodes in N1 which are the only
nodes to provide highest reachability to node in N2;
5: Stop
```

Once the route discovery process is complete, then any node in network can transfer packets to any another node through Packet Forwarding Algorithm described in Fig.2(c).

Fig. 2(c) – Packet Forwarding Algorithm from S to D in OLSR

```
Input: S node, D node, RT.
Output: Successful transmission of packets from S to D
1: Start
2: if node S wants to send packet to node D then
3:      Forward packet P to next hop n in RT towards node D;
4:      if node n == D then
5:              Transfer packet to Destination D;
6:              Set Transfer_Successful =True;
7:              Goto step 25;
8:          else
9:              if tuple exists in duplicate set of RT then
10:                 if (D_add == Ori_add and D_seq_no == msg_seq_no)
then
11                      if (d_retransmitted == FALSE ) then
12:                             Goto step 3;
13:                     else
14:                             Discard the packet;
15:                     end if;
16:                 else
17:                             Create tuple t in duplicate set;
18:                             set t.D_addr    = Ori_add;
19:                             set t.D_seq_num = msg_seq_num;
20:                             Goto step 9;
21:                 end if;
22:             else
23:                 Resume Route Calculation process;
24:             end if;
25: Stop.
```

Flooding in OLSR minimized through the use of MPR nodes. Link reliability does not require in OLSR protocol as every node sends packets periodically and sequential delivery does not matter. OLSR protocol is best suited for dense network. An increase in number of mobile nodes causes to increase in number of control overhead messages. OLSR requires considerable amount of time to rediscover the broken link. OLSR require more processing power than other protocols to maintain the information of both one-hop and two-hop neighbors.[25]

GRP Protocol

GRP is an OPNET's custom proactive routing protocol. Routing of GRP is based on shortest geographical distance. Though this protocol falls under proactive category, source node can initiate the process of route discovery if route is not available to the destination. This approach of GRP comes under hybrid routing protocol. In GRP, position of each node is marked by Global Positioning System and flooding optimization is done using quadrant scheme. Size of quadrant is custom built. Hello protocol is used by every node to list all the neighbors.

One of the important concept known as backtracking is used by GRP for blocked routes [12]. Algorithmic steps for GRP are as shown in Fib 3.

GRP gives better performance through the use of backtracking. Global Positioning System gives exact position of nodes in GRP. But for shorter interval GRP may work in reverse manner. Packets dropping rate may increase as blocked routes are increased [26].

Fig. 3 GRP Protocol

```
Algorithm 5: Geographic Routing Protocol
Input: Node S, node D
Output: Successful transmission
1: Start
2: Divide the network area in m number of quadrants.
3:      if  node S wants to send some packets to node D then
4:          Start Route Discovery process – Flood_pkt (DQ, D, Quad_no);
5:          if node crosses Quadrant boundary then
6:              Start Route Discovery process for node D in that quadrant.
7:              if intermediate node = Destination D then
8:                      Destination node D start flooding NIG packets;
9:                      if NIG packet reached to S then
10:                         Starts Transmission process through NIG;
11:                         Goto step 36;
12:                     else
13:                         Goto step 5;
14:                     end if;
15:             else
16:                     Goto step 5;
17:             end if;
18:         else
19:             Goto step8;
20:         end if;
21:         if transmission process blocked at node B then
22:             Search nearest node to reach to D;
23:             if not found then
24:                     if node S reached then
25:                         Drop packet; Goto step 36;
26:                     else
27:                         Goto step 23;
28:                     end if;
29:             else
30:                     Start transmission process;
31:             end if;
32:         end if;
33:     else
34:         Goto step 3;
35:     end if;
36: Stop.
```

Table-1. Shows the characteristic comparison of above three MANET Routing Protocols (AODV, OLSR and GRP).

Table-1 – AODV, OLSR and GRP

Parameter	AODV	OLSR	GRP
Network Organization	Flat	Flat	Flat – Hierarchical
Topology dissemination	When required	Periodical	Both
Route Availability	Computed as per need	Always available	Both
Communication Overhead	Low	Low because of MPR	Medium
Use of GPS	No	No	Yes
Link Support Status	Bidirectional	Unidirectional	Unidirectional
Flooding Mechanism	Broadcasting to every node	Use of MPR for flooding	Flooding within Quadrant
Packets Used	RREQ Packet, RREP Packet, RERR Packet Hello Packet.	Hello Packet, Topology Control Packet, MID Packet.	Hello packet, Backtrack packet

III. SIMULATION PARAMETERS AND SETUP

OPNET (modeler 14.5) simulator is used for simulation. Simulation experiments were conducted for three MANET routing protocols (AODV, GRP and OLSR) by varying number of mobile nodes (25, 50, 75 and 100) on 5kmX5km fixed sized network. Every mobile node supports transmission data rate of 11Mbps, generating packets of 1024 bytes, after every 2 seconds. Random Waypoint (RWP) mobility model is used for defining mobility pattern of nodes. Mobile nodes are moving at 10 meters/sec speed. Table-2 contains simulation parameters, Table-3 is the traffic generation parameters and Table-4 shows mobility configuration parameters.

Table-2**:** Simulation Parameters

SNo	Parameter	Value
1	Number of Mobile Nodes	25, 50, 7 5 and 100
2	Campus Network Size	5KmX5Km
3	Routing Protocols	AODV, GRP and OLSR
4	Simulation Time	5 Minutes

Table-3: Traffic Generation Parameters

SNo	Parameter	Value
1	Traffic Start Time (seconds)	1.0
2	Packet Inter-arrival Time (Seconds)	2
3	Packet Size (bytes)	1024
4	Traffic Stop Time (seconds)	End of Simulation
5	Transmission Data Rate (Mbps)	11

Table-4: Mobility Configuration Parameters

SNo	Parameter	Value
1	Mobility Model	Random Waypoint
2	Speed (meters/seconds)	10
3	Pause Time (Seconds)	10
4	Start Time (Seconds)	10
5	Stop Time (Seconds)	End of Simulation

IV. RESULT ANALYSIS AND DISCUSSION

The performance of three MANET routing protocols AODV, GRP and OLSR are compared based on throughput and delay by varying number of mobile nodes.

a) Throughput comparison

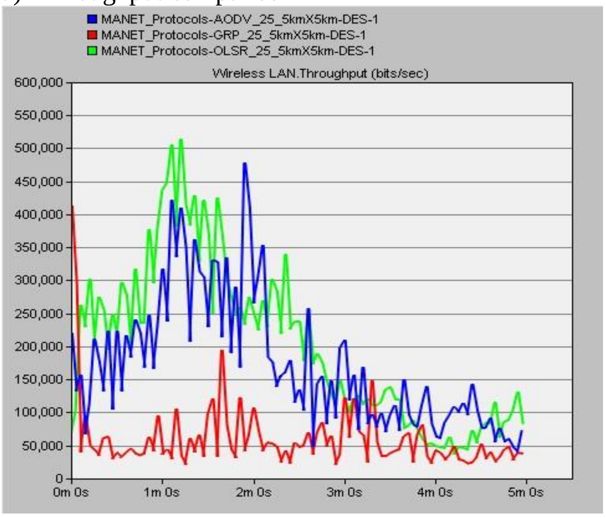

Figure-4 Throughput comparison of three networks running AODV, GRP, OLSR routing Protocols with each network containing 25 mobile nodes.

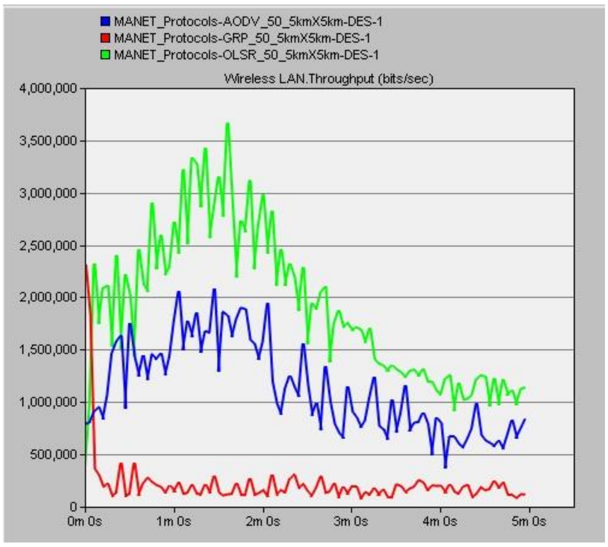

Figure-5: Throughput comparison of three networks running AODV, GRP, OLSR routing Protocols with each network containing 50 mobile nodes**.**

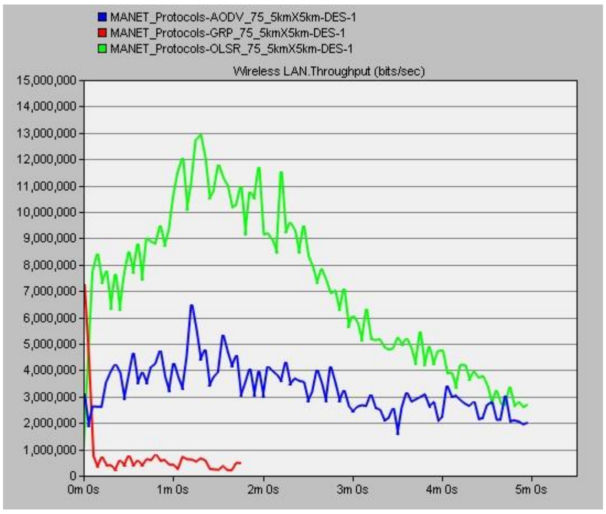

Figure-6: Throughput comparison of three networks running AODV, GRP, OLSR routing Protocols with each network containing 75 mobile nodes.

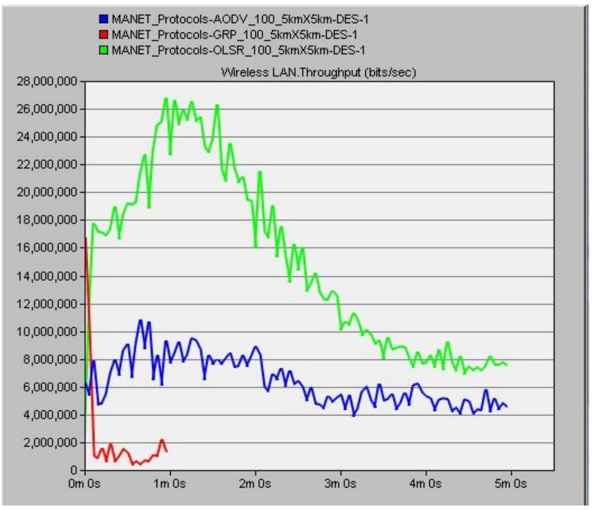

Figure-7: Throughput comparison of three networks running AODV, GRP, OLSR routing Protocols with each network containing 100 mobile nodes.

Fig. 4-7 gave a comparison between number of packets sent per unit time-Throughput versus number of nodes.

The throughput (Mbps) comparison of AODV, GRP and OLSR networks for varying number of mobile nodes is given in Figure-8.

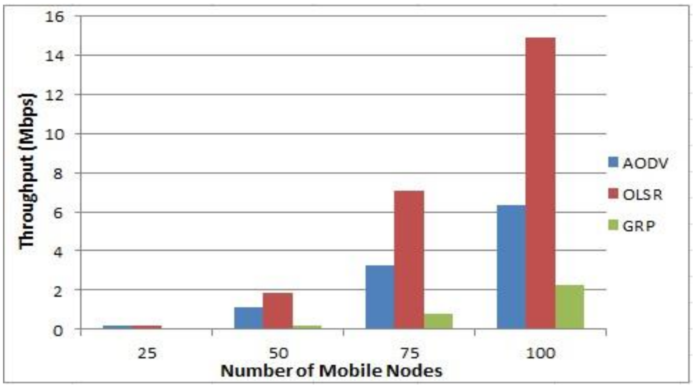

Figure-8: The throughput (Mbps) comparison of AODV, GRP and OLSR Networks for varying number of mobile nodes

It was observed that, both AODV and OLSR offer approximately same and better throughput than GRP when network containing 25 mobile nodes. Figure-8 shows that throughput offered by OLSR is increasing extensively with increasing number of mobile nodes.

b) Delay comparison:

Fig. 9 and 10 compares the delay of three network protocols for 25 nodes and 100 respectively.

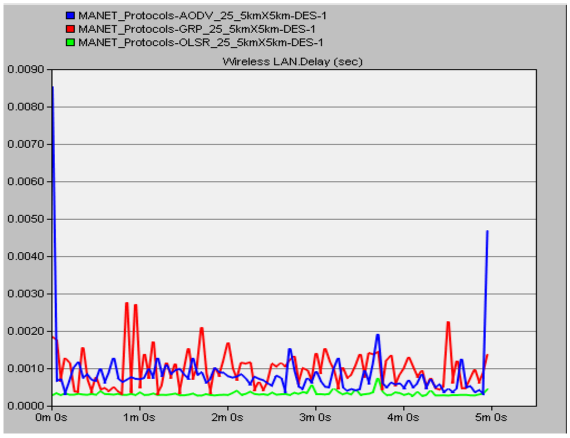

Figure-9: Delay comparison of three networks running AODV, GRP, OLSR routing Protocols with each network containing 25 mobile nodes.

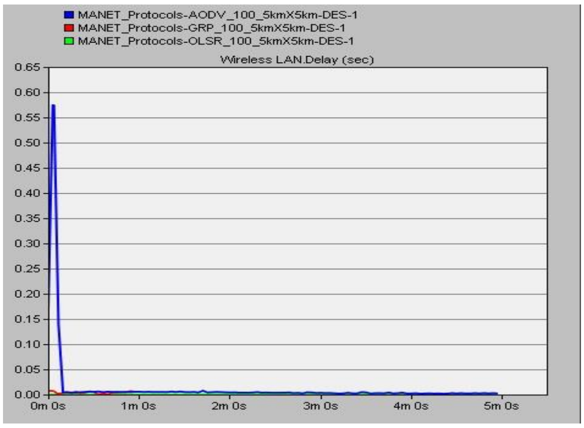

Figure-10: Delay comparison of three networks running AODV, GRP, OLSR routing Protocols with each network containing 100 mobile nodes.

The delay (seconds) comparison of AODV, GRP and OLSR networks for varying number of mobile nodes is given in Figure-11.

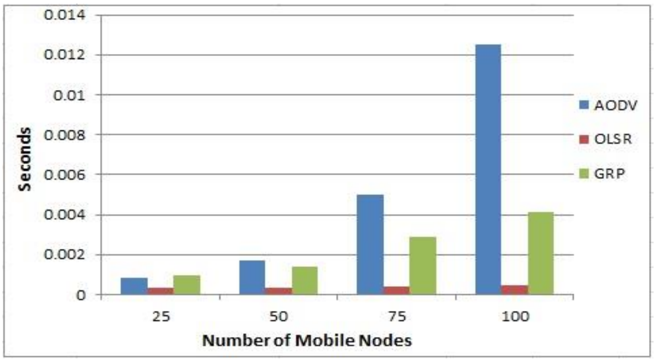

Figure-11: The delay (seconds) comparison of AODV, GRP and OLSR Networks for varying number of mobile nodes

It was observed that, OLSR is offering minimum delay, i.e. for 25 mobile nodes. With increasing number of mobile nodes, delay of OLSR network approximately remains constant but delay of AODV and GRP network is increasing gradually.

V. CONCLUSION

This paper talks about three most widely used MANET routing protocols and compared the performance of these protocols by running those protocols over 5 Km X 5 Km fixed sized network with varying number of mobile nodes from 25 to 100. These simulation experiments are performed on OPNET modeler 14.5. The simulation result shows that for increasing number of mobile nodes OLSR offers better throughput than AODV and GRP routing protocols. Also, OLSR protocol offers minimum delay than AODV and GRP routing protocols. Hence, this paper concludes that OLSR gives better performance than AODV and GRP for varying number of mobile nodes on fixed sized MANET.

The work done in this paper might be helpful for the researchers who wants to do research on mentioned protocols for MANET.

This paper can be enhanced by analysing and comparing these three protocols (ADOV, OLSR and GRP) under different mobility model and different type of traffic sources with respect to other performance metrics.

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