MANET Routing Protocols Comparison for Performance Evaluation

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Abstract *— Mobile Ad-Hoc Network (MANET) is a set of wireless mobile nodes dynamically form spontaneous network which works without centralized administration. Due to this characteristic, there are some challenges that protocol designers and network developers are faced with. These challenges include routing, service and frequently topology changes. Therefore, routing discovery and maintenance are critical issues in these networks. There are also limited battery power and low bandwidth available in each node. Efficient routing has always been a matter of concern for MANETs. While reactive protocols are competing with the performance of proactive protocols, hybrid protocols have attempted to brew the best of both.*
In this paper, we evaluate the performance of five MANET routing protocols using simulations: AODV, DSR, GRP, OLSR and TORA. Our evaluation metrics are end-to-end delay, network load and throughput. Most of the papers consider only the use of IPv4, but here we also consider the use of IPv6 in addition to MPLS technology.

Keywords- *MANET, MPLS, Routing Protocols, OPNET, AODV, DSR, OLSR, TORA.*

I. INTRODUCTION

Mobile Ad hoc Network can actually be defined as a network that lacks an infrastructure and this might look the other way around of wired network. It primarily serves as a mobile mesh network. It co-exists with both mobile node and fixed node. The nodes in MANET can be instrumental in serving both as host and router. The far-fetched capability of MANET can be attributed to mobile nodes, to form and setup a network connection in places that lack suitable communication infrastructure, and can provide best means of communication in times of natural disasters, etc. The dynamic topology of MANET has the characteristics to empower MANET to work either as a standalone network or to be connected via internet cloud or satellite. Deployment of MANET has features for companies to customize it and to fit in small time campuses to backhaul networks [1].
MANET has incorporated the features of self-configuration and self-maintenance to extend its vast expansion to sizeable number of users to a more worldwide popularity. It is in comparison to wired network has given more advantages and this has left too many rooms for the research to take its course to help explore the maximum potential of this field. The identification of experimental Request for Comments (RFC) since 2003 is used. Research work is in the incremental stage and is in full swing on the protocols like Ad hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Optimized Link State Routing (OLSR). The cornerstone of these pieces of research provide interface between mobile nodes in a more reliable and efficient way [5].

II. CLASSIFICATION OF ROUTING PROTOCOLS IN AD-HOC NETWORKS

The routing protocols are used to find path from source to target destination. Existing routing protocols can be classified in many ways, but most of these are done depending on routing strategy and network structure [1]. According to routing strategy, routing protocols can be categorized as: (1) Proactive routing protocols [3][4], (2) Reactive routing protocols [3][4] and (3) Hybrid routing protocols (Proactive +Reactive) [5].

A. Proactive Routing Protocols

In proactive (table–driven) protocols all nodes exchange with their neighbours information about shortest routes to other nodes periodically. After analysing these routes they compute and store the shortest path to each possible destination in a table. [2]. These protocols are not difficult to implement in the network but due to the resource hungry nature, limited energy of the node and slow propagation of routing information it becomes infeasible to use this protocol.

B. Reactive Routing Protocols

In contrast, reactive (on–demand) protocols do not continuously exchange routing information with the neighbours, instead a route is constructed only when it is needed. When a source node needs a route to a destination node it starts a node discovery process, in which route request messages are flooded across the network. The destination node responds to this request hence establishing a route. The route is maintained until destination become unreachable, or source is no longer interested in destination. AODV (Ad-Hoc on Demand Distance Vector Routing Protocol) [6], DSR (Dynamic Source Routing

Protocol) [7], TORA protocol (Temporary-Ordered Routing Algorithm) [8], these are all On Demand (Reactive) Routing Protocols.

C. Hybrid Routing Protocols

It is a combination or an improved version of the above mentioned two protocols. It was proposed to reduce the control overhead of proactive routing protocol and also decrease the latency caused by route discovery in reactive routing protocols. The routing is initially established with some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding. The choice of one or the other method requires predetermination for typical cases.

III. MANET ROUTING PROTOCOLS UNDER INVESTIGATION

There are several protocols proposed for wireless mobile ad-hoc networks (MANETs).) Three protocols are selected from Reactive category namely AODV, DSR and TORA and the fourth is selected from Proactive category namely OLSR whereas the last protocol is selected from Hybrid category namely GRP.

A. Ad-Hoc on Demand Distance Vector (AODV)

AODV is reactive routing protocol which does not discover or maintain a route until or unless requested by nodes. AODV uses destination sequence number to ensure the loop freedom and freshness of route [11]. AODV is capable of both unicast and multicast routing. The operation of this protocol is divided into two functions: route discovery and route maintenance. When a node requests to communicate with another node it starts route discovery mechanism. The source node sends a route request message RREQ to its neighbours and if all those neighbour nodes do have any information about the destination node then they will further send the message to its neighbours and so on until the destination node is found. The node which has information of the destination node sends a route reply message RREP to the initiator of the RREQ message. The path is recorded in the intermediate nodes in the routing tables and this path identifies the route. When the initiator receives the route reply message the route is ready and the initiator can start sending the packets. A route error RRER is reported when the link with the next hop breaks [12].

B. Dynamic Source Routing (DSR)

DSR is also a reactive routing protocol which uses the concept of source routing. In source routing the sender knows complete hop-by-hop route to the destination. All the routes are sorted in the route cache. When a node attempts to send a data packet to a destination for which it does not know the route [13]. In DSR each node maintains a route cache with route entries which are continuously updated as and when route learns new routes [14]. The biggest advantage of DSR is that no periodic routing packets are required. DSR has also the capability to handle unidirectional links [15]. Unlike other protocols DSR requires no periodic packets of any kind at any layer within the network. The sender of the packets selects and controls the route used for its own packets, which also supports features such as load balancing. All routes used are guaranteed to be free of loops as the sender can avoid duplicate hops in the selected routes [16].

C. Temporally Ordered Routing Algorithm (TORA)

TORA is an adaptive on demand routing protocol for multi hop networks. TORA is source initiated specially proposed routing protocols for highly dynamic mobile, multi-hop wireless networks [15]. TORA is based on link reversal algorithms. TORA establishes the routes quickly and minimize the communication overhead by localizing algorithm reaction to topological changes when possible [17]. Instead of using the concept of shortest path for computing routes which take huge amount of bandwidth TORA algorithm maintains the "direction of the next destination" to forward the packets. Thus, the source node maintains one or two a downstream paths" to the destination node through multiple intermediate neighbouring nodes. The three steps involved in TORA are: (a) route creation, (b) route maintenance, and (c) route erasure. TORA uses the concept of "directed acyclic graphs" to establish downstream paths to destination and such DAG is known as "Destination Oriented DAG" [18].

D. Optimized Link State Routing (OLSR)

OLSR is a proactive routing protocol, in which all routes have table for maintaining information to every node in the network. The routes are immediately available whenever needed due to the route tables. OLSR is an optimized version of link state protocol. OLSR uses the concept of Multipoint Relays (MPR) to reduce the possible overhead in the network. OLSR uses two types of control messages: Hello and Topology Control (TC). Hello messages are used to find the link state and neighbouring nodes. TC message is used to broadcast information for own advertised neighbours which includes at least the MPR selector list [19].

E. Geographic Routing Protocol (GRP)

GRP is a position based protocol classified as proactive routing protocol. In GRP the Global Positioning System (GPS) is used to mark the location of node and the quadrants optimize flooding. When a node moves and crosses neighbourhood then the flooding position is updated. The neighbours and their positions are identified by the exchange of "Hello" protocol. The concept of route locking ensures that a node can return its packet to the last node when it cannot keep on sending the packet to the next node. The network is divided into quadrants from Lat, Long (-90,-180) to Lat, Long (+90,+180) [19]. A part from actual geographic coordinates received by the GPS the other approach followed is Reference points in some fixed coordinates system [20].

IV. TRADITIONAL IP ROUTING

In traditional IP routing, routing tables are built by every router in the network by the use of different routing protocols such as OSPF (Open Shortest Path First), RIPC (Routing Information Protocol), IS-IS (Intermediate System-to-Intermediate System) or BGP (Border Gateway Protocol). Every router in the network has to individually make routing decisions for each incoming IP packet after the arrival of a packet to verify the next hop for the packet based on the destination address of the packet given in the IP header of the packet.

V. MPLS

MPLS (Multi-protocol Label Switching) is a relatively advanced technology, which is mainly responsible for high performance packet control and mechanism [9]. It does this by the information contained in the labels attached to the IP packets to forward such packets through a network. It merges the strength of layer 2 switching and layer 3 routing to form an IP network with a high level of performance. MPLS has evolved into a vital technology which efficiently operates and manages IP network due to its superior characteristics [10]. The purpose of MPLS is to guarantee speed, traffic engineering, Quality of Service (QoS) and scalability of the network and is also useful for VPNs (Virtual Private Networks). MPLS is not a substitute for IP, but it extends the IP architecture by adding new functions to it. The MPLS domain has two major kinds of switches; namely the MPLS edge switches, which basically consist of the LERs (Label Switch Routers). When a packet enters into an MPLS domain, a label is attached to the packet. A label has no internal structure and is a short and fixed unit. This MPLS label is between the Data Link Layer and the Network Layer and the packets are forwarded based on the MPLS labels.

VI. PERFORMANCE PARAMETERS

OPNET modeller supports different parameters for the measurement and performance evaluation of MANET networks under different routing protocols. These parameters have different behaviours for overall network performance [22]. We evaluate three parameters in our study on overall network performance. These parameters are delay, network load, and throughput.

A. Delay

The packet end-to-end delay is the time from the generation of a packet by the source up to the destination reception, so this is the time that a packet takes to go across the network. This time is expressed in seconds (sec) [22].

B. Network Load

Network load represents the total load in bit/sec submitted to wireless LAN layers by all higher layers in all WLAN nodes of the network [21]. When there is more traffic coming into the network, and it is difficult for the network to handle all this traffic it is called the network load. An efficient network can easily cope with large traffic coming in, and to make the best possible network, many techniques have been introduced [22].

C. Throughput

Representing the total data traffic in bits/sec successfully received and forwarded to the higher layer by the WLAN MAC [20].

VII. SIMULATION METHODOLOGY

Simulation works are performed using OPNET Modeler 14.5 which supports file transfer protocol. The first step was to create and design the network. Figure (1) shows the simulation environment of one scenario containing 25 mobile nodes. The nodes were spread randomly over an area of 1000m × 1000m, with a number of 25 nodes in all the scenarios. The first scenario implemented IPv4, the second scenario implemented IPv4 with MPLS, the third scenario implemented IPv6 and the forth scenario implemented IPv6 with MPLS. The simulation was run for one simulation hour with a seed value of 128. The mobility model used was “Random Waypoint Model”. Random waypoint is most widely used mobility model in which a node randomly chooses a destination, called waypoint and moves towards it in a straight line with a constant velocity [1].

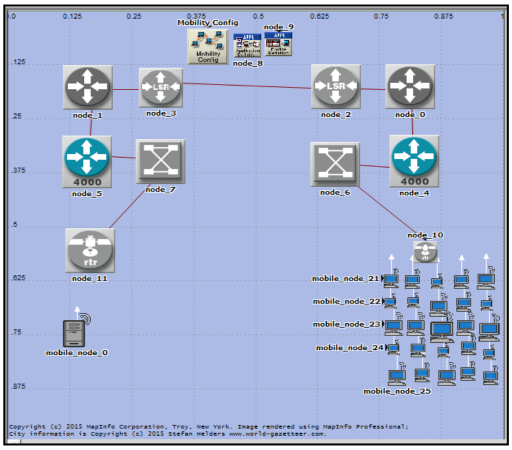

Figure 1: Simulation environment.

The proposed values of simulation parameters used are outlined in Table 1.

Table 1: Simulation parameters.

Simulation Parameter	Value
Number on Nodes	25
Simulation Time	1 hour
Simulation Area	1000m × 1000m
Routing Protocols	AODV, DSR, OLSR, TORA and GRP
Node Movement Model	Random Waypoint
Application Name	FTP (High Load)
Bandwidth	802.11g 54Mbps

The performance of the simulated results is analysed according to different performance metrics. Such quantitative measurement is useful as a prerequisite for assessing or evaluating the performance of network or even to compare the performance using different routing protocols.

VIII. SIMULATION RESULTS

In this section we analyse the performance of routing protocol based on the results obtained after simulation experiments are conducted on routing protocols. The main target of this paper is to evaluate the performance and behaviour of each routing protocol with respect to the effect of using MPLS on IPv4 and IPv6 with the MANET routing protocols. The simulation environment of one scenario contains 25 mobile nodes. The nodes were spread randomly over an area of 1000m × 1000m, with a number of 25 nodes in all the scenarios. The first scenario implemented IPv4, the second scenario implemented IPv4 with MPLS, the third scenario implemented IPv6 and the forth scenario implemented IPv6 with MPLS. The simulation was run for one simulation hour with a seed value of 128. The mobility model used was "Random Waypoint Model". Random waypoint is most widely used mobility model in which a node randomly chooses a destination, called waypoint and moves towards it in a straight line with a constant velocity [6].

A. Delay

Delay in case of 25 node using IPv4 without MPLS for the five MANET protocols studied in this experiment is shown in Figure 2, from which we conclude that AODV and OLSR have high delay results. Also, it is found that GRP and TORA have less delay. DSR depicts the lowest delay.

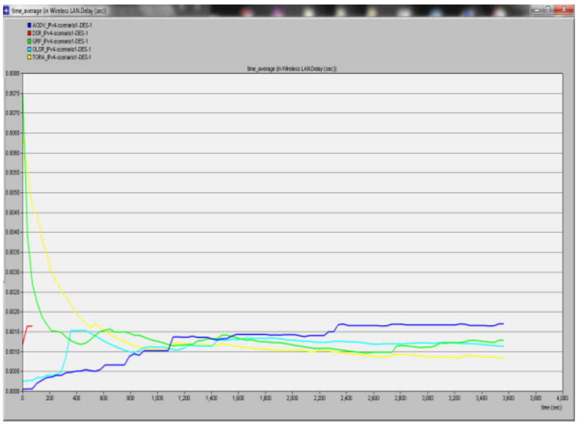

Figure 2: Delay of the five MANET routing protocols using IPv4.

According to simulation results in Figure 3, delay of AODV using IPv4 with MPLS is increased compared with the results without using MPLS. DSR expressed the higher delay, TORA and GRP have lower values, while OLSR has the lowest delay.

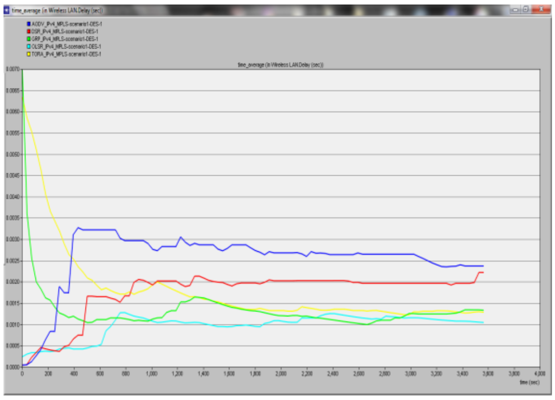

Figure 3: Delay of the five MANET routing protocols using IPv4 with MPLS.

Figure 4 show the result of scenario of using IPv6 with 25 nodes without MPLS. It shows that DSR has the highest delay, GRP and TORA have less delay, and OLSR is lower, while AODV has almost no delay at all.

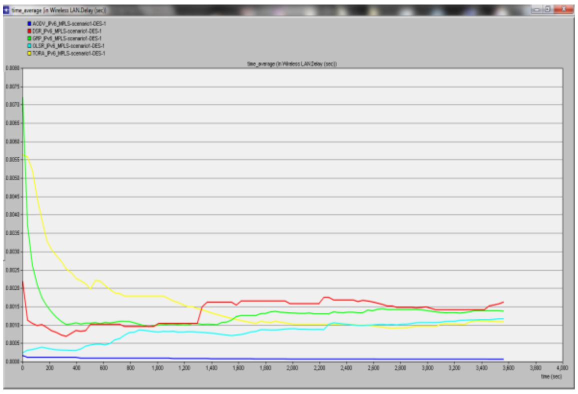

Figure 4: Delay of the five MANET routing protocols using IPv6.

With using MPLS with IPv6 as seen in Figure 5, DSR, TORA, OLSR and GRP all seems to have similar low results in delay compared with that

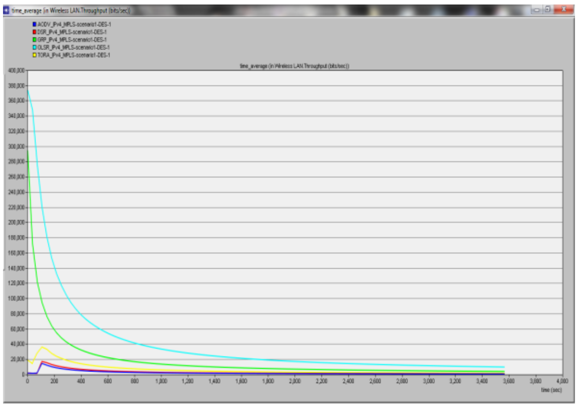

Figure 5: Delay of the five MANET routing protocols using IPv6 with MPLS.

without using MPLS, while AODV still have delay almost equal to zero.

B. Throughput

According to simulation results in Figure 6, OLSR has a high throughput results, GRP starts with a high throughput at the beginning of the simulation and then decreases, AODV starts with a throughput almost equal to zero and then peaks up and then returns to zero along the rest of the simulation, DSR seems to have no throughput at all, TORA starts with low throughput and decreases to almost zero.

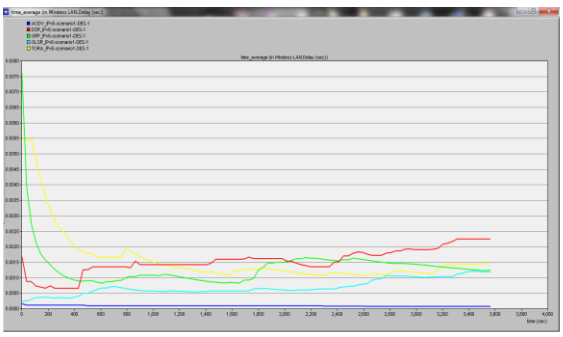

Figure 6: Throughput of the five MANET routing protocols using IPv4.

With using MPLS with IPv4 as seen in Figure 6, OKSR and GRP both starts with high throughput at the beginning of the simulation and the decreases with higher results of OLSR than GRP, TORA starts with low throughput and then peaks up and decreases to almost zero, both AODV and DSR starts with almost zero throughput and then peaks up little bit up and returns to zero, with both having the least lower results among the other protocols.

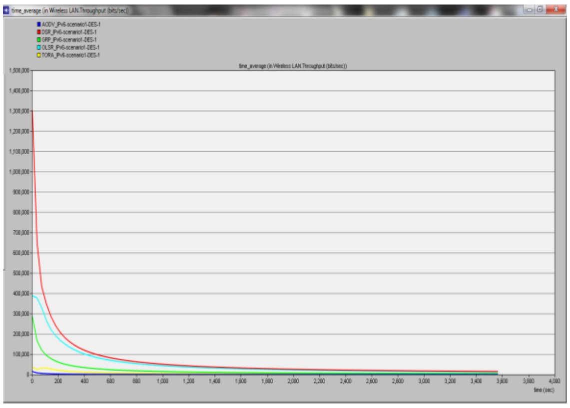

Figure 7: Throughput of the five MANET routing protocols using IPv4 with MPLS.

Throughput while using IPv6 without MPLS for the five MANET protocols is shown in Figure 7, it shows that DSR has the highest throughput at the beginning of the scenario and then decreases, GRP and OLSR has less throughput results, finally TORA and AODV have the lowest results.

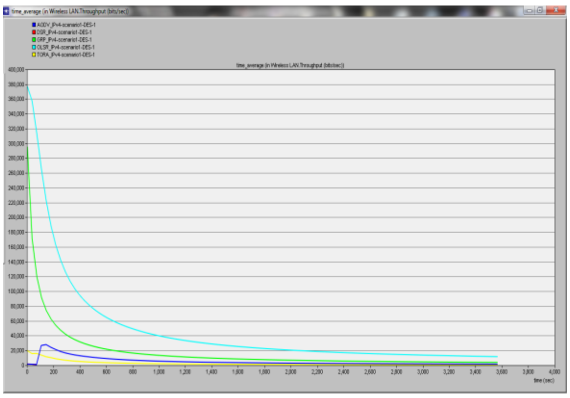

Figure 8: Throughput of the five MANET routing protocols using IPv6.

Figure 8 shows us that with using MPLS with IPv6, DSR has the highest throughput at the beginning of the simulation and then decreases, OLSR and GRP also starts with high throughput but then decreases but with less throughput compared with DSR, TORA and AODV have the lowest results with throughput almost equal to zero.

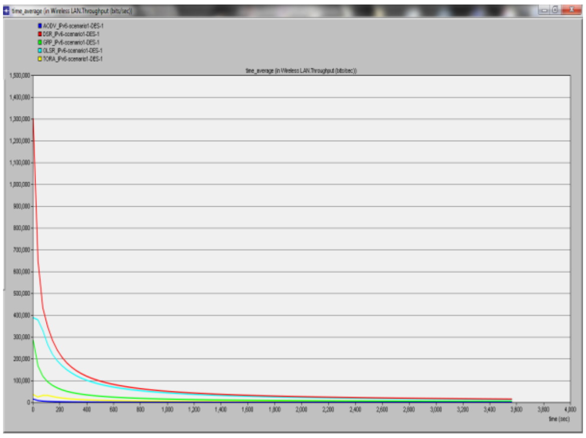

Figure 9: Throughput of the five MANET routing protocols using IPv6 with MPLS.

C. Network Load

According to simulation results in Figure 10, OLSR has a high load results, GRP starts with a high load at the beginning of the simulation and then decreases, AODV starts with a load almost equal to zero and then peaks up and then returns to low amount of load along the rest of the simulation, DSR seems to have no load at all, TORA starts with high load and decreases to lower amount of load.

With using MPLS with IPv4 OLSR still have high load results, GRP starts with high load results but then falls to lower results, TORA starts with lower results but then peaks up and then goes to lower results along the rest of the scenario, both AODV and DSR starts with low results of load and then peaks up with a results of AODV higher than that of DSR, as shown in Figure 11.

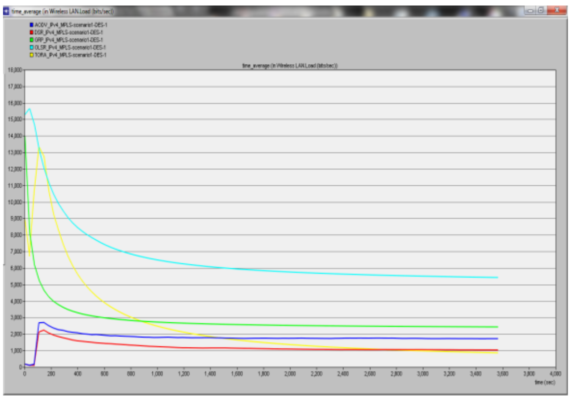

Figure 10: Load of the five MANET routing protocols using IPv4.

Load while using IPv6 without MPLS for the five MANET protocols is shown in Figure 12, it shows that DSR has the highest load at the beginning of the scenario and then decreases, OLSR starts with high results and then decreases but still higher than that of DSR, GRP and TORA starts with a little bit high results and then decreases finally AODV have the lowest results.

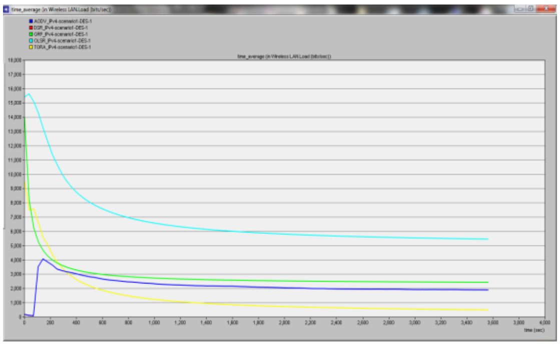

Figure 11: Load of the five MANET routing protocols using IPv4 MPLS.

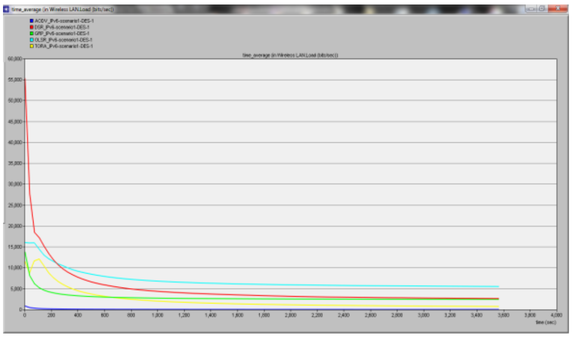

Figure 12: Load of the five MANET routing protocols using IPv6.

Figure 13 shows us that with using MPLS with IPv6, DSR has the highest load at the beginning of the simulation and then decreases, OLSR and GRP also starts with high load but then decreases but with less load compared with DSR, TORA and AODV have the lowest results with load almost equal to zero.

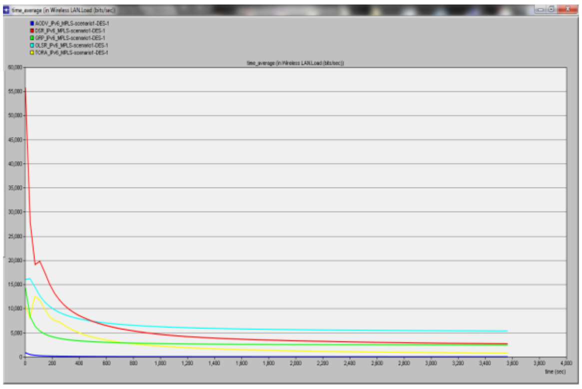

Figure 13: Load of the five MANET routing protocols using IPv6 with MPLS.

IX. CONCLUSION

In this paper, comparison for performance evaluation of AODV, DSR, GRP, OLSR and TORA was analysed using OPNET modular 14.5. The protocols were tested using the same parameters with high load FTP and random waypoint.

We checked the behaviour of these protocols with respect to three performance metrics: delay, network load and throughput with bandwidth 802.11g. Figures of 2 to 13 show the behaviour of the MANET under all the routing protocols for fixed number of nudes among using IPv4 and IPv6 with and without MPLS. Obviously some routing protocols performed better than the others, but none of the five protocols performed better among all the scenarios and techniques used in our experiments. Hence for every technique from the techniques used in our experiments there will be a protocol that will perform better than the other MANET protocols and this is one of the most outcomes that our paper results provides.

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