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Comparative Performance Analysis on Revised MANET Routing Protocols

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Abstract

Mobile ad-hoc networks (MANETs) operate without having centralized control infrastructure. These are self-forming and self-healing new generation wireless networks. MANETs can be deployed easily and quickly as their deployments are economical. These characteristics make them best suitable for military applications and emergency rescue operations etc., these applications require error free and efficient communication links. Routing protocols in MANETs establishes communication paths between the mobile nodes. Due to mobility of nodes, MANETs acquire dynamic topologies, which postures major challenge in developing new versions of routing protocols for MANETs. Over the decades, numerous researches were conducted towards comparative study on performances of different set of conventional routing protocols in mobile ad-hoc networks. Most of the earlier researches were conducted by varying general network parameters such as node density, node transmit power, node velocity, node pause times, transmission region, transmission range, type of offered traffic load, mobility models etc., autonomously using network simulator-2 (NS-2). This paper addresses the problem in different approach using a simulation model that combines suitable general network scenario with attribute revised models of well-known AODV (Ad hoc On Demand Distance Vector), DSDV (Destination Sequenced Distance Vector) and OLSR (Optimized Link State Routing) routing protocols in MANETs. Here, we have analysed performance of a distinctive 802.11 mobile ad-hoc network on network simulator-3 (NS-3) through various performance evaluating metrics such as; throughput, packet delivery ratio, end to end delay, packet loss and normalized routing load. This paper sketches complete conclusions on performance comparison of revised models of AODV, DSDV and the OLSR routing protocols with respect to different node densities.

Keywords: MANETs, Routing Protocols, AODV, DSDV, OLSR, Simulation

INTRODUCTION

MANETs (Mobile ad-hoc networks) operate without the support of centralized network infrastructure such as; base stations or access points. MANETs possess self-forming and self-healing characteristics [1]. Due to mobility of nodes, MANETs acquire dynamic network topologies. In MANETs, nodes often move out of connectivity range from one another. This postulates key challenge in designing an efficient routing protocol for MANETs [2]. MANETs comprises of small or large set of nodes, these nodes communicates with each other by means of multi-hop wireless links. Nodes in MANETs move from one place to another, their movements and velocity can be random [3]. Mobile ad-hoc networks can be deployed at many diverse applications such as; military operations, disaster operations, conference rooms [4], emergency and rescue operations, collaborative and distributed computing, wireless mesh networks and in commercial applications like vehicle ad-hoc networks [5]. Nodes in mobile ad-hoc networks communicate in a peer to peer mode without having any fixed setup [6]. Laptops, mobile phones and PDAs (Personal Digital Assistants) etc., could be the nodes of mobile ad-hoc networks.

In MANETs, a source and the destination node may not fall with in direct transmission range, they interconnect through multi-hop routing. Some characteristics of mobile ad-hoc networks promotes complications in their smooth operations unlike in infrastructure oriented wired or wireless networks. Such characteristics include; node mobility, inadequate resources, broadcast errors that occur in radio channels, unseen and visible terminal problems. These characteristics also pose major challenges in designing a routing protocol for MANETs.

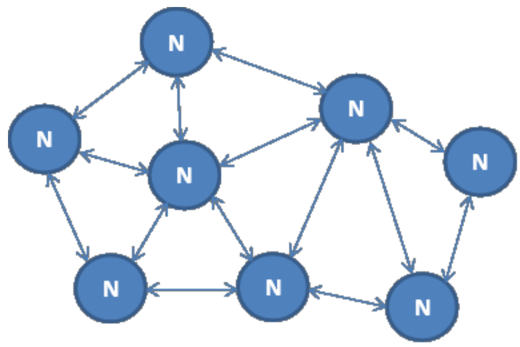

Figure 1: Mobile ad-hoc network

Mobility of nodes prompts MANETs to have dynamic topographies, this causes frequent path breaks for an established communication session [7, 8, 9]. Performance of MANET routing protocols depends upon numerous factors, comprising the multifaceted relationship of routing protocol mechanisms and their specific core parameters settings along with number of nodes in the network, node mobility, traffic strength and node behavior [36]. MANETs may function independently; the aim of mobile ad hoc networking is to deliver quickly deployable means of computing and communication. Mobile ad-hoc networks make use of bandwidth constraint physical layers and time-varying wireless communication links. Due to limited transmission range, MANET nodes communicate with each other through multi hop relaying. A MANET node act as host and the router [11]. These networks are also termed as self-forming and self-healing networks. Routing protocols in MANET are optimized such that hop count between a source and the destination node must be reduced [12]. Figure 1 illustrates a simple mobile ad-hoc network comprising of eight interconnected mobile nodes. MANETs are expected to deliver efficient communication links to the regions where communication infrastructure does not exist. Achieving performance oriented powerful routing is a major challenge in deploying MANETs.

There are various routing protocols available for mobile ad-hoc networks, out of which most popular are; AODV (Ad hoc On Demand Distance Vector), DSDV (Destination Sequenced Distance Vector), DSR (Dynamic Source Routing) and OLSR (Optimized Link State Routing). While designing an efficient routing protocol for MANET, certain characteristics of an ideal routing protocol needs to be considered which includes; fully distributed, adaptive to frequent topological changes, less number of nodes must involve in path computation and maintenance, localized, loop-free, free from decayed paths, reliable transmission, quick convergence, QoS (Quality of Service) provision and optimal usage of memory, computing power, bandwidth and battery power [7] etc. This paper presents performance analysis of attribute revised versions of standard AODV, DSDV and OLSR routing protocols with respect to different node densities.

LITERATURE REVIEW

In order to enhance performances in a typical mobile ad-hoc network, numerous routing protocols have been proposed by the research community. Taing et al., [28] were projected an enhanced DSR called MDSR (Modified DSR), which delivers improved number of hop paths and delays between source nodes to the destination nodes, as compare to the conventional DSR routing protocol. Safa et al., [29] had projected a routing protocol known as HAODV (Heterogeneous AODV), which optimizes the existing AODV routing protocol to upkeep routing in heterogeneous networks such as Wi-Fi and Bluetooth. HAODV regulates an optimum path with the lesser traffic density and high stability. Sjaugi et al., [30] had projected a new kind of route maintenance mechanism for DSR known as DISTANCE. The prime indication is to present a different node referred as 'bridge-node' into the source tables for avoiding link failures. Every node updates its position by piggybacking in packet header. By this technique, they achieved improvement in delays and packet sending ratios. Yi et al., [31] were projected a mobile ad-hoc network routing protocol called CADV (Congestion Aware Distance Vector) to enhance performance of the network with respect to routing load and packet delivery. CADV routing protocol incorporates congestion avoidance approach in a table-driven routing protocol such as DSDV. Bai et al., [32] have developed DOA (DSR over AODV) routing protocol for MANET, aiming on route maintenance process. DOA provides two level route repairs; intra-segment level and intersegment level. When a route fails, an intra-segment repairs it by using available alternative routes within that segment. Yifei et al., [33] have projected a routing protocol known as PC-AODV (Power Control AODV) to enhance network throughput and power consumption. The indication of this work is to institute a path with an suitable data-rate link within the broadcast range and to regulate the transmit power level. Khamforoosh et al., [34] have projected another AODV class routing protocol referred as AODV (CDM-AODV) (Centre base Distance Multi-path-AODV). The suggestion is to select two routes from the midpoint of the network. The aim behind it is that there is an opposite association between the distances of the node to the midpoint of network. When demand data packets are sent, response data packets have the info about the midpoint of network and distance between network nodes. Abdelkabir Sahnoun et al., [37] have introduced an energy efficient and path reliability protocol for proactive mobile ad-hoc network routing.

The proposed schemes motivated previous works on mobile ad-hoc networks on comparison of routing performances by extensive simulations. Biao et al., [35] inspected the performance of AODV, DSDV, DSR and TORA routing protocols through extensive simulations with growing number of network nodes in mobile ad-hoc networks. Nurul et al., [36] studied joint node density, packet length, and mobility in mobile ad-hoc networks considering OLSR, AODV, DSR and TORA routing protocols for performance comparisons. They revised few protocol parameters for their simulation based analysis. Their conclusion reveals that the node density and mobility has a significant impact on underlying routing protocols. Rakesh Kumar Jha and Pooja Kharga [26] were studied comparative performance analysis of AODV, DSDV, OLSR and DSR using NS3 Simulator, their study was on conventional models of these routing protocols for different set of network nodes. Dinesh Singh et al., [38] have studied ccomparative performance analysis of LANMAR, LAR1, DYMO and ZRP routing protocols in MANET using random waypoint mobility model. Qutaiba Razouqi et al., [27] have studied extensive performance analysis of standard DSDV, DSR, and AODV Routing Protocols for different network scenarios. Haseeb Zafar et al., [39] were surveyed different reactive and hybrid routing protocols in MANETs. D.Loganatahan and P.Ramamoorthy, [40] have studied performance analysis of enhanced DSDV protocol for efficient routing in wireless ad hoc networks, they introduced multicast parameters based DSDV routing protocol to enhance the energy efficient of ad hoc networks.

Teressa Longjam and Neha Bagoria [17] were studied performance comparison of standard AODV and DSDV routing protocols for different network node sets. Our research works are primarily focusing on well-known routing protocols in MANETs namely, AODV, DSDV and the OLSR.

In our earlier works, we have worked upon extensive performance analysis of standard models of AODV, DSDV and OLSR routing protocols [21, 25] for different network parameters. Later on, we have conducted many experiments on AODV, DSDV and OLSR routing protocols by altering core attributes of the protocol parameters and compared their performances with that of standard models in order to achieve performance progression [12, 23, 24]. This paper is focused on performance analysis of attribute revised models of the standard AODV, DSDV and OLSR routing protocols in mobile ad-hoc networks.

CLASSIFICATION OF ROUTING PROTOCOLS

Based on dissimilar measures, routing protocols in mobile ad-hoc networks can be categorized into number of types which includes; based on topology of routing, based on consumption of specific resources, based on routing information update mechanism and based on usage of time-based information for routing. However, these classifications are not reciprocally exclusive as some of the routing protocols fall in multiple classes [7].

Based on topology of routing

Based on routing topology, MANET routing protocols are categorized as; hierarchical and flat topological routing protocols. Examples of hierarchical topology based routing protocols are; CGSR (Cluster-head Gateway Switch Routing), FSR (Fisheye State Routing), HSR (Hierarchical State Routing). Examples of flat topology based routing protocols are; DSR (Dynamic Source Routing), AODV (Ad-hoc On Demand Distance-Vector), ABR (Associativity Based Routing), SSA (Signal Stability-based Adaptive Routing), FORP (Flow Oriented Routing Protocol), and PLBR (Preferred Link Based Routing).

Based on consumption of specific resources

Based on consumption of specific resources routing protocols in mobile ad-hoc networks are classified as power aware routing and geographical information assisted routing. Example of power aware routing protocol is PAR (Power Aware Routing) and example of geographical information assisted routing is LAR (Location-Aided Routing).

Based on routing information update mechanism

Based on routing statistics update mechanism, routing protocol in MANETs are classified as; proactive or table driven, reactive or on-demand and hybrid. Examples of proactive routing protocols are; DSDV (Destination Sequenced Distance Vector), WRP (Wireless Routing Protocol), CGSR, STAR (Source Tree Adaptive Routing), OLSR (Optimized Link State Routing), FSR, HSR and GSR (Global State Routing). Examples of reactive routing protocols are; DSR, AODV, ABR, SSA, FORP and PLBR. Examples of hybrid routing protocols are; CEDAR (Core Extraction Distributed Ad-hoc Routing), ZRP (Zone Routing Protocol) and ZHLS (Zone-based Hierarchical Link State).

Based on usage of time-based information for routing

Based on usage of time-based information for routing, routing protocols in mobile ad-hoc networks are classified as; future time-based and past time-based routing protocols. Examples of future time-based routing protocols are; FORP, RABR (Route-lifetime Assessment Based Routing) and LBR (Life Based Routing). Examples of past time-based routing protocols are; DSDV, WRP, STAR, DSR, AODV, FSR, HSR and GSR.

PROACTIVE AND REACTIVE ROUTING PROTOCOLS

Proactive or table-driven and reactive or on-demand routing protocols fall in the category of ‘routing information update mechanism’. These routing protocols function in different approaches; some of them are discussed below.

Proactive or table-driven routing protocols

All the nodes which use proactive or table-driven routing protocols maintain topological information of the network by using routing tables. These routing tables get exchanged periodically among all the nodes by flooding. In proactive routing protocols, when a node requires establishing communication link to the destination, it executes a path-finding algorithm over the routing tables. Proactive routing protocols are entirely relying on available routing tables to ensure accurate and efficient paths between a source and the destination node. Large dynamic networks may face convergence issues [2, 21].

Reactive or On-demand routing protocols

In reactive or on-demand routing protocols, route demands made by the associate nodes of the network are processed. Reactive routing protocols do not maintain routing tables (topological information of the network). Instead, they use connection establishment process in order to obtain the necessary path on the basis of necessities. These routing protocols do not exchange routing information periodically as it is not required [13, 7].

Here, we have considered three routing protocols for our analysis namely, AODV (reactive routing protocol), DSDV and OLSR (proactive routing protocols).

AD-HOC ON DEMAND DISTANCE-VECTOR ROUTING (AODV)

Ad hoc on-demand distance vector routing protocol finds paths using on-demand approach, a path is created when it is needed. In AODV, new routes are recognised by the help of DSN (Destination Sequence Numbers) and the next hop information is stored at the source nodes and the intermediate nodes of the network. When a path is not available for required destination, the AODV broadcasts RREQ (Route Request) packets throughout the network. Multiple routes may be obtained for different destinations for a RREQ. The AODV utilizes destination sequence numbers to conclude the updated path to the destination. In AODV, nodes update their route information only when the DSN of the newly received data packet is greater than the last DSN available with it.

The RREQ packet holds information such as identification number of the source node, identification number of the destination node, source and the destination sequence numbers, broadcast identification number and the TTL (time to leave) field [14]. Upon receiving the RREQs, the intermediate nodes prepare a RREP (Route Reply) when they have valid path to the requested destination else, they forward it to the other nodes in the network. Upon receiving multiple RREQs, the nodes discard the duplicate copies of such RREQs. Those intermediate nodes that has valid paths to the requested destination or the destination node for which the RREQ was generated are permitted to send the RREP packets to the source node. During path breaks, the intermediate nodes which holds the valid routes or the destination node itself generates a RERR (Route Error) packet and floods it throughout the network. In AODV, the broken paths are not get repaired locally, upon receiving the acknowledgement about the path breaks, the source node re-establishes the path to the destination by using higher link layers. When the path breaks are identified at the intermediate nodes, then these intermediate nodes sends a RREP with the infinity (∞) as hop count value.

DESTINATION SEQUENCED DISTANCE VECTOR ROUTING (DSDV)

The destination sequenced distance vector routing protocol is originally developed by enhancing the conventional distributed Bellman-Ford algorithm. The DSDV is one of those routing protocols which were first proposed for the mobile ad-hoc networks [15]. In DSDV, every node maintains a table which holds the information of shortest distance to every other node in the network. Earlier, the Distributed Bellman-Ford (DBF) procedure was functional successfully in most of the PSNs (Packet Switched Networks). DBF procedure is used to estimate the shortest path between source nodes to the destination nodes. Usage of DBF procedure leads to some routing loops problems. In order to prevent these looping problems, a new parameter called DSN (Destination Sequence Number) was incorporated in the DSDV [16]. Table-driven nature of the DSDV provides readily available routes to every other node instantly. It means routes to all the other nodes are readily available at every node at all times [7]. In order to keep updated network topology, the shortest path detailed tables are exchanged between all the nodes in the network at regular intervals of time. This exchange of tables between network nodes occurs even for substantial changes in local network topology. DSDV is almost same as conventional Routing Information Protocol (RIP) except the new attribute in routing table that is the DSN (Destination Sequence Number) [17].

In DSDV, updating of routing table is done in two ways namely, incremental updates and full dumps. An incremental update proceeds with only NDPU (Network Data Packet Unit), where as a full dump may proceed with multiple NDPUs. The DSDV uses incremental updates when a node does not detect substantial variations in the local network topology and the full dumps process is employed during substantial changes in local network topology or when an incremental update needs multiple NDPUs. In DSDV, the destination nodes initiates the table updates with a latest sequence number which is at all times greater than the earlier sequence number. Network nodes which receives updated tables from other nodes either update their tables as per received table updates or pause it for a while to select the best update among the multiple versions of the same update received from other nodes of the network [7].

OPTIMIZED LINK STATE ROUTING (OLSR)

The optimized link state routing is a proactive type of routing protocol in MANETs, which was developed based on the link state algorithm [18]. The OLSR routing protocol operates on multipoint relaying mechanism, by which forwarding up of link state packets materializes. The OLSR optimizes the conventional link state routing algorithm. In OLSR, optimization is done in two different ways; by minimizing the size of the control packets and by minimizing those numbers of links which participates in the forwarding of link state packets [7]. In OLSR, optimization procedures are used to extract topological information [19]. During topological changes, the OLSR initiates flooding process to broadcast new topological information throughout the network. During topological changes, the OLSR initiates flooding process to broadcast new topological information throughout the network.

OLSR uses multi point relays (MPRs) to minimize the flooding, table-driven feature of the OLSR helps it to broadcast information pertaining to the updated routing tables all over the network. OLSR announces only its subset of links in order to minimize the size of the link states. Subsets are the neighbors of each node in the mobile ad-hoc network and are selected to carry updates of link states. Subsets of nodes carry the responsibility of forwarding of data packets and these subsets of nodes referred as MPRs [24]. OLSR uses multi point relays in the optimization processes due to which periodic link state updates are possible. In OLSR, during formation of new links and during breakage of already existing links, the link state update mechanism does not generate additional control packets. In thick deployment of MANETs, the OLSR achieves higher efficiencies by the help of optimization of link state updating.

The OLSR routing protocol uses various control messages, some of them are; HELLO, TC (Topology Control), HNA (Host and Network Association) and MID (Multiple Interface Declaration) [20]. OLSR transmits these control messages periodically and it does not necessitate usage of control message delivery. Due to which OLSR experiences minimum amount of control message losses. HELLO messages hold information associated with link status and neighbour node details, TC messages broadcasts neighbours of network nodes, HNA messages provide sharing of external routing information and MID messages broadcasts capability of multiple interface connectivity of a host [24].

PERFORMANCE METRICS

There are various metrics available to calculate performances of mobile ad-hoc network routing protocols [26, 25], out of which some of them are considered over here.

Average Throughput

Average throughput is the amount of data communicated from the source node to the destination node through the network in a unit time stated in Kbps (Kilobits per second).

$$\text{Throughput} = \frac{(\text{Received Bytes Total} \times 8)}{(1024 \times \text{Simulation Time})} \quad (1)$$

Greater values of throughput deliver improved and enhanced performance. It is derived in Kbps.

Packet Delivery Ratio (PDR)

PDR is the ratio of total received packets to the total sent packets.

$$\text{PDR} = \frac{(\text{Received Packets Total})}{(\text{Sent Packets Total})} \times 100\ \% \quad (2)$$

Larger values of PDR provide improved and higher performance. PDR is derived in percentage (%).

Average End to End Delay (EED)

EED is the average time interval between data packets produced at the source node and effective delivery of these packets at the destination node.

$$\text{EED} = \frac{\text{Delay Sum}}{\text{Total Packets Received}} \quad (3)$$

Lesser values of end to end delay provide better and improved performance. It is derived in ms (mille seconds).

Packet Loss (PL)

PL is the difference between the total packets sent and the total packets received.

$$\text{PL} = (\text{Total Packets Sent}) - (\text{Total Packets Received}) \quad (4)$$

Lesser values of packet loss provide better and enhanced performance. PL is derived as number of packets.

Normalized Routing Load (NRL)

NRL is the ratio of number of routing packets transferred to the total data packets received [27].

$$\text{NRL} = \frac{\text{Number of Sent Routing Packets}}{\text{Number of Total Received Data Packets}} \quad (5)$$

Larger values of NRL provide better and improved performance however, larger values of NRL lead to smaller efficiency in terms of bandwidth consumption [25, 27].

SIMULATION SCENARIO

Network and Protocols Modeling

Mobile nodes were positioned randomly within a 300x1500 m region, channel capacity and transmit power were set to 2 Mbps and 7.5dBm respectively. Each and every node takes their movements in the network region according to random waypoint mobility model. Nodes move at the velocity of 20 m/s without having any pause times. Table 1 illustrates the general network parameters used for this simulation, Table 2, Table 3 and Table 4 shows the core parameters of the routing protocols used to change their standard versions [12, 23, 24]. Each and every simulation run lasted for 150 seconds excluding 50 seconds of transient period of the simulator. NS-3 is an open source discrete-event based network simulating software developed specially for research and educational purposes. NS-3 is licensed under GNU GPLv2 license and it is publicly available for research and development. The NS-3 project builds a solid simulation core, easy to use and debug. "NS-3 core caters the needs of the simulation workflow, from the simulation configuration to trace collection and analysis. The NS-3 simulation core supports research on both IP and non-IP based networks" [22]. Majority of NS-3 users emphases on wireless/IP simulations. NS-3 is developed using C++ high level programming language with the optional python bindings. NS-3 has enhanced simulation reliability. It is not backward adjusted with NS-2 (Network Simulator-2). NS-3 is built from the scratch to replace application program interfaces (API s) of NS-2.

Table 1: General parameters used in simulation

Network Parameter	Value Assigned
Node Density	30,40,50,60,70,80,90,100
Simulation Time set to	150 Seconds
Pause or halt Time	0
Node Velocity	20 m/s
Network Region	300x1500 m
Source/Sink connections	10 Numbers
Transmit power set to	7.5 dBm
Wi-Fi operation mode	Ad-hoc
Node Mobility Model used	Random Waypoint
Size of the Data Packet	64 Bytes
Wi-Fi Rate	2 Mbps
Data Rate (Sent)	2.048 Kilobits per second
Routing Protocols used	AODV,DSDV,OLSR

Table 2: AODV parameters used in simulation

Protocol Parameter	Value Assigned
Net diameter	45
Traversal Time (Network)	4.5 seconds
Route Request rate limit	20 route requests per Second
Route Request Retries	3
Timeout of Active Route	5 Seconds
Time for Route discovery	9 Seconds
HELLO Interval Time	2 Seconds
Traversal Time (Node)	50 Millie Seconds
Hello message loss allowed	3 messages
Time out for My Route	18 Seconds
Wait Time for next hop	60 Millie Seconds
Buffer Timeout	3 Seconds
Timeout (blacklist)	13.5 Seconds
Delete Time Period	25 Seconds
Queue Length (Maximum)	64 Packets
Queue Time (Maximum)	30 Seconds

Table 3: DSDV parameters used in simulation

Protocol Parameter	Value Assigned
Settling Time set to	3 Seconds
Hold Time set to	2 Seconds
Update Interval (periodic)	10 Seconds
Queue Length (Maximum)	300 Packets
Queued Packets (Maximum)	6 Packets per destination
Queue Time (Maximum)	10 Seconds
Time for Route Aggregation	2 Seconds
Weighted factor	0.875
Buffering	Set to : True
Weighted Settling Time	Set to : False
Route Aggregation	Set to : False

Table 4: OLSR parameters used in simulation

Protocol Parameter	Value Assigned
Time Interval set for emission of HNA messages	3 Seconds
Time Interval set for emission of TC messages	3 Seconds
Time Interval set for emission of HNA messages	2 Seconds
HELLO Time Interval	4 Seconds
Duplicate Holding Time	30 Seconds
Node Willingness set to	OLSR_WILL_ALWAYS

Validation of Network Model

Network simulators may provide incorrect results if all the parameters of simulation are not correctly configured. Hence, validation of simulation model becomes a key part of any simulation based study. The NS-3 simulation model presented in this paper was tested as per the NS-3 simulation guidelines.

RESULTS AND COMPARATIVE ANALYSIS

Comparative performance study of revised AODV, DSDV and OLSR routing protocols on a typical 802.11 MANET has been carried out considering eight node density scenarios; N = 30,40,50,60,70,80,90 and 100 with a node velocity of 20 m/s and 7.5 dBm transmit power. Where 'N' is set of nodes.

Throughput

Packet data obtained from the simulation based experiments have been used to calculate the throughput. Throughput was calculated as per throughput metrics. Figure 2 illustrates the throughput of AODV, DSDV and OLSR routing protocols with respect to different node densities. As compare to AODV and DSDV, OLSR has shown better performances for lesser and dense node densities. When we compare throughputs of AODV and DSDV, both the protocols performed equally for lesser node densities and for larger number of node densities, DSDV has shown better results in terms of network throughput. For 90 numbers of nodes, the throughput of the AODV has decreased and for 100 numbers of nodes, it has resumed its performance level.

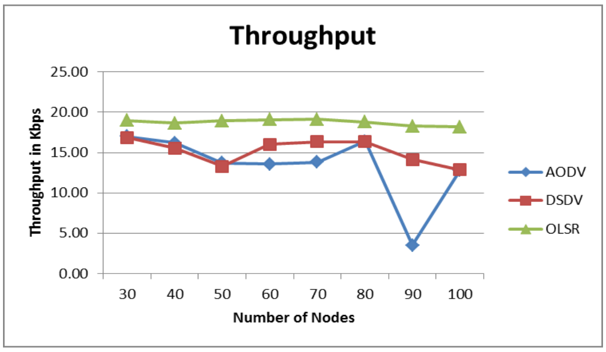

Figure 2: Throughput

Packet Delivery Ratio (PDR)

Here, as compare to AODV and DSDV, the OLSR routing protocol has delivered the data packets better for every value of 'N'. For lesser value of 'N', packet delivery performance of the AODV and DSDV were equal. However, DSDV has shown better packet delivery as compare to the AODV routing protocol. Figure 3 demonstrates the performances of all the three routing models.

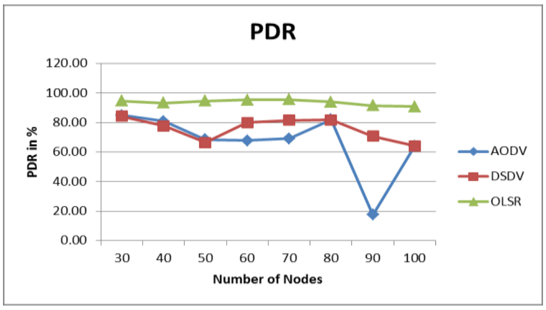

Figure 3: Packet delivery ratio

End to End Delay (EED)

Delay scenarios reveal better performance of the OLSR as it encountered less delay during packet transmission. As compare to AODV, DSDV protocol has lesser delay for high node densities. Figure 4 shows the and to end delay during data transmission.

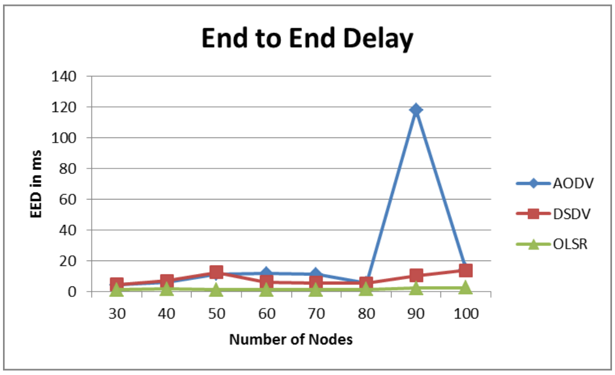

Figure 4: End to end delay

Packet Loss (PL)

Figure 5 reveals the packet loss scenarios in AODV, DSDV and OLSR. As compare to AODV and DSDV, the OLSR routing protocol has experienced less number of packet losses. DSDV has less packet losses for higher number of nodes whereas; AODV has large number packet losses.

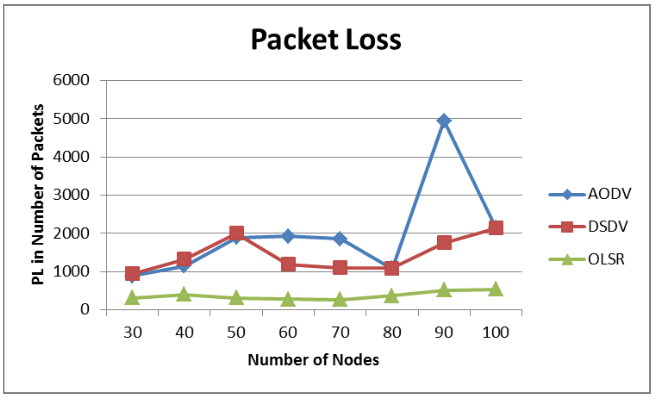

Figure 5: Packet loss

Normalized Routing Load (NRL)

Like in earlier results, NRL results also conclude better performance of the OLSR routing protocol. As compare to AODV, DSDV has shown better performance for higher node densities. The AODV routing protocol has shown least performances in terms of NRL for all the values of 'N'. Figure 6 reveals performances of all the three routing protocols in terms normalized routing load.

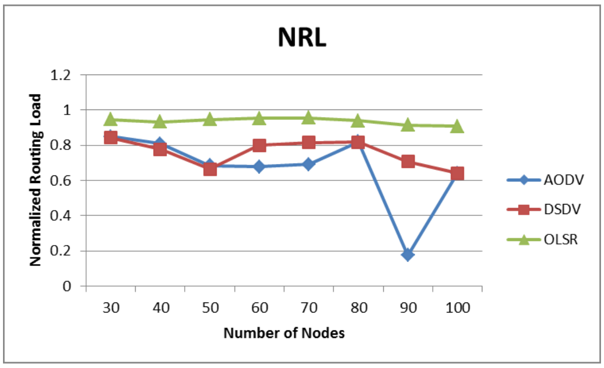

Figure 6: Normalized routing load

CONCLUSION

As per our analysis and experimental setup we used, it is concluded that the revised OLSR routing model has performed better in terms of throughput, packet delivery ratio, end to end delay, packet loss and normalized routing load. Results of AODV and DSDV protocols reveals that; for lesser node densities, performances of both the routing models were shown equal performances but, as node density increases, the DSDV protocol has shown better performances in terms of all the metrics discussed above. However, performance of the routing protocols depend upon various other parameters like; network size, transmission range, transmission region, number of source/sink connections, mobility of the nodes, mobility models, Wi-Fi rate, traffic scenarios etc. Further research can be taken ahead using diversified simulation scenarios comprising of different network and protocol parameters.

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