CHAPTER-6

Performance Analysis of Standard and Revised DSR Routing Models

6.1 Introduction

In order to strengthen better and error-free connectivity in mobile ad hoc networks, more research is required on routing protocols. There are numerous routing protocols available for mobile ad hoc networks. In previous chapters, we have analysed performances of the AODV, DSDV and OLSR routing protocols. In this chapter, we have analysed performances of one more well-known routing protocol in mobile ad hoc networks namely, the DSR (Dynamic Source Routing). The DSR routing protocol fall under the category of reactive routing protocols in MANETs. Based on the topology of routing, mobile ad hoc network routing protocols are categorized as; hierarchical and flat topological routing protocols. Dynamic source routing protocol is an example of flat topology based routing protocol [Siva Ram Murthy *et al.* (2007)]. As compare to conventional wireless networks, issues and challenges are more prominent in mobile ad-hoc networks because of their dynamic topographies. Some of them are; bandwidth restriction, energy limitation, unavailability of up-to-date network information, atmospheric noise, network congestion, collision, hidden and exposed terminal problems and security [Saad *et al.* (2013)].

As discussed in previous chapters, nodes of mobile ad-hoc networks have to operate as host and the router. Mobile ad-hoc networks operate on multi-hop transmissions, mobility of nodes makes MANETs to face frequent path breaks between communicating nodes. A source node intensive to communicate with a destination node has to communicate across multiple hops in order to get a shortest and efficient path to that destination [Kannan Shanmugam *et al.* (2016)]. Routing protocols plays important roles such as exchanging of path information among network nodes, ensuring best path between a source and destination nodes. During route discovery, routing protocols follows some standards like; life time of the link, power requirement, hop distance, obtaining broken path data, repairing broken paths, spending less processing power and consuming least amount of bandwidth [Siva Ram Murthy *et al.* (2007)]. Some features such as resource allocation, node mobility and dynamic topographies mark the routing procedure a key challenge [Kannan Shanmugam *et al.* (2016)].

In MANETs, routing protocols are available in two forms namely, unicast and multicast. Unicast routing protocols communicate using single channel whereas multicast protocols communicate using multiple channels. CSMA-CA (Carrier Sense Multiple Access – Collision Avoidance) uses single-channel communication and CDMA (Code Division Multiple Access), TDMA (Time Division Multiple Access) uses multi-channel communications [Haseeb Zafar *et al.* (2011)]. The dynamic source routing is a reactive or on-demand unicast routing protocol communicate using single channel [Arunima Patel *et al.* (2012)]. Fig.6.1 demonstrates connectivity among nine numbers of nodes ‘N’ in a typical MANET.

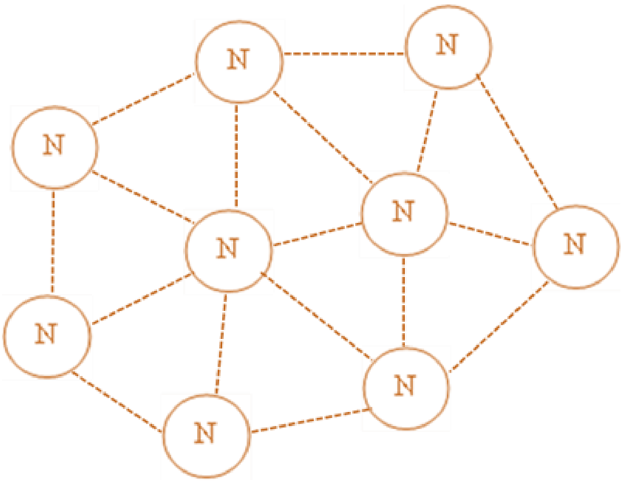


Fig.6.1. Connected Mobile ad hoc network

This chapter reports analysis on standard and attribute revised models of dynamic source routing protocol. Routing attributes of the standard DSR routing protocol were revised in order to have a revised DSR model. Performances of the revised DSR model were tested on different network sizes and compared it with the performances of the standard DSR model using various performances evaluating metrics.

6.2 Dynamic Source Routing

Dynamic source routing is a reactive or on-demand type routing protocol in MANETs. DSR supports unicast communication and it takes advantages of source routing algorithm [Rjab Hajlaoui *et al.* (2015)]. DSR is also called as demand driven routing protocol developed for multi-hop relaying MANETs [Rahul Malhotra *et al.* (2015), Sharma *et al.* (2014), Prinu *et al.* (2014)]. Reactive routing protocols accomplish route discovery process and exchange routing information when a source node demands a path to the destination node. The dynamic source routing protocol was developed to save bandwidth unnecessarily consumed due to control over heads. Bandwidth restrictions on control over heads are achieved by removing periodic table update messages; DSR does not require periodic transmissions of beacons or hello messages [Siva Ram Murthy *et al.* (2007), Johnson *et al.* (1996)]. This protocol supports maintenance of active routes and utilizes caches for storing path information. It employs source routing as complete path is included in DSR heading and ropes unidirectional links. DSR is used in Microsoft mesh networks [Shadi *et al.* (2015), David *et al.* (2001)].

6.3 Route Discovery

Like other on-demand routing protocols, DSR establishes routes by flooding route request packets throughout the network. Route intended source node initiates this flooding process when it does not have direct and valid route to the destination. Upon receiving the route request, the destination node responds to the source by sending a route reply message. Following example illustrates process of route discovery in DSR. If a source node ‘S’ initiates a communication with the destination node ‘D’, it generates RREQ (Route Request) message and floods it throughout the network because node ‘S’ does not have a valid route to ‘D’. RREQ messages holds information such as; source address, source ID (Identity), destination address, destination ID with an exclusive sequence number generated by the source node ‘S’. Upon receiving the RREQ, intermediate nodes checks the sequence number and either generate a RREP (Route Reply) message for the source node ‘S’ or forwards the RREQ message to other nodes in the network. Intermediate nodes generate RREP only when they have valid routes to the destination. Before forwarding the RREQ, intermediate nodes add their own address and ID in the RREQ and stores it in their cache.

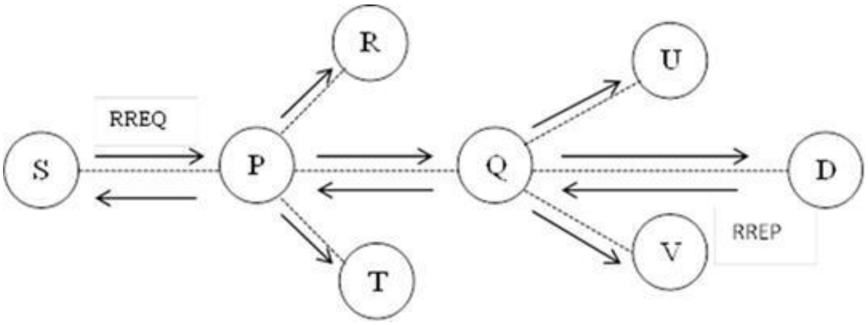


Fig.6.2. Path discovery in DSR

Fig.6.2 illustrates the process of route discovery in DSR; dotted lines represents connectivity between the nodes, forward arrows signifies RREQ transmission and backward arrows denote transmission of the RREP message. When source node 'S' floods the RREQ, immediate node 'P' receives the RREQ, but it has no valid path to 'D' hence forwards it to nodes 'R', 'T' and 'Q' including its own address to the source path. Node 'Q' too does not have a valid path to node 'D'; it forwards the RREQ to nodes 'U', 'V' and node 'D'. Node 'D' is the destination, so it generates the RREP message and passes it to the source node through nodes 'Q' and 'P'. Shortest route between node 'S' and 'D' is S-P-Q-D. During path discovery process, every node which forwards the RREQ, stores the path information in the send buffer. RREQ, RREP and RERR (Route Error) messages lives a short time period and are discarded by the nodes after their time out period. During path breaks, the source node re-initiates the route discovery process [Rjab Hajlaoui *et al.* (2015)]. During path discovery, every node acquires new path information, repetition of hop paths are avoided in order to elude control overheads.

6.4 Route Caching

In DSR, every hop caches new path they learned during path establishment process. Communicating hops may also learn to new paths during overhearing modes. Path caching helps in achieving speedy path discovery and it decreases RREQ flooding [Rjab Hajlaoui *et al.* (2015)]; DSR upholds stored paths in a tree format, a node which initiates RREP from its path cache must evade hop duplication. A node addresses a route request only when it possesses valid routes in its route cache, when multiple nodes initiate RREP at the same time, it leads to RREP squall. However, RREP squall can be reduced by setting random delay at replying nodes which initiates RREP. When network nodes initiate concurrent RREPs, collision of data packet occur. Path cashing in DSR involves cache structure, cache capacity and cache timeout [Rahul Malhotra *et al.* (2015)]. DSR uses route snooping by which intermediate nodes keeps overheard routes in their cache for future usage [Bhagchandani *et al.* (2013)].

6.5 Route Maintenance

The DSR routing protocol maintains routes in five different strategies namely, circulation of RERR messages, packet salvaging, auto route shortening, RREQ hop limits and preventing RREP squalls. In circulation of RERR messages strategy, upon receiving a RERR message the source node binds it with the new RREQ message and circulates this to its neighbouring nodes. All the network nodes which receive the new RREQ message get the information about the RERR. This helps to prevent stale route entries in the node caches. In packet salvaging strategy, data packets are marked as salvaged and a packet is salvaged only once to prevent routing loops. Where, address gets splitting into two parts; prefix and suffix addresses. Prefix address refers to used hops whereas suffix address refers to route cache address. Packet salvaging strategy prevents backtracking from the existing node to a previously traversed node [Qutaiba Razouqi *et al.* (2013)].

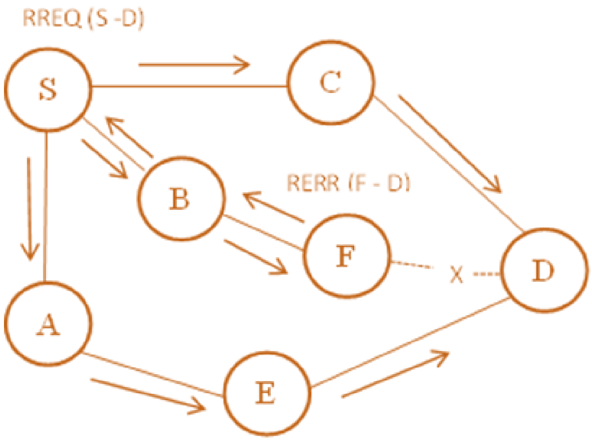


Fig.6.3. Route maintenance in DSR

Fig.6.3 illustrates the process of route maintenance in DSR. Here, the source node ‘S’ initiates a route discovery by generating a RREQ (S-D) to fetch the route up to the destination node ‘D’. The shortest available route from ‘S’ to ‘D’ is S-B-F-D, but there is a route break between nodes ‘F’ and ‘D’. Node ‘F’ generates a RERR (F-D) message and spreads it all around the network. Upon receiving RERR (F-D) message, the source node ‘S’ looks into its cache for other available routes to the destination node ‘D’. If there are no routes in the cache, the source node again generates a new RREQ to get a route up to the destination node ‘D’. Other alternate routes to the destination node ‘D’ are S-C-D and S-A-E-D.Upon detecting broken link, a node initiates route maintenance by generating a route error message and floods it. Then the node deletes the broken link route from its cache [Charles. E. Perkins (2008)].

6.6 Performance Assessment

Performance assessment of standard and attribute revised DSR routing models were completed with the help of various performance assessment metrics such as; the throughput, packet delivery ratio, end to end delay, packet loss and normalized routing load like in previous chapters. Definitions and mathematical formula of these metrics were discussed in detail at section 3.4.1 of this thesis. Performance improvements in a MANET routing protocol can be achieved by obtaining higher values of network throughput, data packet delivery and minimum end to end delays with lesser data packet losses. Higher values of normalized routing load (NRL) deliver enhanced protocol performances and at the same time, higher NRL values indorses lesser efficiency with respect to consumption of bandwidth [Qutaiba Razouqi *et al.* (2013), Rakesh Kumar Jha *et al.* (2015)].

6.7 Materials and Methods

Performance analysis on the standard and revised models of the DSR routing protocol were completed by the help of network simulator -3 (version 3.25) over the server grade CentOS (version 5.1) operating system on an Acer server. Obtained packet data (results from the simulation based experiments) were used to calculate performance evaluating metrics. Various experiments were performed for different set of node densities to test the performances of the revised DSR model over its standard version. Standard algorithmic script of the DSR routing protocol was altered with new attribute values in order to have its new design. “Manet_Routing_Compare” script was used to compare and test the performances of either DSR routing models.

As discussed in section 6.6, performance evaluation of either routing models of the DSR routing protocol was carried out by the help of some standard metrics namely, the throughput, packet delivery ratio, end to end delay, packet loss and the normalized routing load. As discussed in previous chapters, NS3 is a discrete event based open source software available for educational purposes including research. It holds the GNU GPLv2 license and openly accessible for R&D (Research and Development) activities. Usage and debugging of this network simulator is easy as “it forms a compact simulation core”. This network simulator provides all the support from simulation configuration to the results for simulation based experiments. It has extensive research provisions on IP (Internet Protocol) and non IP based computer networks.

6.7.1 Network Modeling

Fifty numbers of moving nodes were placed inside a rectangular network region of size; 300 x 1500 meters. Mobile nodes ensure their mobility at a velocity of twenty meter per second within this region as per random way point mobility model (RWPMM). Ten numbers of fixed source-sink connections were fixed for data transmission. Communication channel capacity was set to 2 Mbps with 7.5dBm transmit power. Simulation run time was set to 200 seconds (transient period: 50 seconds). Table - 6.1 shows the network parameters used in the simulation.

Table - 6.1: Network parameters used in simulation

Network Parameter	Value
MANET Routing Protocol	DSR
Data Transmission Rate	2 Kbps
Rate of Wi-Fi	2 Mbps
No. of Source/Sink Connections	10
Network Expanse (Rectangular)	300 x 1500 meters
Node Mobility Speed	20 meters per second
Node Transmit Power	7.5 dBm
Wi-Fi mode	Ad-hoc
Mobility Model	Random Way point mobility model
Data Packet Size	64 Bytes
Simulation Time	200 seconds
Node Pause Time	No pause time
Node Concentration	30,40,50,60,70,80,90,100

6.7.2 Protocol Modeling

The standard DSR routing protocol has many core parameters which are responsible in achieving better functioning of the protocol. Here, standard attributes of some core parameters have been altered to study protocol behavior and to test the protocol performances in terms of throughput, PDR, EED, PL and NRL. The DSR parameters considered for this study were shown in Table - 6.2.

Table - 6.2: DSR parameters used in simulation

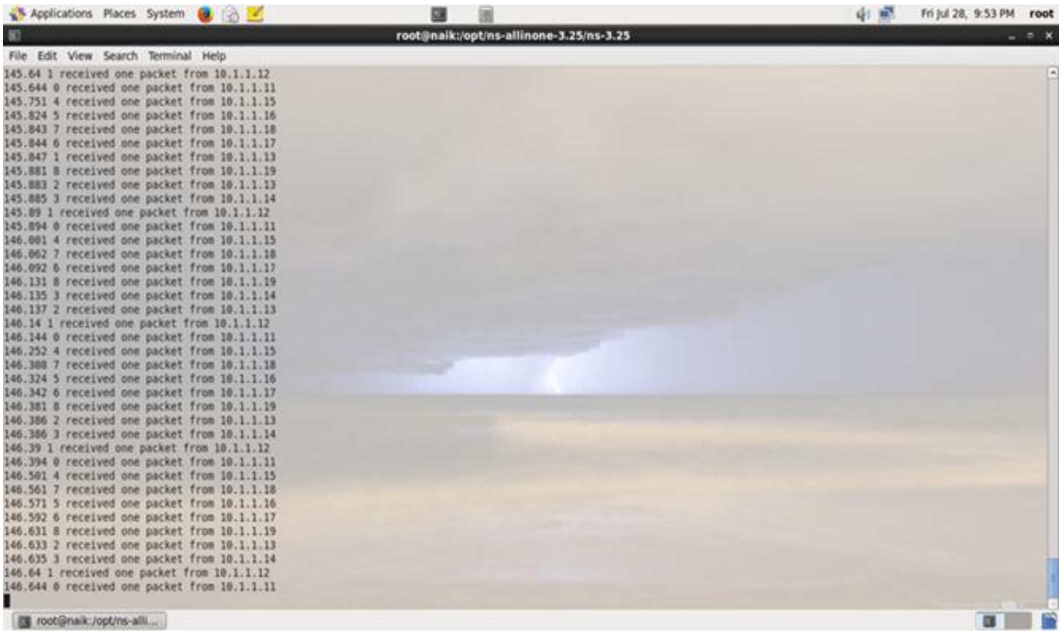
Protocol Parameter	Assigned Value
"MaxSendBuffTime"	25 seconds
"MaxMaintLen"	40
"MaxMaintTime"	20 seconds
"RouteCacheTimeout"	400 seconds
"MaxEntriesEachDst"	25
"SendBuffInterval"	550 seconds
"NodeTraversalTime"	30 milliseconds
"RreqRetries"	12
"MaintenanceRetries"	3
"NonPropRequestTimeout"	25 milliseconds
"MaxSalvageCount"	12
"BlacklistTimeout"	5 seconds
"GratReplyHoldoff"	2 seconds
"RequestPeriod"	550 milliseconds
"MaxRequestPeriod"	15 seconds
"MinLifeTime"	2 seconds
"RetransIncr"	25 milliseconds
"MaxNetworkQueueSize"	500

6.8 Results and Discussions

In this chapter, comparative performance analysis of standard and revised DSR routing protocols have been presented. Where, attributes of core performance parameters of the standard DSR routing protocol were revised and modeled as the revised DSR. Experiments on dynamic source routing models were carried out to study their behavior and performances at different node population scenarios. Various experiments were conducted to test the revised DSR routing model by considering 30,40,50,60,70,80,90 and 100 set of network nodes (small and large node sets).

Obtained results were compared with the results of the standard DSR routing model. Screen shot of a running program script was shown in Fig.6.4. As compared to standard DSR routing model, the revised model has gained improved network throughput, better data packet delivery between the source and destination nodes. The revised model has attained minimum delays in delivering data packets to the destination nodes with less packet losses and routing overheads.

Compared to previous studies, where only performance of different standard routing protocols were analyzed by varying different network parameters [Parma Nand *et al.* (2011), Mohapatra *et al.* (2012)], offered traffic (load) [Dimitra Kampitakia *et al.* (2014)], media access control protocols and node velocities [Uma Rathore Bhatt *et al.* (2014)] using network simulator-2. The present study managed to obtain better performing revised DSR routing model considering protocol parameters into account with the help of network simulator-3.



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145.64 1 received one packet from 10.1.1.12
145.644 0 received one packet from 10.1.1.11
145.751 4 received one packet from 10.1.1.15
145.824 5 received one packet from 10.1.1.16
145.843 7 received one packet from 10.1.1.18
145.844 6 received one packet from 10.1.1.17
145.847 1 received one packet from 10.1.1.13
145.881 8 received one packet from 10.1.1.19
145.883 2 received one packet from 10.1.1.13
145.885 3 received one packet from 10.1.1.14
145.89 1 received one packet from 10.1.1.12
145.894 0 received one packet from 10.1.1.11
146.001 4 received one packet from 10.1.1.15
146.062 7 received one packet from 10.1.1.18
146.092 6 received one packet from 10.1.1.17
146.131 8 received one packet from 10.1.1.19
146.135 3 received one packet from 10.1.1.14
146.137 2 received one packet from 10.1.1.13
146.14 1 received one packet from 10.1.1.12
146.144 0 received one packet from 10.1.1.11
146.252 4 received one packet from 10.1.1.15
146.308 7 received one packet from 10.1.1.18
146.324 5 received one packet from 10.1.1.16
146.342 6 received one packet from 10.1.1.17
146.381 8 received one packet from 10.1.1.19
146.386 2 received one packet from 10.1.1.13
146.386 3 received one packet from 10.1.1.14
146.39 1 received one packet from 10.1.1.12
146.394 0 received one packet from 10.1.1.11
146.501 4 received one packet from 10.1.1.15
146.561 7 received one packet from 10.1.1.18
146.571 5 received one packet from 10.1.1.16
146.592 6 received one packet from 10.1.1.17
146.631 8 received one packet from 10.1.1.19
146.633 2 received one packet from 10.1.1.13
146.635 3 received one packet from 10.1.1.14
146.64 1 received one packet from 10.1.1.12
146.644 0 received one packet from 10.1.1.11
```

Fig.6.4. DSR Script under execution

Packet data obtained from the simulation experiments were utilized to calculate different performance evaluating metrics discussed in the materials and method section. Table - 6.3 explores data sheet of the DSR routing models where, STD.DSR refers to the standard DSR and REV.DSR refers to revised DSR routing model.

Table - 6.3: DSR data sheet

No. of Nodes	Throughput in Kbps		PDR in %		EED in mille seconds		Packet Loss		NRL	
	STD.DSR	REV.DSR	STD.DSR	REV.DSR	STD.DSR	REV.DSR	STD.DSR	REV.DSR	STD.DSR	REV.DSR
30	12.37	12.98	61.87	64.88	15.41	13.53	2288	2107	0.619	0.649
40	12.75	12.84	63.75	64.20	14.22	13.94	2175	2148	0.638	0.642
50	11.41	12.55	57.07	62.73	18.81	14.85	2576	2236	0.571	0.627
60	12.93	12.98	64.65	64.88	13.67	13.53	2121	2107	0.647	0.649
70	11.92	12.94	59.58	64.68	16.96	13.65	2425	2119	0.596	0.647
80	10.94	12.51	54.68	62.57	20.72	14.96	2719	2246	0.547	0.626
90	12.86	12.93	64.32	64.63	13.87	13.68	2141	2122	0.643	0.646
100	13.04	13.30	65.20	66.48	13.34	12.60	2088	2011	0.652	0.665

(i) Throughput

As compared to standard DSR routing model, the revised DSR model has better network throughput. Maximum bandwidth passed through the network was 13.30 Kbps for 100 set of nodes. Throughput achieved for other node sets were presented in Table - 6.3 and throughput graphs were shown in Fig.6.5.

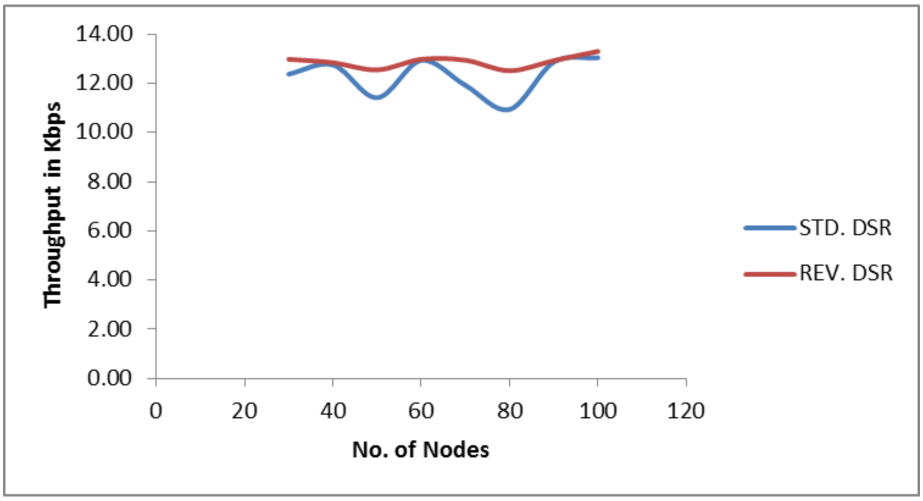

Fig.6.5. Throughput vs. No. of Nodes

(ii) PDR (Packet Delivery Ratio)

For different node densities, REV.DSR has shown constant and better packet delivery from the source node to the destination node. Packet delivery ratio of the STD.DSR was found fluctuating. The PDR results were shown in Fig.6.6.

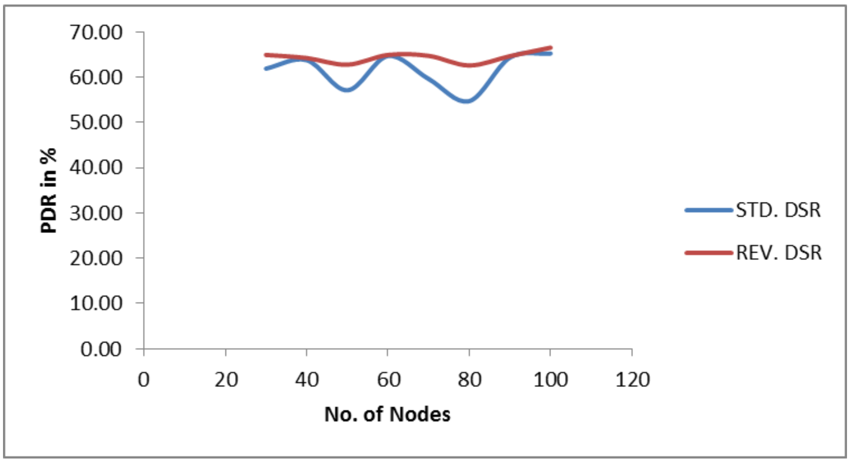

Fig.6.6. Packet Delivery Ratio vs. No. of Nodes

(iii) EED (End to End Delay)

The revised DSR has encountered lesser delays in delivering the data packets between a source and the destination nodes, whereas the standard DSR has met with larger delays during data transmission session. Delay scenarios of both the routing models were presented in Fig.6.7.

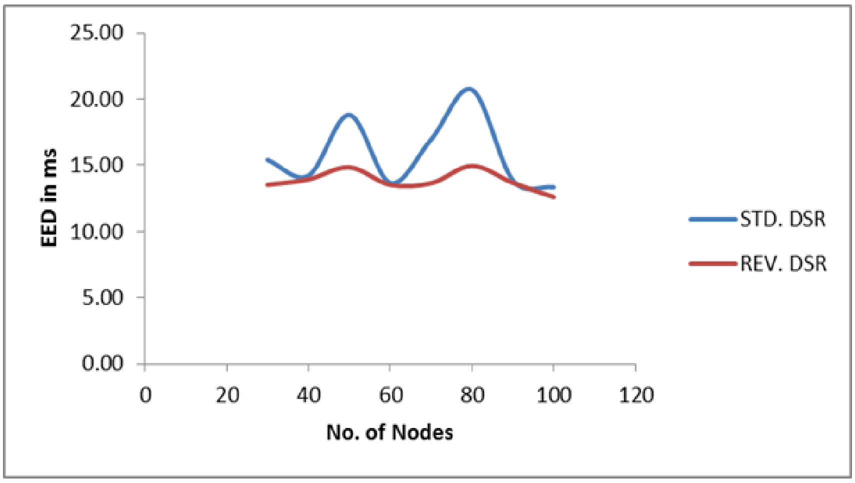

Fig.6.7. End to End Delay vs. No. of Nodes

(iv) PL (Packet Loss)

Data packet losses encountered in either routing models were shown in Fig.6.8. Revised model has shown better performances by achieving minimum packet losses as compared to the standard DSR routing model.

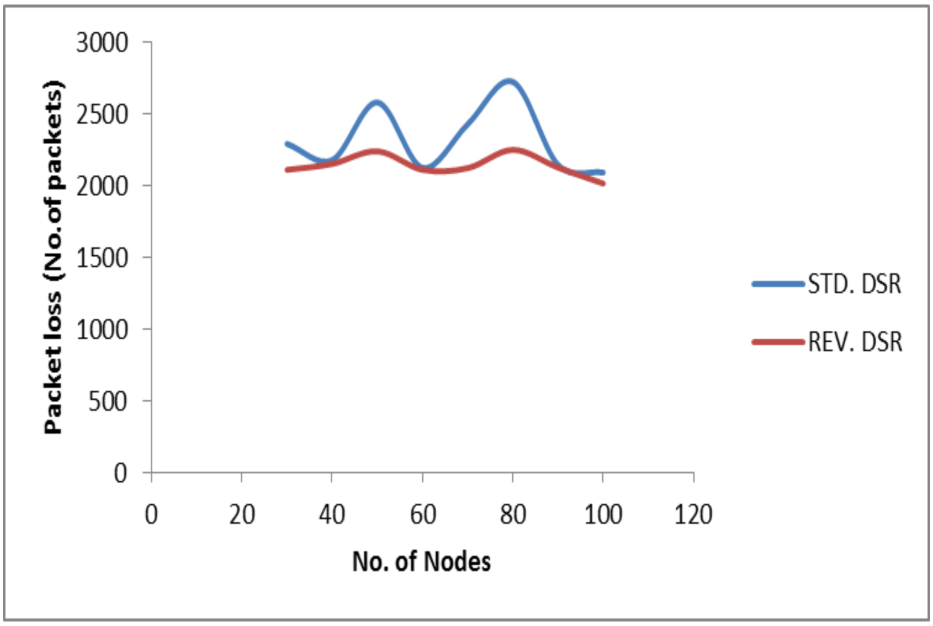

Fig.6.8. Data Packet Loss vs. No. of Nodes

(v) NRL (Normalized Routing Load)

Normalized routing load scenarios in either routing models were shown in Fig.6.9. The REV.DSR has shown better NRL results as compare to the STD.DSR by having minimal routing overheads. However, better performing routing model may devour additional bandwidth.

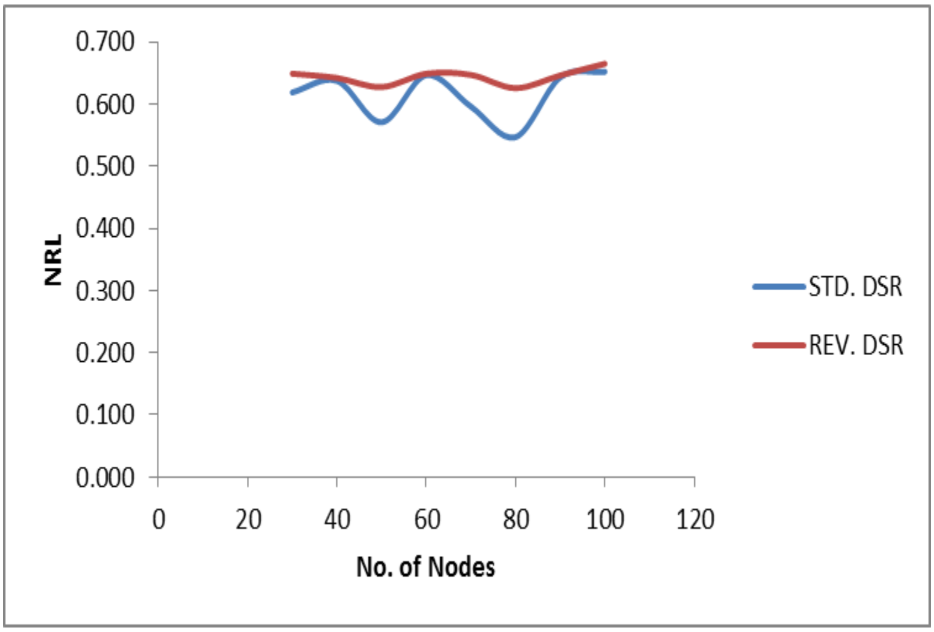

Fig.6.9. Normalized Routing Load vs. No. of Nodes

6.9 Conclusion

According to simulation results and performance calculations, the revised DSR routing model has emerged with remarkable improvements in its performances as compared to the standard DSR routing model. The revised DSR model has improved throughput, better packet delivery, least end-to-end delays, minimum packet losses and lesser routing overheads. These results were achieved by the general network parameters and the attributes of some core parameters set for this analysis on standard DSR routing model. Parameter attributes of the standard DSR routing protocol model were altered for testing and research based studies. Further research on standard and revised DSR routing models can be taken ahead for large network node sets, different simulation scenarios comprising of different network and protocol parameters with different attribute values and QoS (Quality of Service) concerns.

Routing protocols are considered as most important protocols in mobile ad hoc networks because; they establish paths between network nodes for effective and error-free communication. Due to infrastructure less nature of mobile ad hoc networks, they are very helpful at locations where network infrastructure does not exist. Some applications of these networks include; military operations, emergency rescue operations (during flood, earthquake etc.) etc. In order to strengthen mobile ad hoc networks in terms of effective connectivity among nodes, a better performing routing protocol is quite essential. This study will empower scientists and engineers to test and select effectively performing routing protocols while designing protocol suits for mobile ad hoc networks. This study will help researchers for further improvements, critical analysis on DSR routing protocol.