CHAPTER-3

Study and Analysis of Different Node Density and Pause Time Effects

3.1 Introduction

This chapter proposes study and simulation based analysis of different node density and node pause time effects over AODV, DSDV and OLSR routing protocols in mobile ad hoc networks. Performances of these protocols vary with the variation in node density and node pause times. Node density refers to number of nodes that constitutes a mobile ad-hoc network and the node pause time refers to node halt time. In other words, node pause time refers to nodes those are in the state of mobility gets halts for some particular time interval. As discussed earlier, networks without having any centralized fixed infrastructure or central administration are commonly known as MANETs, which are made up of small or large set of mobile nodes communicate through the wireless medium. These Networks require best routing protocols to establish error free and efficient communication links. MANETs has the property of dynamically changing topology due to its mobile nodes, which travel from one place to another. Overall performance of these routing protocols depends upon various network and protocol parameters. Mobile ad hoc networks have the characteristic of self-forming and self-healing. The routing algorithms of the routing protocols ensure selection of routes and connectivity between the nodes.

This chapter presents study and performance analysis on standard AODV (Ad hoc On Demand Distance Vector), DSDV (Destination Sequenced Distance Vector) and OLSR (Optimized Link State Routing) routing protocols. Performance analysis on these routing protocols have been carried out with the help of NS-3 (Network Simulator-3) by varying node density (Number of nodes) and node pause time (node halt time). Different performance metrics such as; the throughput, packet delivery ratio, end to end delay, packet loss and normalized routing load have been considered for the analysis. A mobile network is a set of wireless nodes which move freely from one point to another without any fixed infrastructure [IR 7, Anuj K.Gupta *et al.* (2011)]. Due to mobile nature of network nodes, MANETs acquire dynamic network topologies. Any network node can openly establish connection with other nodes subjected to the transmission range of other nodes. Mobile ad hoc networks are lively subject of popular researches because of their applications in Wi-Fi/802.11 supported portable devices [Royer *et al.* (1999)]. The aim behind all the new researches is to improve performances of the MANETs by improving performances of the routing protocols they use. The process of selection of routes is performed by the routing protocols with the help of routing algorithms. MANET survivability varies with different routing protocols. Their survivability also depends on the factors like; node density, node pause time, varied transmission power and mobility speed etc.

MANET routing protocols are designed to regulate efficient and error free communication links between the mobile nodes. Advancement in technology have achieved performance improvements in small, mobile wireless units like laptops, mobile phones etc. [Tafazolli *et al.* (2007)]. Based on procedure of route discovery, routing protocols are classified into three main types; proactive or table driven, reactive or on demand and hybrid. Hybrid routing protocols are the combination of proactive and reactive protocols [Arunima Patel *et al.* (2012)]. Fig.3.1 shows a mobile ad-hoc-network constituted by the portable nodes.

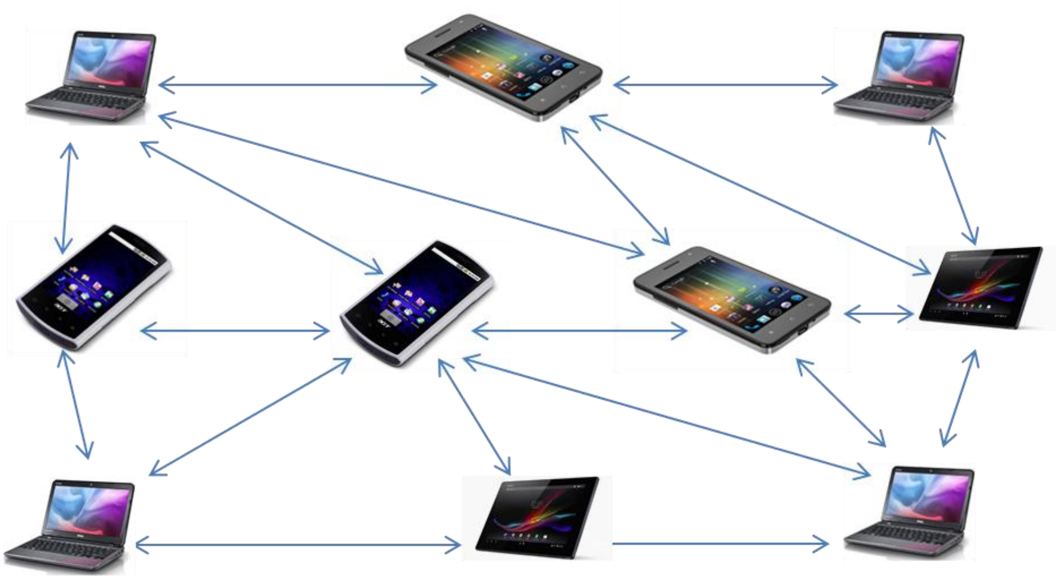

Fig.3.1.Mobile ad-hoc Network with Portable Nodes

In mobile ad-hoc networks, mobile nodes communicate with each other using multi hop wireless links, these networks are generally deployed for various diverse applications like military networks, conference rooms and in commercial applications like; vehicle ad-hoc networks [Pucha *et al.* (2007)]. Due to mobility nature of the nodes, the physical network topology of these networks often changes randomly. MANETs do not possesses any stationary infrastructure like access points thus, every node acts as router. These routers then forward the forwarding packets to all their neighboring nodes.

There are many routing protocols available for mobile ad hoc networks, among them some well-known are; AODV (Ad hoc On Demand Distance Vector), DSDV (Destination Sequenced Distance Vector), OLSR (Optimized Link State Routing), DSR (Dynamic Source Routing), and TORA (Temporally Ordered Routing Algorithm) [Huhtonen *et al.* (2004), Benzaid *et al.* (2002), Jayakumar *et al.* (2008), Taing *et al.* (2006), Rango *et al.* (2008), Giannoulis *et al.* (2005), Yu *et al.* (2007)]. Performance of the routing protocols depends on various factors like; complex interplay of the protocol mechanisms and their specific parameter settings with traffic intensity, mobility, node density and conduct of the mobile wireless nodes. This chapter addresses comparative performance analysis of AODV, DSDV and OLSR routing protocols with the varied number of nodes and their pause time in different scenarios namely, Scenario-I and Scenario-II.

3.2 Related Works

Many researchers have studied simulation based comparative performance analysis of standard MANET routing protocols and presented their results to the research community for further research. Most of them used NS-2 (Network Simulator-2) in their analysis. Related research works have been discussed in detail at section 2.7 of this thesis.

3.3 MANET Routing Protocols

There are numerous routing protocols available for mobile ad hoc networks. AODV, DSDV and OLSR are some well-known among them. Routing protocols are responsible for establishment of correct and efficient routes between mobile network nodes. Routing is a process which discovers error free routes between a source and the destination node and it make sure correct and timely delivery of data packets.

3.3.1 Ad-hoc On Demand Distance Vector (AODV)

AODV is developed for mobile ad-hoc networks and for other wireless ad-hoc networks. It is a reactive routing protocol; AODV was developed by C.Perkins, S.Das and E.Belding-Royer during July, 2003 [IR 8]. In AODV, discovery of route takes place subjected to route requests received from the neighboring nodes [Vinay P.Virada *et al.* (2012)]. AODV maintains newest routing information by using route discovery procedures and updated routing tables [Ashish Bagwari *et al.* (2012)]. Process of path discovery takes place when a source node transmits RREQ (Route Request) message throughout the network until required destination reached. Upon receiving RREQ message, the destination node generates RREP (Route Reply) message for the source node to ensure the path. During path breaks, the destination node generates a RERR (Route Error) message and transmits it through the network so that every node receives it.

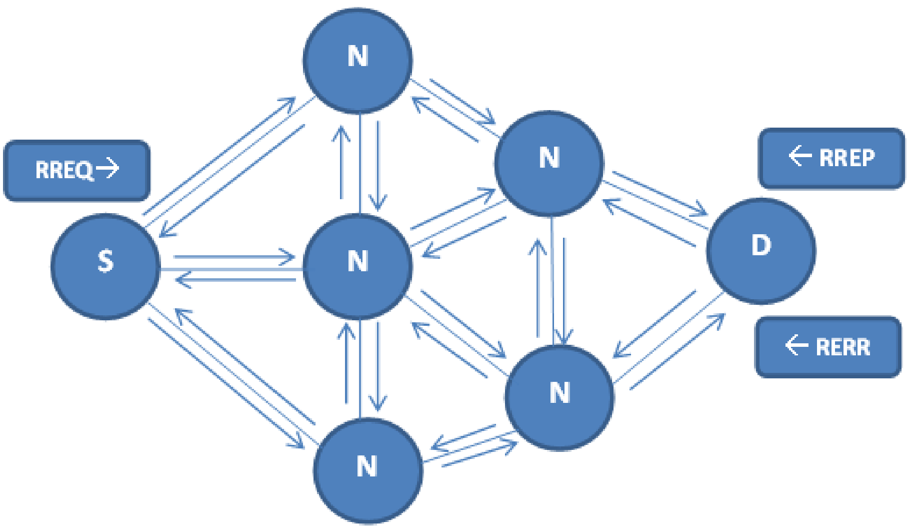

Fig.3.2. Message transmission in AODV

In Fig.3.2, the source node 'S' is transmitting RREQ message, whereas the destination node 'D' is transmitting RREP message throughout the network of mobile nodes 'N'. The destination node 'D' generates RERR message during path break between the source node 'S' and the destination node 'D'.

3.3.2 Destination Sequenced Distance Vector (DSDV)

DSDV is one of the proactive routing protocols in mobile ad-hoc networks. DSDV is an altered version of DBF (Distributed Bellman-Ford) technique. This technique is utilized to calculate the shortest path. DBF technique creates certain routing loops. The DSDV is developed to suppress this looping problem with the help of DSN (Destination Sequence Number) [Sreekanth Vakati *et al.* (2013)]. DSDV is similar to the RIP (Routing Information Protocol) excepting the DBF technique. In DSDV, mobile nodes transmit updated routing information and incremented sequence number throughout the network. In this routing protocol, route selection process is carried out by the distance vector shortest path algorithm. DSDV minimizes its transmission overheads by using two updated packets which are: “full dump “and “incremental dump”. The full dump packet holds the routing data and the incremental dump holds only the changed data successively previous full dump.

3.3.3 Optimized Link State Routing (OLSR)

OLSR is one of the proactive protocols in mobile ad hoc networks. OLSR was developed based on link state routing algorithm which uses optimized technique to extract information pertaining to the network topology [Dilpreet Kaur *et al.* (2013)]. In OLSR, when change in network topology occurs, flooding of information to all the network nodes happens. These flooding are minimized by the help of MPR (Multi Point Relays). Table driven nature of the OLSR helps to broadcast updated routing tables to all the mobile nodes of the network. Various control messages are used in OLSR routing protocol, namely, HELLO, TC (Topology Control), HNA (Host and Network Association) and MID (Multiple Interface Declaration).

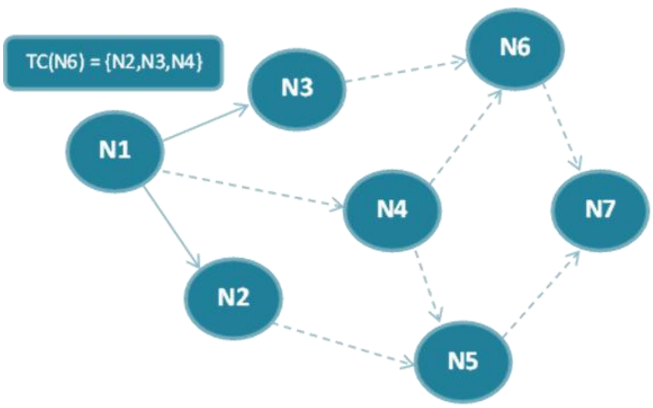

Fig.3.3.Control message transmission in OLSR

The OLSR broadcasts these control messages periodically that is why OLSR is not required usage of control message delivery. This helps OLSR to have reasonable losses in control messages. Fig.3.3 illustrates the processing of TC message from the node ‘N1’ to the network of seven mobile nodes; ‘N1’, ‘N2’, ‘N3’, ‘N4’, ‘N5’, ‘N6’ and ‘N7’. Where, ‘N2’, ‘N3’, and ‘N4’ are the neighbor nodes of the mobile node ‘N1’.

3.4 Performance Metrics

Various metrics are available for analyzing performances of the MANET routing protocols. Following metrics were taken into account for calculating performances of the standard AODV, DSDV and OLSR routing protocols [Rakesh Kumar Jha *et al.* (2015)].

3.4.1 Throughput

Throughput is the total data transmitted from the source node to the destination node in a time unit which is expressed in Kilobits per second (Kbps).

$$\text{Throughput} = \frac{(\text{Total Received Bytes} \times 8)}{(\text{Simulation Time} \times 1024)} \tag{3.1}$$

Unit of throughput is Kbps. Higher values of the throughput provide better performance.

3.4.2 Packet Delivery Ratio (PDR)

Packet Delivery Ratio is the fraction of amount of received packets to the amount of sent packets.

$$\text{PDR} = \frac{\text{Amount of Received Packets}}{\text{Amount of Packets Sent}} \times 100\% \tag{3.2}$$

PDR is derived in % (percentage). Higher values of PDR provide better performance.

3.4.3 End to End Delay (EED)

EED is the average time interval between packets generated at the source and effective delivery of these packets at the destination. EED is the fraction of delay sum to the packets received.

$$\text{EED} = \frac{\text{Delay Sum}}{\text{Packets Received}} \tag{3.3}$$

EED is derived in mille seconds (ms). Lower values of EED provide better performance.

3.4.4 Packet Loss (PL)

Packet loss is the difference of total packets sent and the total packets received.

$$\text{Packet Loss (PL)} = (\text{Total Packets Sent}) - (\text{Total Packets Received}) \tag{3.4}$$

Packet loss is derived in number of packets.

3.4.5 Normalized Routing Load (NRL)

NRL is the ratio of the numbers of transmitted routing packets to the number of packets received [Qutaiba Razouqi *et al.* (2013].

$$\text{NRL} = \frac{\text{Number of Routing Packets Sent}}{\text{Number of Packets Received}} \tag{3.5}$$

Higher values of the NRL deliver better and enhanced performance however, higher values leads to less efficiency of the routing protocol in terms of bandwidth consumption.

3.5 Simulation Setup

Simulation setup for this analysis was set by installing NS-3(Network Simulator-3) version 3.13 in a 64bit machine on the CentOS Linux platform. 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 simulation configuration to trace collection and analysis. The NS-3 simulation core supports research on both IP and non-IP based networks" [IR 9]. Majority of NS-3 users emphases on wireless/IP simulations. NS-3 does not support APIs of NS-2 [Rakesh Kumar Jha *et al.* (2015)]. NS-3 supports real-time schedulers which simplifies number of "simulations-in-the-loop". Packets generated by the NS-3 can be emitted and receive on real network devices. NS-3 is aligned with the simulation needs of modern networking research. The MANET routing compare script was configured for different network sizes and different node pause times separately for each routing protocol. Other general network parameters were kept identical for both the factors. Separate experiments were conducted for each node sets and node pause time values.

3.6 Results and Discussions

Simulation based experiments and performance comparison of standard AODV, DSDV and OLSR routing protocols were carried out in two different scenarios; in first scenario, effects of different node densities were studied and in the other, effects of different pause times have been studied. Simulation scenarios and obtained results are illustrated in the following tables and graphs.

(A) Simulation Scenario - I (SS-I)

General Network parameters that were taken into account for simulation scenario-I are mentioned in the Table - 3.1. In scenario SS-I, number of nodes were varied keeping 10 number of source/sink connection fixed.

Table - 3.1: Network Parameters for SS-I

1	Number of Nodes	30,40,50,60,70,80,90,100
2	Simulation Time	150 seconds
3	Pause Time	No pause time
4	Wi-Fi mode	Ad-hoc
5	Wi-Fi Rate	2Mbps (802.11b)
6	Transmit Power	7.5 dBm,
7	Mobility model	Random Waypoint mobility model
8	No.of Source/Sink	10
9	Sent Data Rate	2048 bits per second (2.048Kbps)
10	Packet Size	64 Bytes
11	Node Speed	20 m/s
12	Protocols used	AODV, DSDV and OLSR
13	Region	300x1500 m
14	Loss Model	Friis loss model

(i) Throughput: Obtained experimental packet data have been used to calculate the throughput as per throughput metrics, results so obtained are mentioned in Table - 3.2.

Table - 3.2: Throughput in Kbps (SS-I)

No. of Nodes	AODV	DSDV	OLSR
30	16.04	14.95	18.27
40	17.93	14.3	16.93
50	14.47	12.64	17.99
60	1.87	14.87	18.91
70	9.73	14.58	18.99
80	11.62	15.6	18.60
90	0.68	13.47	17.47
100	1.42	13.58	18.45

Fig.3.4 explores performances of AODV, DSDV and OLSR in terms of average throughput with the increasing node density. OLSR protocol has shown better performances as compared to AODV and DSDV. The AODV protocol has performed better than DSDV for smaller number of nodes but, DSDV has shown better performance for larger number of nodes.

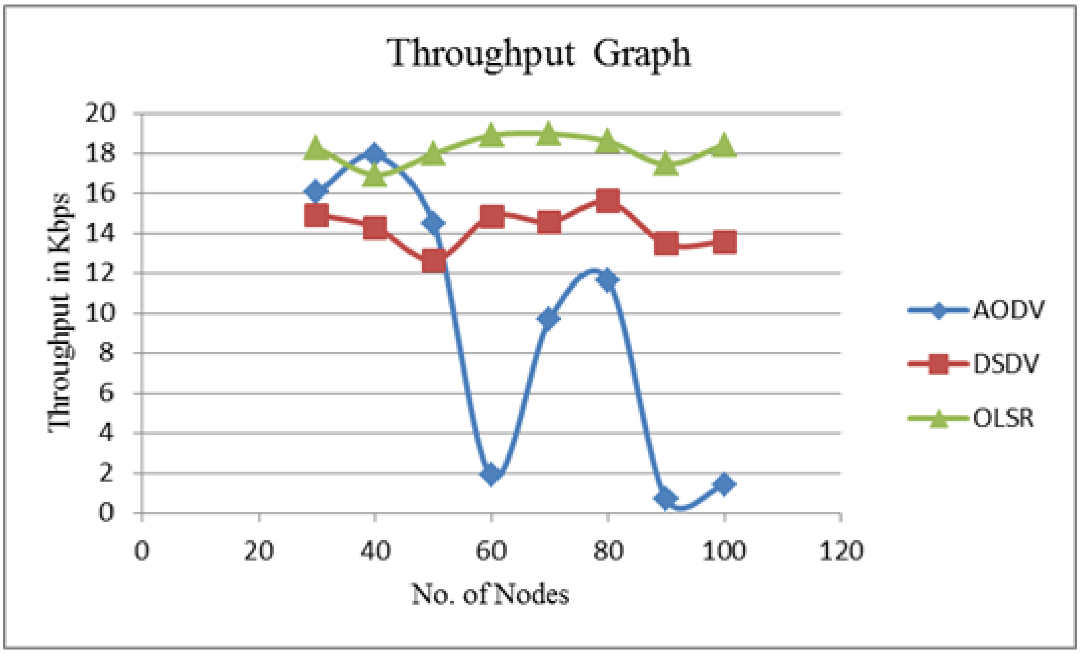

Fig.3.4. Throughput over No. of nodes (SS-I)

(ii) Packet Delivery Ratio (PDR): Data shown in Table - 3.3 were extracted from the experimental packet data and the metrics of the packet delivery ratio.

Table - 3.3: Packet Delivery Ratio in % (SS-I)

No. of Nodes	AODV	DSDV	OLSR
30	80.22	74.73	91.33
40	89.63	71.52	84.67
50	72.33	63.22	89.93
60	9.35	74.35	94.55
70	48.63	72.88	94.97
80	58.08	77.98	93.00
90	3.42	67.33	87.37
100	7.08	67.88	92.25

Packet delivery ratio of the OLSR routing protocol was found better than that of AODV and DSDV. Here, AODV has performed well for smaller number of nodes however; DSDV has shown better results for higher number of nodes. Fig.3.5 shows the performance graphs of all the three routing protocols.

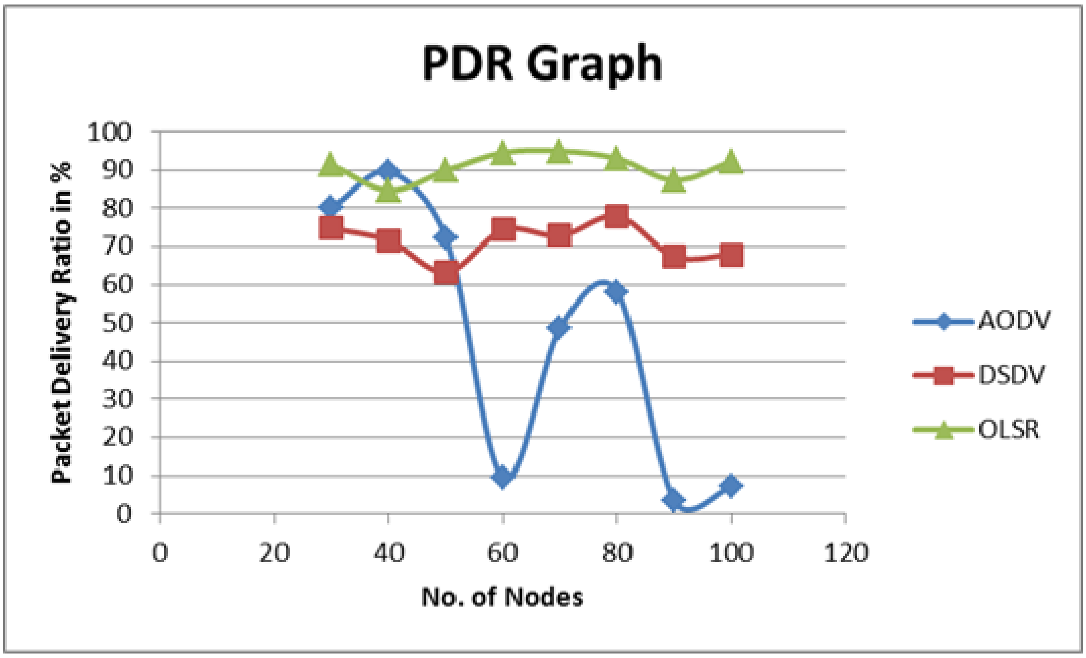

Fig.3.5. PDR over No. of nodes (SS-I)

(iii) End to End Delay (EED): Table - 3.4 shows the data sheet of end to end delay in AODV, DSDV and OLSR routing protocols. These were calculated using obtained experimental data and by performance metrics of EED.

Table - 3.4: End to End Delay in Mille Seconds (ms) (SS-I)

No. of Nodes	AODV	DSDV	OLSR
30	6.17	8.45	2.37
40	2.89	9.96	4.53
50	9.56	14.55	2.80
60	242.38	8.62	1.44
70	26.41	9.30	1.33
80	18.04	7.06	1.88
90	706.71	12.13	3.62
100	327.94	11.83	2.10

OLSR has shown better results (less delay) as compare to rest two routing protocols. However, when comparing performances of AODV and DSDV, the AODV protocol has performed well for smaller number of nodes and the DSDV has shown better performance for higher number of nodes in terms of end to end delay. Fig.3.6 explores performances of AODV, DSDV and OLSR.

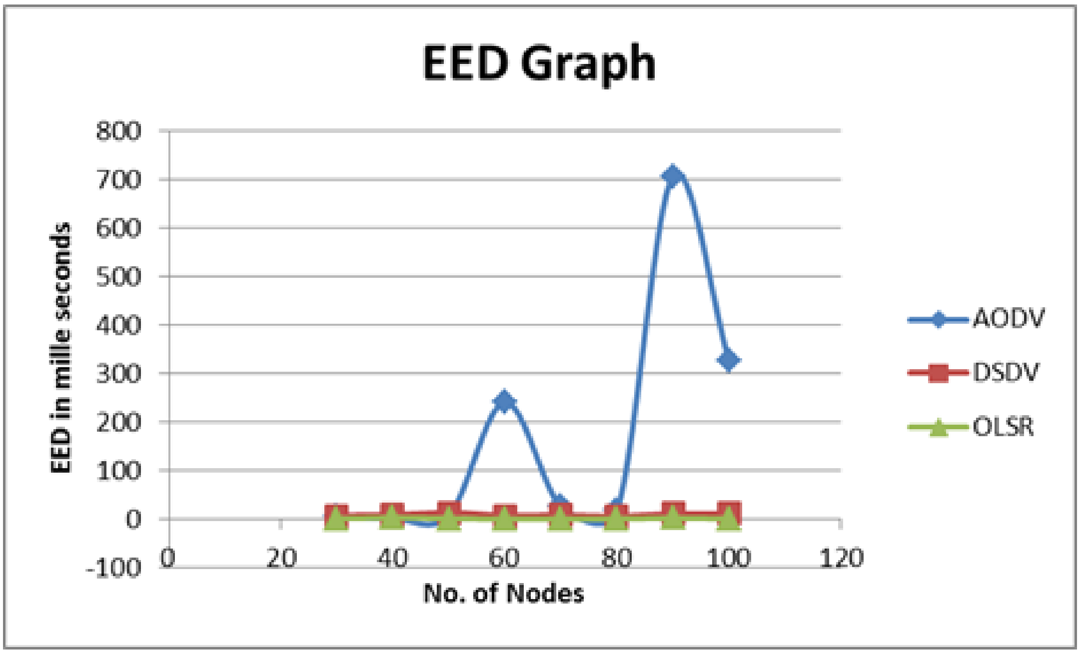

Fig.3.6. EED over No. of nodes (SS-I)

(iv) Packet Loss (PL): The OLSR protocol has least number of packet losses as compare to AODV and DSDV. Table - 3.5 explores the packet losses found in all the three routing protocols.

Table - 3.5: Packet loss in No. of packets (SS-I)

No. of Nodes	AODV	DSDV	OLSR
30	1187	1516	520
40	622	1709	920
50	1660	2207	604
60	5439	1539	327
70	3082	1627	302
80	2515	1321	420
90	5795	1960	758
100	5575	1927	465

When comparing performances of AODV and DSDV, AODV has lesser packet losses for smaller number of nodes and the DSDV protocol has less number of packet losses for the higher number of nodes. Fig.3.7 shows the packet losses in AODV, DSDV and OLSR protocols for increasing node density.

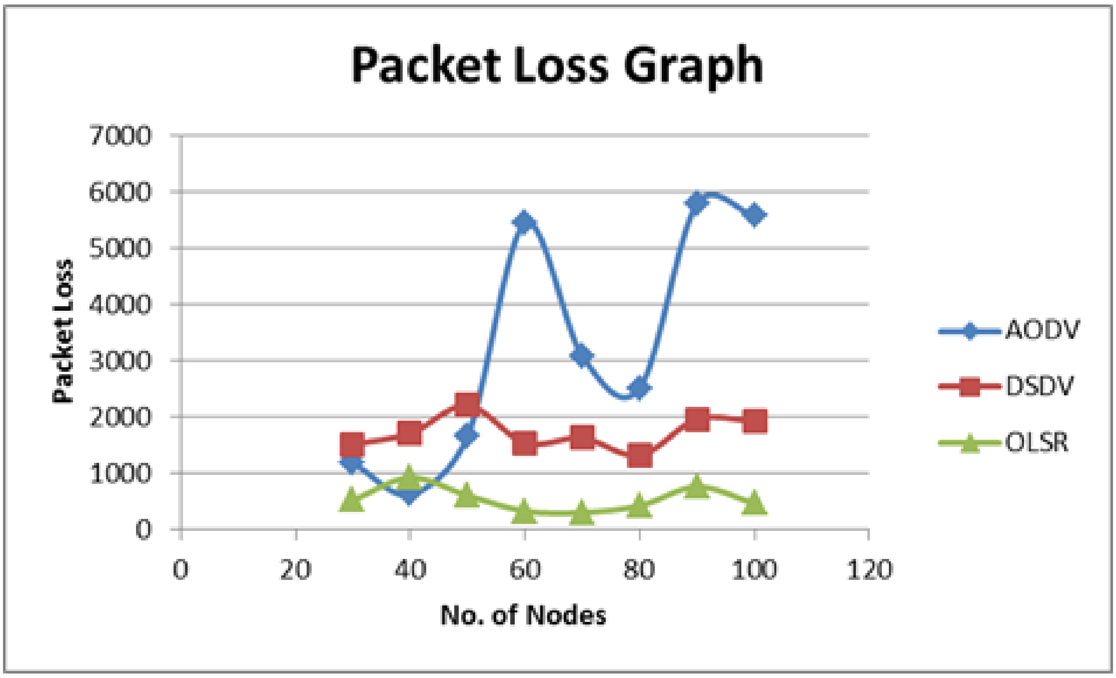

Fig.3.7. Packet loss over No. of nodes (SS-I)

(v) Normalized Routing Load (NRL): NRL data sheet revealed in Table - 3.6 shows better performance of the OLSR protocol as compare to AODV and DSDV protocols.

Table - 3.6: Normalized Routing Load (SS-I)

No. of Nodes	AODV	DSDV	OLSR
30	0.802	0.747	0.913
40	0.896	0.715	0.847
50	0.723	0.632	0.899
60	0.094	0.744	0.946
70	0.486	0.729	0.950
80	0.581	0.78	0.930
90	0.034	0.673	0.874
100	0.071	0.679	0.923

Like in other metrics discussed above, AODV has better values of NRL for smaller number of nodes and DSDV protocol has performed well for higher number of nodes. Fig.3.8 explores NRL scenarios in AODV, DSDV and OLSR protocols for increasing number of nodes.

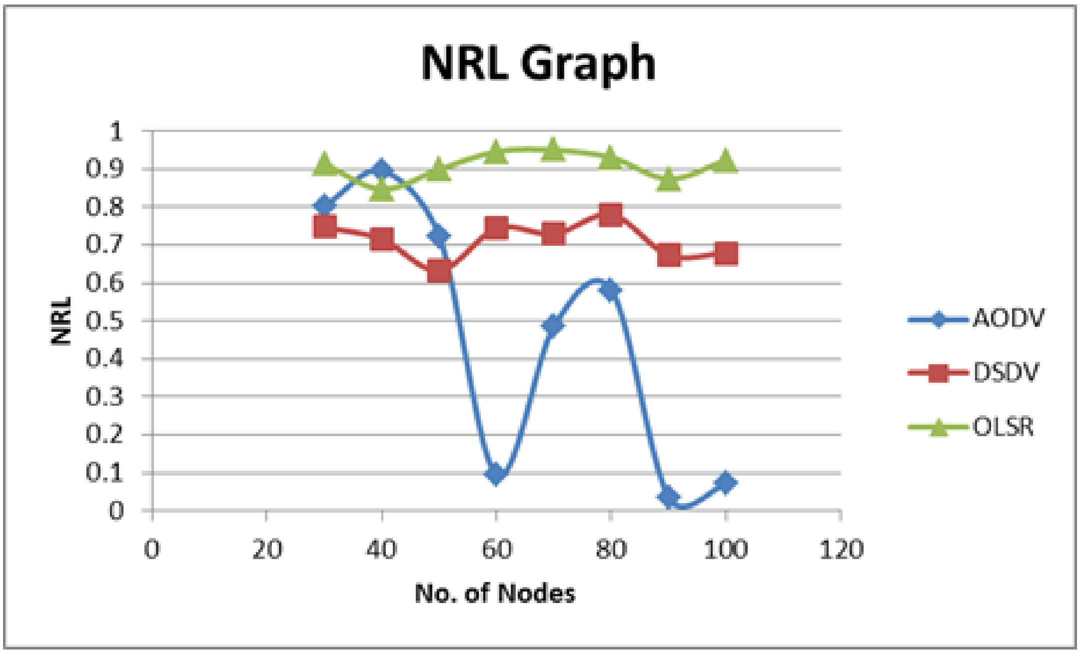

Fig.3.8. NRL over No. of nodes (SS-I)

(B) Simulation Scenario - II (SS-II)

General Network parameters for SS-II were chosen as per Table - 3.7. In SS-II, pause times of nodes were varied by keeping 10 numbers of fixed source/sink connections. Random waypoint mobility model was used for this experiment.

Table - 3.7: Network Parameters for SS-II

1	Number of Nodes	50
2	Simulation Time	150 seconds
3	Pause Time (Seconds)	5,10,15,20,25,30
4	Wi-Fi mode	Ad-hoc
5	Wi-Fi Rate	2Mbps (802.11b)
6	Transmit Power	7.5 dBm,
7	Mobility model	Random Waypoint mobility model
8	No. of Source/Sink	10
9	Sent Data Rate	2048 bits per second (2.048Kbps)
10	Packet Size	64 Bytes
11	Node Speed	20 m/s
12	Protocols used	AODV, DSDV and OLSR
13	Region	300x1500 m
14	Loss Model	Friis loss model

(vi) Throughput: As per the obtained results from the experiments and metric calculations, average throughput of the OLSR routing protocol was found better for varied node pause times as compare to AODV and DSDV. Table - 3.8 shows the throughput data sheet.

Table - 3.8: Throughput in Kbps (SS-II)

Pause Time in Seconds	AODV	DSDV	OLSR
5	2.88	12.96	17.91
10	5.20	13.25	17.80
15	13.55	14.31	17.48
20	16.27	12.75	18.74
25	16.42	12.21	18.69
30	14.21	12.76	18.27

When comparing AODV and DSDV, AODV was better performing for higher node pause times. However, DSDV was showing better results for smaller values of node pause time. Fig.3.9 displays the performances of routing protocols for increasing node pause times.

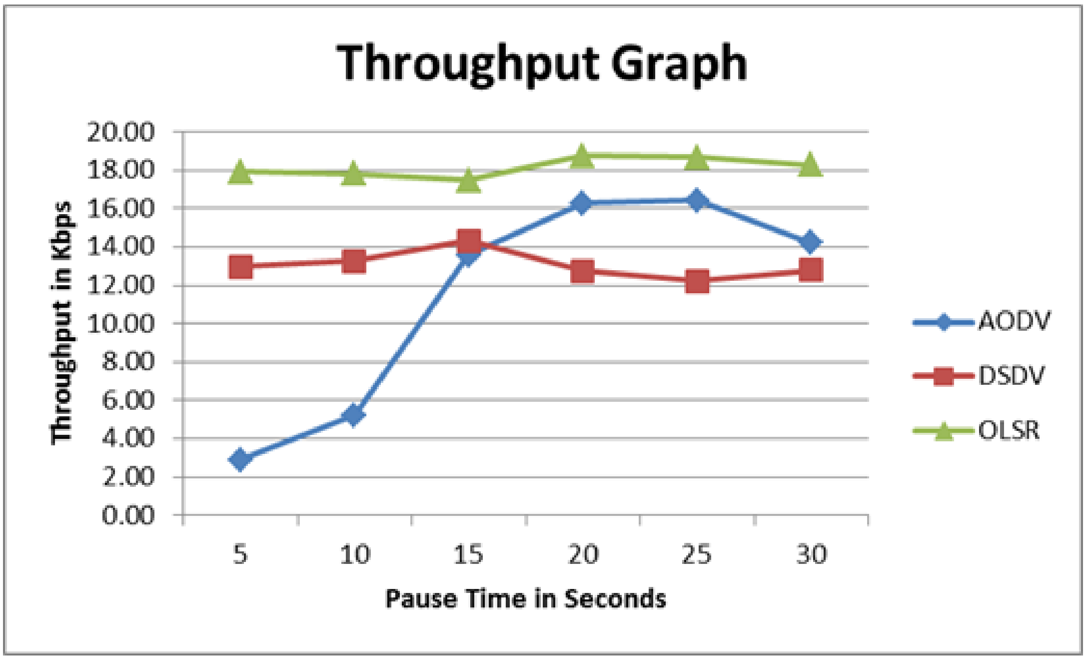

Fig.3.9. Throughput over Pause Time (SS-II)

(vii) Packet Delivery Ratio (PDR): As per data sheet shown in Table - 3.9, packet delivery ratio of the OLSR routing protocol was shown better results as compare to AODV and DSDV protocols for different node pause times.

Table - 3.9: PDR in % (SS-II)

Pause Time in Seconds	AODV	DSDV	OLSR
5	14.42	64.82	89.55
10	25.98	66.23	89.02
15	67.77	71.53	87.40
20	81.37	63.73	93.72
25	82.10	61.03	93.45
30	71.07	63.78	91.35

When comparing performances of the AODV and DSDV protocols, AODV has shown better performances for higher node pause times. However, DSDV has shown better results for the lower pause times. Fig.3.10 displays the performance status of the AODV, DSDV and OLSR for increasing values of node pause times.

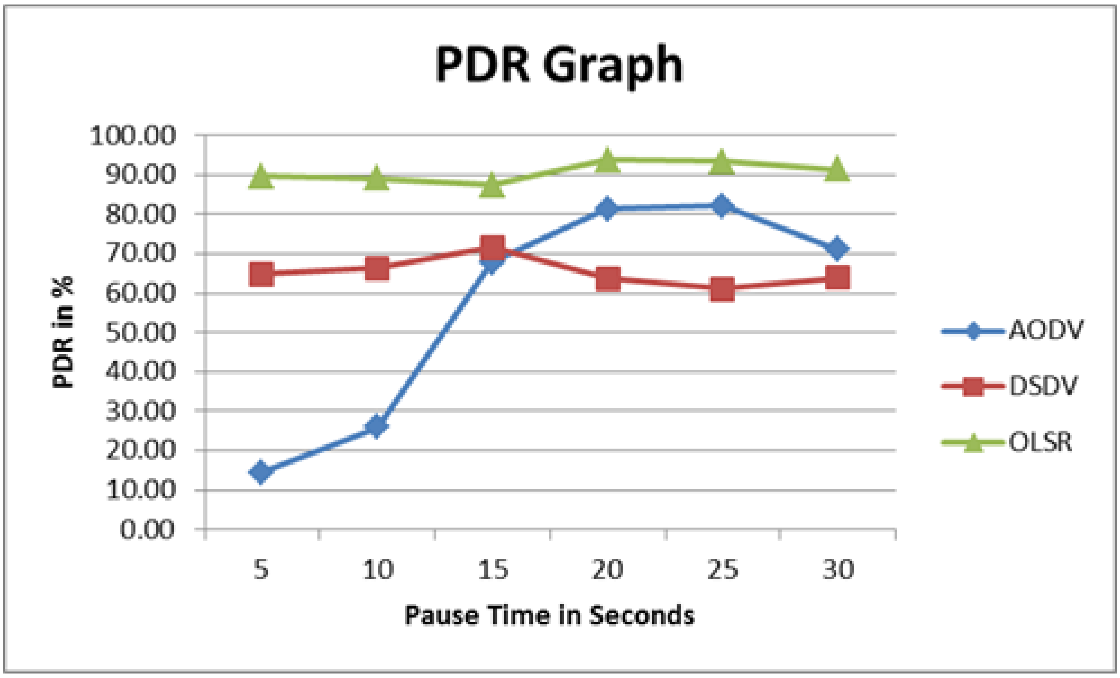

Fig.3.10. PDR over Pause Time (SS-II)

(viii) End to End Delay (EED): Among all the three routing protocols, OLSR has shown better performances in terms of end to end delay. The OLSR protocol has least end to end or round trip delays as compare to AODV and DSDV routing protocols. Table - 3.10 indicates EED data sheet.

Table - 3.10: EED in Mille Seconds (ms) (SS-II)

Pause Time in Seconds	AODV	DSDV	OLSR
5	148.410	13.570	2.920
10	71.220	12.750	3.080
15	11.890	9.950	3.600
20	5.730	14.230	1.680
25	5.450	15.960	1.750
30	10.180	14.200	2.370

Results shows that; the AODV has larger delays for lesser pause times, but it has lesser delay values for higher node pause times. The DSDV protocol has lesser delay values for lesser node pause times as compare to AODV. Fig.3.11 shows EED graphs of the protocols.

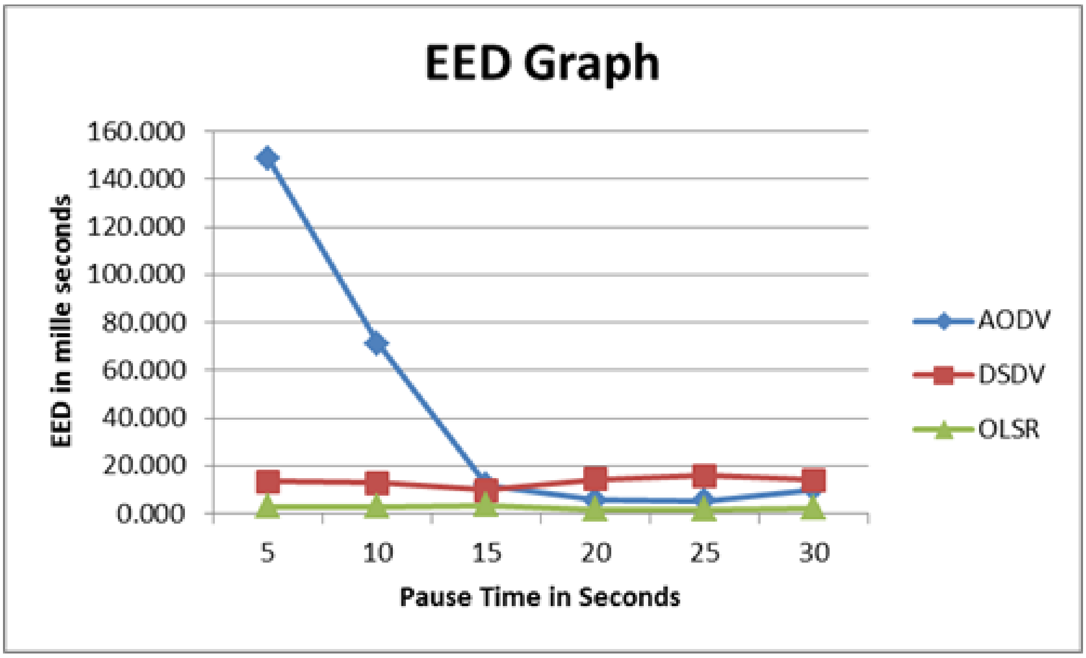

Fig.3.11. EED over Pause Time (SS-II)

(ix) Packet Loss (PL): As compare to AODV and DSDV, OLSR has experienced lesser packet losses for different node pause times. Table - 3.11 displays data sheet of packet losses in the AODV, DSDV and OLSR protocols.

Table - 3.11: Packet loss in No. of packets (SS-II)

Pause Time in Seconds	AODV	DSDV	OLSR
5	5135	2111	627
10	4441	2026	659
15	1934	1708	756
20	1118	2176	377
25	1074	2338	393
30	1736	2173	519

When comparing performances of AODV and DSDV, DSDV protocol has lesser packet losses for lesser pause time values and AODV has lesser packet losses for higher node pause times. Fig.3.12 illustrates the packet loss scenarios in all the three routing protocols.

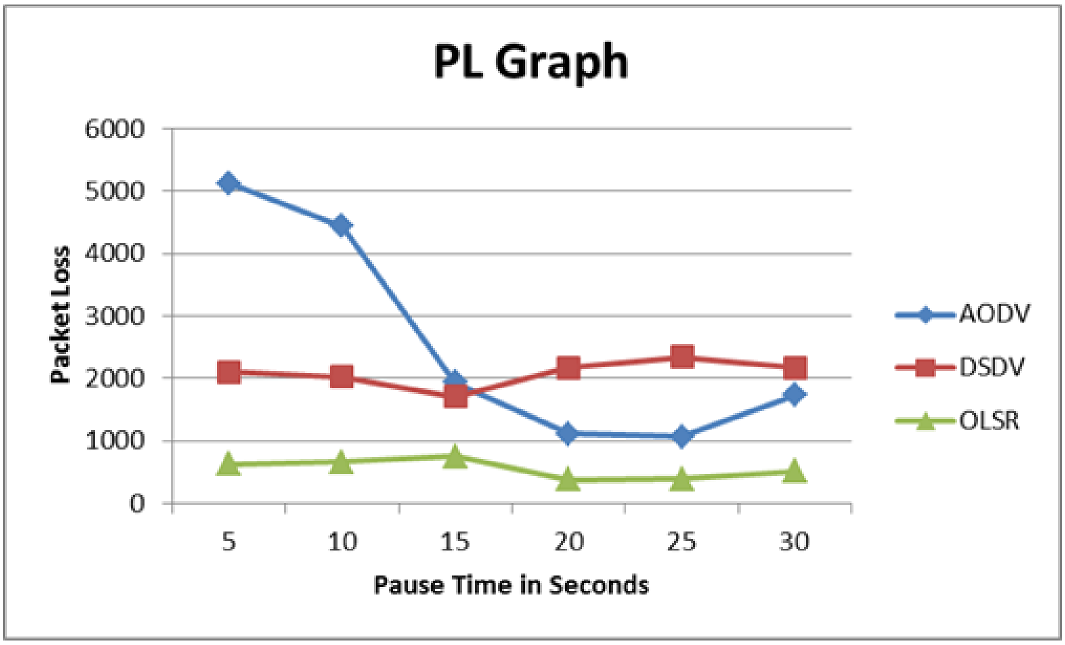

Fig.3.12. PL over Pause Time (SS-II)

(x) Normalized Routing Load (NRL): Data sheet shown in Table - 3.12 explores that the regularized routing load in OLSR routing protocol was better as compare to AODV and DSDV protocols for different values of node pause times.

Table - 3.12: Normalized Routing Load (SS-II)

Pause Time in Seconds	AODV	DSDV	OLSR
5	0.144	0.648	0.896
10	0.260	0.662	0.890
15	0.678	0.715	0.874
20	0.814	0.637	0.937
25	0.821	0.610	0.935
30	0.711	0.638	0.914

When comparing performances of AODV and DSDV, the AODV protocol has shown better performances for higher pause times and the DSDV has shown better results for lesser node pause times. Fig. 3.13 shows NRL graphs of AODV, DSDV and OLSR protocols. The green line in the graph shows the performance of the OLSR routing protocol, likewise; blue line represents performance of the AODV protocol and the brown line represents performance of the DSDV routing protocol.

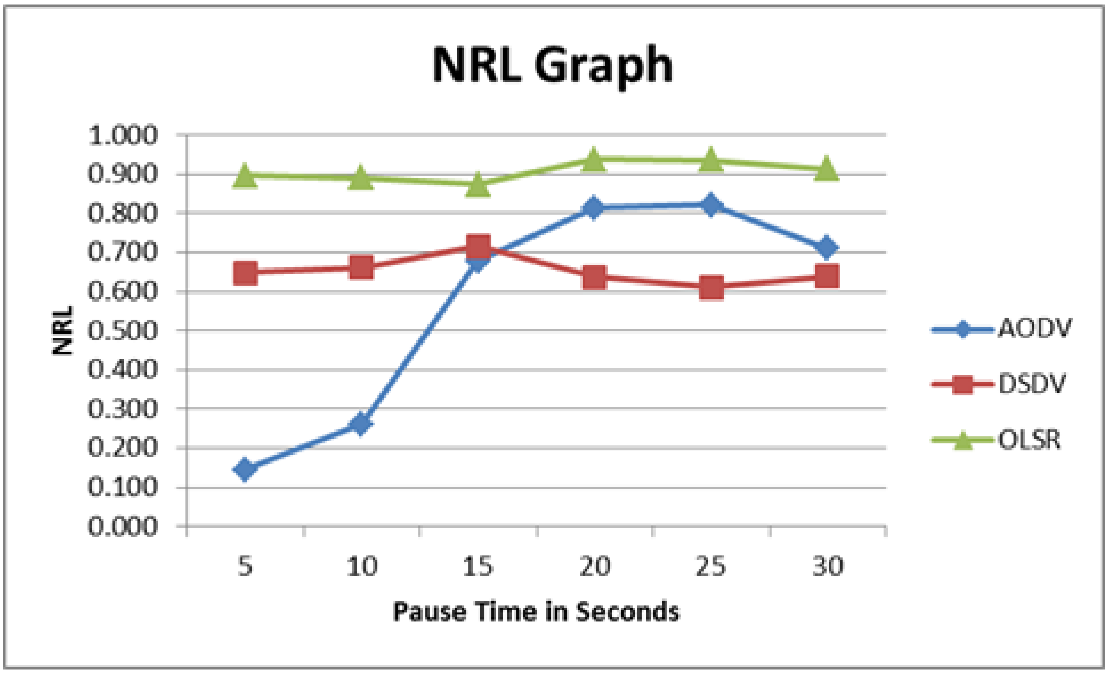

Fig.3.13. NRL over Pause Time (SS-II)

3.7 Conclusion

This chapter presented the node density and the node pause time effects over the performances of the standard AODV, DSDV and the OLSR routing protocols. As discussed earlier, various factors affect the performances of routing protocols. Here, two such factors; node density and node pause time were taken into account to study and evaluate the performances of the routing protocols. There were two scenarios fixed for each effect; scenario I and scenario II. As per results of both the scenarios, it was noticed that; as compared to AODV and DSDV, performance of the OLSR routing protocol was found better in all the metric calculations.

In scenario-I, network throughput of OLSR protocol was better as compared to AODV and DSDV. As far as AODV and DSDV are concerned, initially throughput of the AODV was better, but after some point, decrease in throughput was noticed. Throughput of the DSDV routing protocol was better when it was compared with the AODV protocol. In rest metrics also, the OLSR routing protocol was performed well as compare to AODV and DSDV. Experimental results of AODV and DSDV shows that; for lower values and higher values of node density and pause times, it was observed that in some cases (some values of varied node density), AODV had shown better performances and in some other cases (some other values of varied node density), DSDV had shown better results.

In scenario-II also, the OLSR routing protocol had shown better and enhanced performances as compared to AODV and DSDV routing protocols. As far as AODV and DSDV are concerned, DSDV had shown better performances in some cases of varied node pause times and AODV had shown better performances in some other cases of varied values of node pause times. These conclusions are laid based on obtained experimental results through the version of the network simulator used and the network parameters set for the analysis. However, performance of the MANET routing protocols also depends on various factors like, transmit power, no. of source/sink connections, node velocity, transmission region, transmission range, type of traffic load, Wi-Fi rate and packet size etc.

Finally, it is concluded that; out of all the three routing protocols (AODV, DSDV and OLSR) of MANETs, performance of the OLSR routing protocol was better for varied values of the node density and node pause times. In chapter 4, effects of node velocity and transmit power on the performances of standard AODV, DSDV and OLSR routing protocols have been discussed. In chapter-5, performance analysis on standard and attribute revised models of AODV, DSDV and OLSR routing protocols have been accomplished.