CHAPTER-4

Investigations on Diverse Node Velocity and Transmit Power Effects

4.1 Introduction

This chapter presents study and simulation based investigations of diverse node velocity and transmits power effects on AODV, DSDV and OLSR, the well-known routing protocols in mobile ad hoc networks. As already discussed in previous chapters, MANET is an infrastructure less decentralized wireless network, which do not depend on centralized association or switching points. MANETs has some unique characteristics, they self-organize self-configure themselves. Ad-hoc network routing protocols postulate communication between routers and prompt them to select routes between a source and the destination. Route choices are performed by the routing algorithms. Mobile ad-hoc networks have been the emphasis of research interest since last three decades. In ad-hoc networks, nodes connect each other dynamically in a random manner. The dynamic topographies of mobile ad-hoc networks require improved version of the routing protocols. As a wireless ad hoc network, MANET has a routable networking scenario with self-forming and self-healing capabilities without having a centralized infrastructure. This chapter addresses comparative performance analysis of the standard AODV, DSDV and OLSR routing protocols considering different values of node velocity and node transmit power with the help of network simulator. Various performance evaluating metrics such as; the throughput, packet delivery ratio, end to end delay, packet loss and normalized routing load were used to evaluate performances of the routing protocols.

Computer networks are group of network devices and computers which shares different user services, information and user applications with each other, these can be wired or wireless. Mobile ad hoc network is a momentary wireless network which emerges without using any existing network infrastructure and without any centralized network administration system. Mobile ad-hoc network nodes are mobile in nature, hence, topology and organization of these networks changes frequently. Due to dynamic topologies, MANET nodes have to act as host and the router, they bear all the routing activities. Often, due to random topographies of mobile ad hoc networks, routing become challenging. Considering routing strategy, MANET routing protocols can be classified as proactive (table-driven) and reactive (on demand) protocols and while considering organization of the network, these can be classified as flat routing; geographic position assisted routing and hierarchical routing [Teressa Longjam *et al.* (2013)]. Fig.4.1 illustrates quick formation of simple mobile ad-hoc network constituted by different wireless devices.

Fig.4.1.Quick Formation of MANET

The influence of transmit power in data propagation is presently one of the key issues in Mobile ad hoc networks and transmission power is a key parameter [Ramanathan *et al.* (2002)]. Characteristics of the mobile ad hoc networks can be altered by altering the transmit power. “As power increases, the influence of mobility decreases and the effective density increases” [IR 10]. Network survivability varies with different routing protocols in various environments like; variable transmit power, mobility speed and node density. This chapter involves study and analysis of impact of varying node velocity and node transmit power.

A high transmit power influences higher connectivity by increasing the straight links realized by the member nodes of the network [Rajneesh Kumar Gujaral *et al.* (2013)]. Prevailing MANET routing protocols are designed to determine routes by procedures of flooding at full transmission power. Routing protocols are optimized in order to reduce the number of hops from source to the destination. Here, the routing protocols are simulated with NS-3 (Network Simulator-3) under Random waypoint mobility model (RWMM). Fig.4.2 demonstrates another type of a simple, easily deployable and economical mobile ad-hoc network with member nodes 'N'.

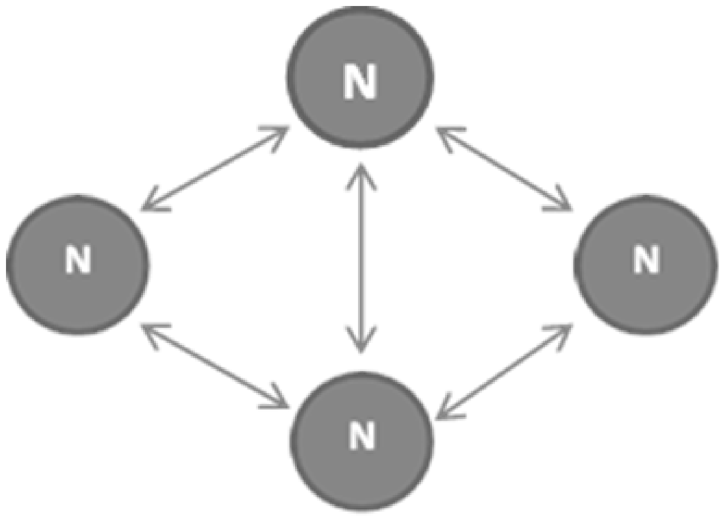

Fig.4.2.Mobile ad-hoc network with member nodes 'N'

4.2 Some Well-Known Routing Protocols

Routing protocol is a resolution that controls how nodes decide the ways of routing packets between a source and the destination. In mobile ad hoc networks, nodes have to determine their network topology. A new node announces its presence and it listens to the announcements broadcasted by its neighbors. As discussed earlier, based on routing information update mechanism, MANET routing protocols are classified as reactive or on-demand, proactive or table-driven and hybrid routing protocols. However, the classifications of ad-hoc network routing protocols are not reciprocally limited as they fall in multiple classes [Siva Ram Murthy *et al.* (2007)]. Fig.4.3 presents different types of routing protocols in MANETs [Perkins *et al.* (2007)].

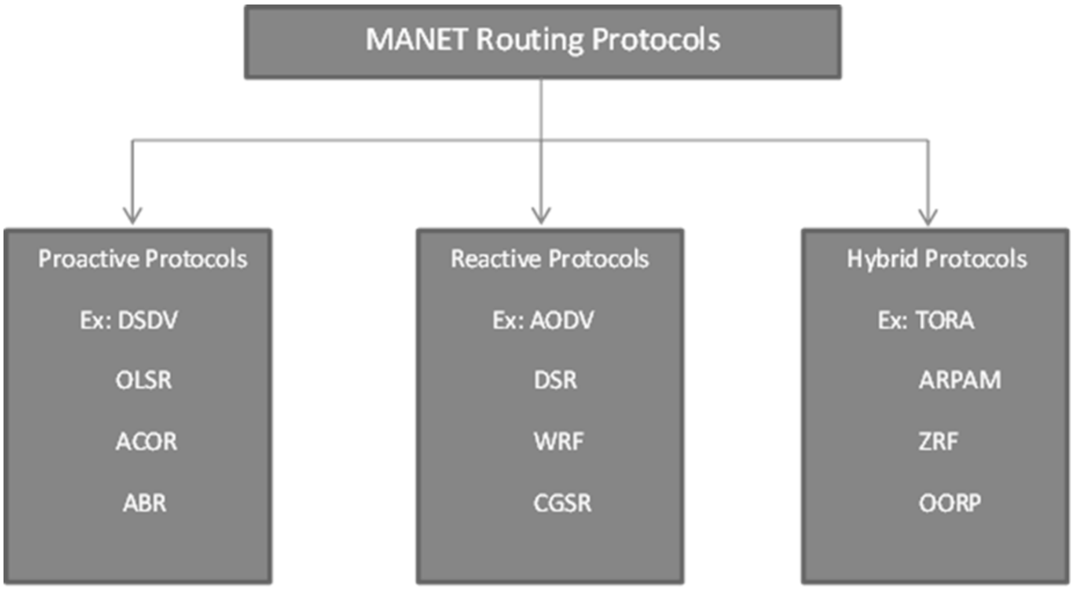

Fig.4.3.Types of MANET Routing Protocols

MANET routing protocols related with the concerns like appeared and disappeared of nodes in different locations [Rakesh Kumar Jha *et al.* (2015)]. These routing protocols need to have smaller routing tables in order to reduce routing link overheads.

4.3 Routing Aspects in MANETs

Routing is a process by which route discovery takes place between source nodes to the destination nodes. In MANET, each and every mobile node acts as a host and the router. The most important aim of routing algorithms in ad hoc network is to create an precise and error free paths among all the member nodes and to make sure correct and timely discharge of packets [Rutvij H. Jhaveri *et al.* (2012)]. Ad hoc wireless network is made up of a set of mobile nodes also called as hosts connected each other by wireless links. Routing protocols that seeks a route to be followed by the data packets from a transmitting source node to the receiving destination node used in conventional wired networks cannot be straightly realistic in mobile ad-hoc networks. This is because of their highly dynamic topological scenarios and absence of conventional infrastructure for central controls such as; access points or base stations, bandwidth-constrained wireless links and energy or resource constrained mobile nodes. Network nodes ensure the required communication links by means of routing processes. Routing processes use routing tables which are maintained by each and every node of the network. Routing tables consists of information pertaining to network topology and link related information of already established routes and the requested fresh routes. Network nodes periodically exchange the routing tables with their neighbor nodes and all the other nodes in the network. Routing related information is generally flooded in the entire network.

4.4 Reactive and Proactive Routing Protocols

Reactive routing protocols are on-demand routing protocols in which, route requests generated by the member nodes of the network are processed [Ashok M.Kanthe *et al.* (2012)]. Reactive or on-demand type routing protocols do not maintain the information related to network topology, they get the required path when it is necessary by the help of a process called connection establishment process. Thus, reactive routing protocols do not exchange routing information periodically. If a source node sends a route request to a destination node, the protocol establishes a path between them. Proactive routing protocols are table-driven; therefore, timely updated routing tables are helpful to establish a path between a source and the destination node. Using proactive routing protocols, every node maintains the information pertaining to the network topology in the form of routing tables which are exchanged periodically. Routing tables holds information related to the network topology, link path information and the detailed information pertaining to every member node of the ad hoc network. When a node necessitates a path to a particular destination, that node processes an appropriate route-discovery algorithm over the topological information it maintains.

4.5 Energy Consumption in MANETs

The process of communication and computation involves consumption of energy in nodes of the network. Existing mobile nodes in the network are in four modes as given in equation 4.1. While communication proceeds, the nodes undertake different transition states. From equation 4.2, we could notice that in sleep mode, the mobile node consume low power as compare to other states of the nodes [IR 11].

$$E_{pt} = E_{oh} + E_a + E_i + E_s \tag{4.1}$$

$$E_a = E_t + E_r \tag{4.2}$$

$$E_s \cong 0 \tag{4.3}$$

$$E_t = E_{pt} + E_{pd} \tag{4.4}$$

Where,

E_{pt} = packet transmission energy

E_{oh} = packet over hear

E_a = active packet energy

E_i = idle packet energy

E_s = sleeping packet energy

E_t = transmit packet energy

E_r = received packet energy

E_{pd} = path discovery energy

4.5.1 Consumption of Power in Transmission Mode

During transmission, a source node sends data packets to the destination node. Transmission energy refers to the energy required by a node to transmit the data packet. Transmission energy is totally depends on the size of the data packet. Therefore, the transmission energy has the following formula [IR 11]:

$$E_t = (PL \times 330) \div (2\times10^6) \tag{4.5}$$

$$P_T = E_t \div T_t \tag{4.6}$$

Where,

E_t = transmit packet energy

PL= packet length

P_T = transmission power

T_t = time taken to transmit the data packet

4.5.2 Consumption of Power in Reception Mode

Reception energy is referring to the energy required by a node to receive a data packet from the other nodes of the network. The energy in received mode is formulated as follows [IR 11]:

$$E_r = (PL \times 230) \div (2\times10^6) \tag{4.7}$$

$$P_r = (E_r) \div (T_r) \tag{4.8}$$

Where,

E_r = reception energy

P_r = reception power

T_r = time taken to receive the data packet

PL = packet length

4.5.3 Consumption of Power in Idle mode

In idle mode, a packet will be in idle mode that is it neither transmit a packet nor receive any packet. In idle mode, the packet in idle mode consumes same amount of energy as an active node takes to receive the packet. In idle mode, nodes which are in idle state does not involve in data communication [IR 11]. The power consumption in idle mode is given by:

$$P_i = P_r \tag{4.9}$$

Where,

P_i = power consumed in idle mode

P_r = power consumed in reception mode

4.5.4 Consumption of Power in Overhearing Mode

In overhearing state, a node hears to the packet which is not sent for it. Consumption of energy in this mode is equal to energy consumed in reception mode. Therefore, consumption of power in overhearing mode is given by [IR 11] :

$$P_o = P_r \tag{4.10}$$

Where,

P_o = power consumed in overhearing mode

P_r = power consumed in receiving mode

4.6 Node Mobility and RWMM (Random Waypoint Mobility Model)

Mobility is the key attribute in ad-hoc networks. Modeling movement of a set of nodes is important for evaluating performance of a mobile ad-hoc network [Ho *et al.* (2007)]. This project involves a typical random waypoint mobility model and Friis loss model. A mobility model describes the exact location of a mobile node at any time. The random waypoint model was originally projected by Johnson and Maltz. It is one of the most widespread mobility models used to evaluate MANET routing protocols because of its ease and extensive availability [Johnson *et al.* (1996)]. The movement of nodes is governed in the following manner; every node starts by resting for a set time in seconds. The node then selects a random destination in the simulation zone and a random velocity between 0 and some determined speed. The node travels to this endpoint and again pauses for a set time period prior to another random position and speed. This enactment is repeated for the entire simulation time [Broch *et al.* (1998)].

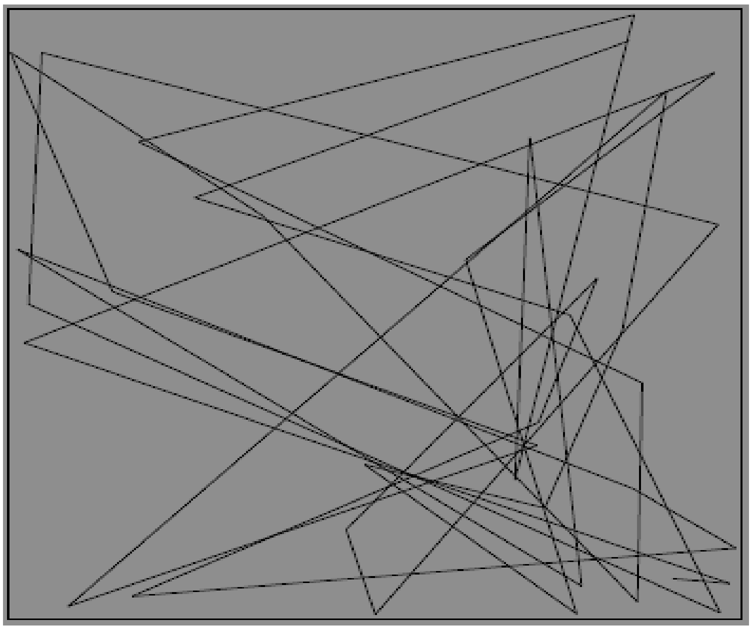

Fig.4.4. Movement pattern of nodes in RWMM

Fig.4.4 illustrates the distribution of the nodes in the simulation area and the distribution of the node speeds varying over the simulation time [Philipp Sommer *et al.* (2007)]. In RWMM, each node moves from one way point to another way point along with the zigzag line.

4.7 Route Discovery in AODV

AODV is a reactive or on demand distance vector routing protocol [Perkins *et al.* (2003)]. Algorithm of AODV creates routes between nodes only when the routes are requested by the source nodes providing the network flexibility to allow nodes to enter and leave the network at will. Routes remain active only as long as data packets are travelling along the paths from the source to the destination. Active routes get time out and close when the source node stops sending packets. In AODV, the source node initiates route discovery by sending a RREQ (route request) packet. Broadcasted RREQ packet then spread throughout the network till it reaches the actual destination or it gets reply from any intermediate node that holds the latest route information of that destination. While dispatching RREQ message to the destination, the intermediate nodes updates RREQ information in their routing table.

AODV protocol supports symmetric links only. Symmetric link information helps network nodes to maintain cache of the route and utilize the sequence number of the destination for every entry of the route. AODV has limited route discovery mechanism. When RREQ packet reaches the destination, a RREP (route reply packet) will generate at the destination and it will be sent to the source. When link breaks occurs between the nodes, a RERR (route error packet) packet will be broadcasted among all the member nodes of the network. Member nodes of the network updates RERR message in their routing tables and eradicate the link breaks [Sreekanth Vakati *et al.* (2013)]. Fig.4.5 shows the route establishment process in AODV, where ‘S’ is the source node, ‘D’ is the destination node and ‘N’ are the member nodes in the Network.

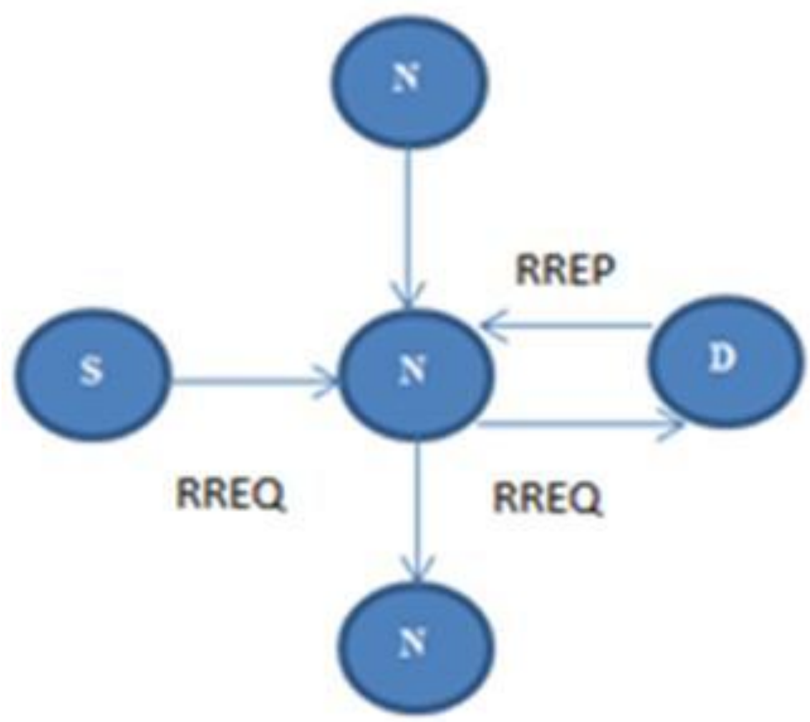

Fig.4.5. Establishment of route in AODV

Fig.4.6 reveals the processing of Route Request message from the source node (SN) 1 to the destination node (DN) 8 through different routes [IR 12].

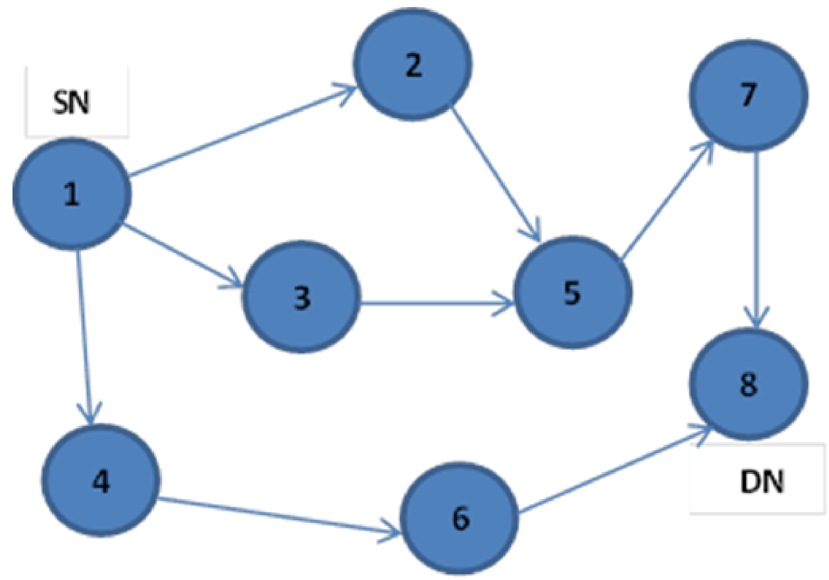

Fig.4.6. Processing of RREQ message in AODV

Fig.4.7 determines the processing of Route Reply message from destination node (DN) 8 to the source node (SN) 1 through shortest route [IR 12].

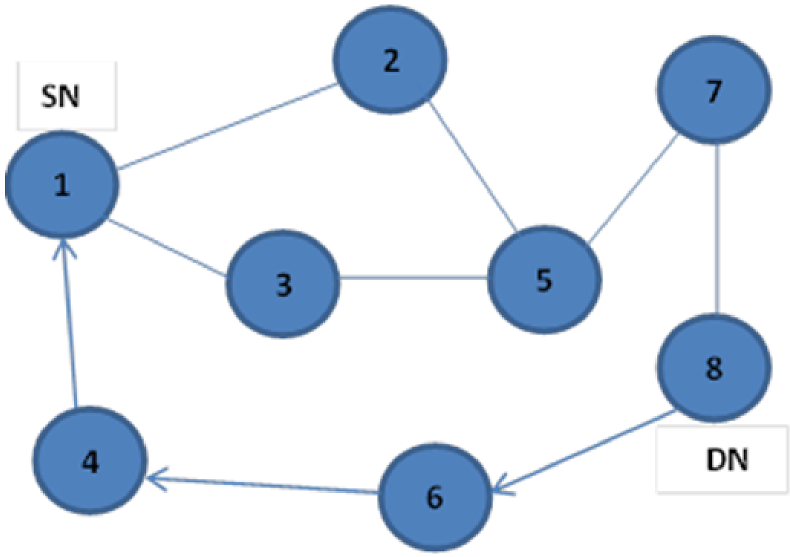

Fig.4.7. Processing of RREP message in AODV

4.8 Packet Forwarding in DSDV

DSDV is a proactive routing protocol in mobile ad hoc networks. It is originally based on the Bellman-Ford routing algorithm [Rakesh Kumar Jha *et al.* (2015)]. Distributed Bellman-Ford (DBF) technique was applied effectively in most of the packet switched networks and the DSDV routing protocol is a modified version of this technique. DBF technique is very helpful in calculating the shortest paths between source nodes to the destination nodes. Re-known drawback of this technique is forming of routing loops. In DSDV, a new parameter called Destination Sequence Number (DSN) has been hosted to reduce routing loops problems of the DBF technique [Sreekanth Vakati *et al.* (2013)]. DSDV is almost same as conventional Routing Information Protocol (RIP) except an attribute in routing table that is destination sequence number [Teressa Longjam et al. (2013).

In DSDV, network nodes forward the data packets which contain timely updated routing information and incremented sequence numbers to all their neighbors. This packet forwarding process updates each and every node with up-to-date link information along with the routing table. This updating keeps the nodes in the network capable to create path between source nodes to the destination nodes. Distance vector shortest path algorithm selects the requested routes. DSDV protocol promotes two types of updated packets called “FULL DUMP” and “INCREMENTAL

DUMP". Transmission overheads are reduced by the help of these two updated packets. These updated dump packets are broadcasted through the entire network by all the nodes. The "full dump" packet holds the routing data whereas the "incremental dump" holds only the changed data since the last "full dump". As compare to other MANET routing protocols, DSDV has much link overheads. This negative aspect of DSDV limits it for small scale deployments.

Table - 4.1: Node N4 packet forwarding in DSDV

Destination	Next hop	Metric	Sequence No.
N1	N2	2	S406_N4
N2	N2	1	S128_N1
N3	N2	2	S564_N2
N4	N4	0	S710_N3
N5	N6	2	S392_N5
N6	N6	1	S076_N6
N7	N6	2	S128_N7
N8	N6	3	S050_N8

Table - 4.1 and Fig.4.8 illustrates packet forwarding in DSDV routing protocol. In Table - 4.1, node 'N4' is forwarding destination sequence numbers to its neighbor nodes 'N6' and 'N2' [IR 13]. Illustration figure has eight member nodes of the network namely, N1, N2, N3, N4, N5, N6, N7 and N8.

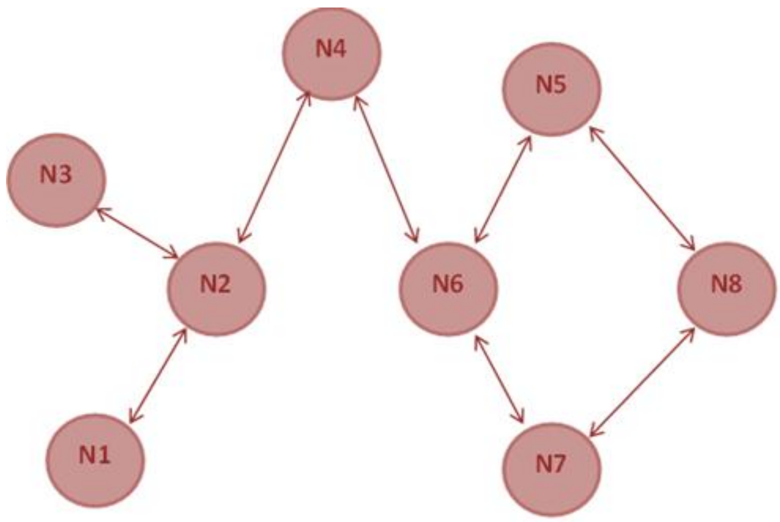

Fig.4.8. DSDV in operation

4.9 Selection of MPR in OLSR

Optimized link state routing (OLSR) is a table-driven or proactive routing protocol. It was originally developed based on the link state algorithm [Dilpreet Kaur *et al.* (2013)]. Optimized nature of OLSR routing protocol helps in reducing “flooding duplication” in highly linked networks. In OLSR, each and every node of the network exchanges network topology information periodically. The periodic nature of the OLSR generates large amount of link overheads. These link overheads are reduced by the help of MPR (Multi Point Relays). MPRs are set of neighboring nodes which are selected by every network node. MPRs that are chosen by every node of the network as a set of neighboring nodes only forwards routing messages throughout the network periodically [Clausen *et al.* (2003)].

Routing calculations are carried out by MPR for a link from the source to the destination. OLSR routing protocol supports three types of mechanisms namely, adequate topology information, effective flooding of control traffic and neighbor sensing [Rakesh Kumar Jha *et al.* (2015)]. In order to discover neighbor of the network node and link information, OLSR uses HELLO control messages. Topology Control (TC) messages are utilized to broadcast information about self- published neighbors including list of the MPR selector. In OLSR, each node transmits control messages periodically. Therefore, OLSR does not necessitate using reliable control message delivery; henceforth, OLSR protocol can endure reasonable control message losses.

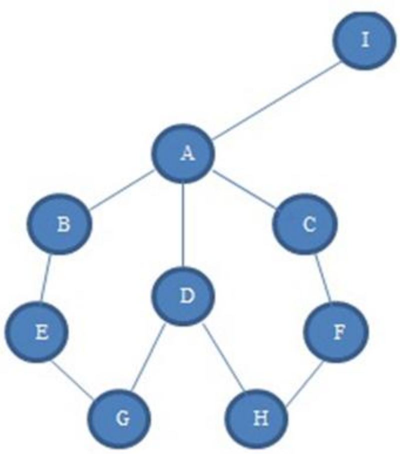

Fig.4.9. Selection of MPR in OLSR

Table - 4.2: MPR selection scenario

Network Node	First hop neighbors of node A	Second hop neighbors of node A	MPR
A	B, D, C, I	E, F,G ,H	D

Fig.4.9 and Table - 4.2 demonstrates the selection of MPR in OLSR. If we consider potential of node 'A', nodes 'C' and 'D' cover all the nodes that are second hop neighbors of node 'A'. Therefore, node 'D' is selected as node 'B's MPR node as shown in Table - 4.2 [Mohanapriya Marimuthu *et al.* (2013)]. OLSR is a table driven ad-hoc network protocol, it uses optimized technique in extracting topology related information. In OLSR, change in topology reasons to flooding of information to all the nodes of the network, which is reduced by multi-point relays. Table driven feature of OLSR helps it to have updated routing information in various tables [Clausen *et al.* (2003)]. OLSR uses four types of control messages: HELLO, TC, MID and HNA.

<u>HELLO</u>: This message is transmitted to all the neighbors periodically. This message helps in getting information related to link status and the neighbor of the host.

<u>TC</u> (Topology Control): This message is sent periodically to the neighbors, it helps in broadcasting neighbors of the member nodes of the network.

<u>HNA</u> (Host and Network Association): HNA message is broadcasted to share information pertaining to the external routing. It holds network related information.

<u>MID</u> (Multiple Interface Declaration): This message is broadcasted throughout the network to inform all the member nodes that the host can have multiple interfaces of the OLSR. MID message lists the connection log of a node.

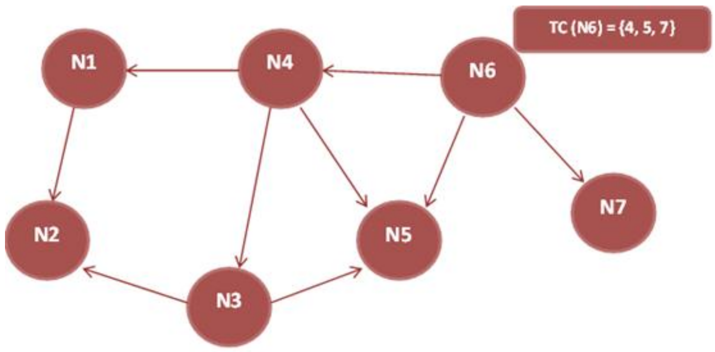

Fig.4.10. OLSR in operation

Fig.4.10 illustrates the operation of OLSR routing protocol. Node 'N6' generates a TC message broadcasting its neighbor set that is TC (N6) = { 4, 5 ,7 } and sends it to its neighbors 'N4', 'N5' and 'N7'. Node 'N4' forwards the message TC (N6) to its neighbors 'N1', 'N3' and 'N5'. Node 'N3' then forwards the message TC (N6) to its neighbors and so on, until the message reaches every node [IR 14].

4.10 Performance Calculations

Performance evaluations of standard AODV, DSDV and OLSR routing protocols have been calculated by using following metrics. Obtained packet data from different experiments was used to calculate these matrices.

(1) Throughput = (Received Bytes × 8) / (Simulation time × 1024) (4.11)

(2) Packet Delivery Ratio = (total received packets) / (total sent packets) ×100 % (4.12)

(3) End to end Delay = (Delay sum) / (Received Packets) (4.13)

(4) Packet Loss = (Total Sent Packets) – (Total Received Packets) (4.14)

(5) NRL = (No. of Routing Packets Sent) / (No. of Received Data Packets) (4.15)

As discussed earlier, throughput is the amount of data transferred from source node to the destination node in a unit time stated in Kbps (Kilobits per second) [Rakesh Kumar Jha *et al.* (2015)]. It is calculated in Kbps. Larger value of the throughput delivers improved performance. Packet delivery ratio (PDR) is the ratio of total received packets to the total packets sent. It is calculated in percentage (%). Higher value of PDR delivers improved performance. End to end delay (EED) is the average time interval between packets generated at the source node and delivery of the packets at the destination node. It is the fraction of delay sum to the received packets. It is calculated in ms (mille second). Lesser values of end to end delay provide improved performance. Packet loss (PL) is the difference of total sent packets and the total received packets. It is calculated as number of packets. Normalized routing load (NRL) is the ratio of number of transmitted routing packets to the number of received data packets [Qutaiba Razouqi *et al.* (2013)]. Higher values of NRL provide better and improved performances however, higher values of normalized routing load leads to lesser efficiency in terms of consumption of bandwidth.

4.11 Experimental Setup

Behaviour and performance testing of standard AODV, DSDV and OLSR were studied and experimented by the help of Network Simulator (NS3) version 3.13 installed in a 64 bit high end machine over Cent OS Linux platform. As discussed in the earlier chapters, NS3 is an open source discrete-event network simulator [IR 15]. NS3 is developed by the help of high level programming language that is, C++ with some optional bindings with the python. It has enhanced simulation reliability. In order to replace Application Program Interfaces (APIs) of NS2, the NS3 was built from the scratch [Rakesh Kumar Jha *et al.* (2015)]. MANET routing compare script was configured for different values of node velocity and transmission power for each routing models. Other general network parameters were kept same as in earlier studies of node density and pause time effects.

4.12 Results of Experiments

Simulation based experiments on standard AODV, DSDV and OLSR routing protocols were carried out by keeping 10 numbers of source/sink connections fixed and considering different values of node moving speed and node transmission power. Different values of node velocity and node transmit power considered for these experiments were; 10 m/s, 20 m/s, 30 m/s and 3.5dBm, 4.5dBm, 5.5dBm, 6.5dBm, 7.5 dBm, 8.5dBm, 9.5dBm respectively. Simulation scenarios, obtained results and performance comparisons of routing protocols are shown in two cases; (1) Results of varied node velocity and (2) Results of varied transmit power, in the following tables and graphs.

(1) Analysis of Node Velocity Effects

A typical MANET consisting of 50 numbers of nodes was created to study behavior and performances of the standard AODV, DSDV and OLSR routing models for different node velocities. General network parameters set for this analysis were shown in Table - 4.3. Network nodes were placed in a 300 x 1500 m rectangular region without pause or halt time. Wi-Fi mode was set to ad-hoc mode with a rate of 2Mbps (Megabits per second). Source/sink pairs were set to 10 numbers with a transmit power of 7.5dBm. These tests were conducted for three different node velocities; 10 m/s, 20 m/s and 30 m/s.

Table - 4.3: General Network Parameters (Case 1)

1	Number of Nodes	50
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	7.5dBm
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	First case : 10 m/s Second case : 20 m/s Third case : 30 m/s
12	Protocols used	1. AODV 2. DSDV 3. OLSR (For all the cases)
13	Region	300x1500 m
14	Loss Model	Friis loss model

(i) Throughput

As per results obtained and throughput calculations, throughput of the OLSR routing protocol was found better as compare to DSDV and AODV routing protocols. Throughput result sheet of all the three routing protocols is shown in Table - 4.4.

Table - 4.4: Throughput results of AODV, DSDV and OLSR (Case 1)

Node Speed in m/s	Throughput in Kbps		
	AODV	DSDV	OLSR
10	13.42	13.59	18.59
20	14.46	12.64	17.98
30	15.15	14.97	17.86

When throughput results of AODV and DSDV were compared, throughput of the DSDV protocol was found better for node speed 10 m/s. For node speeds; 20 m/s and 30 m/s, throughput of the AODV protocol was found better. Fig.4.11 reveals performance graphs of the routing protocols for different node velocities.

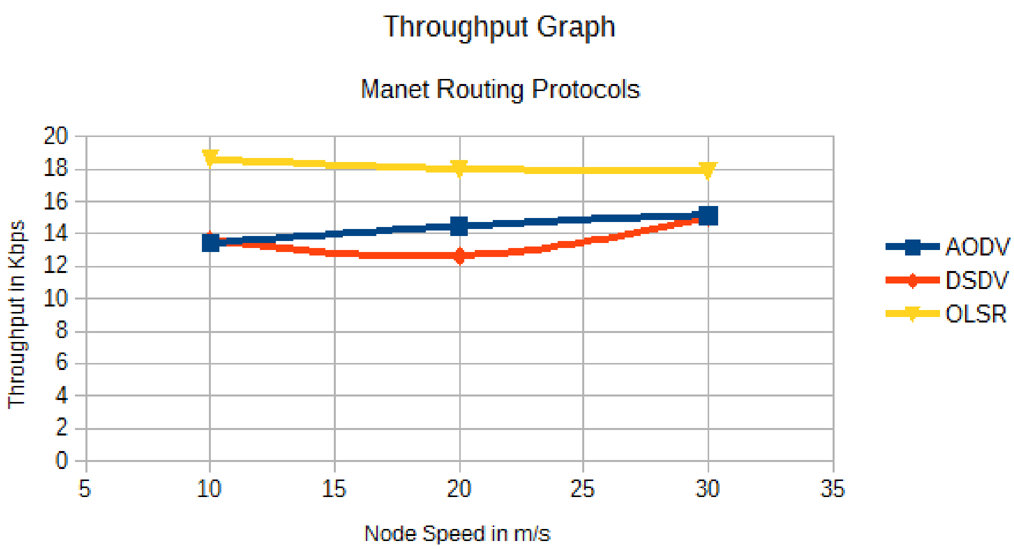

Fig.4.11. Throughput over increasing node speed (Case 1)

(ii) Packet Delivery Ratio (PDR)

Results of packet delivery ratio indicate better performance of the OLSR routing protocol. As compared to AODV and DSDV, the OLSR protocol has shown better performances for different node velocities. Table - 4.5 explores the experimental results of AODV, DSDV and OLSR.

Table - 4.5: Packet delivery ratio results of AODV, DSDV and OLSR (Case 1)

Node Speed in m/s	Packet delivery ratio in %		
	AODV	DSDV	OLSR
10	67.11	67.96	92.98
20	72.33	63.21	89.93
30	75.76	74.85	89.31

For 10 m/s, PDR results of DSDV were better, whereas AODV was better performing for the node velocities; 20 m/s and 30 m/s. Fig.4.12 shows the packet delivery ratio graphs of all the three routing protocols for different node velocities.

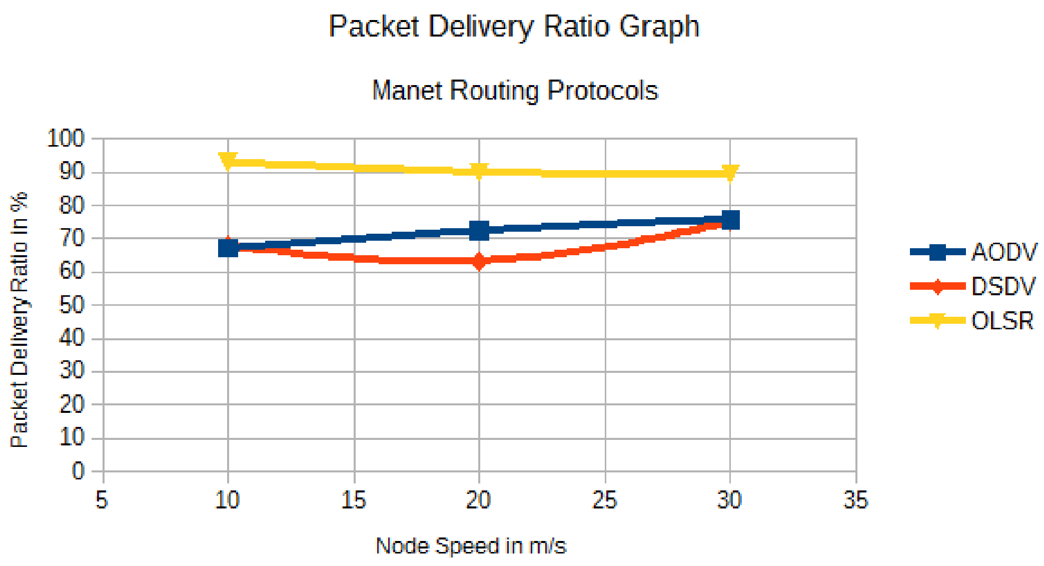

Fig.4.12. PDR over increasing node speed (Case 1)

(iii) End to End Delay (EED)

Data sheet shown in Table - 4.6 represents end to end delay scenarios in all the three routing protocols for different speeds of node mobility. Like in previous metrics, OLSR has better results of EED gaining lesser values. The OLSR protocol has least effects of delay as compared to AODV and DSDV routing protocols.

Table - 4.6: End to end delay results of AODV, DSDV and OLSR (Case 1)

Node Speed in m/s	End to end delay in ms		
	AODV	DSDV	OLSR
10	0.0122	0.0117	0.0018
20	0.0095	0.0145	0.0027
30	0.0079	0.0084	0.0029

When network nodes were at the speed of 10 m/s, the DSDV protocol has least delays however, for node speeds; 20 m/s and 30 m/s, AODV protocol has minimum delays as compare to DSDV routing protocol. Fig.4.13 displays the EED performances of the AODV, DSDV and OLSR protocols for the node speed variation in between 10 m/s and 30 m/s.

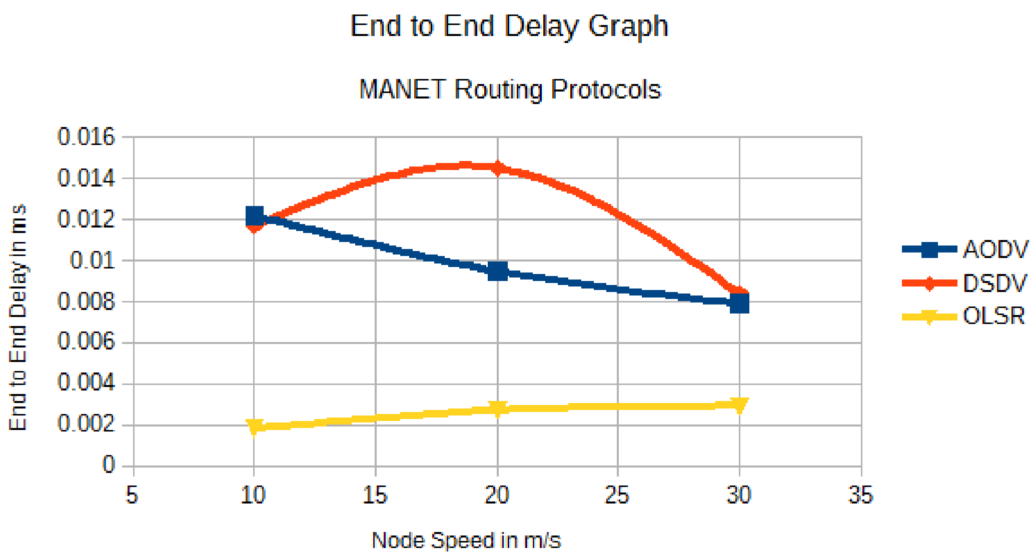

Fig.4.13. End to end delay over increasing node speed (Case 1)

(iv) Packet Loss (PL)

Results of packet losses in AODV, DSDV and OLSR protocols shows better performances of the OLSR routing protocol; it has least loss of 421 numbers of packets. AODV protocol has gone through an extreme loss of 1973 numbers of packets when node velocity was at 10 m/s.

Table - 4.7: Packet loss results of AODV, DSDV and OLSR (Case 1)

Node Speed in m/s	Packet loss in no. of packets		
	AODV	DSDV	OLSR
10	1973	1922	421
20	1660	2207	604
30	1454	1509	641

Table - 4.7 shows packet losses encountered in AODV, DSDV and OLSR routing protocols. The DSDV routing protocol has lost 1922 numbers of packets during node speed 10 m/s, whereas, AODV protocol has faced 1973 numbers of data packet losses for node speed 10 m/s. When node speed was at 20 m/s and 30 m/s, AODV protocol has minimum number of packet losses as compare to DSDV. Fig.4.14 presents packet losses scenarios in routing protocols at different node velocities.

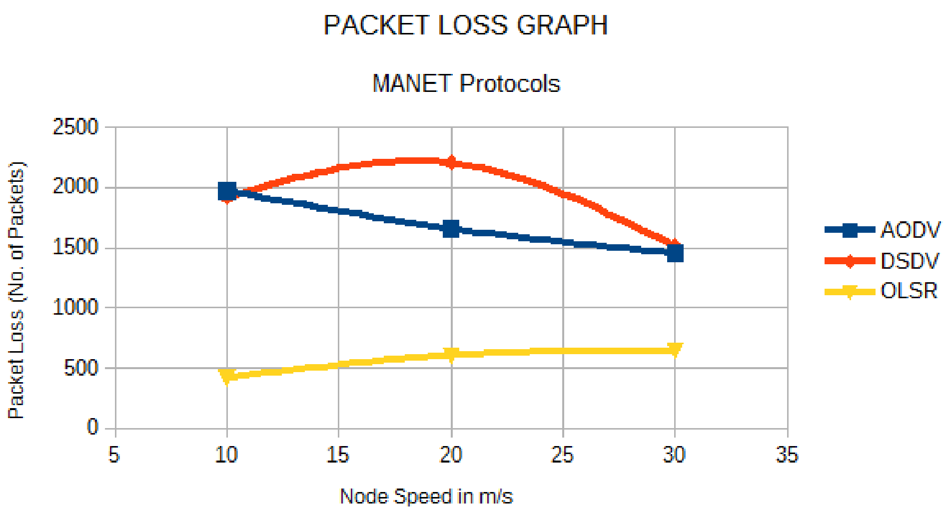

Fig.4.14. Packet loss over increasing node speed (Case 1)

(v) Normalized Routing Load (NRL)

Results of regulated load on routing protocols present better results of the OLSR routing as compared to AODV and DSDV protocols. However, minimum values of regulated routing load may consume more bandwidth but still, usage of OLSR is better in terms of performance. Table - 4.8 explores NRL values of AODV, DSDV and the OLSR.

Table - 4.8. NRL results of AODV, DSDV and OLSR (Case 1)

Node Speed in m/s	Packet loss in no. of packets		
	AODV	DSDV	OLSR
10	0.671	0.679	0.929
20	0.723	0.632	0.899
30	0.757	0.748	0.893

Fig.4.15 presents the regulated routing load results of all the three routing protocols. Where, the OLSR protocol has minimum values of NRL for node speeds; 10 m/s, 20 m/s and 30 m/s. DSDV protocol has shown better NRL results when nodes were at the speed of 10 m/s. The AODV protocol has better NRL results at node speeds; 20 m/s and 30 m/s.

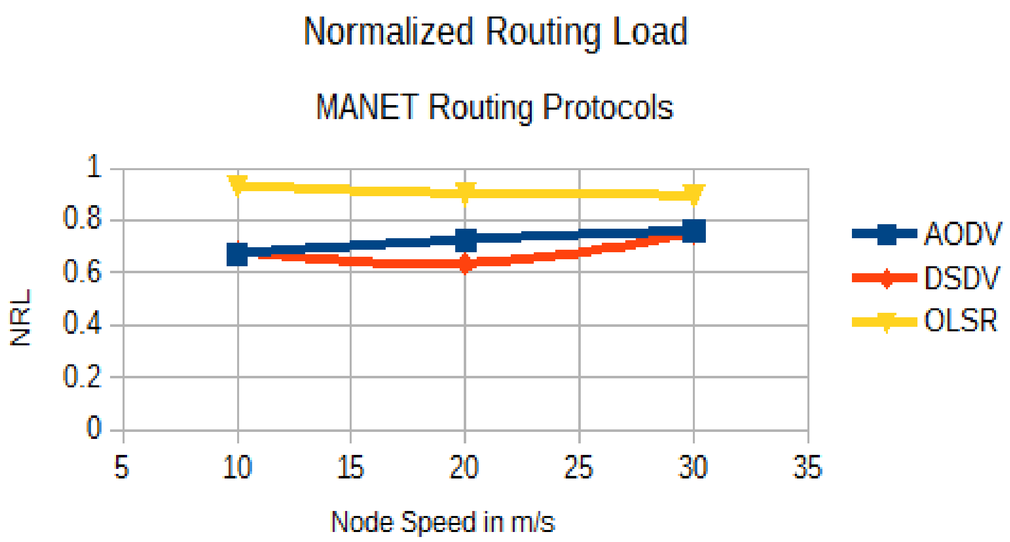

Fig.4.15. NRL over increasing node speed (Case 1)

(2) Analysis of Transmit Power Effects

This section presents results of the AODV, DSDV and OLSR routing protocols for diverse node transmission power values. Here, transmit power of nodes was set to different values; 3.5dBm, 4.5dBm, 5.5dBm, 6.5dBm, 7.5dBm, 8.5dBm and 9.5dBm in order to study performances and behavior of the routing protocols. Different performance metrics such as; throughput, packet delivery ratio, end to end delay, packet loss and regulated routing load were used to analyze the performances of the standard AODV, DSDV and OLSR routing protocols. Simulation region was set to 300 x 1500 meters keeping 50 numbers of network nodes with random waypoint mobility and friss loss models. Details of the general network parameters chosen for this analysis are shown in Table - 4.9.

Table - 4.9: Simulation Scenario of AODV, DSDV and OLSR (Case 2)

1	Number of Nodes	50
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	3.5dBm, 4.5dBm, 5.5dBm, 6.5dBm, 7.5dBm, 8.5dBm and 9.5dBm.
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

Throughput is an important factor for analyzing performances of the MANET routing protocols. For different values of node transmit power, the OLSR routing model has gained better throughput as compared to AODV and DSDV protocols. Table - 4.10 explores throughput results of the routing protocols.

Table - 4.10: Throughput (Case 2)

Transmit power in dBm	Throughput in Kbps		
	AODV	**DSDV**	**OLSR**
3.5	11.22	10.81	13.30
4.5	13.60	12.29	15.18
5.5	10.61	12.61	16.07
6.5	15.25	11.38	17.22
7.5	14.46	12.64	17.98
8.5	17.71	14.45	18.16
9.5	3.74	16.80	19.18

When comparing throughputs of AODV and DSDV protocols, throughput of the DSDV was better for transmit power values; 5.5dBm and 9.5dBm. For the rest transmit power values, AODV routing protocol has achieved better throughput. Fig.4.16 presents throughputs of all the three routing protocols.

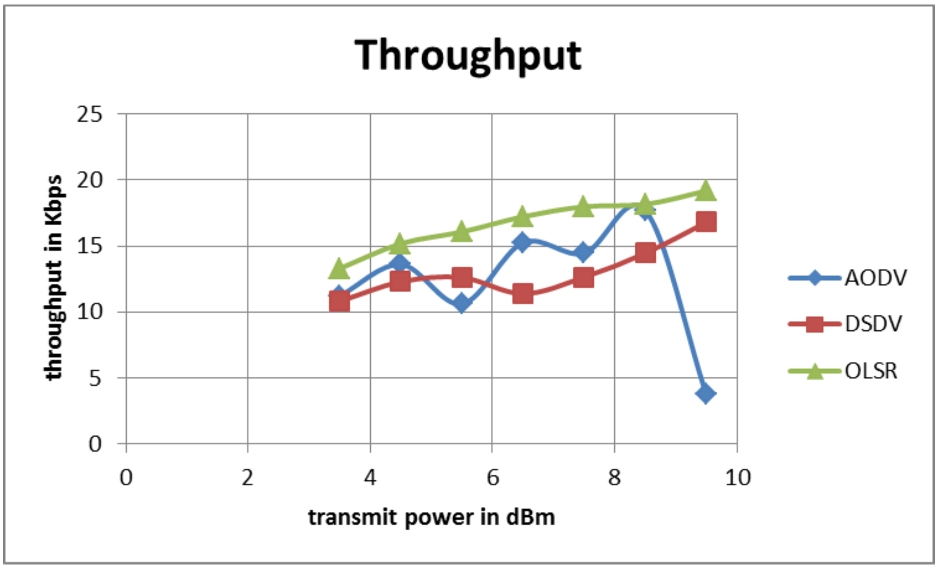

Fig.4.16. Throughput over transmit power (Case 2)

(vii) Packet Delivery Ratio

As compared to results of AODV and DSDV protocols, the OLSR routing protocol has shown better performance results in delivering data packets. The OLSR protocol has achieved maximum packet delivery of 95.90 % of the sent data packets. Table - 4.11 shows the packet delivery scenarios in AODV, DSDV and OLSR protocols.

Table - 4.11: Packet Delivery Ratio (Case 2)

Transmit power in dBm	Packet delivery ratio in %		
	AODV	DSDV	OLSR
3.5	56.11	54.08	66.53
4.5	68.03	61.46	75.90
5.5	53.05	63.08	80.38
6.5	76.26	56.93	86.13
7.5	72.33	63.21	89.93
8.5	88.58	72.28	90.81
9.5	18.71	84.01	95.90

Fig.4.17 explores the performances of all the three routing protocols. As compared to DSDV, the AODV protocol has achieved better packet delivery for transmit power values; 3.5dBm, 4.5dBm, 6.5dBm, 7.5dBm and 8.5dBm. The AODV protocol has achieved maximum delivery of 88.58 % data packets, whereas, DSDV protocol has achieved maximum of 84.01 %. DSDV has shown better results for transmit power values; 5.5dBm and 9.5dBm.

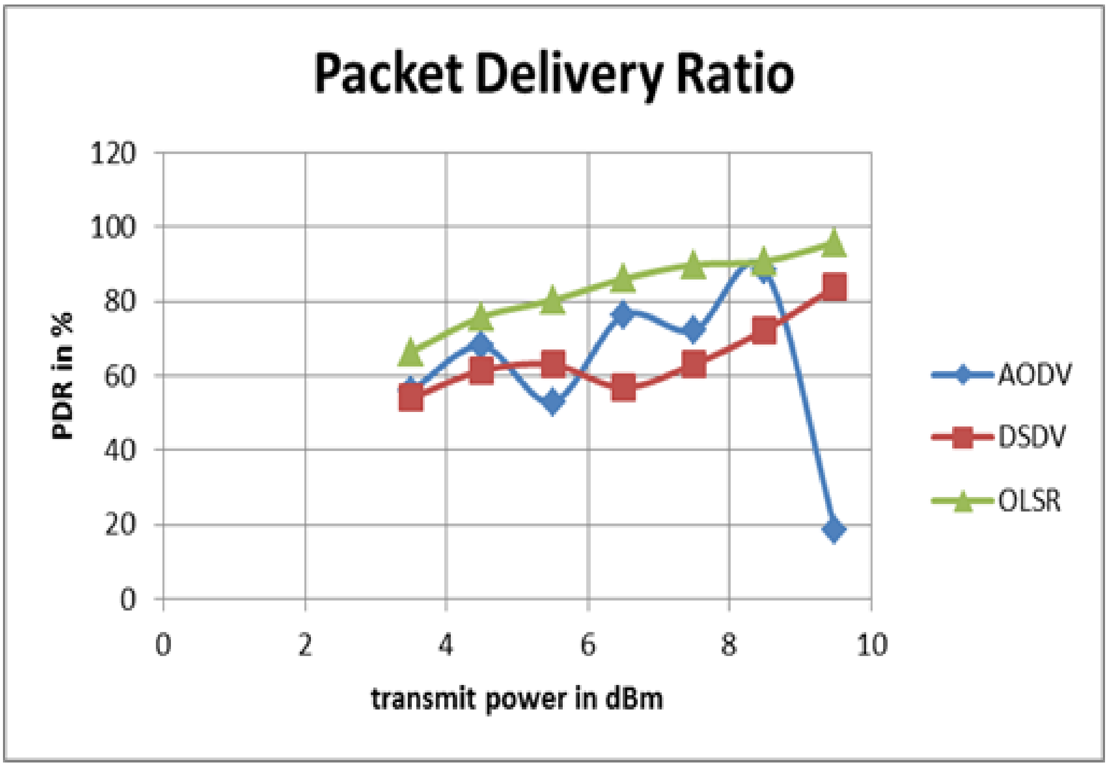

Fig.4.17. PDR over transmit power (Case 2)

(viii) End to End Delay

Reduced delay values helps in achieving delivery of data packets in the specified time interval.

According to results shown in Table - 4.12, the OLSR protocol has encountered minimum end to end delays as compared to AODV and DSDV protocols. The OLSR protocol has achieved better data delivery with minimum delays.

Table - 4.12: End to End Delay (Case 2)

Transmit power in dBm	End to end delay in ms		
	AODV	**DSDV**	**OLSR**
3.5	19.55	21.22	12.57
4.5	11.74	15.67	7.93
5.5	22.12	14.63	6.10
6.5	7.77	18.91	4.02
7.5	9.56	14.54	2.79
8.5	3.22	9.58	2.52
9.5	108.57	4.75	1.06

As compared to DSDV, AODV has minimum delays for transmit power values; 3.5dBm, 4.5dBm, 6.5dBm, 7.5dBm, 8.5dBm. For the rest values of transmit power, DSDV has shown better results. Fig.4.18 shows delay performances of the routing protocols discussed.

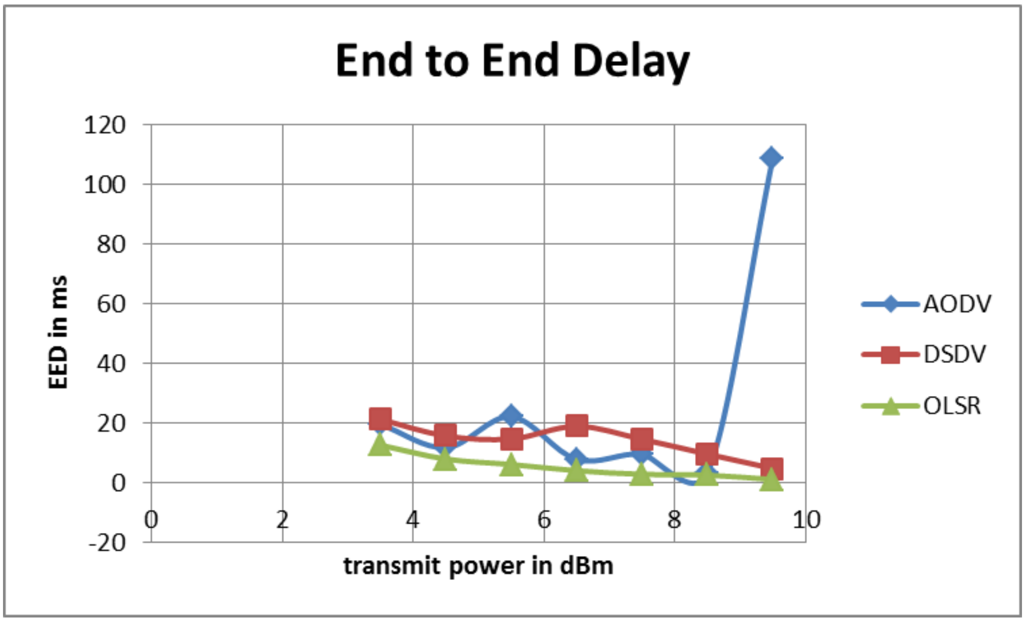

Fig.4.18. End to end delay over transmit power (Case 2)

(ix) Packet Loss

During transmission process, data packets encounter losses due to radio fatalities. Results of packet losses encountered in AODV, DSDV and OLSR routing protocols concludes better performance of the OLSR routing protocol. As compare to results of AODV and DSDV, the OLSR protocol has minimum packet losses gaining minimum loss of 246 packets. Table - 4.13 shows packet loss scenarios in the routing protocols.

Table - 4.13: Packet Loss (Case 2)

Transmit power in dBm	Packet loss in No. of packets		
	AODV	DSDV	OLSR
3.5	2633	2755	2008
4.5	1918	2312	1446
5.5	2817	2215	1177
6.5	1424	2584	832
7.5	1660	2207	604
8.5	685	1663	551
9.5	4877	959	246

When comparing results of AODV and DSDV, AODV has minimum packet losses for the transmit powers; 3.5dBm, 4.5dBm, 6.5dBm, 7.5dBm and 8.5dBm, it has minimum packet losses of 685 number of packets for 8.5dBm. DSDV has shown better results for 5.5dBm and 9.5dBm. Fig.4.19 explores these performances.

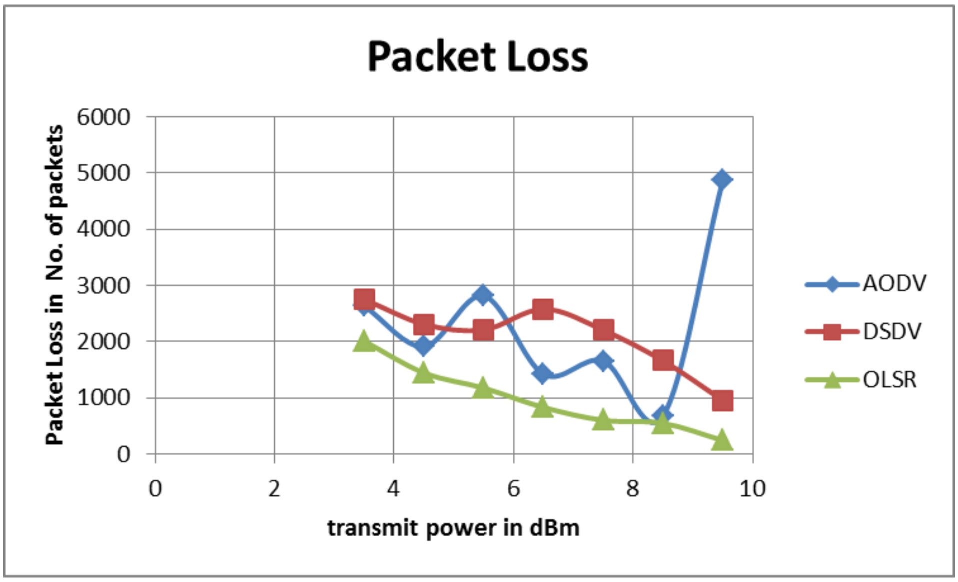

Fig.4.19. Packet loss over transmit power (Case 2)

(x) Normalized Routing Load

Higher values of regulated routing load declare better performances of the routing protocols in mobile ad-hoc networks. However, higher values may results in consuming more bandwidth. Analysis of NRL declares better performance of the OLSR as compare to AODV and DSDV routing protocols. Table - 4.14 shows the result sheet of NRL values.

Table - 4.14: Normalized Routing Load (Case 2)

Transmit power in dBm	NRL		
	AODV	DSDV	OLSR
3.5	0.561	0.541	0.665
4.5	0.680	0.615	0.759
5.5	0.531	0.631	0.804
6.5	0.763	0.569	0.861
7.5	0.723	0.632	0.899
8.5	0.886	0.723	0.908
9.5	0.187	0.840	0.959

Comparison of the results of AODV and DSDV concludes that; in some cases, AODV was found to be the better performer, in other cases, DSDV has better results for varied values of transmit power. Fig.4.20 demonstrates NRL values achieved by the AODV, DSDV and OLSR.

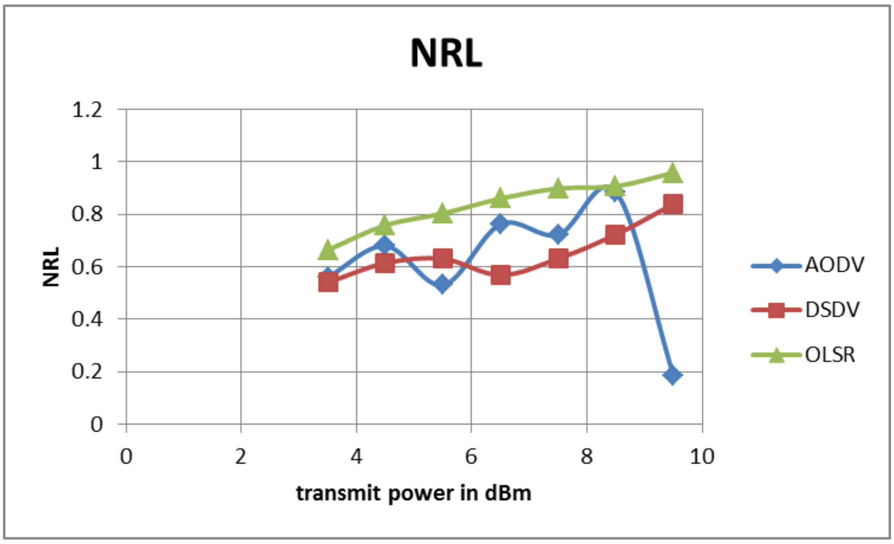

Fig.4.20. NRL over transmit power (Case 2)

4.13 Conclusion

In this chapter, different Node velocity and Transmit Power Effects on standard mobile ad-hoc network routing protocols (AODV, DSDV and OLSR) were studied and analysed. In first case, analysis of varied node velocity effects were taken into account and in second case, analysis of varied transmit powers were considered. Analysis of varied node velocity effects concludes that the performance of the OLSR routing protocol was better as compare to AODV and DSDV in terms of all the performance metrics used (throughput, packet delivery ratio, end to end delay, packet loss and normalized routing load).

Comparison of AODV and DSDV routing protocols concludes that; in some cases, performances of the AODV routing protocol was better and in some other cases, performances of the DSDV routing protocol were good for different values of node velocity. Analysis of varied transmit power effects concludes that the performance of the OLSR routing protocol was better as compare to AODV and DSDV protocols in terms of all the performance metrics discussed above. Comparison of AODV and DSDV protocols concludes that; in some cases, performances of the AODV routing protocol was better and in some other cases, performances of the DSDV routing protocol were better for different values of transmit power.

Finally, it is concluded that; analysis of node velocity and transmit power effects on AODV, DSDV and OLSR routing protocols has settled better performance of the OLSR routing protocol. As compared to AODV and DSDV routing protocols, the OLSR routing protocol has shown better performances in all the performance evaluating metrics. In chapter 5, analysis of performance enhancing parameters in AODV, DSDV and OLSR routing protocols have been discussed in detail.