Chapter 4

Routing Protocols under different Mobility Models, Node Density and Speed

4.1 Introduction

In this chapter, the factors taken into account are routing protocols, mobility models, speed of node and density of node. The performance metrics includes throughput, end to end delay and packet loss. The protocols simulated are DSR [70], LAR [73], OLSR [65] and ZRP [72], choosing one from each group discussed above. The available comparative studies use random waypoint model, where no prior information is available for the movement of nodes [5, 6, 7, 8, 9, 10]. We have considered random waypoint model, along with other models, which are suitable for specific scenarios e.g. Random Way Point, Gauss Markov, Reference Point Group Mobility and Manhattan Grid model. Studies are carried out in GloMoSim simulator which provides a scalable simulation environment for wireless networks. From the results it is evident that with the change in mobility pattern, speed and density of the nodes the performance varies.

Organization of the rest of chapter is as follows. In section 4.2, state of the art is discussed followed by a description of the simulation setup in section 4.3. Results are given in section 4.4. Chapter is concluded in section 4.5.

4.2 State of the Art

Looking at the available literature, it is found that there are many studies done on MANET earlier. Some of them are very detailed while others are more technical. In late 90's researchers started working on MANETs, as these networks were thought of getting more useful in the future.

A very initial study was done by Das et al. [5] in 1998. They routing protocols were evaluated at packet level. The simulator used for this purpose was MaRS (Maryland Packet Simulator). They compared AODV, DSR, TORA, DSDV, EXBF and SPF. The observation was that although the routing load was lowered in new protocols, the link state and distance vector protocols gave better performance in terms of packet delivery and end to end delay. The work was extended for more cases [6] of node speed and density in 2000 with same set of protocols.

The same year authors [7] compared AODV, DSDV, DSR and TORA routing protocols on NS2 (Network Simulator 2). Random Way Point mobility model (RWP) was used for movement of nodes. For the above mentioned algorithms, the authors evaluated packet delivery ratio, routing overhead and path optimality. The node density was fixed at 50.

An important work was done by X Hong et al. [8] in 1999. They presented a survey of mobility models in cellular and multi-hop networks. They showed that group motion occurs frequently in ad-hoc environments, and based on this designed a group mobility model called RPGM (Reference Point Group Mobility model). They also showed that by changing the value of parameters in RPGM, many other mobility models can be modelled. They applied this mobility model to study the behavior on clustering and routing. The simulator used was parallel simulation language Maisie. The node density was fixed at 100 and protocols compared were DSDV, AODV and HSR. For the first time they showed that performance of routing protocol depends on the choice of mobility model.

In 2000, Lee et al. [9] compared the performance of multicast protocols in ad-hoc environment. The protocols comprised of AMROUTE, FLOODING, ODMRP, CAMP and AMRIS. The metrics obtained were packet delivery ratio, number of data packets transmitted per data packet delivered, number of control bytes transmitted per data bytes delivered and number of control and data packets transmitted per data packet delivered. The number of multicast nodes was 20 with speed from 0 kmph to 72 kmph. The simulator chosen was GloMoSim. Authors concluded that mesh based protocols outperforms tree based protocols.

Authors in [10] proposed two multi path techniques for DSR protocol. It utilizes disjoint paths. For simulation MARS simulator was used and node density was fixed at 60. The mobility model was designed based on some pre-defined distribution. Performance metrics for simulation included fractions of packets dropped, end to end delay, number of route discoveries and routing load. The authors concluded that multipath routing is better than single path routing and if all the intermediate nodes are provided shortest paths, then the performance is slightly better than providing only source with alternate paths.

In 2002, a comparative study of CBR and TCP performance on OLSR and AODV protocols was done by T. Clausen et al. [11]. The variation was done for traffic, density and mobility. The common used traffic type for MANET is CBR, but the internet uses TCP. For a heterogeneous environment consisting of both, what will be the effect of TCP and CBR? Which will be preferred? The number of nodes was fixed at 50, and random waypoint mobility model was used. The simulator used was NS2. The metrics studied were control traffic overhead, delivery ratio, path length, delay, total transfer time and normalized routing load. The conclusion from the paper was, the protocols may perform comparatively when exposed to CBR, but when the same scenario is exposed to TCP, it significantly affects performance.

Barrett et al. [12] conducted a comparative analysis of IEEE 802.11, CSMA and MACA media access protocols. They considered only static ad-hoc networks. The GloMoSim simulator was used to obtain number of received packets, average latency of each packet, long term fairness and throughput. They concluded that typically, all protocols degrade significantly at higher packet injection rate. Also, it happens rather sharply.

To analyze the impact of mobility on performance of routing protocols for ad-hoc networks, a framework named IMPORTANT was proposed by F. Bai et al. [8]. The mobility models used were RWP, RPGM, Freeway mobility and Manhattan mobility model. The density of nodes was fixed at 40. NS 2 was used for simulation. The routing protocols considered were DSR, AODV and DSDV. The authors showed that performance of protocol shows drastic variations across mobility models. So the performance rankings of protocols will change with a change in mobility model.

An energy based performance comparison of AODV, DSR, TORA and DSDV was done by B. Chen et al. [13]. The mobility models employed were Random Waypoint, RPGM and Manhattan grid model. The simulator used was NS 2 and node density was fixed at 50. The authors concluded that reactive protocols are more sensitive to speed than proactive protocols. It is more challenging to route packets over Manhattan grid model over the others. For group movement reactive protocols are better than proactive protocols.

T. Kunz [14] provided an in depth study of one to one and many to many communication in MANET. The protocols studied were unicast routing protocol (DSR and AODV), Multicast routing protocol (ADMR, ODMRP and Extension of AODV) and Broadcast protocols (FLOOD and BCAST). Simulations were conducted on NS2 and number of nodes was fixed at 50. The performance metrics included packet delivery ratio and latency. The authors concluded that broadcast protocols, in particular BCAST perform well and that too without a high overhead.

A multilayer analysis of the influence of mobility models on AODV protocol was done by Gomez et al. [15]. The traffic flow was considered to be TCP. The performance analysis was done at three layers viz. physical layer, network layer and transport layer. The mobility models considered were RWP, Gauss Markov model, Manhattan Grid and RPGM model. The simulator used was NS2 and density of nodes was fixed at 20. The authors concluded that higher speeds does not necessarily means lower throughput.

To implement the ant mobility model which is based on the actual movement of a group of ants, simulations were conducted by Liao et al. [16].The effect of this mobility model on DSDV, DSR and AODV is examined. For the worthiness of the model ant mobility is compared to random waypoint model for same set of protocols. The simulator used is NS2. The number of nodes for the simulation is 50. The metrics evaluated were packet throughput ratio, average end to end delay and normalized routing load. The authors concluded that trace models like ant mobility are more accurate than synthetic models like random waypoint mobility. But this accuracy comes at a cost of difficult and time consuming process.

Atsan et al. [17] classified and compared the performance of mobility model for MANET protocols. The protocol studied was AODV and simulator chosen was SWANS. Four mobility models were considered viz. random direction, boundless simulation area model, random walk and random waypoint model. The metrics considered were average message activity, average route request completion rate and average RREQ message sent per route added. The density of node was fixed at 50. Authors concluded that although RAP does not give the best performance for all the used performance metrics, it is most consistent for varying simulation levels.

A realistic simulation based study of MANET protocols was made by Marinoni et al. [18]. They proposed a new and realistic Urban Mobility Model (UMM), which models realistic user motion and signal propagation in a city like scenario. The mobility models namely RWP, UMMoff (UMM with radio constraints activated) and UMMon (UMM with radio constraints deactivated) were applied on DSR protocol. The number of sender/receiver was 20 pairs for all experiments. NS2 was used for simulation. The metrics calculated were packet delivery ratio, end to end delay, path length and routing overhead. The authors concluded that trivial RWP is too simplistic and too narrow in its scope. Hence a realistic model like UMM can be a better choice.

Pirzada et al. [19] compared performance of multi-path AODV and DSR protocols in hybrid mesh networks.NS2 was the preferred simulator. The number of mesh clients was fixed at 50 and number of mesh routers was fixed at 16. Random waypoint model was considered for mobility. Packet loss, aggregate good put, packet delivery percentage, routing packet overhead, average latency and path optimality were the metrics calculated. The authors concluded that mesh networks with inclusion of mesh router gives better performance.

G. Jayakumar et al. [20, 21] compared performance of DSR and AODV for random waypoint and Manhattan grid model. The node density was fixed at 20 nodes. The performance metrics included packet delivery fraction, average end to end delay, normalized routing load and normalized mac load. The simulator used was NS2. The authors observed a very clear trend between mobility metric, connectivity and performance.

In 2009 Karthikeyan et al. [22] studied the performance of broadcasting methods in MANET. The techniques employed for broadcasting was simple flooding and probability based flooding. The simulations were performed on NS2. The number of mobile nodes was fixed at 24. The performance metric included normalized routing load for DSDV protocol. The authors concluded that probabilistic broadcast performs better than simple flooding.

A comparative performance analysis of DSDV, AODV and DSR routing protocols was done by Tuteja et al. [23]. For simulation, NS2 was used. The metrics included packet delivery ratio, throughput, end to end delay and routing overhead. 25 nodes were considered for simulation. Random waypoint model was used to define movements of node. The authors concluded that with the increase in mobility of nodes performance degrades irrespective of the choice of three discussed protocols.

Unicast and broadcast routing protocols of MANET were evaluated by Debnath et al. [24]. Both one to one and many to many communications were addressed in detail. DSR and BCAST protocol were simulated on NS2. The number of nodes was fixed at 50. Mobility model used was random waypoint mobility model. The performance metrics included packet delivery ratio, packet latency, normalized routing load, normalized mac load and throughput. The authors concluded that BCAST protocol works well in most scenarios and is robust even with high traffic environments.

Barakovic et al. [25] compared the performance of MANET routing protocols AODV, DSR and DSDV. Simulations were carried on NS2. Packet delivery ratio, average end to end delay and normalized routing load were the performance metrics. The numbers of source nodes varied from 10 to 30. The mobility of nodes was defined by random waypoint model. The conclusion form the study was that all the protocols reacted in similar ways for low mobility and low load conditions, while DSR outperformed AODV and DSDV with increasing mobility and load.

In 2011, Mohapatra et al. [26] studied the effect of change in network size, mobility and pause time on AODV, OLSR and DSDV. The number of nodes was fixed at 30. The choice of simulator was NS2 and that of mobility model was random waypoint model. Throughput, Routing overhead, delay and packet delivery ratio were calculated for varying number of nodes, varying pause time and varying network area. The authors concluded that for highly mobile random network OLSR is preferred.

Performance comparison of relatively newer set of protocols viz. LANMAR, LAR1, DYMO and ZRP was done by Singh et al. [27]. Qualnet simulator was chosen for the experiments. 50 nodes were considered for the scenario. Random waypoint model was used to define the mobility pattern of nodes. The performance metrics were average end to end delay, packet delivery ratio, throughput and average jitter. The authors concluded that LANMAR is the best scheme in terms of end to end delay and jitter while LAR1 is best in terms of packet delivery ratio and throughput.

A comparative study was done by Saada et al. [28] to evaluate the performance of protocols. GloMoSim simulator was used for experiments. To compare the performance DSDV, AODV, ARPM and SHARP protocols were considered. The number of nodes was different for different scenarios. For static scenario, it was fixed at 70 while for dynamic scenario it varied from 10 to 140. Random waypoint model was the mobility model and the metrics included overhead, route discovery delay and throughput. The conclusion derived from the work was that DSDV is better for small networks and AODV is better for large networks.

From the above given analysis, we conclude that although a lot of comparative studies have been carried out on MANET routing protocols based on one or more mobility models, most of them have relied on Random waypoint model, which due to its probabilistic nature is unrealistic. Most of the work has been done considering either variation in node density or node speed along with mobility models. We have considered variation in speed and density of nodes together as a parameter to study the effects on a wider perspective. Also for the choice of mobility models we have considered RWP, MG, GM and RPGM. We have taken a candidate protocol from each group of protocols viz. reactive, proactive, location based and geographic.

4.3 Simulation Setup

To study the performance of routing protocols we evaluated throughput, end to end delay and ratio of packet loss. The metrics are described as follows.

Throughput: It is the ratio of number of packets received at destination to the number of packets originated at source. The source follows CBR (Constant bit rate) traffic. It depicts the loss rate.

Throughput = Data packets received / Data packets sent

End to end delay: It is the average amount of time that is taken by a packet to reach final destination from source. It includes the route discovery wait time, which a node may experience in case a route is not available.

Average delay = $\frac{tr - ts}{Pr}$, where ts is the packet send time, tr is the packet receive time and Pr is the total number of packets received.

Packet loss: It is the fraction of packet lost on their route to destination. The loss is usually due to congestion on the network and buffer overflows.

Packet loss = Number of lost packets / number of received packets

To generate mobility patterns for MG, RWP, GM and RPGM Bonn Motion tool is used. We have studied the impact of speed and node density on performance of the network. To compare the protocols, same set of scenarios is utilized for each one. The simulator used is GloMoSim [83]. The simulation parameters are given below in table 4.1.

Parameter Name	Value
Speed of node	0 to 20 m/s
Density of node	5 to 200
Number of CBR sources	10
Speed of CBR link	10 packets per second
Packet Size	512 bytes
Wireless Radio	802.11
Transmission Range	50 m
Transmission rate	1 Mbps
Area of simulation	1500m x 1500m
Simulation time	300 seconds

Table 4.1 Simulation setup

The parameters chosen for mobility models namely Random waypoint, gauss Markov, Manhattan Grid and Reference point group mobility model are listed in table 4.2.

Model	Parameter	Value(s)
RWP (Random Way Point)	Pause time	0 sec
	Min. speed	0 m/s
	Max. Speed	20 m/s
MG (Manhattan Grid)	No. of blocks along y-axis	2

	No. of blocks along x-axis	10
	Min. Speed	0 m/s
	Max. Speed	20 m/s
	Probability of going straight	0.5
	Probability of going right	0.25
	Probability of going left	0.25
RPGM (Reference Point Group Mobility)	Average no. of nodes per group	5
	Max. distance to center of group	5 m
	Min. Speed	0 m/s
	Max. Speed	20 m/s
GM (Gauss Markov)	Min. Speed	0 m/s
	Max. Speed	20 m/s

Table 4.2: Parameters for mobility models

4.4 Results and Discussion

4.4.1 Throughput

LAR, OLSR, DSR and ZRP were tested under RWP, MG, RPGM and GM models. We varied the speed of the nodes from 0 to 20 m/s at interval of 5. The node density was varied from 50 to 200 in the intervals of 50. From the results, it is clear that LAR and OLSR outperform others in terms of throughput. The results are given in Fig. 4.1 to 4.4. Throughput metrics is almost equal to 100 % for OLSR and LAR. But, in the case of random waypoint model although OLSR still outperforms others but the throughput is reduced largely. This is due to the fact that in random waypoint model link breakage is more often for higher speeds and hence the throughput decreases for almost all protocols. At higher speeds i.e. 10 to 20 m/s LAR and OLSR are the preferred choice for better throughput. But, at lower speeds the case changes, LAR behaves better than others for RWP and RPGM. Also, the applications which utilize RWP should use LAR for lower speeds. While the applications, which uses other mobility models can either opt for OLSR or LAR for all cases of mobility and speed.

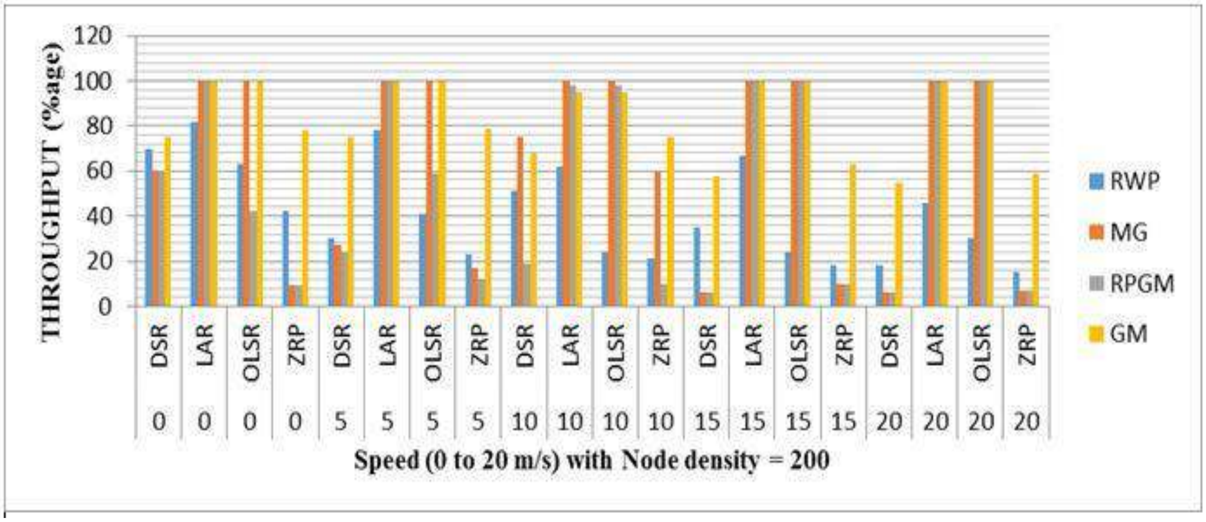

Figure 4.1: Throughput at Node Density 200, with speed varying from 0 to 20 m/s

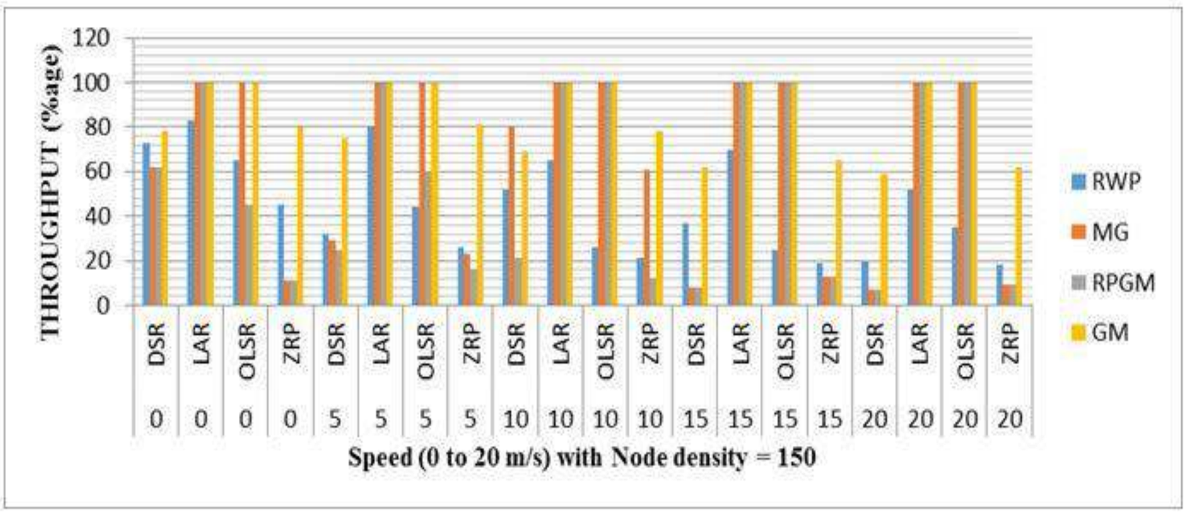

Figure 4.2: Throughput at Node Density 150, with speed varying from 0 to 20 m/s

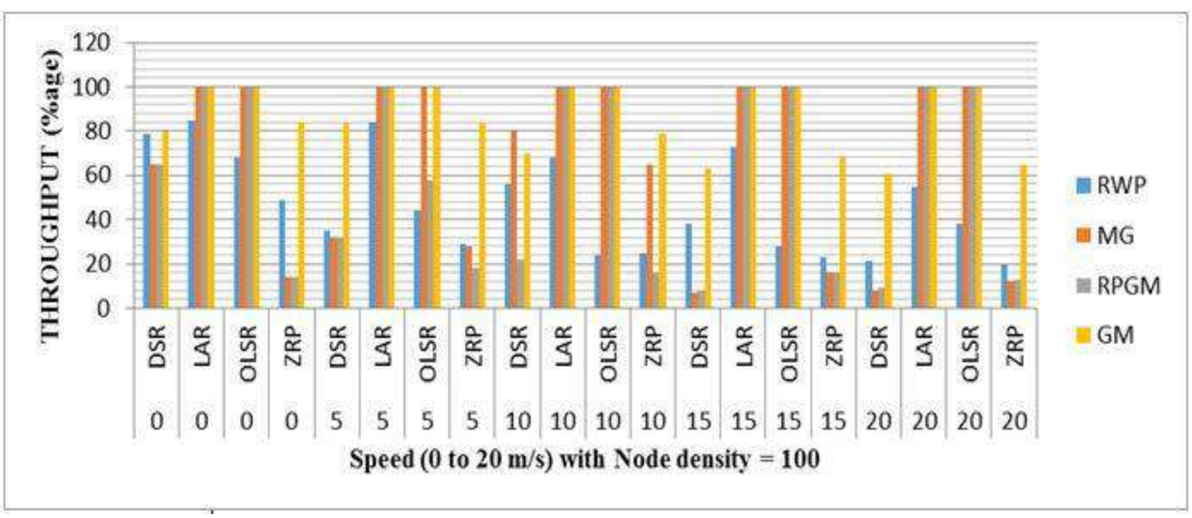

Figure 4.3: Throughput at Node Density 100, with speed varying from 0 to 20 m/s

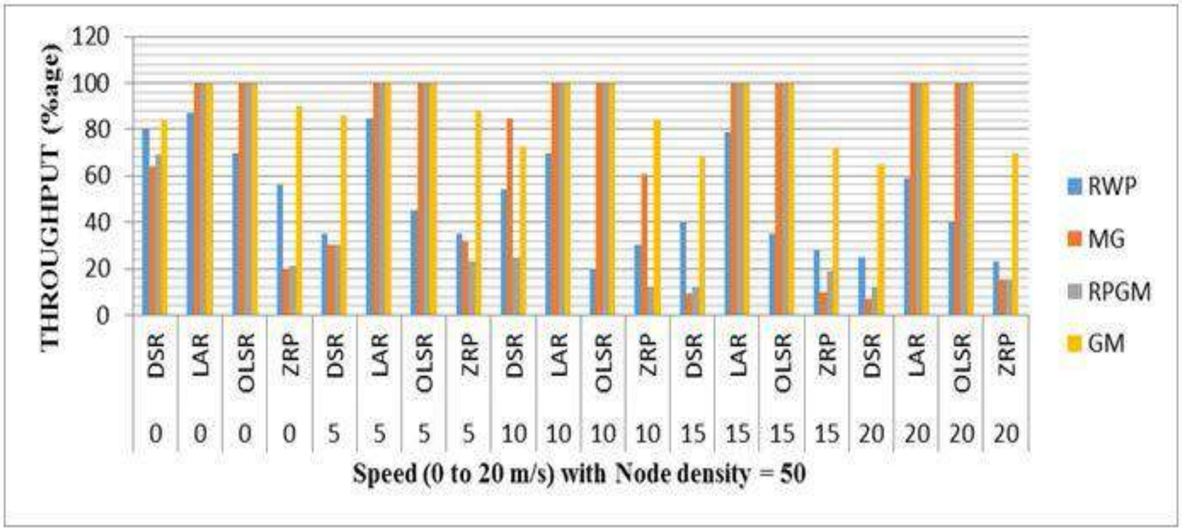

Figure 4.4: Throughput at Node Density 50, with speed varying from 0 to 20 m/s 6.2

4.4.2End to End Delay

The results for end to end delay are shown in Fig. 4.5 to 4.8. The values for delay for some case is very small, and to make that portion visible additional sub graph is given, which highlights the smaller values. These sub graphs are numbered from 4.5a to 4.8a. The speed of the nodes is varied from 0 to 20 m/s in steps of 5 and node density is varied from 50 to 200 in steps of 50. LAR exhibits lowest end to end delay for almost all the cases of speed and node density compared to other protocols. With increase in speed and number of nodes the delay also increases. It happens because at higher speeds, connectivity decreases and hence accounts for higher delays. The applications which require less end to end delay should use LAR, as is clear from the above discussion.

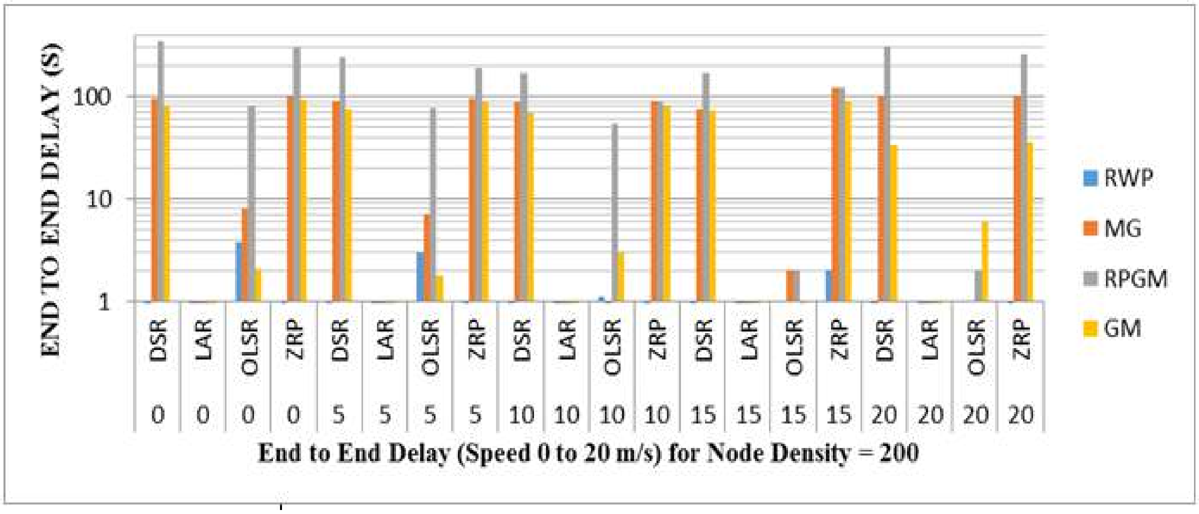

Figure 4.5: End to End Delay at Node Density 200, with speed varying from 0 to 20 m/s

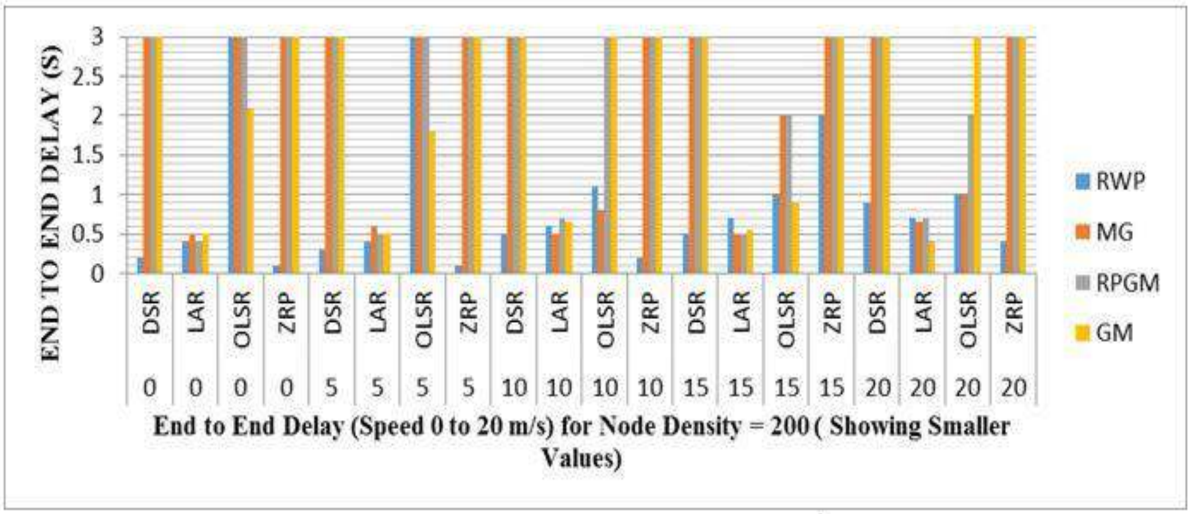

Figure 4.5a: End to End Delay at Node Density 200, speed varying from 0 to 20 m/s (Only smaller values are shown)

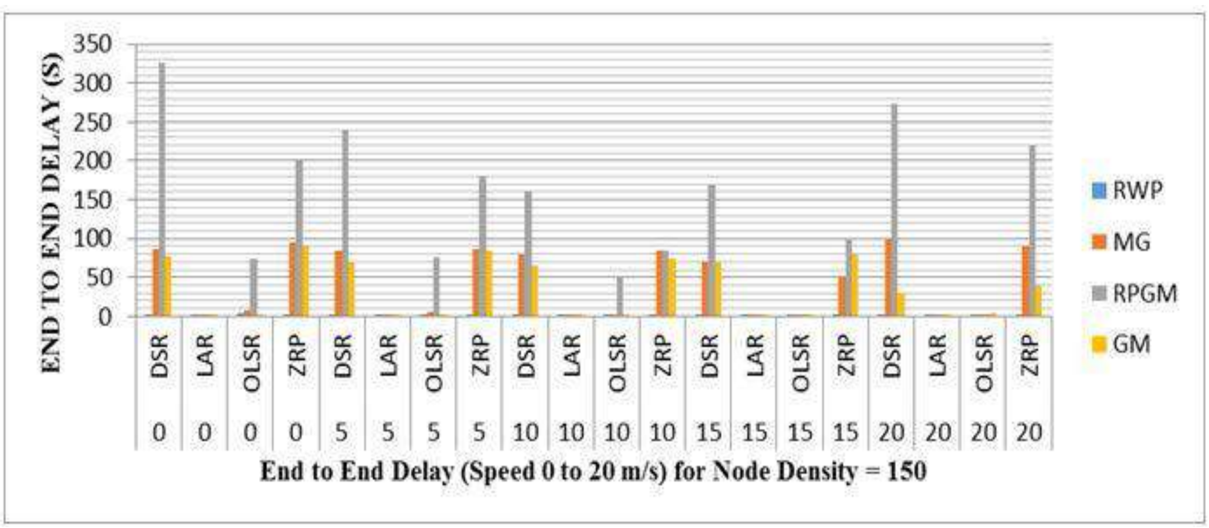

Figure 4.6: End to End Delay at Node Density 150, with speed varying from 0 to 20 m/s

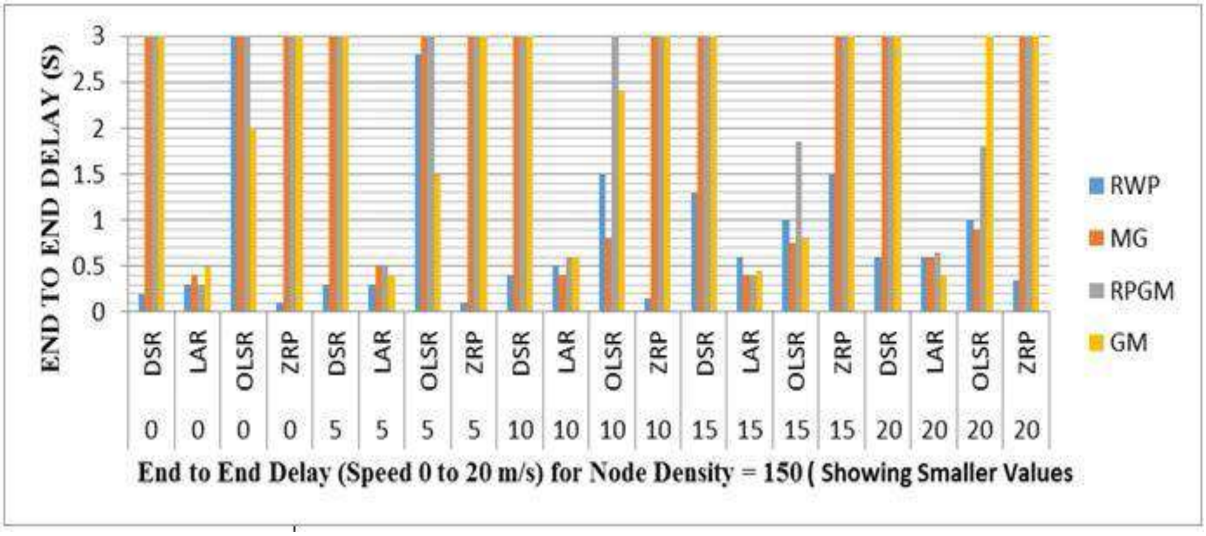

Figure 4.6a: End to End Delay at Node Density 150, speed varying from 0 to 20 m/s (Only smaller values are shown)

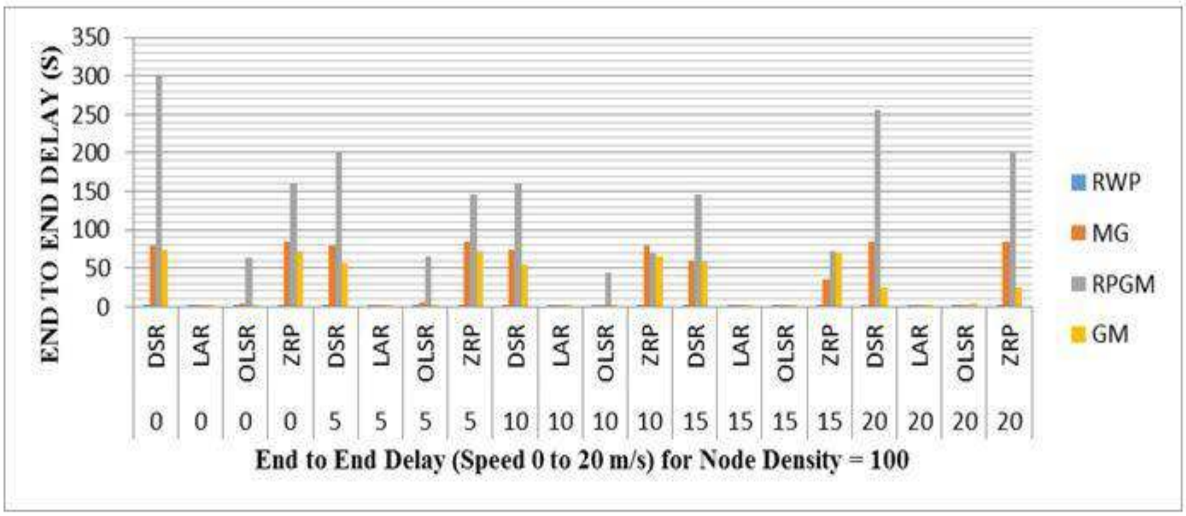

Figure 4.7: End to End Delay at Node Density 100, with speed varying from 0 to 20 m/s

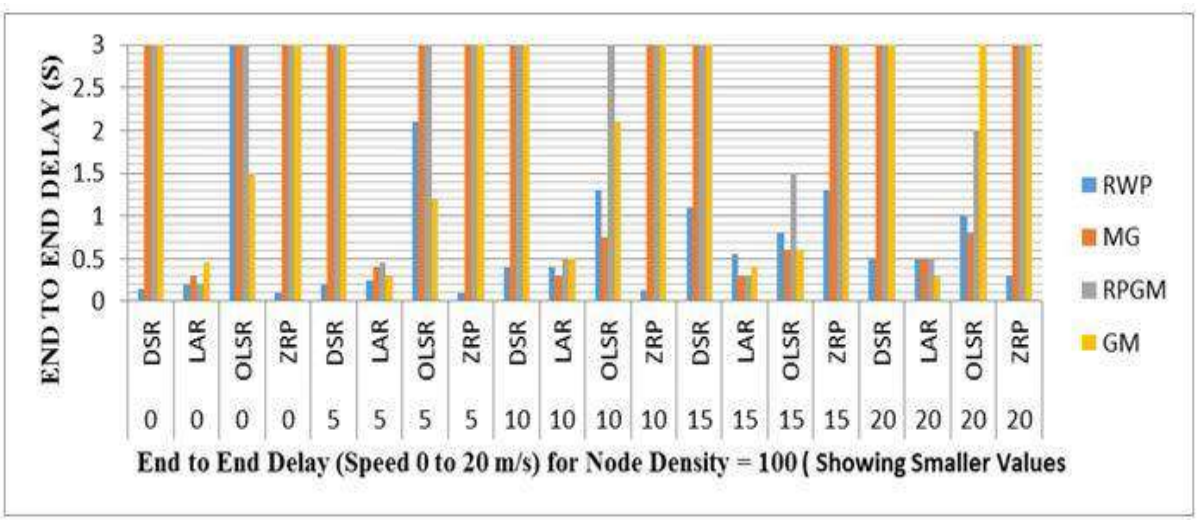

Figure 4.7a: End to End Delay at Node Density 100, speed varying from 0 to 20 m/s (Only smaller values are shown)

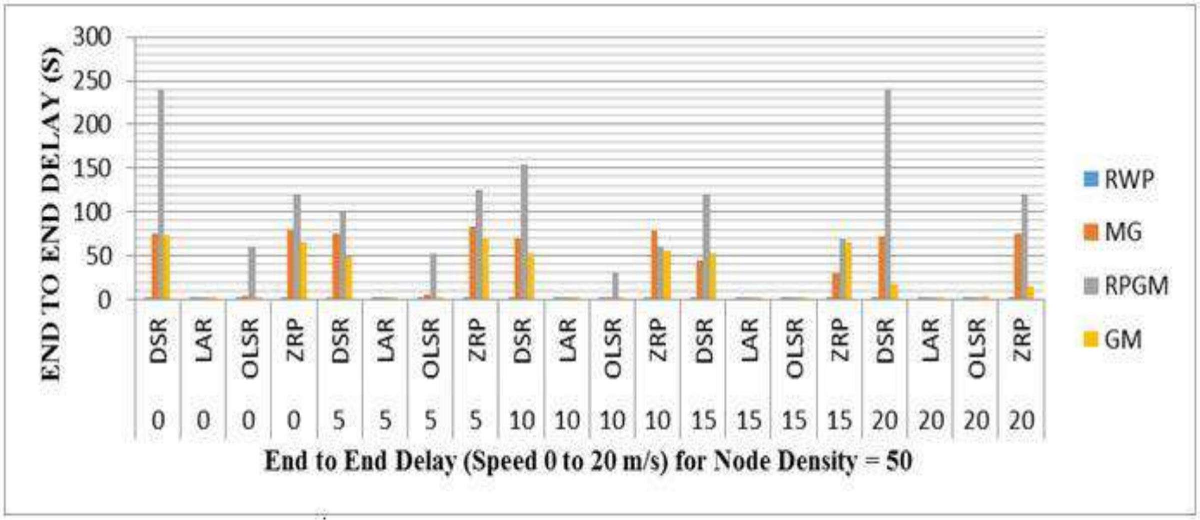

Figure 4.8: End to End Delay at Node Density 50, with speed varying from 0 to 20 m/s

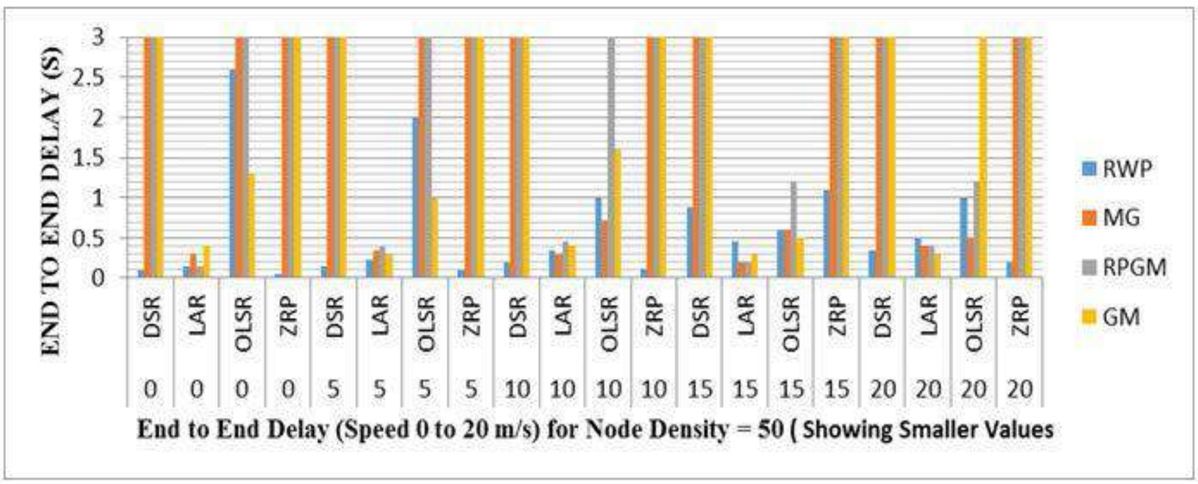

Figure 4.8a: End to End Delay at Node Density 50, speed varying from 0 to 20 m/s (Only smaller values are shown

4.4.3Packet Loss

The results for packet loss are shown in fig 4.9 to 4.12. The speed of the nodes is varied from 0 to 20 m/s in steps of 5 and node density is varied from 50 to 200 in steps of 50. At all node density, Gauss Markov model gives the lowest packet loss for all protocols, especially LAR and OLSR. This can be due to the fact that the value of speed and direction at the nth location is dependent on the previous value and a random variable. It means that probability of a node to remain in its old entirety is more, hence incurring low packet loss. LAR has the least packet loss with respect to other protocols for almost all cases of node speed and density except random way point model. With increase in speed the probability of packet loss also increases. It happens because at higher speeds, connectivity decreases and hence accounts for packet loss delays. The applications which require less packet loss should use LAR, as is evident from the results.

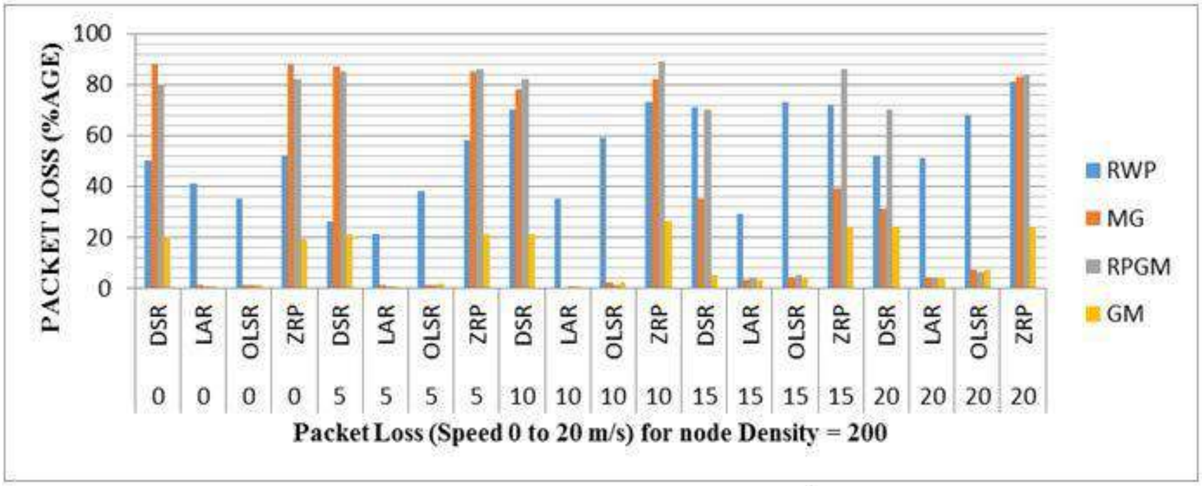

Figure 4.9: Packet Loss at Node Density 200, with speed varying from 0 to 20 m/s

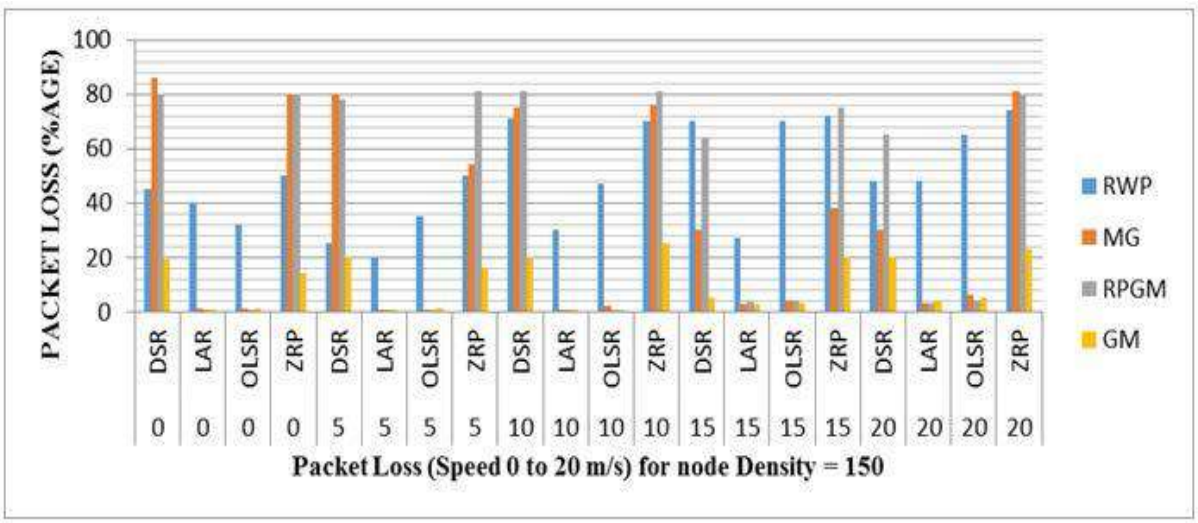

Figure 4.10: Packet Loss at Node Density 150, with speed varying from 0 to 20 m/s

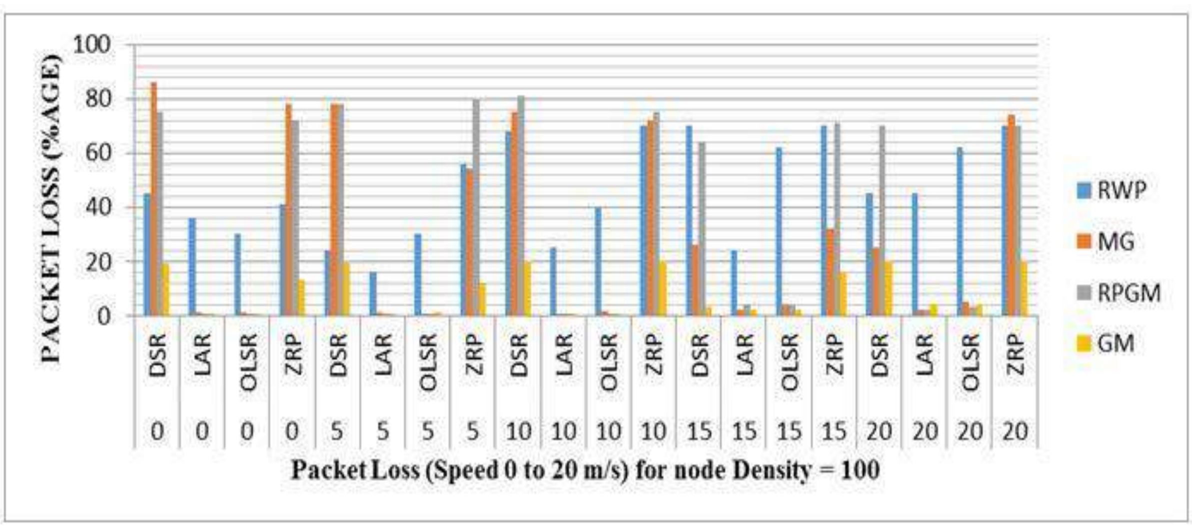

Figure 4.11: Packet Loss at Node Density 100, with speed varying from 0 to 20 m/s

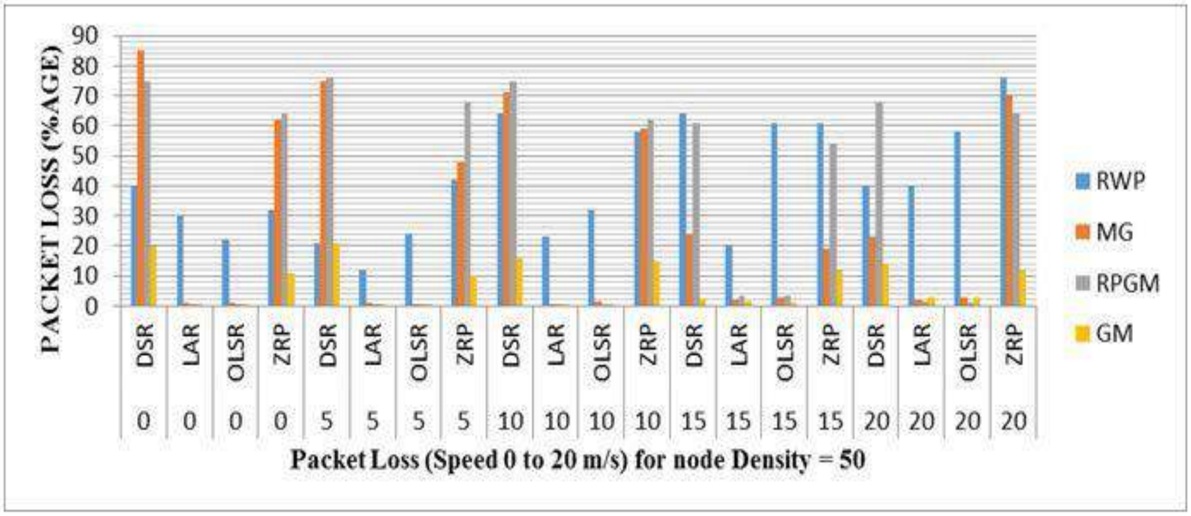

Figure 4.12: Packet Loss at Node Density 50, with speed varying from 0 to 20 m/s 7

The suggested applications for the above discussed variations are shown in table 4.3

Mobility Model	Speed	Density	Application	Suggested protocol(s)
Manhattan Grid	Low	Sparse	People's movement in a city	LAR/OLSR
		Dense	City Traffic	LAR/OLSR
	High	Sparse	Fighter aircrafts marching for operation	LAR/OLSR
		Dense	Shareable Internet access in high density urban area	LAR/OLSR
RPGM	Low	Sparse	Mountaineering campaign	LAR
		Dense	Soldiers movement in a troop	LAR/OLSR
	High	Sparse	Disaster relief operation	LAR/OLSR
		Dense	Fighter aircrafts marching for operation	LAR/OLSR
GM	Low	Dense	Meetings/Conferences	DSR/LAR/OLSR
	High	Sparse	Under water networks	OLSR/LAR
		Dense	VANET	LAR/OLSR

Table 4.3: Suggested applications.

4.5 Conclusions

In this work we presented a simulation based performance analysis of MANET routing protocols. From the reactive, proactive, geographic and location based protocols, one candidate protocol was chosen for analysis. The mobility models used were random way point, Gauss Markov, Manhattan Grid and reference point group mobility model. The variation in node speed was done from 0 to 20 m/s and node density from 50 to 200. The analysis of the throughput suggests that LAR and OLSR with MG model gives 100 %, due to the fact that a restriction in mobility area in a grid betters the throughput. LAR and OLSR give best performance in RPGM, due to the presence of a group leader, who is responsible for the mobility of the group and even distribution of group members. Due to localization property LAR performs better under RWP. This is due to the fact that in RWP model the nodes are distributed such that they are able to move freely and independently of others.