Performance analysis of MANET routing protocols considering mobility models

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Abstract: *Today MANET is not restricted to only military battlefield application where nodes are moving in like directed graph. Now MANET is used for various applications like disaster relief application, mobile classroom etc.. The mobility is important parameter to be considered while measuring or comparing the performance for various applications under MANET. The mobility parameters are the starting location of mobile nodes, their movement direction, velocity range, speed changes over time. The mobility of the nodes affects the number of average connected paths, which in Turn affect the performance of the routing algorithm. So, the performance of the MANET varies according to the applications as well as mobility model. This paper evaluates the performance of AODV routing protocol on mobility issue with Random Waypoint and Manhattan Grid mobility model using NS-2 simulator to measure the Routing Load, Average end-to-end delay and Throughput metrics. The simulation results show that AODV performance is better in Random Waypoint model than Manhattan Grid mobility model.*

Keywords: *End-to-End Delay, MANET, Manhattan Grid (MG), Random Way Point (RWP), Routing Load, Throughput.*

I. Introduction

Initially, MANETs was developed and deployed as per military needs. Today, MANET is applied in almost all fields such as emergency search-and-rescue operations, commercial environments, home and enterprise networking, entertainment, meetings or conventions in which persons wish to quickly share information, and data acquisition operations in inhospitable terrain with mobile nodes. The MANET is defined as a collection of mobile nodes where each node is free to move arbitrarily in an infrastructure-less environment. The nodes are mobile with random movements and varying speed can make the network topology very dynamic and complex.

The various factors such as transmission range, buffer space for message storage, battery power, computing power, data traffic and mobility cause variation in performance of MANET. The mobility [2, 6] is one of the factors affecting network performance in significant way. The movement of nodes in MANET causes link disconnections will be affecting the performance of the routing protocols. Therefore, there is a need to study mobility models to understand what degree of nodes mobility affecting routing protocol performance [4, 7]. The studies show that different mobility models have different characteristics and serve different purposes [19, 22].

Therefore, instead of using same Mobility Model [3, 8, 10] for every instance, the researchers should select various mobility models to study its behavior and effects on Network performance [11, 13, 16]. Selecting mobility model that describes movements of the nodes is one of the important factor selections for simulating the MANET for comparative study [10, 20, 21].

II. Literature Review

Ashutosh [4] analyzed the behavior of MANET routing protocols under three mobility models with the varying nodes, have similar performance for all protocols. The result is decrease of the network performance in some models or some give excellent performance. There is optimum performance for small networks of around 50 nodes in an area of 700 m × 700m.

Bhavyesh [5], the performance of a routing protocol varies widely across different mobility models and one model cannot be applied to other model, as per his experimental study with Random Waypoint, Group Mobility, Freeway and Manhattan models for routing protocols DSR and DSDV.

M.K. Jeya [12], the routing protocol AODV perform better than DSDV, TORA and DSR protocols under Random based mobility models (Random Way Point model, Random Walk model, and Random Direction model).

Narinder [14], results show that, Vector Mobility Model performs better than Random Way Point Model for AODV, OLSR and GRP routing protocols for the network size of 25nodes and 50 nodes.

In the work of Zahid [23], the performance of routing protocols is similar for Random Waypoint, Random Walk, Reference Point Group, Gauss Markov, Manhattan Grid mobility models in high density network topology. Whereas RPGM is suitable model for multi-path routing protocols under a moderate dense network topology.

III. Problem Statement

The mobility of the nodes affects the number of average connected paths, which in turn affect the performance of the routing algorithm [5, 12, 14, 23]. Most of the study has happened on MANET routing protocols for different applications without considering the node scalability with small to large network (10 - 200 nodes) with mobility. The MANET is used in different scenarios as in city streets, in big shopping malls, university campus, in conferences and for specific military purposes and vehicular ad-hoc network having the mobility and scalability. There is need to study the routing protocol performance suitable in different scenarios of mobility.

IV. Objective

To study the performance of routing protocol in MANET considering nodes mobility and scalability issues for routing load, End-To-End delay and throughput metrics.

V. Routing Protocol

As MANET do not rely on any existing infrastructure, the nodes themselves form network and communicate through means of wireless communications. Mobility causes frequent topology changes and may break existing paths [1, 9]. Reestablishment and managing path is carried out by routing protocols. The major types of routing protocols [17] are Proactive, Reactive and Hybrid. Proactive or table driven routing protocols attempt to maintain up-to-date routing information of all nodes by periodically disseminating topology updates throughout the network, Reactive or on demand driven routing protocols attempt to discover a route only when a route is needed and Hybrid protocols inherit the features from both proactive and reactive routing protocol.

AODV is a reactive [15] or Source-initiated On-demand protocol. It has minimum number of required broadcasts by creating routes on demand basis instead of maintaining a complete list of routes [7, 22]. AODV routing protocol is considered for this study because of its on demand nature to gain better performance of it [12]. The AODV can be the right selection for getting good performance for the applications like cafeteria, conferences, shopping mall, vehicular ad-hoc network etc., where one of the mobility models exists.

VI. Mobility Models

In MANET, mobility models describe the different mobility pattern of moving nodes. There are two major types of mobility models, Traces and Synthetic models. Traces are those mobility patterns that are observed in real life systems [13]. Traces comprise representation of real time movement of nodes in the network [1]. Synthetic models realistically represent node movement without using real network traces [1, 13]. Synthetic models are of two types, Entity and Group mobility models. In Entity Mobility Models mobile nodes move independently within the simulation area. They include Random Waypoint, Random Walk, Manhattan Grid, City, Gauss-Markov. In Group Mobility Models all the mobile nodes are arranged in a group and the mobility of nodes depends upon the movement pattern of the whole group i.e. all the nodes move together collectively. They include Reference Point, Nomadic and Pursue. Fig-1 shows all these types of mobility models for MANET.

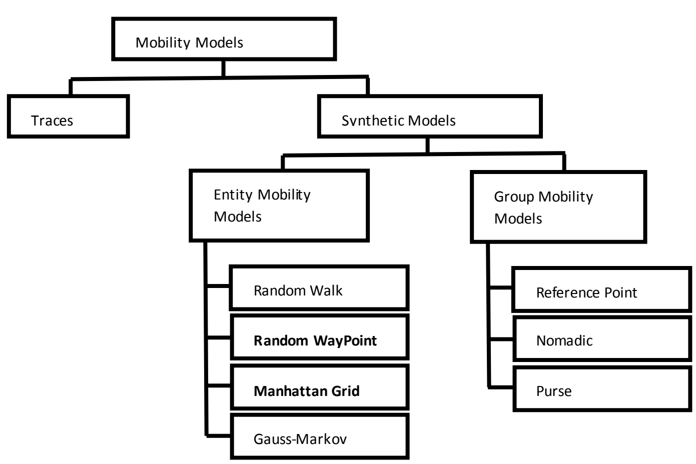

Fig-1Classification of Mobility models

The performance of routing protocols can vary depending upon the type of mobility model exists for a specific application. In this paper the Random Way Point and Manhattan Grid mobility model are considered and routing protocol performance is evaluated. The differences of Random Way Point and Manhattan Grid mobility model are important to designer for selecting routing protocol and predicting the performance of MANET.

6.1The Random Waypoint Mobility (RWPM):

The Random Waypoint Model was first proposed by Johnson and Maltz and it has become a 'benchmark' for other mobility models. It is used to compare the performance of MANET routing protocols because of its simplicity and wide availability [9]. The Random Waypoint model is popular and commonly used mobility model in research community.

In Random Waypoint model, for any instant, a node randomly selects a destination and moves towards the selected destination with a velocity chosen randomly from a uniform distribution [0, V_{max}], where V_{max} is the maximum allowable velocity for every mobile node. After reaching the destination node stops for a duration called 'pause time' parameter and it again chooses a random destination and repeats the whole process until it stop. This behavior of RWPM is to be consider for performance measurement for simulation. The example of a topography indicating the movement of nodes for Random Way point Mobility Model is shown in Figure-2.

Movement of people in a cafeteria or mall, and movement of nodes in a conference are some of its practical applications. Mathematically, if currently a node is at point $d(x - 1, y - 1)$ then the next waypoint is given as: $d(x, y) = d(x - 1, y - 1) + V_i$ [1].

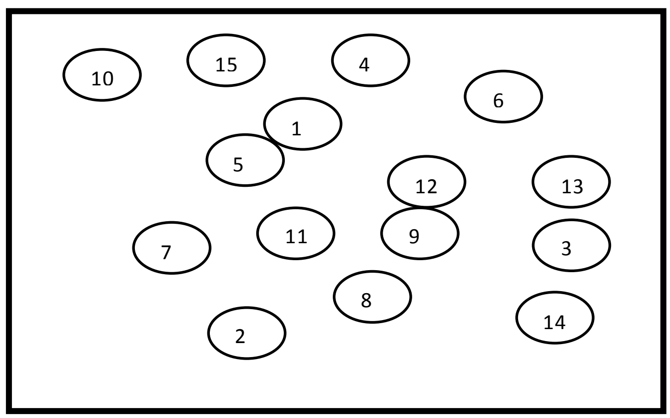

Fig-2: Topography for Random Way point Mobility Model

6.2 Manhattan Grid Mobility Models:

The Manhattan Grid mobility model was introduced to emulate the movement pattern of mobile nodes on streets defined by maps in cities. It is useful in modeling movement in an urban area where a pervasive computing service between portable devices is provided. Maps are composed of a number of horizontal and vertical streets used in this model. Each street has two lanes in each direction (North and South direction for vertical streets, East and West for horizontal streets). The mobile node is allowed to move along the grid of horizontal and vertical streets on the map. At the intersection of a horizontal and a vertical street, the mobile node can turn left or turn right or can go straight.

The probability to take turn in four directions is 25%, while 50% in case of two directions. In Grid environment nodes movement depends on its surrounding and its previous movement [23]. This choice is probabilistic: the probability of moving on the same street is 0.5, the probability of turning left is 0.25 and the probability of turning right is 0.25. The velocity of a mobile node at a particular time slot is dependent on its velocity of its previous time slot. A node velocity is also restricted by the velocity of preceding node on the same lane of the street. Thus, the Manhattan Grid mobility model is highly spatial dependence and highly temporal dependence and geographically also restricted. Figure-3 is an example of Manhattan Mobility Model topography indicating the movement of nodes under restricted boundaries.

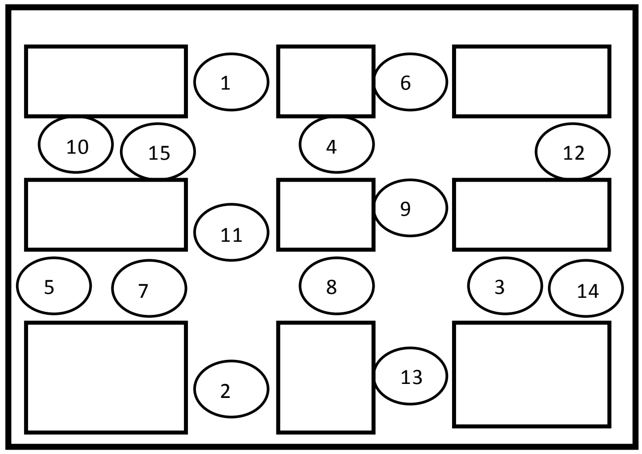

Fig-3: Topography for Manhattan Mobility Model

VII. Simulation Setup

The performance of AODV reactive routing protocol in MANET with Random Way Point and Manhattan Grid mobility patterns for varying node density [18] is measured using NS-2 Network Simulator. The communication parameters, movement parameters and the performance metrics considered for the study are specified below.

7.1 Communication parameters for the study: The simulation is set for varying node density starting from 10 nodes and ending on 200 nodes in the denomination of 10, 20, 25 and 50. The other parameters in Table-1, are Constant Bit Rate (CBR), transmission data rate is 8 packets/ second.

Table-1 Communication Parameters selected for simulation

Parameter	Value
Traffic	Constant Bit Rate
No. of nodes	10, 20, 30, 50,75, 100, 150, 200
Transmission Rate	8 packets/sec

7.2 Movement parameters for the study: To study the effect of mobility patterns on routing performance, Random Way Point and Manhattan Grid are considered with two scenarios.

In First scenario, realistic mobility pattern of node is set to Random Waypoint Mobility Model, where a node is allowed to move arbitrarily in any direction randomly for the restricted area of 500m X 500m with the velocity of 0.5 meter per second as minimum and 1.5 meter per second as maximum and angle is varying in between 0 to 2π. At the destination the node **'pause time'** is fixed to10 seconds before selecting another destination. This phenomenon repeated for the duration of 600 seconds in the simulation. The operation is performed for the scalability of 200 nodes starting from 10 nodes with the denomination of 10, 20, 25 and 50 nodes.

In Second scenario, Manhattan Grid mobility model for 500m X 500m area space having 5 number of horizontal and 5 number of vertical grids. Each grid has two lanes in each direction (North and South direction for vertical grids, East and West for horizontal grids). The mobile node is allowed to move along the horizontal and vertical grids on the map with the minimum speed 0.5 meter per second and maximum speed as 1.5 meter per second. At the intersection of horizontal and vertical grid, the mobile node can turn left, can turn right or can go straight. In such grid environment nodes movement depends on its surrounding and on its previous movement. The probabilities of moving on the same street is 0.5, turning left is 0.25 and turning right is 0.25 are assumed as per standard probability calculation. The velocity of a mobile node is dependent on its previous velocity. Table-2 shows movement parameters for both scenarios stated as above.

Table-2: Movement Parameters considered for simulation

mobility model / Parameter	**Scenario-1 for Random waypoint**	**Scenario-2 for Manhattan Grid**
Simulator	NS-2	NS-2
Simulation time	600 seconds	600 seconds
Area of network	500m x 500m	500m x 500m
Pause time	10 seconds	10 seconds
Min. speed of nodes	0.5 meter/sec	0.5 meter/sec
Max. speed of nodes	1.5 meters/sec	1.5 meters/sec
Pattern of nodes movement	Random	No. of grids along x-axis : 5 No. of grids along y-axis : 5 Probability of going straight : 0.5 Probability of turn right : 0.25 Probability of turn left : 0.25

7.3 Performance metrics for evaluation:

The performance of the simulated results is analyzed using following performance metrics[7]:
Throughput: It is rate of successful data transfer in the network and measured as the ratio of total bytes in a packet received at destination and with time taken. Throughput is expressed in terms of bytes per second or bits per second.

$$Throughtput = \frac{\sum Received\ packet\ size}{Stop\ Time - Start\ Time} \quad \text{bytes/sec or bits/sec} \qquad (1)$$

2) Avg. End-to-End Delay (E2E): Average time taken by a specific packet is the time to travel from source to destination in a network. It is measure as the total number of time taken for each packets divided by total number of packet received at the destination, is expressed in terms of seconds.

$$Avg.End - To - End\ Delay(E2E) = \frac{\sum(Packet\ Sent\ Time - Packet\ Received\ Time)}{\sum(Packet\ Received)} \qquad (2)$$

3) Normalized Routing Load (NRL): The ratio of Number of Routing Packets Received to the Number of Data Packets Received is bits per second (bits/sec).

$$Normalized\ Routing\ Load\ (NRL) = \frac{NRpr}{NDpr} \qquad (3)$$

Where, *NRpr* is the Number of Routing Packets Received and *NDpr* is the Number of Data Packets Received.

VIII.SIMULATION RESULTS AND ANALYSIS

8.1Routing Load: The simulation results on ‘routing load’ incase of Random Waypoint and Manhattan Grid mobility models using AODV routing protocol are analyzed and tabulated in Table-3 and graphically presented in Figure-4 to understand the performance differences.

Table-3: Comparative Routing Load for RWP and MG mobility model with AODV routing protocol for varying node density

Sr. No.	**Nodes density**	**Performance Metric Routing Load (kbps) for AODV using mobility model as**		**Difference of Routing Load- RWP and MG (kbps)**
		RWP	MG	
1	10	0.003	0.021	0.018
2	20	0.006	0.063	0.057
3	30	0.008	0.079	0.071
4	50	0.011	0.123	0.112
5	75	0.026	0.133	0.107
6	100	0.04	0.546	0.506

7	150	0.056	0.53	0.474
8	200	0.138	0.62	0.482

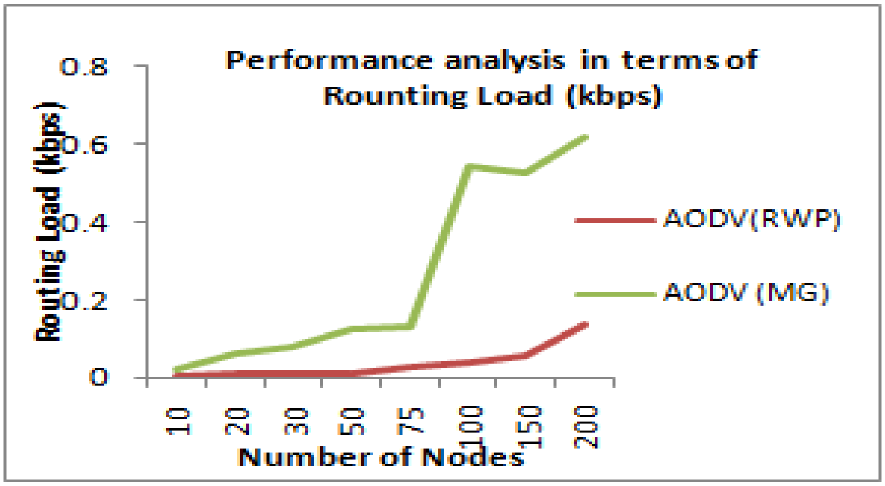

Fig-4: Comparison of routing load for RWP and MG Mobility Model for AODV for AODV routing protocol for different node density

Observations: From the Table-3, it is observed that **'routing load'** in Manhattan Grid mobility is higher than Random Way Point mobility model while using AODV routing protocol, but the difference is very small and it is in between 0.018 kbps to 0.506 kbps. In Manhattan Grid mobility model **'routing load'** has increased drastically from 0.133 kbps to 0.546 kbps when node density has changes from 75 to 100 nodes. Further for 150 nodes and 200 nodes the routing loads are 0.53 kbps and 0.62 kbps respectively. While in case of Random Way point mobility model the routing load lies in between 0.003 kbps to 0.138 kbps. Performance of AODV is better in Random Way Point mobility model than Manhattan Grid mobility model for the scalability 10 nodes to 200 nodes.

When nodes are moving faster there is higher rate of disconnection that creates more route errors so frequent re-initialization of route discovery process happens. For higher overhead of routing packets the routing load is higher that results in degradation of routing protocol efficiency. The **'routing load'** has increased drastically from 0.133 kbps to 0.546 kbps, 0.53 kbps and 0.62 kbps in with number of nodes values changing from 75 to 100, 150 and 200 nodes.

8.2 End-to-End Delay: The performance metric '**end-to-end delay**' is important and it helps to take decision on the performance of application in a MANET. The AODV routing protocol performance for '**end-to-end delay**' for Random Waypoint mobility model and Manhattan Grid mobility model obtained simulated values are represented in Table-4 and Figure-5 for the analysis.

Table-4: Comparative End-to-End Delay for RWP and MG mobility model with AODV routing protocol for varying node density

Sr. No.	Nodes density	End-to-End Delay for the mobility models		Difference in End-to-End Delay for RWP and MG (ms)
		Random Way Point (ms)	Manhattan Grid (ms)	
1	10	7.78	9.39	1.59
2	20	8.30	10.83	2.53
3	30	7.90	11.55	3.65

4	50	7.89	15.56	7.67
5	75	8.06	15.71	7.65
6	100	11.82	15.27	3.45
7	150	11.80	17.17	5.37
8	200	18.65	28.69	10.04

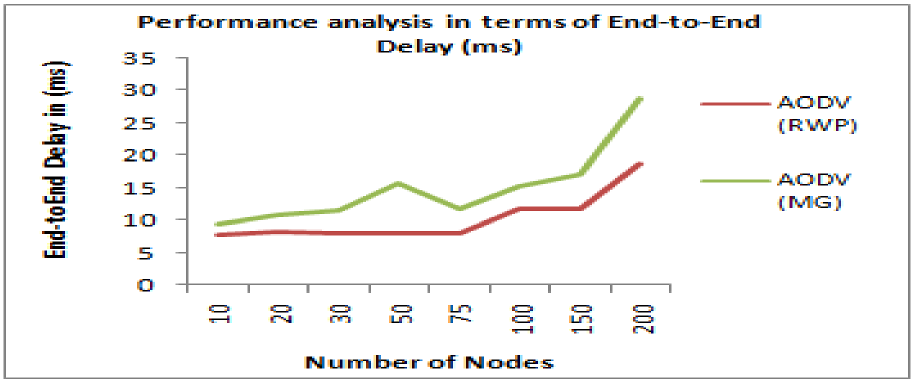

Fig-5: Comparison of delay for RWP and MG Mobility Model for AODV for AODV routing protocol for different node density

Observations: From Table-4, it is observed that ***'end-to-end-delay'*** value in Random Way Point mobility model is always less than Manhattan Grid mobility model for varying node of density as considered in this simulation. In case of Random Way Point mobility model ***'end-to-end delay'*** for AODV routing protocol is almost same for 10-75 nodes that is minimum 7.78 ms and maximum 8.06 ms. When node density is 100 and 150 the **'end-to-end-delay'** is 11.82 ms and 11.80 ms but when node density is 200 the delay value is 18.65 ms. Similarly, in Manhattan Grid mobility model the '**end-to-end delay**' is almost same up to 30 nodes and the average delay value is 10.59 ms, from 50 to 150 nodes the average delay value is 15.92 ms and for 200 nodes it is 28.69 ms.

So, the performance of AODV routing protocol for the metric '**end-to-end delay'** is better in Random Way Point mobility model than Manhattan Grid mobility model. A higher value of **end-to-end delay** means that the network is more likely to be congested and hence the routing protocol does not perform well. Specifically in case of Manhattan Grid there is restriction on the movement of the nodes as the grid patterns having crossings that increases the congestion.

8.3 Throughput: The performance metric **'throughput'** obtains for AODV routing protocol used for Random Waypoint Mobility Model and Manhattan Mobility Model in this simulation experiment, is tabulated in Table-5 and graphically presented in Figure-6.

Table-5 Comparative Throughput for RWP and MG mobility model with AODV routing protocol for varying node density

Sr. No.	**Nodes density**	**Performance Metric Throughput (kbps) for AODV using mobility model as**		**Difference of Throughput- RWP and MG (kbps)**
		RWP	**MG**	
1	10	282.80	282.80	0
2	20	282.92	282.46	0.46
3	30	283.44	282.23	1.21

4	50	282.89	282.28	0.61
5	75	283.11	282.66	0.45
6	100	283.42	281.11	2.31
7	150	283.73	281.32	2.41
8	200	279.44	281.12	1.68

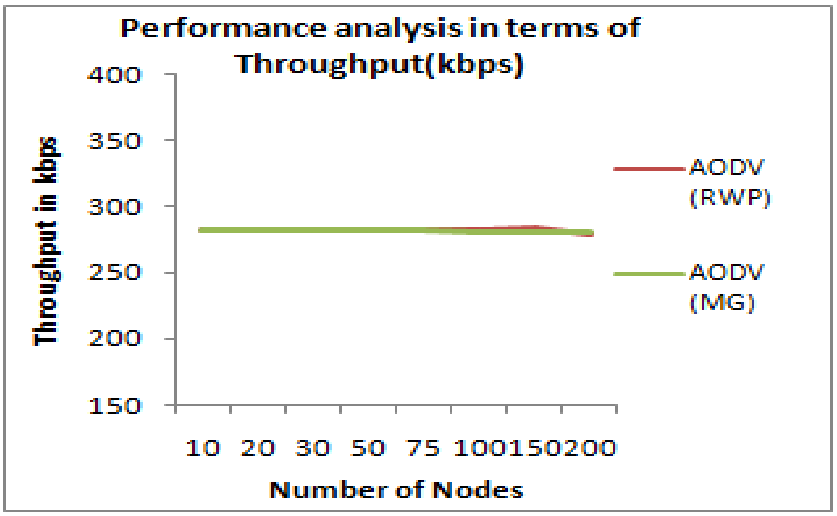

Fig-6: Comparison of throughput For RWP and MG Mobility Model for AODV routing protocol for different node density

Observations: Performance of AODV routing protocol in Manhattan mobility model and Random Way Point is almost same as per Table-5 and Figure-8.

IX. Conclusion

With the fortification in MANET technology the lifestyle are changing and giving new height to business world also. The applications of MANET is spreading and becoming important area of study with changing scenarios where mobility is a factor affecting the performance of MANET routing protocol. In the mobility scenarios, MANET nodes are free to move arbitrarily or in restricted pattern. For arbitrarily or in restricted pattern, the two mobility models Manhattan Grid Mobility model and Random Way Point mobility model have been considered in this study for the performance evaluation of AODV routing protocol.

The simulation study results on Routing Load, End-to-end delay and Throughput metrics shows that AODV routing protocol performance is better in Random Way Point mobility model than Manhattan Grid Mobility model because traffic are moving arbitrarily in Random way Point. In Manhattan Grid, the nodes movement depends on its surrounding and its previous movement. Due to this restriction of node movement in MG mobility model the routing load is increased as compared with RWP mobility model. This is because in RWP mobility model routing protocol performance is dependent on two factors speed and pause time.

The Manhattan Grid mobility model is highly spatial (relating to position) and temporal dependent due to geographical restriction. The 'end-to-end delay' in Manhattan Grid mobility model is 0.80% greater for 75 nodes, 0.89% greater for 150 nodes and 0.77% greater for 200 nodes compare to Random Way Point mobility model.

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