



Development of Modified Random Waypoint Mobility Model of Routing Protocol for the Mobile ad-hoc Network

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Abstract: - Mobility models are used to evaluate the network protocols of the ad hoc network using the simulation. The random waypoint model is a model for mobility that is usually used for the performance evaluation of ad-hoc mobile networks. Mobile nodes have dynamic mobility in the ad hoc network, so the mobility model plays an important role to evaluate the protocol performance.

In this article, we developed modify random waypoint mobility (MRWM) model based on a random waypoint for the mobile ad hoc network. In this article, the comparative analysis of modifying random waypoint mobility and random waypoint model on the ad hoc On-Demand Distance Vector (AODV) routing protocol has been done for a large wireless ad hoc network (100 nodes) with the random mobile environment for the 1800s simulation time. To enhance the confidence in the protocol widespread simulations were accomplished under heavy traffic (i.e. 80 nodes) conditions. The proposed model protocol has been investigated with the performance metrics: throughput; packet delivery ratio; packet dropping ratio; the end-to-end delay and normalized routing overhead. The obtained results revealed that the proposed modified random waypoint mobility model reduces the mobility as compared to the random waypoint mobility model and it is trace is more realistic.

Keywords: Protocol; Mobile ad hoc network; Mobility Model; Random Waypoint Mobility; throughput.

1. Introduction

Mobile communication is an increasingly imperative part of every business [1]. To optimize the performance of mobile networks different network's structure are suggested. The mobile ad hoc network is the multi-hop mobile node communication in the wireless environment without having any static arrangement [2]. A node in a wireless network is moveable, and its movement is random in nature. Thus, it is complicated to develop the protocol for such an environment. The wireless network can be established in any structure and nodes are able to communicate within the transmission range. If the destination node is within the range of the source node, then the receiver node directly received the data otherwise sender node transmits the data through the intermediate node. Due to this reason, routing is required in the wireless network [3-4] with dynamic network topology [5]. The traditional protocol is designed for the



fixed infrastructure network so that is not suitable to use in the MANET network. In such a dynamic environment of the node, it is difficult to develop a routing protocol that is able to offer services like routing, quality of service, resource management, network operation, and management for the mobile network. A routing protocol for such a dynamic wireless network can be designed by considering the speed and mobility pattern of the node in the network. Thus, it is very important to identify and trace the node mobility pattern and its effect on the network as well as the protocol performance.

Different models are suggested so far to verify the various protocols. Which, a random waypoint model is one of the most preferable among those models. Some of the models are based on mitigating black hole effects through detection and prevention (MBDP-AODV) based on a dynamic threshold value of the destination sequence number [6], another model for improving the traffic load in the network and identifying a short and secure route detect a number of malicious nodes [7]. This model described the black hole detection using a dynamic source routing (DSR) algorithm for a small network (i.e. 30 nodes) [8], another model is based on a trust-aware scheme to detect the intrusion in the MANET to improve the trust factors along with the direct trust, indirect trust, and the recent trust [9] and enhanced random mobility model, which belongs to the class of random direction models in which the movement trace of individual mobile is considered for short simulation time (i.e. 300sec)[10].

It is difficult to obtain real-life mobility patterns or trace-based mobility models [11] to analyze the wireless ad hoc network. In this study, we have examined the effect of random mobility (or trace-based mobility models) and random waypoint mobility models on routing protocol in MANET.

In this article, section 2 provides detail about the mobility model, section 3 described the comparative study of the random waypoint model and proposed model, section 4 discussed all obtained results and section 5 present the conclusion of the proposed work.

2. Mobility Model

Mobile ad hoc network node has random mobility, so to check the performance of the protocol, it is required to develop a mobility model that defined the movement of the node, and velocity or it describes the characteristic of the node. Numerous protocols are proposed by the researcher and protocols have particular advantages and disadvantages based on the network scenario. Consequently, it is very imperative that select the protocol based on the mobility pattern. To represent the wireless mobility researcher proposed many mobility models such as the random walk mobility model [12], random waypoint mobility model [13], random direction mobility model [14], boundless simulation area mobility model [15], Gauss–Markov mobility model [16], probabilistic version of the random walk mobility model [17] and City Section Mobility Model [18].



It is broadly classified into two categories: trace and syntactic. Real-life mobility pattern of the node created in trace-based mobility model [19]. But to develop such a mobility model and generating mobility trace become the major challenges for long observation time and the large mobile ad hoc network [20]. The various models are already proposed to represent the real-life realistic mobility pattern and characteristics [21]. Recent work evaluates the protocol performance based on the syntactic mobility model [22].

Individual mobile movement and group mobile movement are the two types of the systematic mobility model [23]. The mobility model characterizes the node mobility pattern in the network with respect to time in different network circumstances and other mobility models developed that represents the group of the node traversing pattern. Node moves randomly in the network so syntactic mobility is considered the randomness of the node and based on the randomness it is classified into constrained topology-based models and statistical models. Constrained topology models consider partial randomness and statistical models consider the randomness of the nodes. It allowed the to node moved randomly anywhere in the network with a properly defined speed and direction [24]. Based on the features mobility models are classified into four types as shown in figure 1:

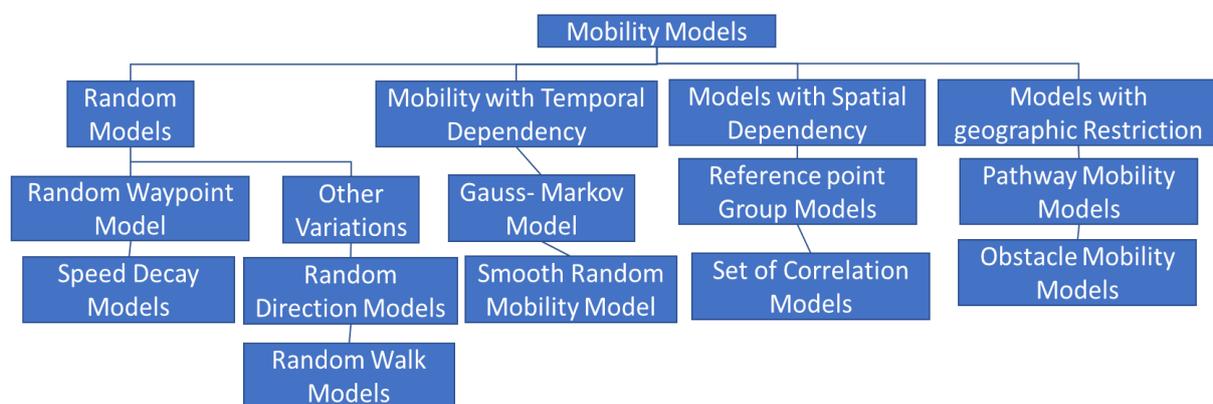


Figure 1: Classification of Mobility Model on the basis of the random models, mobility with temporal dependency, models with spatial dependency and model with geographic restriction.

Random Models: Node moves randomly like the statistical model and based on the randomness properties it is further classified into waypoint, random direction and random walk mobility.

The model with Temporal Dependency: In this model, based on the effect of the node movement history mobility model pattern is decided. It is further classified into Gauss–Markov and smooth random mobility models.

The model with Spatial Dependency: In this mobile model, mobile nodes travel in an interrelated manner. Example: Reference point group mobility model and spatially correlated mobility models.



Models with Geographic restriction: Based on obstacles, streets and freeways mobility model was developed. Example: pathway mobility model and obstacle mobility model.

3. Random Model

In the simulation-based evaluation of the wireless network, it is a very important role in the mobility model. Based on the different network protocols and scenarios researcher chose the different mobility models for the protocol simulation [25,26,27,28]. The random mobility model is more commonly and frequently used by the researcher for the evaluation of the ad hoc protocol performance using the NS2[29] and GloMoSim[30] simulator[31,32]. In this article, we have done a comparative analysis of AODV [33] routing protocol performance in the random waypoint mobility model and the proposed mobility model.

3.1 Random Waypoint Mobility Model:

In this model node velocity, time and random destination point (x, y) coordinate decided randomly when the node reaches the destination also it pauses for some amount of time at the destination. Pause time at the destination will be decided according to the more random variable after the pause time expire it repeats the node mobility movement and it decides the new velocity, pause time and destination coordinate. Similarly, it repeats the process. Starting and destination position defined as the waypoint and node travel distance between the starting to the destination waypoint is called the transition length.

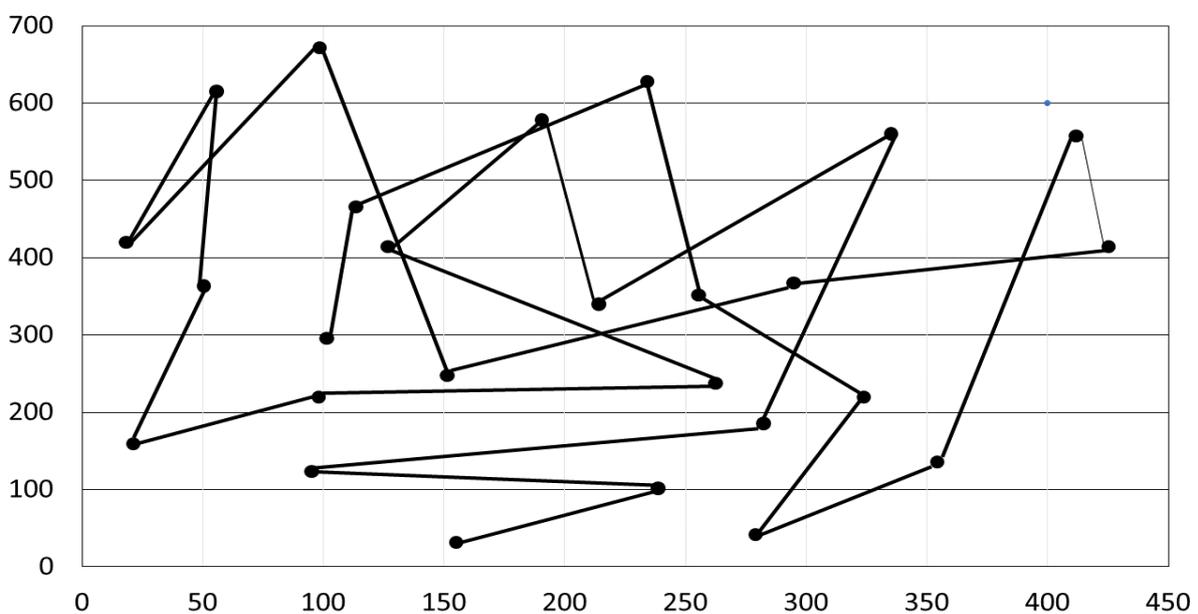


Figure 2: Random waypoint mobility model travelling pattern of a mobile node in random direction with variable speed.



Figure 2. shows the example of the random waypoint mobility model. In the article, we investigated initially an ad-hoc network with all the nodes randomly distributed in the simulation area. Initial randomly choose the node coordinate (133,180), the speed of the node is defined between 0 to 10 m/s and pause time is decided to zero.

To capture and quantify the model speed notion, Johansson, Larsson and Hedman et al. [34] proposed the mobility metric to measure the relative speed between the node I and j at time t is given in equation (1)

$$RS(i, j, t) = | \overline{V_i(t)} - \overline{V_j(t)} / M | \dots\dots (1)$$

The mobility metric \bar{M} is calculated as the measure of relative speed averaged over all node pairs and overall time. It can be defined as eqn (2)

$$\bar{M} = \frac{1}{|i,j|} \sum_{i=1}^N \sum_{j=i+1}^N \frac{1}{T} \int_0^T RS(i, j, t) dt \dots\dots (2)$$

Where $|i,j|$ is the number of distinct node pairs (i, j), n is the total number of nodes in the simulation field (i.e., ad hoc network), and T is the simulation time.

CMU Monarch group added the extension in the NS2 to create the wired as well as wireless simulation environment [35]. To evaluate the routing protocol performance, the “set dest” tool included in the Network Simulation (ns 2) to generate the Random Waypoint model for the routing protocol.

3.2 Modify random waypoint mobility (MRWM) Model

In real life, ad hoc network node moves randomly and due to this the topology of the network change dynamically. So, in the proposed random mobility model having nodes move randomly without any restriction in the network. Also, node mobility direction, Speed and destination point (x, y) very dynamically. To analyze routing protocol performance, we generate dynamic random mobility in a network simulator:

```
$ set mobility [lindex $argv 0]; # Dynamic mobility file. This is used for random mobility using for loop which is not used in the Random waypoint Model.
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Node moves randomly in the network and its location speed and direction vary with respect to the time. So, in this analysis, for the same scenario, we generate a result ten times and take the average result of them.

4. Experiment Work:

Comparative analysis for AODV routing protocol performance in the modified random waypoint mobility (MRWM) and random mobility model has been carried out using Network Simulator 2 (NS2). The parameters specification for the proposed work is given in table1.

Table 1:Parameters Specification is chosen for the experiments.

Parameter	Typical Value
Simulator Version	NS-2.35
Routing Protocols	AODV
Network Space	600 m x 600 m
No. of nodes	100
Mobility Model	Modify Random Waypoint Mobility (MRWM) and Random Waypoint Mobility
Speed	Min 1m/s to Max 10m/s
Traffic Type	UDP
MAC Protocol	IEEE 802.11
Simulation Time	1800s
Packet Size	512

In the comparative analysis, we have used the ad hoc network having 100 mobile nodes and the AODV routing protocol for the data transmission in the network. To check the effect of mobility on the protocol, we increase the traffic in the network. Initially, we analyse AODV protocol performance in the network by using 100 number of node and 10 communicating nodes for the simulation time of 1800sec after that we increase the traffic in the network by 10 up to 80 communicating nodes. In the proposed work, we consider random mobility, so the node moves randomly in the network with a velocity of 10 m/s. The results were carried out by considering the average of the 10 times pattern for each set of the node.



5. Results Analysis

The comparative analysis has been of proposed MRWM with random mobility on network protocol performance is carried out with four performance parameters as discussed below:

Throughput: It measures the ratio of the total number of data received at the receiver from the sender to the time taken by the receiver to receive all the data.

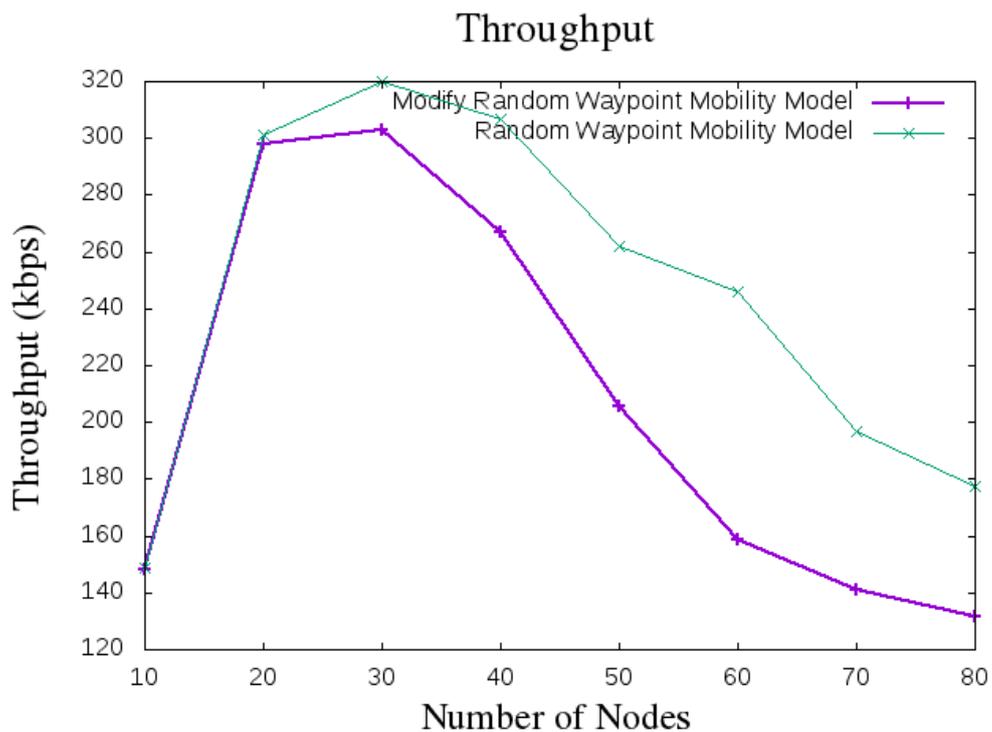


Figure 3: Throughput versus the number of nodes for the proposed model (purple colour with dash marker) and random waypoint model (green colour with cross marker) having similar throughput up to 20 nodes.

Table 2: Throughput analysis of the proposed model with RWP for different nodes

Throughput		
Number of nodes	Modify random waypoint mobility (MRWM)	Random Waypoint Mobility (RWP)
10	147.952	148.52
20	297.709	301.46
30	302.650	320.00
40	267.003	306.61
50	205.784	261.84
60	158.587	245.89



70	140.816	196.91
80	131.620	177.31

Figure 3 shows the AODV protocol throughput analysis in the Modify random waypoint mobility (MRWM) and random waypoint mobility model. The value of the throughput for different nodes is given in table 2.

In the modify random waypoint mobility (MRWM) node mobility is more dynamic compared to the random waypoint mobility So as the number of the connection (10 to 80 communicating node) increase the network effect of the dynamic mobility also increase and it drops more number of the packet in the network compare the random waypoint mobility. At 10 communicating nodes, the modify random waypoint mobility (MRWM) throughput is 147.952 kbps and the random waypoint mobility (RWP) throughput is 148.52 kbps. As the communicating node increase to 80, the throughput of PRM is 131.620 kbps and RWP is 177.31.

Normalized Routing Overhead: It is defined as the total number of routing packets to the total number of delivered data packets at the destinations. Normalized routing overhead for both models at the different number of nodes is shown in figure 4. The obtained values of the normalized routing overhead are given in table3.

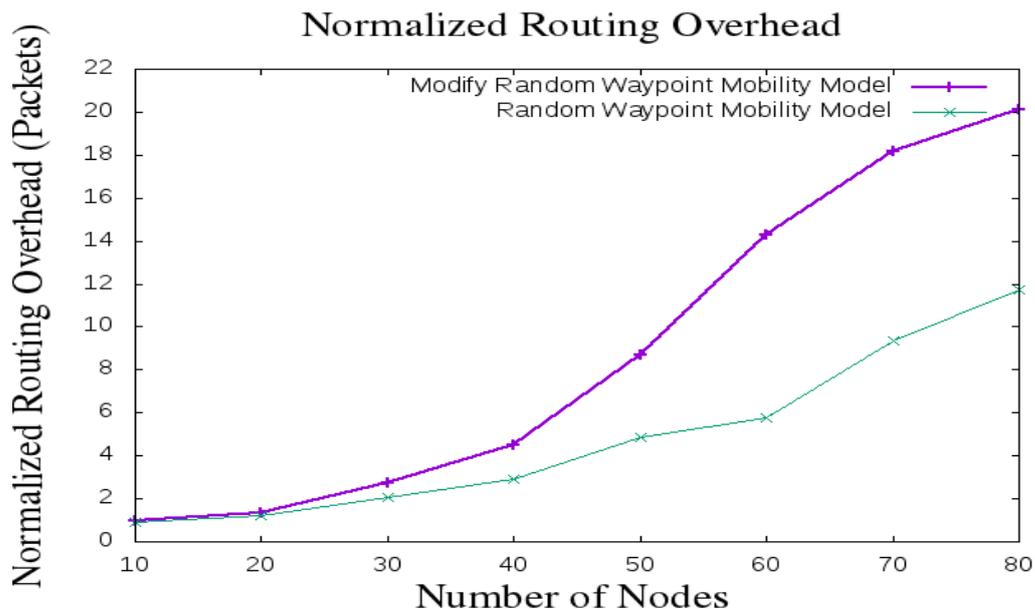


Figure 4: Normalized Routing overhead for the modify random waypoint mobility model (purple colour with dash marker) and random waypoint model (green colour with cross marker) having similar throughput up to 20 nodes after 20 nodes the MRWMM maximum overhead packets.



Table 3: Normalized Routing Overhead

Normalized Routing Overhead		
Number of nodes	Modify random waypoint mobility (MRWM)	Random Waypoint Mobility (RWP)
10	0.9964	0.882
20	1.3501	1.205
30	2.7648	2.052
40	4.4805	2.931
50	8.6825	4.856
60	14.2796	5.766
70	18.1753	9.364
80	20.1124	11.718

In the proposed MRWM node destination coordinate (x,y), speed and pause time are very dynamically compared to the random waypoint mobility and we have taken an average of 10-time results for each set of nodes. Due to this, it is more difficult to maintain the routing path in the network and the more the routing packet required compared to the data delivered at the destination node. So, the normalized routing overhead in the modified random waypoint mobility (MRWM) is higher or increase as the traffic increase from 10 to 80 node in the network. As traffic increases from 10 to 80 nodes, the normalized routing overhead of MRWM and RWP increases from 0.996 to 20.112 and 0.882 to 11.718 respectively in the 100 nodes network.

Packet Dropping Ratio: It is defined as the total number of packet losses divide by the total number of packets sent.

In dynamic node mobility or modify random waypoint mobility (MRWM) model have unpredictable node movement, velocity and node coordinate (x, y) in the network compared to the random waypoint model. The packet drop ratio for MRWM and RWM is shown in figure 5, it is revealed that the more packet drops in the modify random waypoint mobility (MRWM) model compared to the random waypoint mobility at 10 nodes the packet dropping ratio of the MRWM and RWP is 0.964 and 0.63 respectively. All other values for the different number of nodes are given in table 4.

As the traffic increase in the network, the packet dropping ratio also increase in the MRWM compared to the RWP model. MRWM and RWP packet dropping ratios at 80 nodes are 89.03 and 81.14 respectively.

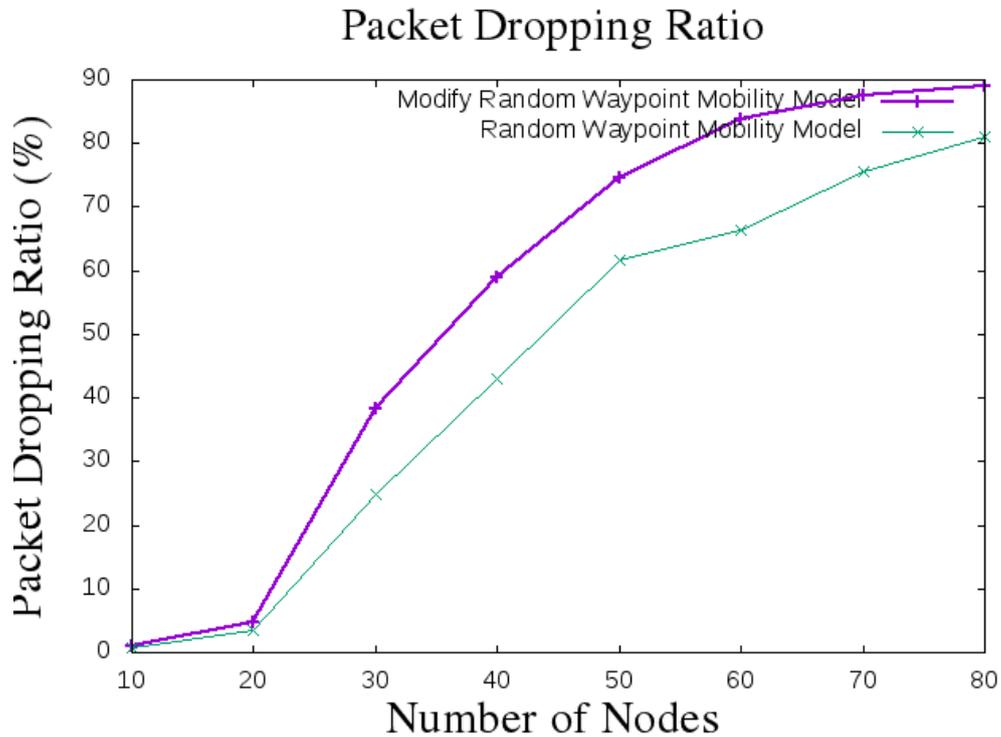


Figure 5: Packet Dropping Ratio for the modify random waypoint mobility model (purple colour with dash marker) and random waypoint model (green colour with cross marker) versus a number of nodes.

Table 4: Packet Dropping Ratio

Packet Dropping Ratio		
Number of nodes	Modify random waypoint mobility (MRWM)	Random Waypoint Mobility (RWP)
10	0.964	0.63
20	4.747	3.53
30	38.259	24.84
40	58.907	43.00
50	74.584	61.64
60	83.699	66.27
70	87.585	75.69
80	89.03	81.14

Packet Delivery Ratio: it is defined as the total number of packets successfully received by the total number of packets sent.



We analyzed the network performance in the network space of 600 m x 600 m. As shown in figure 6, during less traffic (10 nodes) performance of the AODV protocol is more stable compared to the higher traffic. The value of the packet delivery ratio for network space is given in table 5. Now, as traffic increases within the network space from 600m to 600m, it will be dropping more the packet. As node increase from 10 to 80 the packet delivery ratio of the modify random waypoint mobility (MRWM) and random waypoint model is also decrease from 99.036 to 10.97 and 99.37 to 18.86 respectively.

Packet Delivery Ratio

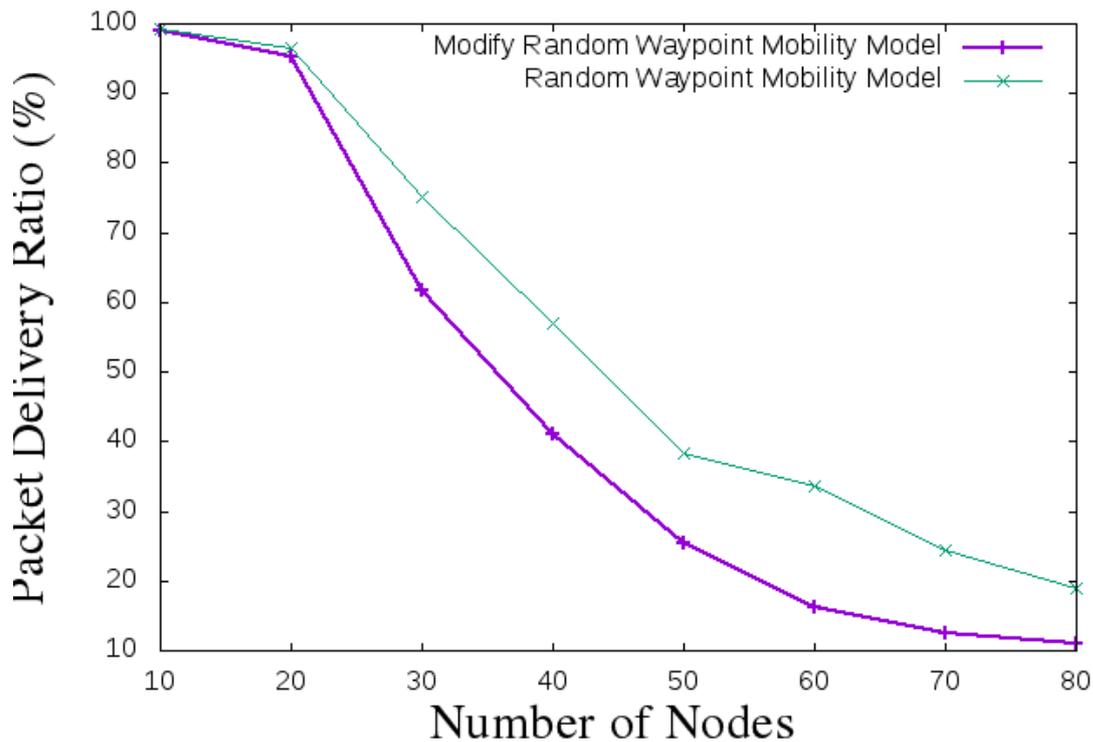


Figure 6: Packet Delivery Ratio for the modify random waypoint mobility model (purple colour with dash marker) and random waypoint model (green colour with cross marker) having a similar ratio of less number of nodes but vary for the greater number of nodes.

Table 5: Packet Delivery Ratio

Number of nodes	Packet Delivery Ratio	
	MRWM	RWP
10	99.036	99.37
20	95.253	96.47
30	61.741	75.16
40	41.093	57.00
50	25.416	38.36
60	16.301	33.73



70	12.415	24.31
80	10.97	18.86

End-to-End Delay: Average time required by all the data to deliver to their destination.

As traffic increases in a 100-node large network, the required end to end delay in modifying random waypoint mobility (MRWM) is higher compared to the random waypoint model. Due to the dynamic mobility, the Modify random waypoint mobility (MRWM) model packet routing path change more frequently compared to the random waypoint model. So, it increases the delay in the network to deliver the packet to the destination. From figure 7 and table 6, it concludes that as traffic increases (10 to 10 nodes) in the network the end-to-end delay of Modify random waypoint mobility (MRWM) and random waypoint model also increases from 0.044 to 7.844 and 0.04 to 7.53 respectively. At 80 traffic nodes, the delay in MRWM (7.844) model is larger at compared to the RWP (7.53).

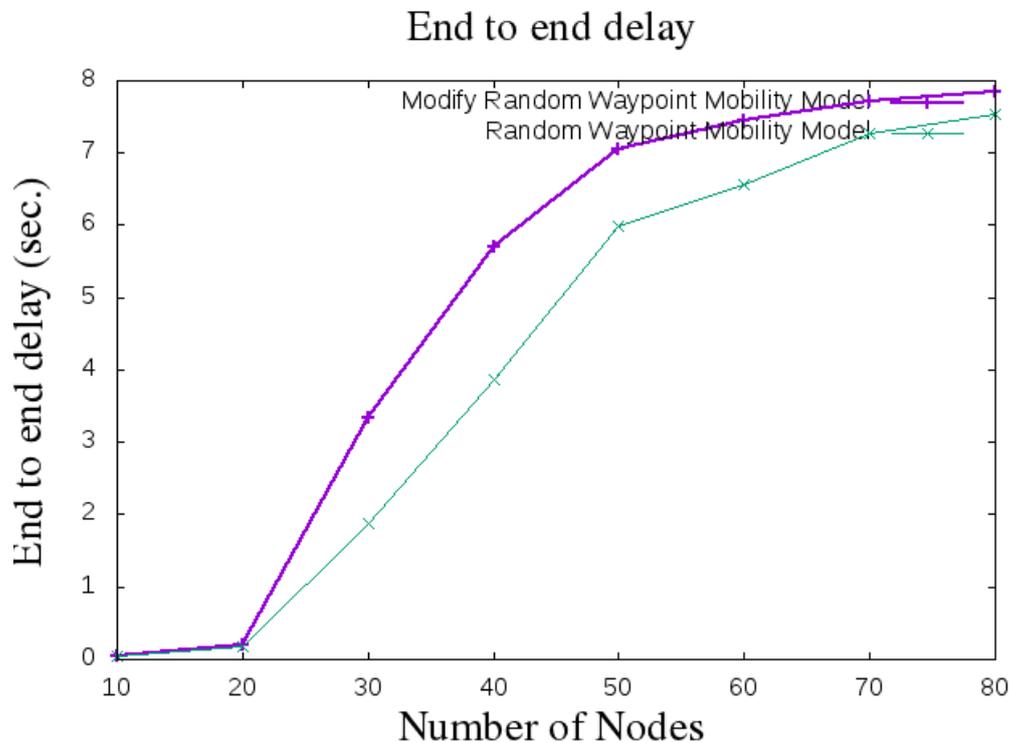


Figure 7: End to End Delay the modify random waypoint mobility model (purple colour with dash marker) and random waypoint model (green colour with cross marker)

Table 6: End to End Delay

End to End Delay		
Number of nodes	Modify random waypoint mobility (MRWM)	Random Waypoint Mobility (RWP)
10	0.044	0.04



20	0.198	0.17
30	3.344	1.88
40	5.705	3.87
50	7.048	5.98
60	7.450	6.56
70	7.720	7.27
80	7.844	7.53

6. Conclusion

In this study, we proposed Modify Random Waypoint Mobility (MRWM) model. The comparative analysis of the proposed model with random waypoint mobility (RWP) environment has been carried out on AODV protocol performance for the large mobile ad-hoc network (i.e.100 nodes) with the traffic increase in the network up to 80 nodes. The effect of the MRWM and RWP environment on AODV protocol has been analyzed with the performance metrics such as throughput, packet delivery ratio, packet dropping ratio, end to end delay and normalized routing overhead. As traffic increase from 10 to 80 nodes with 100 mobile nodes the AODV protocol throughput increase from 147.952 to 131.620 bits/sec and 148.52 to 177.31 bits/sec in MRWM and RWP respectively. Due to the dynamic mobility more, packet drop and less number of the packet deliver in MRWM compare to RWP. As more packets drop, to maintain the routing path protocol required to send more routing packets in the network so at 80 nodes traffic the NRO in 20.1124 & 11.718 in MRWM & RWP respectively. Also, increase the end-to-end delay in the network. From the comparative result, it concluded that the MRWM model mobility pattern more real-life mobility pattern compared to the RWP mobility model.

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Reference

- [1] Libert, Barry, Megan Beck, and Jerry Wind. The network imperative: How to survive and grow in the age of digital business models. Harvard Business Review Press, 2016.
- [2] S. Misra, I.Woungang, and S. C. Misra in (2009),Guide to Wireless Ad hoc Networks, Verlag London, UK, Computer Communication and networks Series, Springer.



- [3] Boukerche, A., Turgut, B., Aydin, N., Ahmad, M. Z., Bölöni, L., & Turgut (2011). Routing protocols in ad hoc networks: A survey. Elsevier Computer Networks Journal, Volume 55, Issue 13, 15, Pages 3032-3080, September 2011.
- [4] Shahzana Memon, Pardeep Kumar, Umair Ali Khan, Tanesh Kumar (2015). Performance Evaluation of Mobile Ad Hoc Routing Mechanisms," Springer Wireless Personal Communications, Vols. Volume 85, Issue 2, p. pp 377–392.
- [5] Shashi Gurung & Siddhartha Chauhan. (2018). A dynamic threshold based approach for mitigating black-hole attack in MANET. Spinger Journal-Wireless Networks.
- [6] T. Camp, J. Boleng, and V. Davies (2002). A survey of mobility models for ad hoc network research. Wireless Comm. and Mobile Computing (WCMC), 2(5):483–502.
- [7] Taher Delkesh & Mohammad Ali Jabraeil Jamali. (2019). EAODV: detection and removal of multiple black hole attacks through sending forged packets in MANETs. Journal of Ambient Intelligence and Humanized Computing volume 10, pages1897–1914.
- [8] Peter Ndajah, Abdoul Ousmane Matine & Mahouton Norbert Hounkonnou (2019). Black Hole Attack Prevention in Wireless Peer-to-Peer Networks: A New Strategy. International Journal of Wireless Information Networks volume 26, pages48–60.
- [9] Neenavath Veeraiah & B. Tirumala Krishna (2019). Trust-aware Fuzzy Clus-Fuzzy NB: intrusion detection scheme based on fuzzy clustering and Bayesian rule. Wireless Networks volume 25, pages4021–4035.
- [10] C. Bettstetter (2001). Smooth is better than sharp: A random mobility model for simulation of wireless networks. In Proceedings of MSWiM'01. ACM.
- [11] Aschenbruck, Nils, Aarti Munjal, and Tracy Camp. "Trace-based mobility modeling for multi-hop wireless networks." Computer Communications 34, no. 6 (2011): 704-714
- [12] Chiang, Kuo-Hsing, and Nirmala Shenoy, A 2-D random-walk mobility model for location-management studies in wireless networks. IEEE Transactions on vehicular technology 53, no. 2 (2004): 413-424.
- [13] Hernández-Orallo, Enrique, and Antonio Armero-Martínez, How Human Mobility Models Can Help to Deal with COVID-19. Electronics 10, no. 1 (2021): 33.
- [14] Carofiglio, Giovanna, Carla-Fabiana Chiasserini, Michele Garetto, and Emilio Leonardi. Route stability in MANETs under the random direction mobility model, IEEE transactions on Mobile Computing 8, no. 9 (2009): 1167-1179.
- [15] Roy, Radhika Ranjan, Boundless simulation area mobility, In Handbook of Mobile Ad Hoc Networks for Mobility Models, pp. 379-403. Springer, Boston, MA, 2011.
- [16] Meghanathan, Natarajan, Impact of the Gauss-Markov mobility model on network connectivity, lifetime and hop count of routes for mobile ad hoc networks, Journal of networks 5, no. 5 (2010): 509.
- [17] Gupta, Anuj K., Harsh Sadawarti, and Anil K. Verma, Performance analysis of MANET routing protocols in different mobility models, International Journal of Information Technology and Computer Science (IJITCS) 5, no. 6 (2013): 73-82.



- [18] Hossain, Md Shohrab, and Mohammed Atiquzzaman, Stochastic properties and application of city section mobility model. In GLOBECOM 2009-2009 IEEE Global Telecommunications Conference, pp. 1-6. IEEE, 2009.
- [19] Casella, Enrico, Marco Ortolani, Simone Silvestri, and Sajal K. Das. Hierarchical syntactic models for human activity recognition through mobility traces. *Personal and Ubiquitous Computing* 24, no. 4 (2020): 451-464.
- [20] Zheng, Q et al (2004). Recent Advances in Mobility Modeling for Mobile Ad Hoc Network Research. Recent advances in mobility modeling for mobile ad hoc network research. Pages 70–75 <https://doi.org/10.1145/986537.986554>.
- [21] Bettstetter, Christian. Mobility modeling in wireless networks: categorization, smooth movement, and border effects, *ACM SIGMOBILE Mobile Computing and Communications Review* 5, no. 3 (2001): 55-66.
- [22] Royer, Elizabeth M., and Chai-Keong Toh., A review of current routing protocols for ad hoc mobile wireless networks, *IEEE personal communications* 6, no. 2 (1999): 46-55.
- [23] Bai, F., Sadagopan, N., & Helmy, A. (2003, March). IMPORTANT: A framework to systematically analyze the Impact of Mobility on Performance of Routing protocols for Adhoc Networks. In *IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No. 03CH37428) (Vol. 2, pp. 825-835)*. IEEE.
- [24] Jardosh, Amit, Elizabeth M. Belding-Royer, Kevin C. Almeroth, and Subhash Suri. Towards realistic mobility models for mobile ad hoc networks. In *Proceedings of the 9th annual international conference on Mobile computing and networking*, pp. 217-229. 2003.
- [25] Chlamtac, Imrich, Marco Conti, and Jennifer J-N. Liu. Mobile ad hoc networking: imperatives and challenges. *Ad hoc networks* 1, no. 1 (2003): 13-64.
- [26] Manjeshwar, Arati, and Dharma P. Agrawal. TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks. In *ipdps*, vol. 1, p. 189. 2001.
- [27] Hong, M. Gerla, G. Pei and C.-C. Chiang (1999). A group mobility model for ad hoc wireless networks, in: *Proc. ACM International Workshop on Modeling, Analysis, and Simulation of Wireless and Mobile Systems (MSWiM)*, Seattle, WA.
- [28] J.G. Markoulidakis, G.L. Lyberopoulos, D.F. Tsirkas and E.D. Sykas (1997) Mobility modeling in third-generation mobile telecommunication systems, *IEEE Personal Comm.* 41–56.
- [29] The network simulator – ns-2 (June 2002). <http://www.isi.edu/nsnam/ns/>
- [30] Glomosim. (November 2002) <http://pcl.cs.ucla.edu/projects/glomosim/> .
- [31] S.R. Das, C.E. Perkins and E.M (2000). Royer, Performance comparison of two on-demand routing protocols for ad hoc networks, in: *Proc. IEEE InfoCom, Tel Aviv, Israel*.
- [32] G. Holland and N.H. Vaidya. (1999). Analysis of TCP performance over mobile ad hoc networks, in: *Proc. ACM International Conference on Mobile Computing and Networking (MobiCom)*, Seattle, WA.



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- [33] J. Broch, D. A. Maltz, D. B. Johnson, Y.-C. Hu, and J. Jetcheva (1988). A performance comparison of multi-hop wireless ad hoc network routing protocols. in Proceedings of the Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking(Mobicom98), ACM.
- [34] P. Johansson, T. Larsson, N. Hedman, B. Mielczarek, and M. Degermark, Scenario-based performance analysis of routing protocols for mobile ad-hoc networks, in International Conference on Mobile Computing and Networking (MobiCom'99), 1999, pp. 195--206.
- [35] CMU Monarch group, CMU Monarch extensions to the NS- 2 simulator (1988) <http://monarch.cs.cmu.edu/cmu-ns.html>