# Evaluating Radio Propagation Models Using Destination-Sequenced Distance-Vector Protocol for MANETs

Mahmood Khan, Muhammad Faran Majeed, Siraj Muhammad and Mah e No

***Abstract* — A mobile ad hoc network (MANET) comprises mobile nodes that can exchange data without an organized network architecture. Radio propagation models have important role in keeping the mobile nodes connected. Three radio propagation models that include shadowing model, free space model and two ray ground model are evaluated and analyzed as a core contribution. These models are implemented in MANETs environments in the light of changing traffic and mobility parameters. The effects of the different radio propagation models are analyzed over the destination-sequenced distance-vector (DSDV) routing protocol. In DSDV, the sequence numbers are used to maintain routes and new routes overcome the old routes when sequence numbers of the old routes become obsolete. To better understand the behavior of radio propagation models, simulations are conducted using Network Simulator-2. The metrics used in simulations include ratio of packet delivery, throughput, average delay, and packet drop ratio in a relation with the pause time and mobility parameters. The obtained results indicate that the two ray ground model is more suited for the DSDV protocol than the random waypoint model in terms of packet success ratio, data packets sent, throughput, and average network delay. Further, the model has a lower value for packets dropped than the Free Space and Shadowing models at higher pause times.**

***Index Terms* — Index Terms---DSDV, mobile ad Hoc network, NS-2, propagation model**

## I. INTRODUCTION

A mobile ad hoc network (MANET) has myriad characteristics such as it is an infrastructure-less network with the self-deployed and the self-configuring capabilities. This type of network is built on the fly and holds many advantages over other networks. A typical MANET is composed of a number of mobile nodes connected in a wireless mode that compose a transient network without bringing the use of any centralized administration or network infrastructure yet in a dynamic fashion [1]. Several protocols have been proposed to be used in such kind of network. Some of them are temporally ordered routing algorithm (TORA), ad hoc on-demand distance vector (AODV) and dynamic source routing (DSR) [2].

In order to perform routing, three major kind of ad hoc routing protocol exist: proactive (or table-driven), reactive and hybrid. The proactive routing protocols help the nodes to establish the routing paths before sending the data, instead being reestablished on demand. Further, the established routes are not changed for a longer time period until a major activity occurs such as link dropping or topological change, etc. While utilizing reactive routing protocols, the routes are established when required i.e., on demand. The discovery of the routes is temporary and are maintained until new routes are discovered. Reactive routing protocols tend to be efficient because they use minimal power and consume very little bandwidth and resources during data exchange. While, hybrid routing protocols have similar traits of both proactive and reactive routing protocols because they incorporate both. Hybrid routing protocols exhibit good performance in large networks of mobile nodes in combined cluster or grid pattern.

### A. *Destination-sequenced distance-vector (DSDV) routing protocol*

Destination-sequenced distance-vector (DSDV) is a kind of proactive routing protocol that is developed on the basis of Bellman–Ford algorithm [3]. With this protocol, sequence numbers are used to maintain routes and new routes overcome the old routes whose sequence number becomes obsolete. The destination node regenerates the sequence numbers and sends them to the source for data exchange. Incremental as well as full dumps are used to send the routing information. As DSDV has a proactive nature, there is a routing table update on every major change that can be in the form of link availability, addition or removal of a node, or accessibility to a network. This makes it infeasible for dynamic environments where the changes occur too frequently.

### B. *Radio propagation models*

Radio propagation models AKA radio frequency propagation models or radio wave propagation models are those models that propagate radio waves from one place to another. There are different kinds of radio propagation models that are utilized in wireless ad hoc networks. Some of the most famous models are discussed below:

#### 1) *Two ray ground model*

This model is the most famous and the most commonly used model. The energy received using this model is represented as the reflections paths between source and destination to the total of the direct line of sight paths. This model produces precise results and is efficient for communication of longer distance paths [4]. The two ray ground model can be defined through following equation.

$$P_r\,(d) = P_t G_t G_r\ (h_t h_r)^2 d^4 L \qquad (1)$$

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Where, $P_t$ is the power with which the signal is transmitted, $G_t$ denotes the gain of the antenna of the transmitter, $G_r$ is the antenna gain of the receiver, L denotes the loss system faces, $h_t$ denotes the height of the transmitter's antenna, and $h_r$ denotes the antenna height of the receiver, respectively.

*1) Free space model*

The free space model is utilized when the distance between the transmitter and receiver is limited. Further, the usage depends upon the clear line of sight between the receiver and the transmitter. Clearer the line of sight better the results. Following is the equation derived by Friis to calculate the power of a signal at a distance from the transmitter in free space [20]:

$$P_r\,(d) = P_t G_t G_r\ (\lambda)^2 d^4\,(4\pi^2)L \qquad (2)$$

Where, $P_t$ is the power of the transmitted signal, $G_t$ is the transmitter's antenna gain, $G_r$ is the receiver's antenna gain, L the loss system faces, and λ represents the wavelength.

*2) Shadowing model*

The shadowing model incorporates path loss in which the received signal's power is denoted by a mean value and a random variable with log-normal is used to denote the variation in the power of the received signal at a certain distance, also known as Gaussian distribution.

*C. Objective*

The main objective of this research is to perform comparative analysis of three propagation models using the DSDV routing protocol and the pause time mobility parameter with various metrics.

In the recent past, there have been thorough investigation and research done on mobile ad hoc networks and routing protocols by research and industrial community. Results of these researches not only provided new information but also indicated some new openings. Below, we present some of those works.

Hossain et al. [5] analyze the performance of the analytical model using Network Simulator-2 (NS-2) under shadowing effects on the network. The ratio of delivery of packets in the case of two ray ground model is better than that of the shadowing model. While, an abrupt decline in the value of probability in the shadowing model results in lower power as compared to decided threshold value. Hossain et al. presented an equation and state that ``the delivery ratio is directly proportional to the probability within the same rectangular area where the link distance virtually increases linearly with the rectangular area." Two solutions are suggested by them to overcome the shadowing effect: first, increment the retry limit of the protocol at MAC layer; second, increase the transmission power.

Kathirvel and Srinivasan [6] assess various routing protocols, specifically, the fish-eye state routing (FSR), the dynamic source routing (DSR), the zone routing protocol (ZRP) and the ad hoc on-demand distance vector (AODV) routing protocols, in the light of various propagation models. Two most important wireless channel characteristics are investigated by them: the shadowing and the path loss. The above mentioned protocols are compared in terms of end-to-end delay, packet delivery ratio, and jitter. The outcomes exhibit a high delivery ratio for reactive routing protocols such as DSR and AODV as a result of using the two ray model and free space path loss model, which does not use shadowing. Further, the results of comparative investigations reveal that the hybrid routing protocols encompass much higher packet success ratios and end-to-end delay values in the case of the free path loss model and no shadowing is constant for reactive routing protocols (for example, DSR and AODV). The results show that DSR and FSR have maximum and minimum delay for all kinds of traffic loads. There are higher end delays for proactive protocols also the jitter increases with pause time.

Matos and Miranda [7] evaluate various propagation models in MANETs in various scenarios. They compared the propagation models under various MANET routing protocols and created a network scenario that was different from that of wired network scenarios. They also conducted simulations in which they used three ad hoc routing protocols with various signal propagation models. The results obtained showed that the log-normal shadowing propagation model degraded the performance of all the protocols investigated. They also observed that a number of radio propagation models cause unpredictability that may jeopardize functioning of many protocols.

Raju and Mungara [8] propose an enhanced technique for improved quality of service (QoS) that uses a ZRP hybrid routing protocol. They compare DSR and AODV to ZRP, by estimating the delay in route acquisition and measuring the reconfiguration of routes, in case of link failure. They use QualNet simulator for performing simulations. Analysis of the results obtained indicate that ZRP had a low throughput in all the simulation sequences, making it not very competitive. Consequently to improve the effectiveness of ZRP, they propose an algorithm that indulge rapid reconfiguration of routes using multicast routing and selective border casting mechanisms during link failure situations. Further, it condenses acquisition delay by controlling query message packets, which in turn reduces the control overhead.

Vetrivela and Reddy [9] propose and implement a new mobility model for ad hoc networks called the move stop deviate (MSD) model. In this model, nodes adopt an arbitrary movement for the first 20 units without changing the tracks and then are stopped for a certain time period. After completing the time span, they diverge in an angular direction among distinct angles. For an instance, a node can only move in angles 0, 45, 90, 135, 180, 225, 270, 315 and the movement further continues until or unless it reaches the boundary. After that, node moves with the same velocity and speed, and travels incessantly in the same angle until it reaches the target. Same procedure is constantly repeated till the simulation ends. Various performance metrics are used to analyze this model, such as routing load, latency and delivery fraction under MANET routing protocols. The

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results of the simulation illustrate that there is a major impact due to usage of the MSD model on the operation of the routing protocols in ad hoc environments. The outcome also shows that the DSR performed effectively with the DSDV protocol.

A routing protocol for MANETs called the position and neighborhood based routing (PNR) is proposed by Ashtiani et al. [10]. To overcome the control overhead caused by the position update messages, global positioning system (GPS) is used in PNR. The comparison between PNR and other routing protocols such as AODV, DSR and optimized link state routing (OLSR) protocol is performed by authors in terms of end-to-end delivery and packet delivery ratio. GlomoSim is used to evaluate the efficiency of these protocols. The observations show that there is less end-to-end delay with high packet delivery ratio with PNR as compared to other protocols. PNR is almost equal to AODV when the constant bit rate (CBR) connections are increased. Also, if the CBR sources are increased the packet delivery is slightly changed in AODV. And in comparison to OLSR, PNR achieves better packet delivery ratio.

Khan and Qayyum [11] conduct simulations on NS-2 using the probabilistic Nakagami radio propagation model, which demonstrates the features of the fading effect in urban environments. The performance of the Nakagami propagation model is investigated under an extremely obstructed urban environment in light of the two routing protocols, OLSR and AODV. An urban scenario, depicting the conditions in the real world, is used. To generate the pattern of nodes' mobility, SUMO traffic simulator is used. Various metrics are tested under the two variants of OLSR. First, that contained the default TC and HELLO message interval values set. Second, messages with short time interval are set. One of the variants of OLSR set with frequent messages results in high delivery ratio and minimum delay with the default variant than AODV. However, the NRO of that OLSR's variant having higher messages frequency resulted better than its other variant. It is revealed that both routing protocols are incapable of conveying large number of packets under realistic channel conditions. The results of evaluations conducted of both routing protocols showed that the success ratio of their delivered packets was low. However, the performance of OLSR is better than AODV while sending frequent control messages in urban environment.

Sivaraman et al. [12] investigated various QoS metrics, such as delay, throughput, and packet delivery ratio (PDR), in varying network area dimensions. One of the major aims of their work is to analyze effect of various QoS metrics on density of nodes in MANETs. Different conditions are examined under which the nodes are moving to produce the better QoS. Simulations are performed to analyze the effects of terrain size and varying number of nodes. The results are presented in graphical format. The nodes move according to the RWP mobility model and to generate the traffic pattern, CBR traffic pattern is used. The obtained results may help other researchers to analyze better parameterization under better working environments.

Different radio propagation models are investigated under varying mobility pattern for MANETs in indoor environment by Lagar-Cavilla et al. [13]. With the help of simulations, authors argue that radio propagation models with most frequently used mobility models are inadequate for indoor conditions. The experiments are conducted using the DSDV and DSR routing protocols. The analysis show that the radio and mobility models affect the two protocols in very distinct ways. The performance varies unpredictably when parametric change occurs even when a single protocol is utilized. The authors emphasize that there is a need for more research with real implementation and evaluation of routing protocols with varying mobility models.

Nasir et al. [14] analyze various propagation models' effects over the DSR protocol in MANETs. They conduct simulations using NS-2, where they examine the performance of DSR using various models. They use average end delay, energy efficiency, normalized control load, and delivery fraction as performance metrics. Further, the propagation models are analyzed through pause time. The conclusions remark that, the free space and two ray propagation models have better packet success ratio, delay, and lower normalized control load than the shadowing model. Furthermore, in a comparison to other models, the shadowing model offers the lowest energy efficiency.

Schmitz and Wenig [15] presented a highly accurate propagation model called the photon propagation model. In simulations conducted using the NS-2 simulator, the model exhibited good performance for ad hoc networks in various scenarios. They evaluate the efficiency of the AODV considering indoor and outdoor scenarios. In indoor scenarios, the photon propagation model has higher delays, frequent route failure, low throughput, and extra routing overhead. The outcomes exhibit that the employing the two ray ground model, the AODV performed much differently than other model. In terms of throughput and delay, higher performance is achieved by the photon propagation model than the two ray ground model in outdoor scenarios.

Stepanov et al. [16] integrate the radio propagation model based on ray tracing. The authors make use of the geographical data of area simulated for propagation of waves using NS-2. They considered the realistic performance of MANETs in outdoor environments. The proposed model is feasible in outdoor scenarios for radio propagation. The authors also exhibit that the practice of using radio propagation models with simulated topologies is virtually sufficient for all common models.

Lagar-Cavilla et al. [17] examine the radio propagation models used extensively and a variety of node mobility models used in MANETs. Their analysis results indicate that these models are not efficient and robust in indoor environments. They also conduct simulations for two routing protocols for MANETs under propagation and mobility models. The results show that the effects on the nodes are not the same across protocols for the propagation and mobility models and change when parameter changes. The evaluations produce new information about the routing protocols in the light of mobility and propagation models.

A comparison of different routing protocols is performed by Ari et al. [18]. The authors compare the

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performance of AODV, DSDV, DSR and core-extraction distributed ad hoc routing algorithm (CEDAR) using different metrics under distinct network conditions. The analysis is based on bit-rates, traffic sources, pause times, area of topology, and different scenarios for mobility. The results show that DSR works efficiently as compared to other protocols under various conditions. DSDV also show low routing packet overhead when other protocols show high average delay with high routing overhead. However, the behavior of AODV is excellent in terms of throughput which is better than that of DSR, but has drawbacks such as delay with high routing overhead. ad and delay.

## II. RESEARCH METHODOLOGY

Our survey of the literature shows that much work has been conducted on MANETs in the light of various propagation models and also to enhance network efficiency different routing protocols are analyzed. The NS-2 simulations are conducted to analyze the traffic and mobility models, different propagation models, and routing protocols for MANETs. The propagation models are investigated in terms of changing pause times under different scenarios. The performance metrics used for the simulations are number of packets sent, number of packets dropped, packet success ratio, and average network delay. The obtained results of the simulations are plotted using MATLAB software.

Following is the research plan to achieve the objectives:

1. Thorough study of the MANET routing protocols in the latest research papers and books.
2. Assessment of literature in the broader view of the proposed research work.
3. Diagnosing routing anomalies in MANETs.
4. Prepare environment for simulation.
5. Install, compile, and configure NS-2 version ``nsallinone-2.35-RC5."
6. Prepare mobility scenarios for RWP model and for traffic CBR model using ``setdest" and ``cbrgen" tools.
7. Extract data from outcomes ``trace files" using the AWK and generate graphs in MATLAB.

### C. *Random waypoint mobility model (RWP)*

The RWP model is an entity-based model that considers unpredictable movements and sudden discontinuation. Different aspects, such as pause times, mobility speed, and change in direction or speed, are considered in RWP. The speed of the nodes is uniformly distributed between minimum and maximum when mobile nodes are selected for a destination that is random. The node pauses for a specified time span when reaches the destination. This time period is represented in the form of a uniform or constant time, for instance, in seconds [19]. After reaching its first destination, node selects a new destination and starts moving toward it. The process persists until the node reaches the last and ultimate destination. For the sake of simulation, the process lasts till the simulation lasts. By the end of simulation, the RWP helps the nodes to follow a zigzag mobility style and converge, disperse and converge again.

### D. *Tools used*

Various network simulation tools are available commercially, each with its own distinct traits to effectively simulate the desired scenario. Examples of such tools include NS-2, OPNET++, MATLAB, QualNet and GlomoSim. In our research, NS-2 is used for the performance evaluation and efficiency of the three propagation models using the DSDV routing protocol. A network animation (Nam) tool is used for generating layout of the topology and performing animations at packet level. To process the text data extracted from the simulations, AWK is used. At the end, MATLAB is used to perform mathematical calculations, creating pivot tables, and generating graphs used in our research.

## III. RESULTS AND DISCUSSION

The two ray ground model, the shadowing model and the free space model are evaluated on the basis of myriad mobility and traffic factors based on the performance metrics such as throughput, packet success ratio, packets sent, ratio of the packets dropped, and average network delay.

### A. *Scenario*

The scenario demonstrates the impact of varying pause time using different metrics mentioned aboves.

#### 1) *Varying pause time effects*

Figure 1 exhibits the packets sent and receive ratio for the two ray ground model, free space model and shadowing propagation model, all using DSDV. There are 50 nodes that move at a maximum speed of 10 m/sec with in an area of 670 m x 670 m. The chart represents the packet success ratios of two ray model, free space model and shadowing model that are virtually equal at 95% with a pause time of 200 sec. But, as the pause time approaches beyond 200 sec, the packet success ratio of free space model and shadowing model decreases as compared to two ray model. When no mobility approaches at 500 sec, the two ray model achieves highest success ratio with a 99% as compared to other models.

TABLE 1. PAUSE TIME VS. PACKET SUCCESS RATIO

| Pause Time (Maximum Speed 10 m/sec) | Two Ray Ground | Free Space | Shadowing |
|---|---|---|---|
| 200 | 94.47 | 94.88 | 94.20 |
| 300 | 94.57 | 93.22 | 92.43 |
| 400 | 96.48 | 95.31 | 95.35 |
| 500 | 99.22 | 95.42 | 95.69 |

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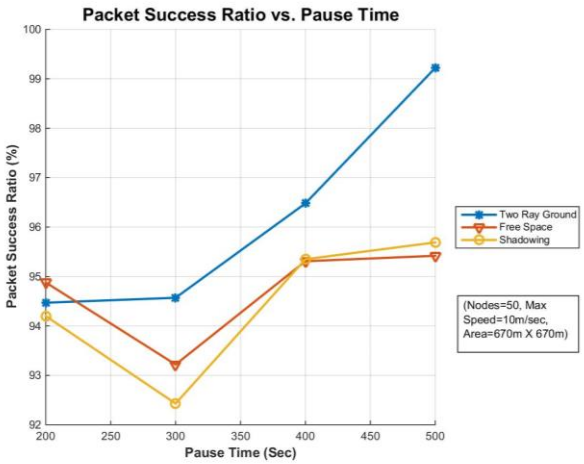


Fig. 1 Pause time in relation with packets success ratio for different models.

TABLE 2. PAUSE TIME VS. THROUGHPUT

| Pause Time (Maximum Speed 10 m/sec) | Two Ray Ground | Free Space | Shadowing |
|---|---|---|---|
| 200 | 1934 | 1912 | 1936 |
| 300 | 1917 | 1914 | 1895 |
| 400 | 1976 | 1973 | 1929 |
| 500 | 2057 | 1807 | 1888 |

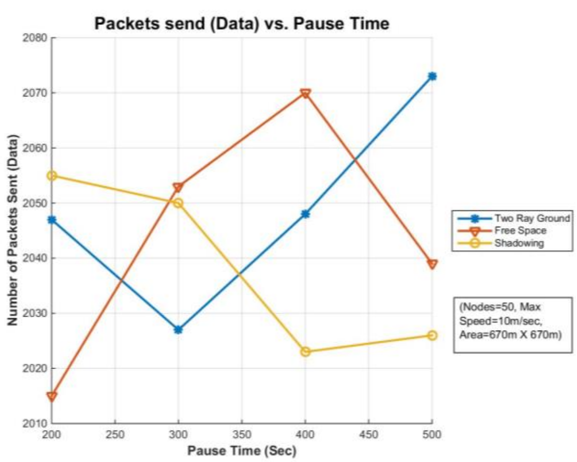


Fig. 2 Pause time in relation with packets success ratio for different models.

Figure 2 shows the effect of the varying pause time with throughput on the two ray ground model, the free space model and shadowing propagation models. The density of the node is 50 nodes moving at a maximum speed of 10 m/sec within and area of 670 m x 670 m. The graph exhibits that at the higher pause time the throughput of all propagation models is good, especially the two ray ground model has performed very impressive.

TABLE 3. PACKETS SEND (DATA) VS. PAUSE TIME

| Pause Time (Maximum Speed 10 m/sec) | Two Ray Ground | Free Space | Shadowing |
|---|---|---|---|
| 200 | 2047 | 2015 | 2055 |
| 300 | 2027 | 2053 | 2050 |
| 400 | 2048 | 2070 | 2023 |
| 500 | 2073 | 2039 | 2026 |

Figure 3 shows the relation between the pause time and the number of data packets sent for two ray ground model, the free space model and the shadowing propagation model. There are 50 nodes moving at a maximum speed of 10 m/sec within the same area of 670 m x 670 m. The chart exhibits that the packets sent by CBR sources is high when using free space model and the pause time is also high using two ray ground propagation models with distinct pause times that include time periods of 400 and 500 seconds, respectively, which results in high packets success ratio.

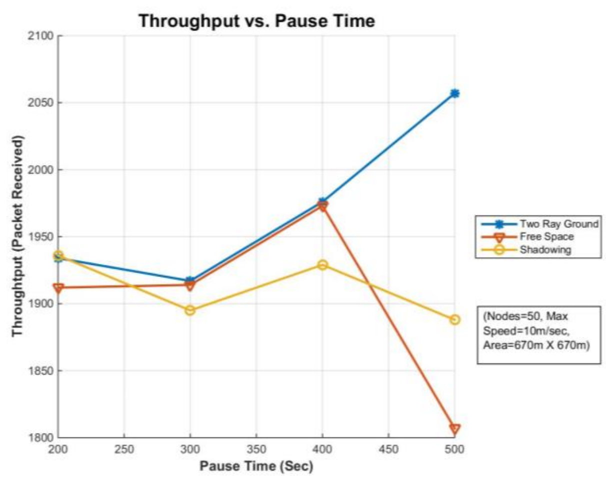


Fig. 3 The effect of pause time in a comparison with throughput on the two ray ground model, the free space model and the shadowing propagation model.

Figure 4 represents the pause time in a relation to the number of data packets dropped. The density of network nodes is 50 nodes moving at a maximum speed of 10 m/sec within the bounded area of 670 m x 670 m. It can be assumed from the graph that at any pause time, CBR sink drops more data packets if shadowing propagation model is used. However, the free space and two ray ground models have the lowest number of packets dropped during the simulation.

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TABLE 4 PAUSE TIME VS. PACKETS DROPPED (DATA)

| Pause Time (Maximum Speed 10 m/sec) | Two Ray Ground | Free Space | Shadowing |
|---|---|---|---|
| 200 | 229 | 182 | 344 |
| 300 | 215 | 258 | 455 |
| 400 | 146 | 194 | 383 |
| 500 | 24 | 331 | 554 |

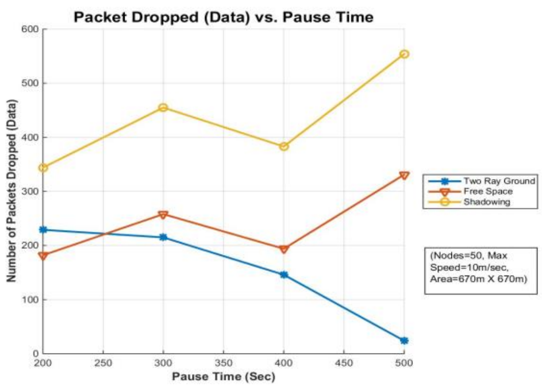


Fig. 4 Pause time in a relation to number of data packets dropped using different models.

Figure 5 represents the pause time in a relation with the average network delay for the two ray ground model, free space model and the shadowing propagation model. The network node density is 50 nodes within the bounded area 670 m x 670 m. It can be assumed from the graph that at any pause time, the shadowing model has higher average network delay than other models. Free space model also shows a slightly longer delay of 500 seconds at pause time. However, two ray model shows the least network delay at any pause time.

TABLE 5. PAUSE TIME VS. AVERAGE NETWORK DELAY

| Pause Time (Maximum Speed 10 m/sec) | Two Ray Ground | Free Space | Shadowing |
|---|---|---|---|
| 200 | 0.040 | 0.063 | 0.071 |
| 300 | 0.042 | 0.058 | 0.092 |
| 400 | 0.041 | 0.055 | 0.058 |
| 500 | 0.048 | 0.081 | 0.170 |

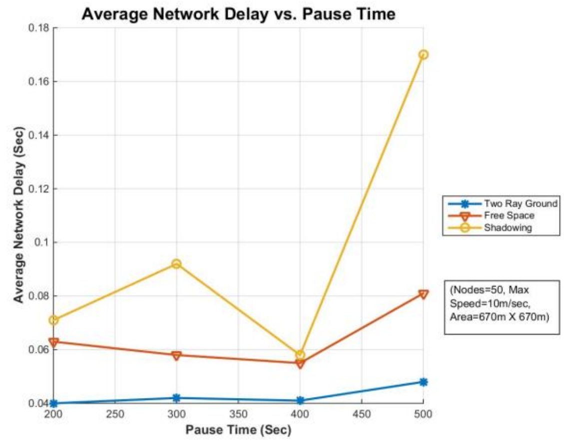


Fig. 5 Pause time in a relation with average network delay for the two ray ground model, free space model and the shadowing propagation model.

## V. CONCLUSION

This paper evaluated the effect of three Ad hoc wireless models (two way ground model, free space model and shadowing model) on the DSDV ad hoc routing protocol using the random waypoint mobility model. Outcomes show that these three models perform differently for the same mobility and traffic parameters. Increasing pause time improved the packet success ratio of all three models. The throughput of all propagation models is good at higher pause times especially that of the two ray ground model. The number of data packets sent by a CBR source is high at higher pause times when using the free space and two ray ground propagation models because of the good packets success ratio. Excessive packets are dropped by a CBR sink when it uses the shadowing propagation model at any pause time. However, during the simulation, the free space and two ray ground models show the least amount of packets drop. The average network delay is longer at any pause time when shadowing model is used, as compared to other models. Free space model also showed slightly longer delays at high pause times. However, the two ray ground model exhibited the lowest network delay at any pause time. The final conclusion of the conducted research can be summarized as the two ray ground and free space propagation models are feasible and suitable for the DSDV protocol and random waypoint mobility model with higher packet success ratio, average network delay, least packet drop ratio as compared to shadowing model, considering the urban environments with traits such as trees, buildings and hills.

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