The Impact of Different Radio Propagation Models for Mobile Ad hoc NETworks (MANET) in Urban Area Environment

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Abstract

Network simulation tools are frequently used to analyze performance of MANET protocols and applications. They commonly offer only simple radio propagation models that neglect obstacles of a propagation environment. The radio wave propagation model has a strong impact on the results of the simulation run. This work shows different radio propagation models into a simulation tool. The model is based on data of the simulation area in urban area. Consequently, we obtain different performance evaluation results. This paper gives insights on the effect of different propagation models for MANETs in indoor and outdoor environments and presents the parameters and the results of simulating using network simulator.
Key words: Mobile Adhoc Network, Propagation models, Mobility Models, Simulation.

1. Introduction

Mobile ad-hoc networks (MANETs) are created spontaneously by wireless communication peers, without relying on a fixed infrastructure. The devices communicate directly with each other when they are in transmission range. Network simulation tools [1], [2] are frequently used to analyze the performance of MANET protocols and applications. These tools model the applications running on mobile devices, the wireless network protocol stack, radio signal propagation, and the mobility of the network users. The radio propagation models used in common MANET simulators assume an obstacle-free area and a free line-of sight between all communicating partners. As a consequence, the communication range is modeled by a simple circle around the mobile device. However, this poorly reflects radio wave propagation in a typical outdoor scenario, like a city center, in which buildings significantly affect the communication between nodes. Nevertheless, the vast majority of publications that investigate MANET protocol and application behavior still rely on such simple models. Due to the nature of self-organization, the dynamic topology caused by mobility and transmission power control, and the multiple-hop routing in MANETs, it is difficult to build a complete analytical model to study the network performance. On the other hand, a real testbed is expensive. Therefore, the simulation study of MANETs is important. In this paper, we study different radio propagation models using ns-2 [2] because it is open source and is widely used in both academia and industry. In ns-2 the radio propagation models have the following features: the Friss-space model is used for short distances and the approximated two-ray-ground model is used for long distances. The shadowing model is employed to characterize the probabilistic multiple path fading during radio propagation. These models are considers data of the simulation area, which are available from urban environment. Radio propagation waves are necessary propagation characteristics for any configuration. The environments systems are intended to be installed are ranging from indoor up to outdoor environment. Hence wave propagation models are required covering whole range including indoor and outdoor environment scenarios. The phenomena which effect radio wave propagation can generally be described by five mechanisms as following; Reflection: is the abrupt change in direction of a wave front at an interface between two dissimilar media so that the wave front returns into the medium from which it originated. Reflecting object is large compared to wavelength. Scattering: is a phenomenon in which the direction (or polarization) of the wave is changed when the wave encounters propagation medium discontinuities smaller than the wavelength results in a disordered or random change in the energy distribution. Diffraction: is the mechanism that the waves spread as they pass barriers in obstructed radio path (through openings or around barriers).Diffraction is an important when evaluating potential interference between terrestrial and stations sharing the same frequency. Absorption is the conversion of the transmitted EM energy into another

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form, usually thermal. The conversion takes place as a result of interaction between the incident energy and the material medium, at the molecular or atomic level. One cause of signal attenuation due to walls, precipitations (rain, snow) and atmospheric gases. Refraction: is redirection of a wave front passing through a medium having a refractive index that is a continuous function of position or through a boundary between two dissimilar media. For two media of different refractive indices, the angle of refraction is approximated by Snell's Law known from optics penetration. Figure.1 shows these mechanisms. We use an existing implementation of the propagation model from a specialized tool. We prove that the usage of radio propagation models change simulation results considerably. The remainder of this paper is structured as follows. In Section II, we present mobility models. Section III gives an overview of different radio propagation models. Section IV describes the scenarios in urban area. Section V presents the description of simulation. Section VI illustrates the results .Section VIIconcludes this paper.

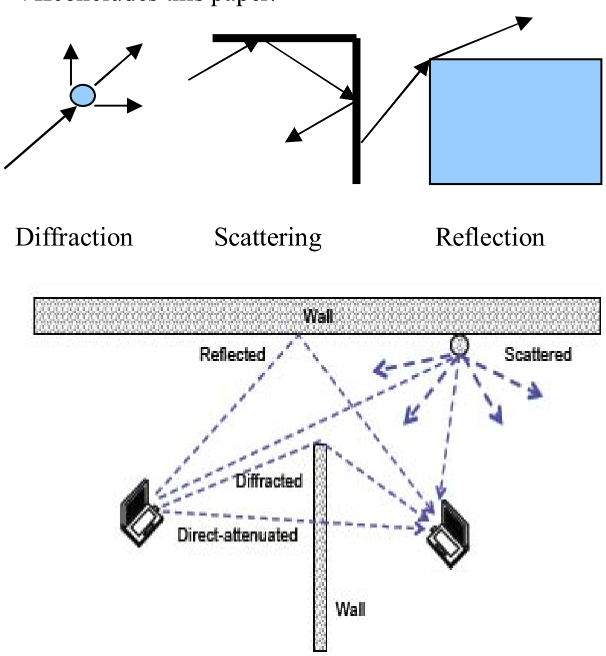

Fig.1, The phenomena effect radio wave propagation

2. Mobility Models

A mobility model is a representation of a certain real or abstract world that contains moving entities. A mobility model is usually used to describe the mobility of an individual subscriber. Sometimes it is used to describe the aggregate pattern of all subscribers. The following discussion attempts a brief overview of the two commonly used mobility models to analyze design systems in wireless ad hoc networks , each with a specific goal and suitable for a specific scenario. Random Way Point mobility model (RWP) [3] [4] [5] [6] is a simple, widely used, model in the many simulation studies of ad hoc routing protocols. In this model each node is assigned an initial position uniformly distributed within a region (rectangular region). Then, each node chooses a destination uniformly inside the region, and selects a speed uniformly from [minspeed, maxspeed] independently of the chosen destination. That means the distributions of nodes' speeds and locations are stationary. To avoid the transient period from the beginning, one solution is to choose the nodes' initial locations and speeds according to the stationary distribution; another one is to discard the initial time period of simulation to reduce the effect of such transient period on simulation results. The node then moves toward the chosen destination with the selected speed along a straight line starting from current waypoint. After reaching the destination, the node stops for duration called "pause time", and then repeats the procedure. All nodes move independently of each other at all times.

Manhattan model is used to emulate the nodes movement on streets defined by maps [4] [5]. The map is composed of a number of horizontal and vertical streets. Each street has two lanes, one in each direction (North and South for vertical streets, and East and West for horizontal ones). Each node is only allowed to move along the grid of horizontal and vertical streets. At an intersection of horizontal and vertical streets, a mobile node can turn left, or right, or go straight with probabilities 0.25, 0.25, and 0.5, respectively. The speed of a mobile node is temporarily dependent on its previous speed If two mobile nodes on the same freeway lane are within the Safety Distance (SD), the velocity of the following node cannot exceed the velocity of preceding node Mobility models capture the geographic restrictions**.** The speed of a node s (t) is updated accordingto:

$$s(t+1) = \min(s\max, \max(0, s(t) + a(t) * X))$$

where X Uniform [−1, 1], and a (t) is Acceleration Speed.

3. Different Radio Propagation models

Radio channels are much more complicated to analyze than wired channels. Their characteristics may change rapidly and randomly. There are large differences between simple paths with line of sight (LOS) and those which have obstacles like buildings or elevations between the sender and the receiver (Non Line of Sight (NLOS)). To implement a channel model generally two cases are considered: large-scale and

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small-scale propagation models. Large scale propagation models account for the fact that a radio wave has to cover a growing area when the distance to the sender is increasing. Small scale models (fading models) calculate the signal strength depending on small movements or small time frames. Due to multipath propagation of radio waves, small movements of the receiver can have large effects on the received signal strength. In the following, four frequently used models for the ns-2 network simulator are described in more detail.

3.1. Free Space Model

This is a large scale model. The received power is only dependent on the transmitted power, the antenna's gains and on the distance between the sender and the receiver. It accounts mainly for the fact that a radio wave which moves away from the sender has to cover a larger area. So the received power decreases with the square of the distance. The free space propagation model assumes the ideal propagation condition that there is only one clear line-of-sight path between the transmitter and receiver. H. T. Friis presented the following equation to calculate the received signal power in free space at distance d from the transmitter [7] [8] [9][10].

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where Pt is the transmitted signal power. Gt and Gr are the antenna gains of the transmitter and the receiver respectively. $L(L \geq 1)$ is the system loss, and λ is the wavelength. It is common to select $G_t = G_r = 1$ and $L = 1$ in *ns* simulations.

3.2. Two Ray Ground Model

The Two Ray Ground model is also a large scale model. It is assumed that the received energy is the sum of the direct line of sight path and the path including one reflection on the ground between the sender and the receiver. A limitation in ns-2 is that sender and receiver have to be on the same height. It is shown that this model gives more accurate prediction at a long distance than the free space model [7] [8] [9][10]. The received power at distance d is predicted by:

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4 L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where ht and hr are the heights of the transmit and receive antennas respectively. To be consistent with the free space model L is added here. The above equation shows a faster power loss than Eqn. (1) as distance increases. However, the two-ray model does not give a good result for a short distance due to the oscillation caused by the constructive and destructive combination of the two rays. Instead, the free space model is still used when d is small.

3. 3. Ricean and Rayleigh fading models

These two models are fading models, meaning that they describe the time-correlation of the received signal power. Fading is mostly caused by multipath propagation of the radio waves. If there are multiple indirect paths between the sender and the receiver, Rayleigh fading occurs. If there is one dominant (line of sight) path and multiple indirect signals, Ricean fading occurs [10].

3.4 . Shadowing model

The shadowing model of ns-2 realizes the log-normal shadowing model. It is assumed that the average received signal power decreases logarithmically with distance. A Gaussian random variable is added to this path loss to account for environmental influences at the sender and the receiver. The shadowing model consists of two parts. The first one is known as path loss model, which also predicts the mean received power at distance d, denoted by $\overline{P_r(d)}$ It uses a close-in distance d0 as a reference. $\overline{P_r(d)}$ is computed relative to $P_r(d_0)$ as follows.

$$\frac{P_r(d_0)}{P_{r(d)}} = \left(\frac{d}{d_0}\right)^{\beta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

β is called the path loss exponent, and is usually empirically determined by field measurement. From Eqn. (1) we know that β = 2 for free space propagation. Table.1 gives some typical values of β larger values correspond to more obstructions and hence faster decrease in average received power as distance becomes larger. $P_r(d_0)$ can be computed from Eqn. (1). The path loss is usually measured in dB. So from Eqn. (18.4) we have

$$\left[\frac{\overline{P_r(d)}}{P_r(d_0)}\right]_{dB} = -10\beta \log\left(\frac{d}{d_0}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The second part of the shadowing model reflects the variation of the received power at certain distance. It is a log-normal random variable that is; it is of Gaussian distribution if measured in dB. The overall shadowing model is represented by

$$\left[\frac{P_r(d)}{P_r(d_0)}\right]_{dB} = -10\beta\log\left(\frac{d}{d_0}\right) \text{..............} (5)$$

Where X_{dB} is a Gaussian random variable with zero mean and standard deviation σ_{dB}. σ_{dB} is called the shadowing deviation, and is also obtained by measurement. Table.2 shows some typical values of σ_{dB} (dB). Eqn. (5) is also known as a log-normal shadowing model. The shadowing model extends the ideal circle model to a richer statistic model: nodes can only probabilistically communicate when near the edge of the communication range [7] [8] [9][10].

Table.1, Some Typical values of path loss β

Environment		β
Outdoor	Free space	2
	Shadowed urban area	2.7 to 5
In building	Line-of-sight	1.6 to 1.8
	Obstructed	4 to 6

Table.2 Some Typical values of shadowing deviation σ_{dB}

Environment	σ_{dB} (dB)
Outdoor	4 to 12
Office, hard partition	7
Office, soft partition	9.6
Factory, line-of-sight	3 to 6
Factory, obstructed	6.8

4. Description of Urban Area Scenarios

To evaluate the impact of the radio wave propagation model on the performance of a Mobile Ad Hoc Network the throughput and delay of multiple constant bit rate (CBR) streams is taken as an indicator. Measurements conducted by several researchers show that most simulators give too good values for these metrics. So any prediction derived from this simulation that concerns real networks is based on false assumptions. In this work, two scenarios are simulated in detail. They represent very different working environments. One is an indoor scenario with low mobility. The second one is an outdoor scenario simulating pedestrian walking through a city. This scenario is characterized by hostile environment for radio waves. Both scenarios share some similarities: Network traffic is created by starting CBR connections between randomly selected nodes. The simulation duration is 900 sec.This section introduces scenarios of urban area environment which is divided in two parts as following:

-Indoor scenario

The indoor scenario is conducted on a simulation area whose layout shown in fig.1. For this layout a map with 2D and some measurements of the radio signal strength exists on an area of 1000m × 1000m. The movement for the nodes is created using random waypoint model. Nodes moving inside building have a very low mobility. Their pause time is equally distributed. The movement speed is distributed uniformly. The number of nodes in a scenario is ten. The maximum number of CBR connections is set to ten; the offered load per connection is 512Byte/s.

-Outdoor scenario

The outdoor scenario is based on the street map of city, when the nodes are on the street, they move as Manhattan mobility model movement pattern. The Buildings act as obstacles for the radio waves and narrow streets may act as wave guides. Buildings have high attenuation but do not completely block the signal. The movement nodes are divided in two groups depending on their speed a "pedestrian" group with a low speed and a "vehicular" group with a higher speed. The pedestrian group of users is moving with a normal distributed speed with a mean of 3 km/h and a standard deviation of 0.3 km/h [4]. The vehicular group of users has also a normal distributed speed but with a mean of 50 km/h and a standard deviation of 2.5 km/h. At each cross-road, users of both groups have can either continue straight with the probability Pr (straight) = 0.5 or turn left/right with the probability Pr (right) = Pr (right) = 0.25. In this paper the area is wrapped around North-South and West-East and the grid is composed of 3 by 3 buildings. The buildings are 300x300 m and the street has two opposite lane, the distance between lane 1 m and the width of lane 6 meter. The movements of a node switch from one mobility model (Manhattan or Random Waypoint) to another based on its location in urban environment.Fig.2 shows the movement of nodes in simulation area using Manhattan and Random Waypoint mobility models.

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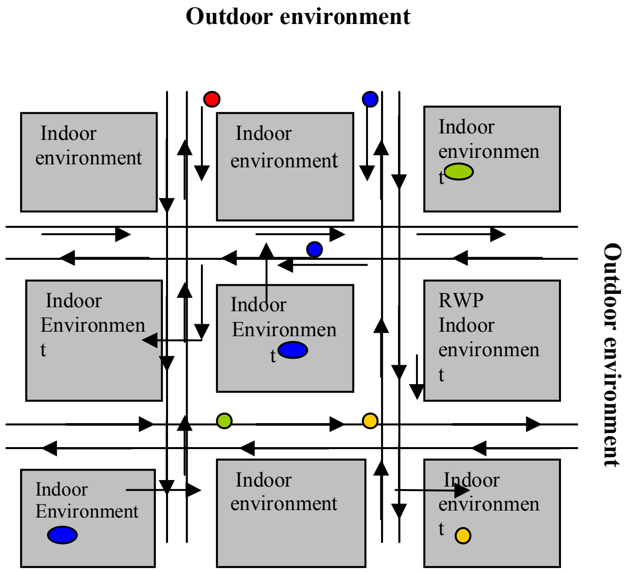

Fig.2, Layout of Urban environment

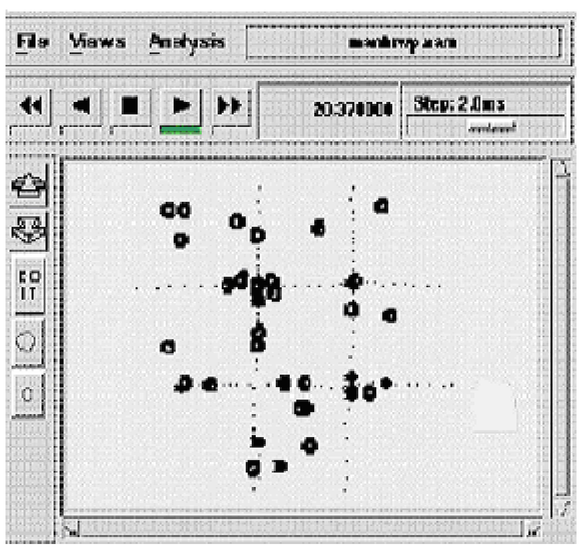

Fig.3, Movement of Nodes in Simulation Field using Manhattan and Random Waypoint

5. Simulation Description

A variety of matrices have been used for the MANET environment. In this section, we study the most popular propagation models, Free Space model, TwoRayGround model, and Shadowing model in the environments where MH and RWP exist. Our evaluations are based on the simulation using Network Simulator (NS-2) environment with CMU wireless adhoc networking extension [7] and we extract the useful data from trace file using mobility trace analyzer tool (version 1.0 beta) [8], then the graphs are generated using Matlab.Simulation environment consists of 10 wireless nodes forming an ad hoc network, moving over a 1000 X 1000 flat space, AODV routing protocol for 900 seconds of simulated time. Each run of the simulator accepts as input a scenario file that describes the exact motion of each node and the exact sequence of packets originated by each node, together with the exact time at which each change in motion or packet origination is to occur. We have generated different scenario files with varying movement patterns and traffic loads (CBR), the traffic consist of cbr type with 10 connections, data rate 1 packet/sec, packet size 512 byte and the transmission range 250m. And then ran against each of these scenario files. When Nodes in street move according to manhattan model otherwise they move according to Random Waypoint model. The movement scenario files we used for each simulation are characterized by a max speed. Each simulation ran for 900 seconds. We ran our simulations with movement patterns generated for 6 different maximum speeds, 10, 20, 30, 40, 50, 60 m/sec with constant pause time 2.0 sec.

6. Simulation Results

The analysis of simulation results is performed based on the standard metrics of number of sent packets, throughput, number of dropped packets, packet delivery ratio and packet routing overhead between different radio propagation models. We conducted our simulations on changing the parameters for mobile nodes' movement scenarios and their connection pattern files. We supposed different speed and pause time for movement scenarios files. The results are divided into two subsections: performance with varying pause time and performance with varying velocity.

Performance with varying velocity:

Figure.3 indicates that shadowing model sends very few packets and free space model send high packets. Figure.4; shows that free space and two ray ground models are better performance than shadowing model when throughput is considered as metric .In contrast, shadowing radio propagation model drops few packets as shown in figure.5, although the results indicate that its throughput is lower than other radio propagation models. Figure.6 evaluates the reliability of packet delivery ratio. In comparison to free space and two ray

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ground radio propagation models, the results in Figure.6 indicate that shadowing radio propagation model is low with respect to the measured delivery rate over a variety of velocities. Our results in Figure 7 show that free space and two ray ground perform consistently well with respect to routing overhead over a variety of velocities.

Performance with varying pause time:
Figure.8 gives approximately the same result as in figure.3 for all propagation models. Figures.9, 11 show that free space and two ray ground models relatively do the same performance when throughput and delivery rate are considered as metrics over a variety of velocities. Figure.10 indicates that free space drops more packets over a variety of pause times. Our results in Figure12 show that free space and two ray ground perform the same result as for different speed with respect to routing overhead but shadowing model has more routing overhead.

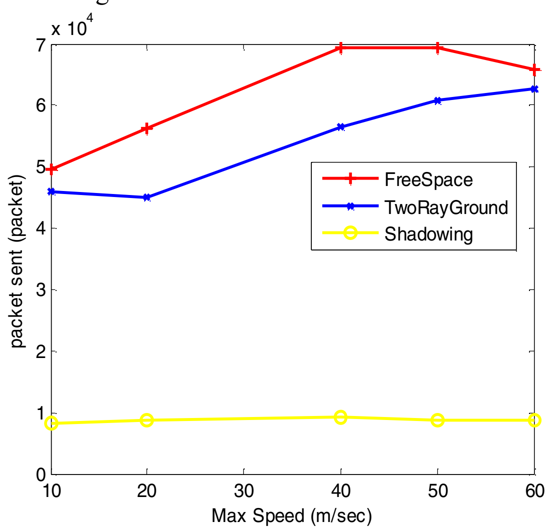

Fig.3, Packet sent vs. speed

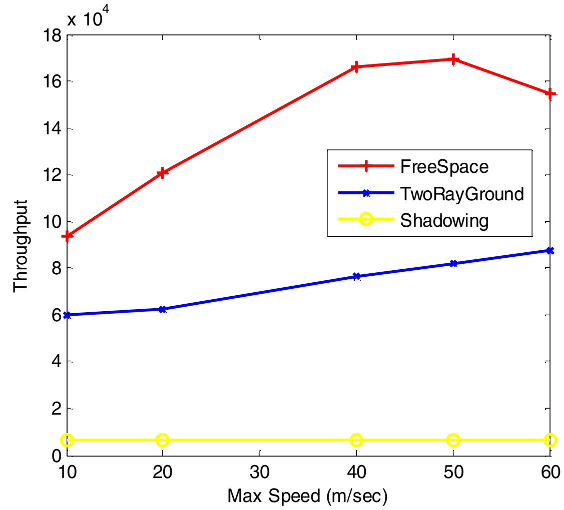

Fig.4, Throughput vs. speed

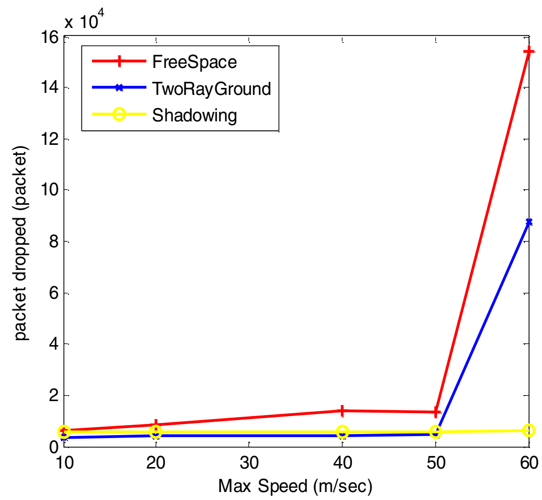

Fig.5, Packet dropped vs. speed

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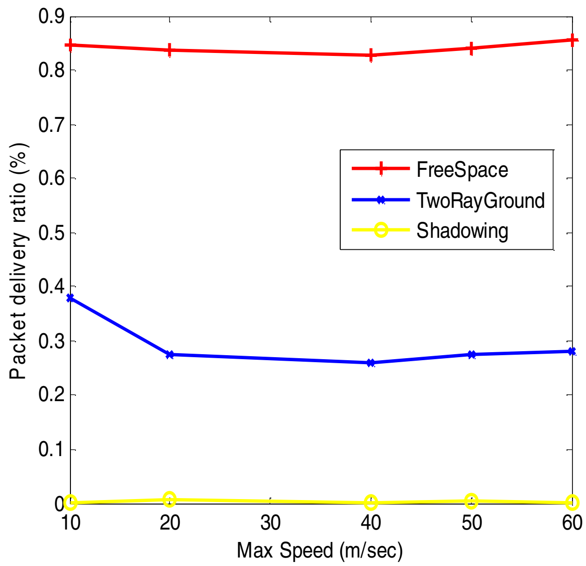

Fig.6, Packet delivery ratio vs. speed

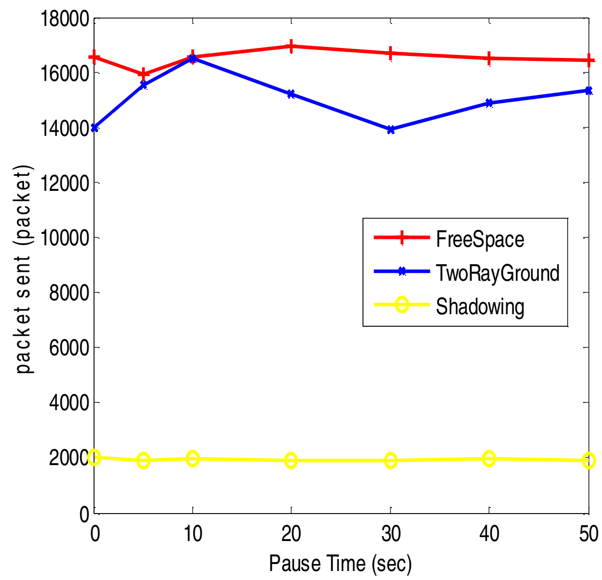

Fig.8, Packet sent vs. pause time

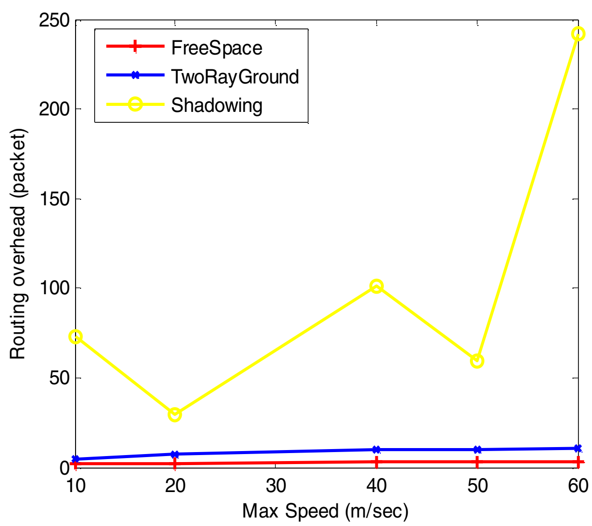

Fig.7, Routing overhead vs. speed

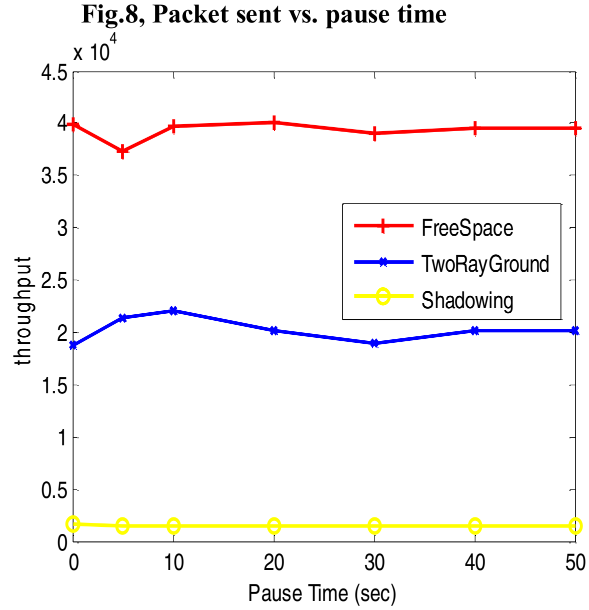

Fig.9, Throughput vs. pause time

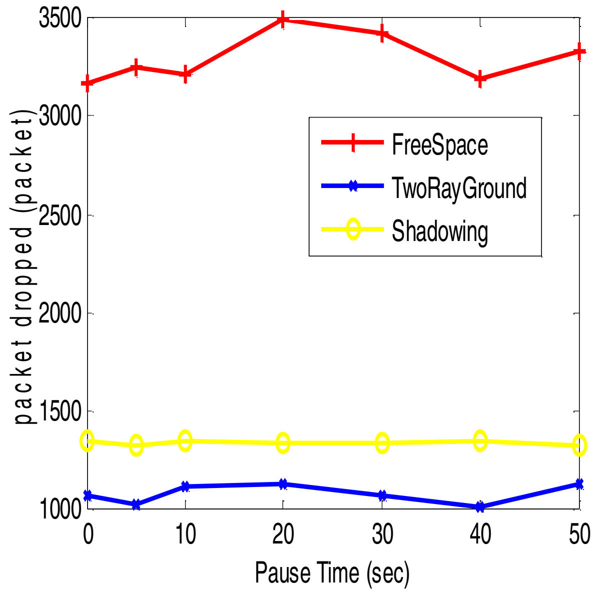

Fig.10, Packet dropped vs. pause time

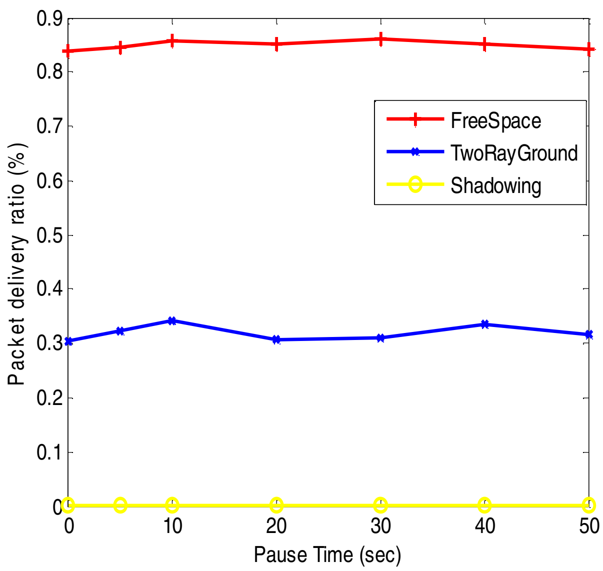

Fig.11, Packet delivery ratio vs. pause time

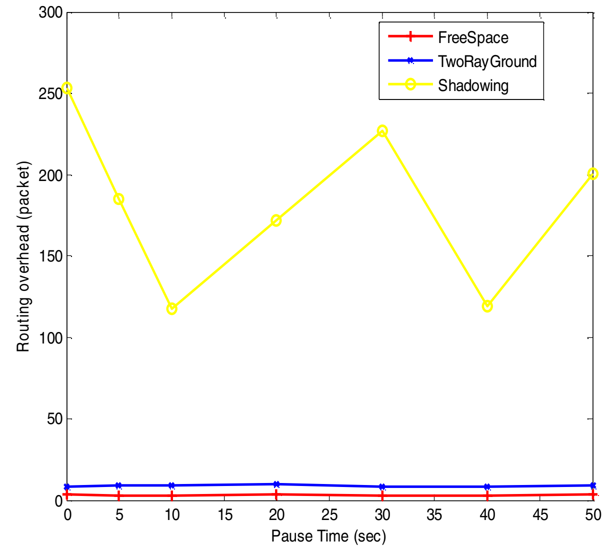

Fig.12, Routing overhead vs. pause time

7. Conclusion

This work presented a radio wave propagation models showed how these models affect the performance of Mobile Ad Hoc Networks in urban area. We present the options available and provide the parameters used in the creation of scenarios for indoor and outdoor environments in an urban environment. We showed the effect of radio propagation models for wave propagation into ns-2. We demonstrated that the usage of more accurate radio propagation model changes simulated topologies considerably between commonly used propagation models. Consequently, we obtain different performance evaluation results. We compared radio propagation models performance variety of metrics, Packets sent, throughput, dropped packets, Packet Delivery Ratio, and packet routing overhead. For movement scenarios case, we supposed maximum speed and pause time. Researchers must be aware of significant difference between the real connection topologies and the topologies obtained with simple models offered by MANET simulation tools. For obtaining quantitative performance evaluation results in the target area, more accurate radio propagation models need to be used.

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