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13 - 16

Performance Analysis and Comparison of various Radio Propagation models and its impact on Routing Efficiency

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Abstract— In this paper, we will do comparison of outdoor and indoor propagation model such as Hata model, Friis propagation model, Nakagami model etc. the propagation model is use to determine the wireless signal strength at the set of receivers for any packet being transmitter by a single transmitter. Infect, the ns–3 simulator presently has 11 different loss models included in the simulator library. Study of these models and comparing their overall performance. This will be done using ns-3 simulator and impact of Routing efficiency on these Radio Propagation Models according to the nature of environment will be studied.

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I. Introduction

A wireless network simulation is the appropriate choice of the Propagation Loss Model to be used to model the performance of a wireless network channel or set of channels. These models are needed in order for the simulator to compute the signal strength of a wireless transmission at the receiving stations which in turn is required to determine whether or not each of the potential receivers can in fact receive the information without bit errors. Each of these models requires different attributes for computation to determine the relative signal strengths at each of the receivers, and correspondingly each of the models have differing levels of accuracy and have different impact on routing efficiency.

The ns–3 simulation tool has 23 different loss models included in the distribution. We categorize those loss models into two groups:

1) Loss models in the first category model the deterministic path loss over the distance from sender to receiver.
2) The second category includes fading models. A stochastic fading process is intended to be applied on top of a path loss model in order to account for the non-deterministic effects caused by moving objects.

Each of these models will be studied based on its nature in outdoor and indoor environments and its impact on routing efficiency. The goal of this work is to categorize each of these ns-3 models in terms of variation in measured results and comparing all the models to see which have better routing efficiency.

II. Previous Work

Previous work performed a detailed study of these models, comparing their overall performance both in terms of the computational complexity of the algorithms, as well as the measured performance of the wireless network being simulated. They focus on the relative computational complexity for each of the models (in terms of computation time per packet transmitted), and report on the variations we observed in measured results. We do not comment on relative accuracy of the measured results of these models, since different models are design to model different environments. It focuses on for 11 models which is supported by ns-3.

III. Literature Survey

Mirko Stoffers and George Riley in paper “Comparing the ns-3 propagation models” compare the ns-3 propagation models in order to study their computational complexity with their default parameters and variation in measured result .They conclude that most of the abstract models won’t work at all with default parameters of ns-3. Nevertheless, for most purposes path loss models are the best choice. All thought they are more computationally complex than the abstract models.

A survey paper “Propagation Models for Next Generation Networks in NS-3” By: Nandini Prasad K S1, Priyanka S P2 Discuss various propagation model in ns-3. Models considered are: FRIIS Propagation Loss Model, Log Distance Model, Jakes Propagation Loss Model, Nakagami Propagation Loss Model, COST-231.

IV. Proposed Work

The main focus of this work is to study the various propagation models supported by ns-3 and its impact on routing efficiency for different environments. Realistic simulating of studying the impact of routing efficiency based on nature of environment is our goal of research. All outdoor and indoor radio propagation models will be compared and analyzed accordingly to model nature’s phenomena. It also includes defining the radio range by using the respective radio propagation models. The ns-3 simulation platform has an implementation of 11 different propagation models for predicting path loss behavior. They are as follows:

A. Friis Propagation Loss Model:

The Friis gives the power received by one antenna under idealized conditions given another antenna some distance away transmitting a known amount of power. The formula was

ISSN: 2321-8169
13 - 16

derived in 1945 by Danish-American radio engineer Harald T. Friis at Bell Labs. In its simplest form, the Friis transmission equation is as follows. Given two antennas, the ratio of power available at the input of the receiving antenna, Pr, to output power to the transmitting antenna, Pt, is given by

Pr/Pt = Gt Gr $\left(\lambda/4\pi R\right)^2$

Where Gt and Gr are the antenna gains (with respect to an isotropic radiator) of the transmitting and receiving antennas respectively, lambda is the wavelength, and R is the distance between the antennas. The inverse of the third factor is the so-called free-space path loss. To use the equation as written, the antenna gain may not be in units of decibels, and the wavelength and distance units must be the same. If the gain has units of dB, the equation is slightly modified to:

Pr = Pt + Gt + Gr + 20 (Gain has units of dB, and power has units of dBm or dBW)

B. Log Distance Propagation loss Model:

The log-distance path loss model is a radio propagation model that predicts the path loss a signal encounters inside a building or densely populated areas over distance. Log-distance path loss model is formally expressed as:

$$PL = P_{Tx(dBm)} - P_{Rx(dBm)} = PL_0 + 10\Upsilon \log_{10}(d/d0) + X_g$$

Where

PL is the total path loss measured in Decibel (dB)

$P_{Tx(dBm)} = 10\log_{10}\frac{P_{Tx}}{1mW}$ is the transmitted power in dBm, where P_{Tx} is the transmitted power in watt.

$P_{Rx(dBm)} = 10\log_{10}\frac{P_{Rx}}{1mW}$ is the received power in dBm, where P_{Rx} is the received power in watt.

PL_0 is the path loss at the reference distance d0.(dB)

D is the length of the path.

d is the reference distance, usually 1 km (or 1 mile).

gamma is the path loss exponent.

C. Jakes Propagation Loss Model:

The Jakes propagation loss model implemented here is described and we call path the set of rays that depart from a given transmitter and arrive to a given receiver. No attributes are defined in jakes propagation model.

Given as:

$$R(t,k) = \sqrt{2/M}\sum_{n=1}^{M} A_k(n)(\cos\beta_n + j\sin\beta_n)\cos(2\pi f_d t\cos\alpha_n + \theta_n)$$

D. Nakagami Propagation Loss Model:

Nakagami-m is a fast fading propagation loss model. The Nakagami-m distribution is applied to the power level. The Nakagami distribution or the Nakagami-m distribution is a probability distribution related to the gamma distribution. It has two parameters: a shape parameter m and a second parameter controlling spread, omega.

The Nakagami distribution is related to the gamma distribution. In particular, given a random variable **Y~Υ (k, θ),**, it is possible to obtain a random variable **X~Nakagami (m, ω)**, by setting **k=m,θ ω/** m , and taking the square root of **Y:**

$$X = \sqrt{Y}$$

The Nakagami distribution f(y; m, Omega) can be generated from the chi distribution with parameter k set to 2m and then following it by a scaling transformation of random variables. That is, a Nakagami random variable X is generated by a simple scaling transformation on a Chi-distributed random variable $Y \sim \chi(2m)$ as below:

$$X = \sqrt{(\omega/2m)}\, Y$$

E. Cost-231 Hata Propagation Loss Model:

The COST Hata model is a radio propagation model that extends the urban Hata model (which in turn is based on the Okumura model) to cover a more elaborated range of frequencies. It is the most often cited of the COST 231 models.

The COST Hata model is formulated as,

$$L = 46.3 + 33.9\log f - 13.82\log h_B - a(h_R) + [44.9 - 6.55\log h_B]\log d + C$$

For suburban or rural environments:

$$a(h_R) = (1.1\log f - 0.7)h_R - (1.56\log f - 0.8)$$

C = 0 dB {for medium cities and suburban areas}

3 dB {for metropolitan areas}

Where,

L = Median path loss (dB)

F = Frequency of Transmission (MHz)

h_B= Base station antenna effective height (m)

d = Link distance (km)

h_R=Mobile station antenna effective height (m)

$a(h_R)$ = Mobile station antenna height correction factor as described in the Hata model for urban areas.

F. *Two Ray Ground Model*:

2-ray Ground Reflected Model is a radio propagation model that predicts path loss when the signal received consists of the line of sight component and multi path component formed predominately by a single ground reflected wave.

In logarithmic units:

$$P_{r(dBm)} = P_{t(dBm)} + 10\log_{10}(G h_t^2 h_r^2) - 40\log_{10}(d)$$

Path loss:

$$PL = P_{tdBm} - P_{rdBm} = 40\log_{10}(d) - 10\log_{10}(G h_t^2 h_r^2)$$

V. Simulation Result

The simulation has been performing for Friis propagation loss and log distance propagation loss model. In order to study the

ISSN: 2321-8169
13 - 16

variation of received power with respect to distance and to obtain carrier sense range by considering default parameters for the Attributes and following graph has been obtained:

1. Friis Propagation Loss Model

Friis equation holds in far field region, where the propagating waves act as a plane waves and the power decay inversely with distance.

Carrier sense range is a physical parameter for a wireless radio. Carrier sense range is determined by the transmission power threshold and path loss of signal power.

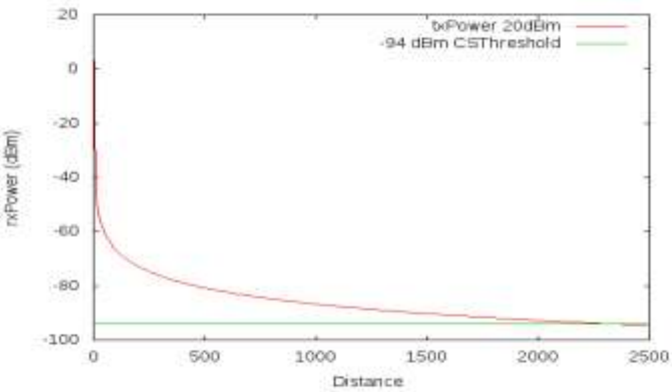

FIGURE 1. Received Power Vs Distance

The above graph indicate that the received power decay as negative square root of distance whereas CSThreshold is uniform throughout.

2. Log Distance Propagation Loss Model

This model indicates that average received signal power decreases logarithmically with distance, whether in indoor or outdoor radio channels.

Path loss exponent indicates the rate at which the path loss increases with distance.

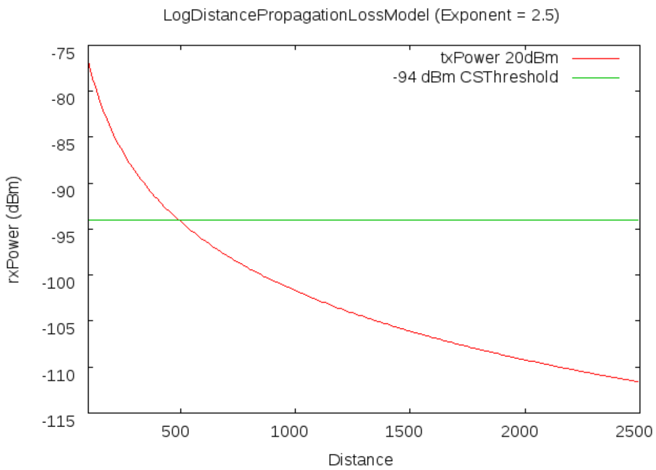

FIGURE 2. Received Power Vs Distance

The above graph indicate that the received power decreases logarithmically with distance and CSThreshold region is higher compare to Friis loss model.

3. Three Log Distance Loss Model in Two Plane

This model indicates that average received signal power decreases logarithmically with distance, whether in indoor or outdoor radio channels.

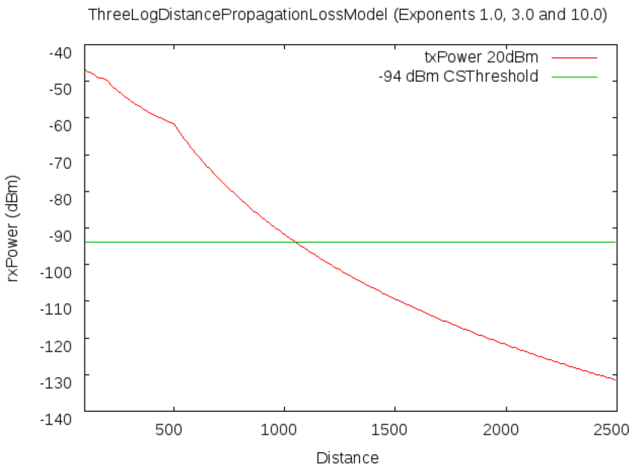

FIGURE 3. Received Power Vs distance

The above graph indicate that the received power decreases logarithmically with distance and CSThreshold region is higher compare to Friis loss model

4. Three Log Distance in 3 Plane

This model indicates that average received signal power decreases logarithmically with distance, whether in indoor or outdoor radio channels.

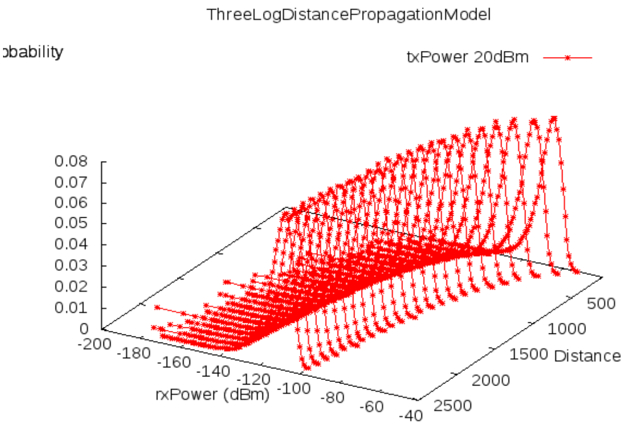

FIGURE 4. Received Power Vs Distance

The above graph indicates variation of local averages in dB of received power (or path loss) tend to be Gaussian when the ensemble is all Tx-Rx locations with the same distance in the same type of environment.

5. Random Propagation Loss Model with Exponential Distribution

This model is supported by Ns-3. This model is only used for indoor environments.

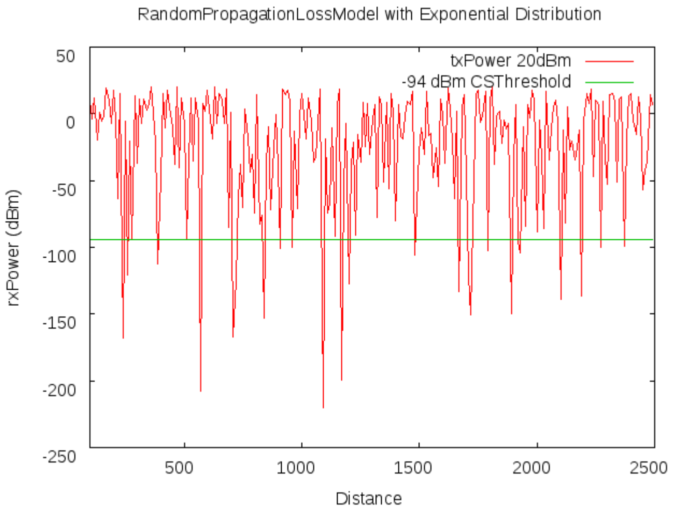

FIGURE 5. Received Power Vs Distance

The above graph indicates that the received power is fluctuating and it is difficult to obtain exact received power for a particular distance whereas, CSThreshold is constant.

6. Nakagami Propagation Loss Model

It is a generalized distribution which can model different fading environments. It has greater flexibility and accuracy in matching some experimental data than the Rayleigh, lognormal or Rice distributions. Rayleigh and one-sided Gaussian distribution are special cases of Nakagami-m model.

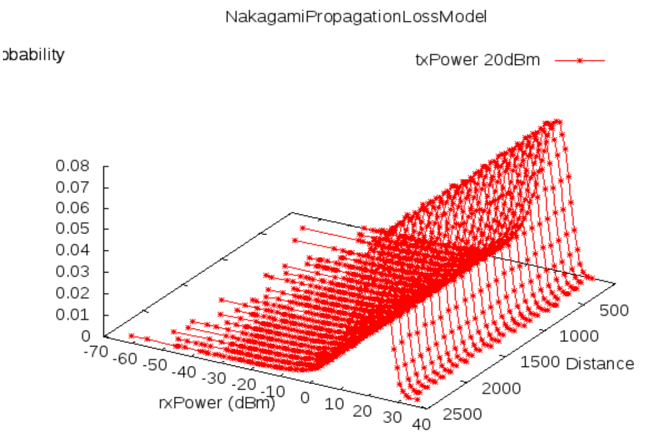

FIGURE 6. Received Power Vs Distance

The above graph is similar to probability density function graph since it is based on gamma distribution. It also indicate that received power is decaying with respect to distance.

7. Three Log Distance And Nakagami Propagation Loss Model

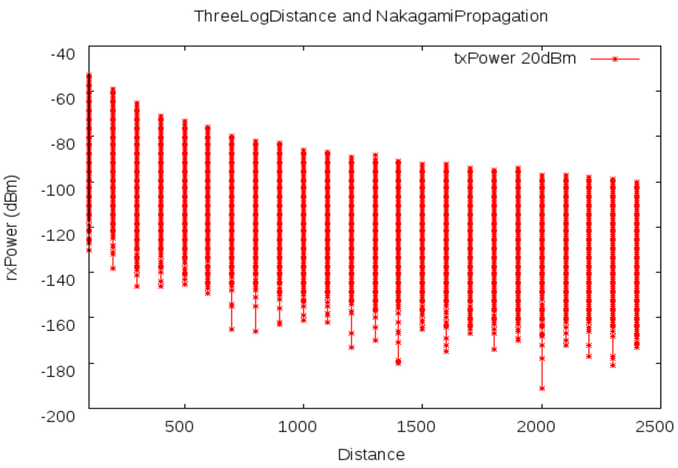

FIGURE 7. Received Power Vs Distance

The above graph indicates the variation of received power with respect to distance when two models i.e. Nakagami and three log distance model are merged together.

VI. CONCLUSION

We studied the various models such as Friis Propagation Loss Model, Log Normal shadowing Model, Nakagami Model, etc. and their received power variation with respect to distance. We also tried merging different models for various scenarios in order to obtain realistic simulation result. Hybrid of several models result is club to obtain realistic result.

VII. FUTURE WORK

Future work can be done by merging the two models and developing new model and implementing it in real life scenario. The models can also be simulated in ns-3.

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