Implementation of Path Loss Model in Wireless Network

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Abstract—*Nowadays the Worldwide Interoperability of Microwave Access (WiMAX) technology begin to be admired and receives growing acquiring as a Broadband Wireless Access (BWA) system. WiMAX has potential success in its line-of-sight (LOS) and non-line-of-sight (NLOS) conditions. Its first release is for LOS and its operating frequency band is 10-66 GHz. For the support of NLOS which cannot be possible in high frequency operating bands it operates between 2 and 11 GHz.There are going to be a sweep all over the world for the deployment of WiMAX networks. Estimation of path loss is very significant in initial deployment of wireless network and cell planning. In this study we compare and analyze five path loss models (i.e. COST 231 Hata mode, SUI model, Ericsson model, Okumura model, Hata model and lee model in urban, suburban and rural environments in NLOS condition. Our main concentration in this thesis is to find out a suiTablemodel for different environments to provide guidelines for cell planning of WiMAX at cellular frequency of 3.5 GHz.*

Keywords—OFDM, NLOS, WIMAX, BWA, UMTS, ASN

I. INTRODUCTION

WiMAX is a standards-based technology sanction the carriage of last mile wireless broadband access as an substitute to wired broadband like cable and DSL. DSL (digital subscriber lines) are not able to provide broadband services in many urban and suburban areas because it can provide services into three mile of region. DSL also does not provide support for terminal mobility. To overcome these difficulties Mobile Broadband Wireless Access which have advantages of high speed quality services like voice, data and multimedia to large number of users is introduced. WiMAX distributesentrenched, ambulant, and movable and mobile wireless broadband connectivity without requirement for directs line-of-sight with a base station. In a typical cell radius disposition of 3-10 kilometers, WiMAX Forum Certified™ systems can be anticipate to hand over capacity of up to 40 Mbps per channel, for fixed and movable access applications. WiMAX is to 802.16 as the Wi-Fi Alliance is to 802.11

Empirical models can be bifurcate into two subcategories namely, time dispersive and non-time dispersive [6]. The denoting the first type is designed to provide information relating to the time dispersive characteristics of the channel i.e., the multipath delay spread of the channel. An example of this type is the Stanford University Interim (SUI) channel models prosper under the Institute of Electrical and Electronic Engineers (IEEE) 802.16 working group [2]. Examples of non-time-dispersive empirical models are ITU-R [7], Hata [8] and the COST-231 Hata model [3]. All these models predict mean path loss as a function of various parameters, for example distance, antenna heights etc.

A. *Features of WIMAX*

- Physical layer is based on OFDM.
- High Data Rate.
- Flexible Architecture.
- Mobility support.
- Scalability.
- Use AES for secured transmission.
- Support fixed and mobile application.

II. DESCRIPTION OF SELECTED MODELS

Propagation models play a crucial role in planning of wireless cellular systems. Moreover, they represent a set of mathematical equations and algorithms that are used for radio signal propagationprophecy in specific regions. They are widely used in wireless communication, mainly for conducting feasibility studies and during the placement. Channel modeling is indispensable for characterization of the impulse response and to predict the path loss of a propagating channel. Therefore, it is very important to have the knowledge about the electromagnetic environment where the system is operated and the location of the transmitter and receiver. This research is focused on Cost 231 Hata Model, SUI (Stanford University Interim) Model, Ericsson Model, HataModel, LeeModel, Okumura model.

A. *COST 231Hata Model*

COST 231 Hata Modelmodel is considered as the most worthy model for rural and suburban environments which have regular building height. Moreover, this model gives more accurate path loss forecast. It recognize various terrains with different parameters.

The basic path loss equation [4] for this COST-231 Hata Model can be expressed as

$$PL = 46.3 + 33.9\log_{10}(f) - 13.82\log_{10}(h_b) - ah_m + \big(44.9 - 6.55\log_{10}(h_b)\big)\log_{10}(d) + c_m \quad (3)$$

Where

- d: Distance between transmitter and receiver antenna (km)
- f: Frequency (MHz)
- h_b: Transmitter antenna height (m)

The parameter c_m has different values for different environments like 0 dB for suburban and 3 dB for urban areas and the remaining parameter ah_m is defined in urban areas as

$$ah_m = 3.20(\log_{10}(11.75h_r))^2 - 4.79 \text{ ,for } f > 400 \text{ MHz} \quad (4)$$

The value for ah_m in suburban area and rural (flat) areas is defined as:

$$ah_m = (1.11\log_{10}(f) - 0.7)h_r - (1.5\log_{10}(f) - 0.8) \quad (5)$$

Where

- h_r: Receiver antenna height (m).

B. Stanford University Interim (SUI) Model

IEEE 802.16 Broadband Wireless Access working group proposed the standards for the frequency band below 11 GHz containing the channel model developed by Stanford University, namely the SUI models. This prediction model arrive from the extension of Hata model with frequency larger than 1900 MHz. The correction parameters are allowed to extend this model up to 3.5 GHz band. In the USA, this model is defined for the Multipoint Microwave Distribution System (MMDS) for the frequency band from 2.5 GHz to 2.7 GHz. [21]

The base station antenna height of SUI model can be addressed from 10 m to 80 m. Receiver antenna top is from 2 m to 10 m. The cell radius is from 0.1 km to 8 km. The SUI model describes three types of terrain; they are terrain A, terrain B and terrain C. There is no proclamation, about any particular environment. Terrain A can be used for hilly areas with moderate or very dense vegetation. This terrain presents the highest path loss, and it is considered as a dense populated urban area. Terrain B is characterized for the hilly terrains with sparse vegetation, or flat terrains with moderate or heavy tree densities. This is the intermediate path loss scheme. This model is considered for suburban environment. Terrain C is suiTablefor flat terrains or rural with light vegetation, here path loss is minimum.[21]

The basic path loss expression of The SUI model with correction factors is proposed as

$$PL = A + 10\,\Upsilon \log_{10}\left(\frac{d}{d_0}\right) + X_f + X_h + s, \text{ for } d>d_0 \quad (6)$$

Where

- d: distance between transmitter and receiving antenna (m)
- d_0:The reference distance 100 (m)
- λ: wavelength (m)
- X_f: Frequency correction factor for frequency above 2 GHz
- X_h : Correction factor for receiving antenna height (m)
- S: correction for shadowing (dB)
- ϒ : Path loss exponent

The random variables are taken through a statistical strategy as the path loss exponent ϒ and the weak fading standard deviation s is defined. The log normally distributed factor s, for shadow fading because of trees and other clutter on a propagations path and its value is between 8.2 dB and 10.6 dB.

The parameter A is defined as

$$A = 20\log_{10}\left(\frac{4\pi d_0}{\lambda}\right) \quad (7)$$

The path loss exponentϒ is given by

$$\Upsilon = a - bh_b + \left(\frac{c}{h_b}\right) \quad (8)$$

Where,

- h_b: Transmitter antenna height (m).

This is between 10 m and 80 m.

The constants a, b and c depend upon the types of terrain, that are given in Table1

The value of parameter$\Upsilon = 2$for free space propagation in an urban area,$3 < \Upsilon < 5$ for urban NLOS environment, and$\Upsilon > 5$ for indoor propagation.

Model Parameter	Terrain A	Terrain B	Terrain C
A	4.6	4.0	3.6
b (m^{-1})	0.0075	0.0065	0.005
c (m)	12.6	17.1	20
S	10.6	9.6	8.2

Table 1: The Constant Values of Different Terrain for Sui Model

The frequency correction factor $X_f$and the correction for receiver antenna height X_h for the model are expressed in:

$$X_f = 6.0\log_{10}\left(\frac{f}{2000}\right) \quad (9)$$

For terrain type A and B

$$X_h = -10.8\log_{10}\left(\frac{h_r}{2000}\right) \quad (10.a)$$

for terrain type C

$$X_h = -20.0\log_{10}\left(\frac{h_r}{2000}\right) \quad (10.b)$$

Where

- f: operating frequency (MHz)
- h_r: Receiver antenna height (m)

For the above correction factors this model is extensively used for the path loss prediction of all three types of terrain in rural, urban and suburban environments.

C. Ericsson Model

To discern the path loss, the network planning engineers are using a software given by Ericsson company is called Ericsson model. This model also straight up on the revamp Okumura-Hata model to allow space for changing in parameters according to the propagation environment [6]. Path loss stated by this model is given by

$$PL = a_0 + a_1\log_{10}(d) + a_2\log_{10}(h_b) + a_3\log_{10}(h_b)\log_{10}(d) - g_1(h_r) + g_2(f) \quad (11)$$

Where

$$g_1(h_r) = 3.2(\log_{10}(11.75h_r)^2) \quad (11.a)$$

$$g_2(f) = 44.49\log_{10}(f) - 4.78(\log_{10}(f))^2 \quad (11.b)$$

And parameters

- f: frequency (MHz)
- h_b: Transmitter antenna height (m)
- h_r: Receiver antenna height (m)

The default values of the parameters (a_0 ,a_1 ,$a_2$and a_3) for different terrain are given in Table 2

Environment	a_0	a_1	a_2	a_3
Urban	36.2	30.2	12.0	0.1
Suburban	43.20	68.93	12.0	0.1
Rural	45.95	100.6	12.0	0.1

Table 2: Values of Parameters for Ericsson Model

D. Hata Model

The Hata model is a verifiable formulation [33] of the graphical path loss data provided by Okumura and is well founded over the same level of frequencies, 150-1500 MHz This empirical model simplifies estimation of path loss since it is a closed form formula and is not depend on empirical curves for the different parameters. The standard representation for median path loss in urban areas under the Hata model is

$$PL = 69.55 + 26.16\log_{10}(f) - 13.82\log_{10}(h_b) - a(h_r) + \left(44.9 - 6.55\log_{10}(h_b)\right)\log_{10}(d) \quad (12)$$

Where

- f:frequency (MHz).

- h_b: Effective heights of the transmitter antenna (m)
- h_r: Receiver antennas (m).
- d: distance from the transmitter to the receiver(km)
- $a(h_r)$: Correction factor for the effective antenna height of the receiver that is described as the size of the area of coverage.

The mobile-antenna correction factor, for small- to medium-sized cities, is given by:

$$a(h_r) = (1.1\log_{10}(f) - 0.7)h_r - (1.56\log_{10}(f - 0.8) \quad (13)$$

In suburban area, path loss is given by:

$$PL = PL(urban) - 2[\log_{10}(\frac{f}{28})]^2 - 5.4 \quad (14)$$

The path loss in open rural area is given by:

$$PL = PL(urban) - 4.78(\log_{10}(f))^2 - 18.33\log_{10}(f) - 40.98 \quad (15)$$

These equation improved performance value of Okumara model, this technique is good in urban and suburban area but in rural areas performance degreases because rural area prediction is depend on urban area. This model is quite worthy for large-cell mobile devices, but not for personal conveyance, systems that cover a circular area of approximately 1 km in radius.

E. Lee Model

Lee's path loss model is based on empirical data chosenso as to model a flat terrain. Large errors arise when the modelis applied to a non-terrain. However, Lee's model has beenknown to be more of a "North American model" than that of Hata [17].

The propagation loss calculated as:

1) Scenario 1: Urban Path loss

$$PL = 123.77 + 30.5 \log10 (d) +10 n \log10 (f/900) - \alpha0 \quad (17)$$

2) Scenario 2: Suburban Path loss

$$PL = 99.86 +38.4 \log10 (d) +10 n \log10 (f/900) - \alpha0 \quad (18)$$

3) Scenario 3: Rural Path loss

$$PL = 86.12 +43.5 \log10 (d) +10 n \log10 (f/900) - \alpha0 \quad (19)$$

$\alpha0 = \alpha1 + \alpha2 + \alpha3 + \alpha4 + \alpha5$
$\alpha1 = (h_b/30.48)$ ^ 2
$\alpha2 = (h_r/3)$ ^ k
$\alpha3 = (P_t/10)$ ^ 2
$\alpha4 = (G_b/4)$
$\alpha5 = G_m$

- d: distance between transmitter and receiver(km)
- f: frequency (MHz)
- α0: correction factor to account for transmitter and receiver antenna heights, transmit powers and antenna gains that differ from the nominal values.
- h_b: Transmitter antenna height (m)
- h_r: Receiver antenna height (m)
- P_t: Transmitted power (dB)
- G_b: Transmitter antenna gain (dB)
- G_m: Receiver antenna gain (dB)

F. Okumura Model

The Okumura's model is an empirical model based on extensive drive test measurements made in Japan at several frequencies within the range of 150 to 1920 MHz and further extrapolated up to 3500 MHz. Okumura's models is developed for macro cells with cells diameters in range from 1 to 100 km. The height of the base station antenna is kept between 30-100 m. The Okumura model has taken into account various propagation variables such as the type of environment and the terrain irregularity.

Okumura prosper a set of curves which provides the median attenuation relative to free space (Amu), in an urban area over a quasi-smooth terrain with a base station effective antenna height (hb) of 200m and a mobile antenna height (hm) of 3 meters. These curves were developed from extensive measurements using vertical Omni-directional antenna at both the base and mobile. In this case curves are plotted as a function of frequency inthe range of 100 MHz to 1920 MHz, and as a function of distance from the base station in the range from 1 km to 100 km. The path loss prediction formula according to Okumura's model is represented as

$$L50(dB) = LF+ Amu(f,d) - G(hb) - G(hm) – GAREA \quad (20)$$

where

- L_{50}(dB) = median value (i.e. 50th percentile) of path (propagation) loss.
- L_F= Free space loss and can be calculated using either Equation (22) or Equation (23). Amu=median attenuation relative to free space.
- $G_{(hb)}$=Base station antenna height gain factor.
- $G_{(hm)}$=Mobile antenna height gain factor.
- $G_{AREA=}$ is the gain or correction factor owing to the type of environment.

Amu(f; d) and G_{AREA} are determined by observing the Okumura curves. The term G(hb) and G(hm) can be calculated by using these simple formulas :

$$G(hb) = 20 \log10\ 1000m > hb > 30m \quad (21)$$
$$G(hm) = 10 \log10 (hm/3)\ hm \leq 3m \quad (22)$$
$$G(hm) = 20 \log10 (hm/3)\ 10m \leq hm \leq 3m \quad (23)$$

Okumura's model is considered to be the simplest and most excellent in terms of accuracy in path loss prediction for mature cellular and land mobile systems in cluttered environment. The main disadvantage of the Okumura model is its sluggish response to rapid changes in terrain condition. Consequently the model is fairly good in urban and suburban areas but not as good (suited) for rural areas.

III. SIMULATION OF MODELS

The desired WIMAX transmitter to receiver distance is varied up to 10 km and the carrier frequency is set to 3.5 GHz. Transmitter antenna height is 10 m in urban and suburban area and in rural area. The receiver antenna height is considered as 10m. In our thesis, we consider five path loss models i.e. Cost 231 Hata Model, SUI model, Ericsson Model, Hata model, Okumura model and Lee model. All these six models work in all three environments i.e. urban, suburban and rural environment. The simulation is carried out with MATLAB. The following Table 3. Presents the parameters applied in simulation to these path loss models.

Parameter	Value
Transmitted Power(P_t)	43dB
Transmitter Antenna Gain(G_b)	18dB
Receiver Antenna Gain(G_m)	18dB
Frequency(f)	3.5GHz
Transmitter Antenna Height (h_b)	70m
Receiver Antenna Height(h_r)	8m

Distance between transmitter and receiver (d)	7km

Table 3: Summary of Parameters and Values used in Simulation

A. Path Loss of Cost 231 Hata Model

In our calculation, receiver antenna height is considered as 8m.Distance between transmitter and receiver is 7km. The numerical results for Cost 231 Hata model in all different environments is shown in Figure1.

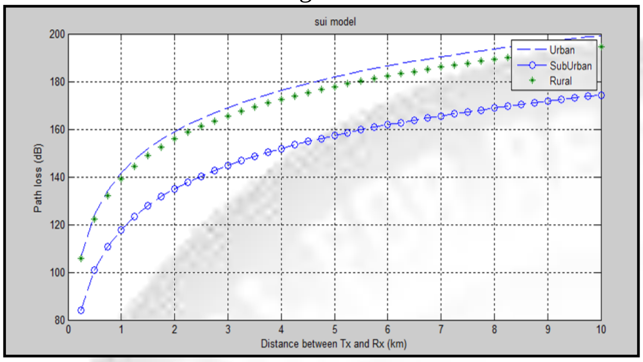

Fig. 1: Path Loss of SUI Model in all Environments

B. Path Loss of Ericsson Model

The transmitter and receiver antenna heights are same as used earlier. The numerical results for Ericsson model in all different environments is shown in Figure 2

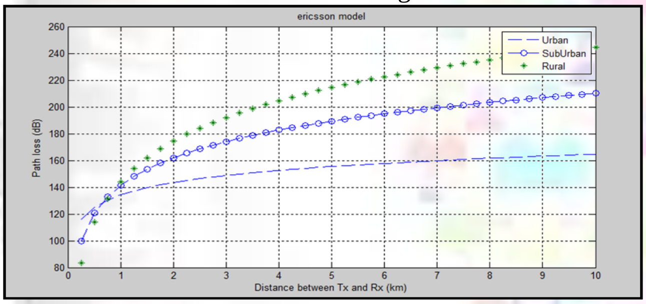

Fig. 2: Path Loss of Ericsson Model in all Environments

C. Path loss of Hata Model

The transmitter and receiver antenna heights are same as used earlier. The numerical results for Hata model in all different environments is shown in Figure 3.

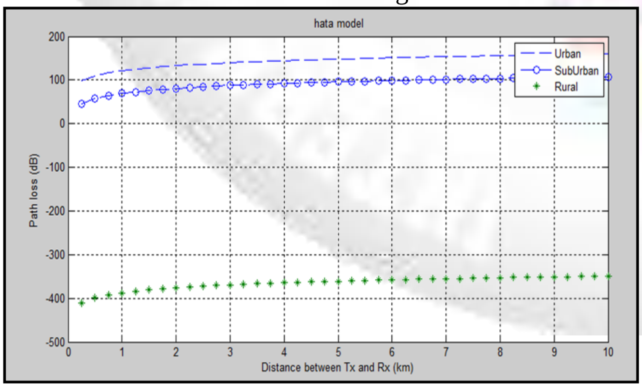

Fig. 3: Path Loss of HataModel in all Environments

D. Path Loss of Lee Model

The transmitter and receiver antenna heights are same as used earlier. The numerical results for Lee model in all different environments are shown in Figure 4.

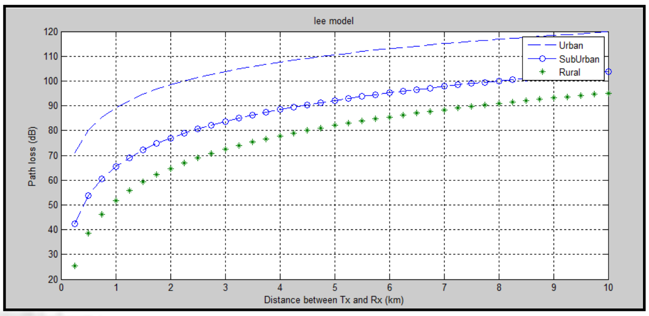

Fig. 4: Path Loss of Lee Model in all Environments

E. Path Loss in Urban Environment

In our calculation, receiver antenna height is considered as 10 m.Distance between transmitter and receiver is 10 km. The numerical results for all five models in urban environment are shown in Figure 5.

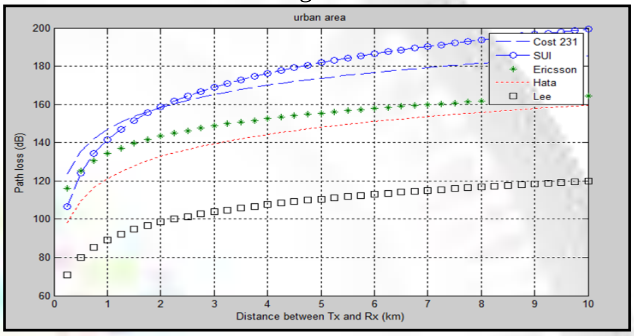

Fig. 5: Path Loss in Urban Environment

F. Path Loss in Suburban environment

The transmitter and receiver antenna heights are same as used earlier. The numerical results for all five models in Suburban environment are shown in Figure 6.

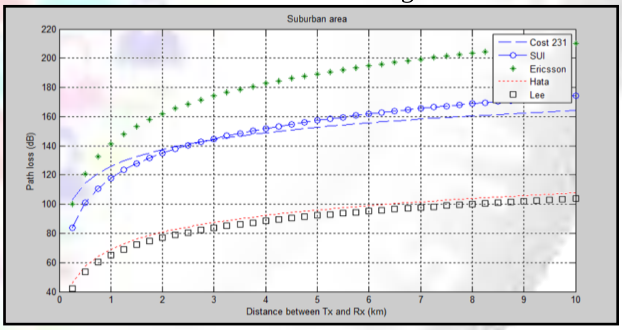

Fig. 6: Path loss in suburban environment

G. Path Loss in Rural Environment

The transmitter and receiver antenna heights are same as used earlier. The numerical result for all five models in rural environment is shown in Figure 7.

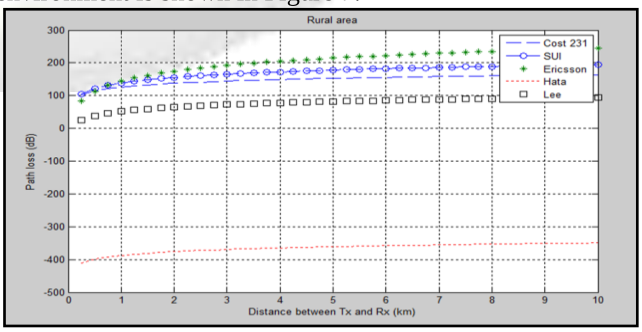

Fig. 7: Path Loss in Rural Environment

IV. ANALYSIS OF MODELS

A. Analysis of Cost 231 HataModel in all Environments

The accumulated result for cost 231 Hata model in all the three environments is shown in Table 4 Note that in the urban environment as the distance between transmitter and receiver increases there is increase in the path loss. At 1 km distance path loss is 146.88 dB and at 10 km the path loss 185.22 dB. Likewise in suburban and rural environment, there is increase in path loss as the distance increase. At 1 km distance path loss is 125.86 dB and at 10 km distance path loss is 164.21 dB. Note that path loss is more in urban environment (185.23 dB at 10km distance) as compared to suburban and rural environment (164.21 dB at 10 km distance).

Distance(km)	Urban	Suburban	Rural
1	146.88	125.86	125.86
2	158.43	137.40	137.40
3	165.18	144.15	144.15
4	169.98	148.94	148.94
5	173.69	152.66	152.66
6	176.72	155.69	155.69
7	179.29	158.26	158.26
8	181.52	160.49	160.49
9	183.48	162.45	162.45
10	185.23	164.21	164.21

Table 4: Path Loss Data of Cost 231 HataModel

B. Analysis of SUI Model in all Environments

The accumulated result for SUI model in all the three environments is shown in Table 5. Note that in the urban environment as the distance between transmitter and receiver increases path loss increase. At the distance of 1km the path loss is 141 dB and at the distance of 10 km the path loss is 199.28 dB. Likewise in suburban and rural environment path loss increases as distance increases. In suburban environment path loss is 117.86 dB at 1km and 174.31 dB at 10km. In rural environment, at 1km the path loss is 139.08 dB and 194.58 dB at 10 km distance. But on comparing the path loss among the three environments, urban environment (199.28 dB at 10 km distance) has more path loss than suburban (174.31 dB at 10 km distance) and rural environment (194.58 dB at 10 km distance). It is also observed that rural environment has more path loss (194.58 dB at 10 km distance) than suburban (174.31 dB at 10 km distance). So it can be conclude that urban has more path loss while suburban has less path loss

Distance(km)	Urban	Suburban	Rural
1	141.43	117.86	139.08
2	158.85	134.85	155.79
3	169.03	144.80	165.56
4	176.26	151.85	172.50
5	181.87	157.32	177.89
6	186.45	161.79	182.27
7	190.32	165.57	185.99
8	193.68	168.84	189.21
9	196.63	171.73	192.04

Table 5: Path Loss Data of SUI Model

C. Analysis of Ericsson Model in all Environments

The accumulated result for Ericsson model in all the three environments is shown in Table 6. Note that in urban suburban and rural environment path loss keep on increasing as the distance between transmitter and receiver keep on increasing. In urban environment the path loss at distance of 1km is 134. 28 dB while at 10km the path loss is 164.58dB. On other hand, in suburban environment the path loss at 1km distance is 141. 28 km and at 10 km distance path loss is 210.01 dB while in rural environment, path loss at 1km is 144.03 dB and at 10km distance, path loss is 244.73 dB. On comparing the three environments, path loss is more at rural environment (244.73 dB. at 10 km distance). Urban environment has least path loss (164.58 dB at 10 km distance) than suburban environment (210.01 dB at 10 km distance). There is a huge change in path loss in all three environments on comparing with each other.

Distance(km)	Urban	Suburban	Rural
1	134.28	141.28	144.03
2	143.40	161.97	174.34
3	148.74	174.07	192.07
4	152.52	182.66	204.65
5	155.46	189.32	214.42
6	157.86	194.76	222.39
7	159.88	199.36	229.13
8	161.64	203.35	234.97
9	163.19	206.87	240.12
10	164.58	210.01	244.73

Table 6:Path Loss Data of Ericsson Model

D. Analysis of HataModel in all Environments

The accumulated result for Hata model in all the three environments is shown in Table 7. Note that in urban suburban and rural environment path loss keep on increasing as the distance between transmitter and receiver keep on increasing. In urban environment path loss is 121.18 dB at 1 km distance and at 10km distance path loss is 159.33 dB. In suburban environment path loss is 69.16 dB at 1 km distance and at 10 km path loss is 107.51 dB. In rural environment, there is path gain. Path gain the negative value of path loss. As the distance increase it comes more close to path loss. At 1km distance path gain is -387.70 dB and at 10 km distance path gain is -349.34 dB. On comparing three environments it is concluded that rural environment has least path loss (-349.3 dB at 10 km distance). Urban environment has more path loss (159.53 dB at 10 km distance) as compared to suburban environment (107.51 dB at 10 km distance).

Distance(km)	Urban	Suburban	Rural
1	121.18	69.16	-387.70
2	132.73	80.70	-376.15
3	139.48	87.45	-369.40
4	144.27	92.25	-364.60
5	147.99	95.96	-360.89
6	151.03	99.00	-357.85
7	153.60	101.57	-355.29
8	155.82	103.80	-353.06
9	157.78	105.76	-351.10
10	159.53	107.51	-349.34

Table 7: Path Loss Data of HataModel

E. Analysis of Lee Model in all Environments

The accumulated result for Lee model in all the three environments is shown in Table 8. Note that in urban suburban and rural environment path loss keep on increasing as the distance between transmitter and receiver keep on increasing. In urban environment the path loss at distance of 1km is 89.26 dB while at 10km the path loss is 119.76 dB. On other hand, in suburban environment the path loss at 1km distance is 65.34 dB and at 10km distance path loss is 103.75 dB while in rural environment, path loss at 1km is 51.60 dB and at 10km distance path loss is 95.10 dB. Urban environment has more path loss (119.76 dB at 10 km distance) than suburban environment (103.75 dB at 10 km distance) and rural environment (95.10 dB at 10 km).On comparing the three environments, rural environment has least path loss.

Distance(km)	Urban	Suburban	Rural
1	89.26	65.34	51.60
2	98.44	76.90	64.70
3	103.81	83.67	72.36
4	107.61	88.46	77.80
5	110.57	92.18	82.01
6	112.99	95.22	85.45
7	115.03	97.80	88.36
8	116.80	100.02	90.90
9	118.36	101.99	93.11
10	119.76	103.75	95.10

Table 8: Path Loss Data of Lee Model

F. Analysis of Path Loss Model in Urban Environments

The accumulated result for all path loss models in urban environments is shown in Table 9.In this simulation transmitter antenna height and receiver antenna height is assumed to be 10 m. transmitted power is estimated as 43 dB. In these conditions, SUI model has more path loss (199.28 dB) as compared to all other models whereas Lee model has least path loss (119.76 dB). After SUI model, cost 231 Hata model has more path loss (185.23 dB). Ericsson model has more path loss (164.58 dB) than Hata model (159.53 dB) but less than Cost 231 Hata model and SUI model. In urban environment the increasing order of path loss models is given by:

SUI model (199.28) > Cost 231 Hata model (185.23)> Ericsson model (164.58) >Hata model (159.53) > Lee model (119.76)

Propagation Model	Transmitter antenna Height(m)	Transmitting power (dB)	Path loss(dB) at 10 m receiver antenna height
Cost 231 Hata model	10	43	185.23
SUI Model	10	43	199.28
Ericsson model	10	43	164.58
Hata model	10	43	159.53
Lee model	10	43	119.76

Table 9: Path Loss Estimate at 10 km Distance in Urban Environment

G. Analysis of Path Loss Model in Suburban Environments

The accumulated result for all path loss models in suburban environments is shown in Table 10.In this simulation transmitter antenna height and receiver antenna height is assumed to be 10 m. transmitted power is estimated as 43 dB. In these conditions, Ericsson model has more path loss (210.01 dB) as compared to all other models whereas Lee model has least path loss (103.75 dB). After Ericsson model, SUI model has more path loss (174.32dB). Cost 231 Hata model has path loss (164.21dB) whereas Hata model has 107.51 dB path losses. In suburban environment the increasing order of path loss models is given by:

Ericsson model (210.01) > SUI model (174.32) > Cost 231 Hata model (164.21) >Hata model (107.51) > Lee model (103.75)

Propagation Model	Transmitter antenna Height(m)	Transmitting power (dB)	Path loss(dB) at 10 m receiver antenna height
Cost 231 Hata model	10	43	164.21
SUI Model	10	43	174.32
Ericsson model	10	43	210.01
Hata model	10	43	107.51
Lee model	10	43	103.75

Table 10: Path Loss Estimate at 10 km Distance in Suburban Environment

H. Analysis of Path Loss Model in Rural Environments

The accumulated result for all path loss models in rural environments is shown in Table 11.In this simulation transmitter antenna height and receiver antenna height is assumed to be 10 m. transmitted power is estimated as 43 dB. In these conditions, Ericsson model has more path loss (244.73 dB) as compared to all other models whereas Hata model has least path loss (-349.35 dB). After Ericsson model, SUI model has more path loss (194.58 dB). Cost 231 Hata model has path loss (164.21) whereas Lee model has 95.11 dB path losses. In rural environment the increasing order of path loss models is given by:

Ericsson model (244.73) > SUI model (194.58) > Cost 231 Hata model (164.21) >Lee model (95.11) >Hata model (-349.35)

Propagation Model	Transmitter antenna Height(m)	Transmitting power (dB)	Path loss(dB) at 10 m receiver antenna height
Cost 231 Hata model	10	43	164.21
SUI Model	10	43	194.58
Ericsson model	10	43	244.73
Hata model	10	43	-349.35
Lee model	10	43	95.11

Table 11: Path Loss Estimate at 10 km Distance in Rural Environment

V. Conclusion

In this paper, various path loss models are simulated in different environments on frequency band3.5 GHz. Based onsimulation result, it is concluded that in cost 231 Hata model path loss is more in urban area(185.23 dB). In SUI model, urban area has more path loss (199.28 dB) while suburban area has least path loss (174.58 dB). In Ericsson model, path loss (244.73 dB) is more in rural are while least in urban area (164.58 dB). In Hata model, urban area has more path loss (159.53 dB) while rural has least path loss (-349.35 dB). In Lee model, path loss (119.76 dB) is more in urban area and least in rural area (95.11 dB). When considered all models in particular environment it can be concluded that in urban environment Cost 231 Hata model has more path loss while lee model has less path loss. Ericsson model has more path loss while Lee model has least path loss in suburban environment. In rural environment Ericsson has more path loss while Hata model has least path loss. It is concluded that no particular model reacts same in different environment. Their path loss is different in different environments. It completely depends on different parameters like height of transmitter antenna, receiver antenna, distance between transmitter and receiver, transmitted power and even radius of the cell.

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