Analysis of Path Loss Models at 3.3GHz to Determine Efficient Handover in Wimax

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***ABSTRACT* - Wimax stands for Worldwide Interoperability for Microwave Access and operate in 2.3GHz, 2.5GHz, 3.3GHz, 3.5GHz (licensed) and 5.8GHz (unlicensed) frequency bands. Path loss models can be used to find Received Signal Strength (RSS) which is an important factor in deciding handover. If RSS is less than a particular threshold value then handover decision is to be taken. For our analysis we have taken Free space Propagation, ECC-33, COST 231 Hata, COST 231 W-I and SUI models compared w.r.t. different environment (high density, medium density and low density) and different height of receiving antenna (2m, 6m, and 10m). Then RSS value are calculated in three environment and comparing RSS with particular threshold we determine which of these models is suitable for avoiding number of handover.**

Keywords: ECC-33, SUI, COST 231 Hata, COST 231 W-I, RSS, Handover

I. INTRODUCTION

One of important feature of wimax is to provide support for mobility and handover is one of important factor in mobility support. So it is required that handover process in wimax be efficient. Number of handover depends on the size of the cell if size of cell is small then number of handover will increase which in turn increase load on network and handover delay. RSS is very useful in deciding for handover, received signal strength can be calculated using path loss values for different propagation models. Path loss is reduction in signal strength when it is transmitted in from of electromagnetic waves between transmitter and receiver and measured in decibel (dB). In this paper our aim is to compare free space path loss, ECC-33, COST 231 Hata, COST 231 W-I and SUI model in different environment and with different receiver antenna height, determining model with minimum path loss in each environment, calculating RSS from path loss values, finding model with RSS greater than a threshold value such model can be adopted to minimize number of handover (frequent handover).

Section 2 gives a brief introduction of path loss models that we have taken for our study. Section 3 gives our simulated results and analysis (using MATLAB). Conclusions are drawn in section 4.

II. PATH LOSS MODELS

Electromagnetic waves are used for transmitting information between transmitter and receiver. Strength of signal reduces due to interaction between electromagnetic waves and environment. Path loss models uses set of mathematical equations and algorithms for prediction of path loss values. Such models are categorized into three categories i.e. deterministic (uses physical law leading propagation of waves), Empirical (based on measurements and observations) and stochastic (uses series of random variables) models. In our study we use only empirical models which are described as follow.

A.) Free-space path loss model

This model is used for finding path loss when there is line-of-sight between transmitter and receiver. Equation for finding path loss is given [1] by:

$$PL(dB) = 20\log_{10}(d) + 20\log_{10}(f) + 32.45 \quad (1)$$

Where, f is frequency of signal in MHz, d Is distance from transmitter in km.

B.) COST 231 Hata model

COST 231 Hata model is introduced as an extension of Hata model. This model cannot be used for measurement on 2.5GHz and 3.5GHz, but correction factors are taken to predict the path loss in this higher frequency range. The basic path loss equation [1] for this COST-231 Hata Model can be expressed as:

$$PL(dB) = 46.3 + 33.9\log_{10}(f) - 13.82\log_{10}(h_b) - ah_m + (44.9 - 6.55(h_b))\log_{10}(d) + c_m \quad (2)$$

Where, d is distance between transmitter and receiver in (km), f is signal frequency (MHz), h_b is height of transmitter antenna (m), c_m is correction factor its value is 0dB for suburban and rural area and 3dB for urban area. ah_m For urban area is given as:

$$ah_m = 3.20(\log_{10}2(11.75h_r)) - 4.79 \quad (3)$$

$$\text{for, f} > 400\text{MHz}$$

ah_m For suburban and rural area is given as:

$$ah_m = (1.11\log_{10}(f) - 0.7)h_r - (1.5\log_{10}(f) - 0.8) \quad (4)$$

Where, h_r is height of receiver antenna in m.

C.) COST 231 W-I Model

This is COST 231 Walfisch-Ikegami model and used as an extension of COST Hata model. It is used for frequencies that are above 2000MHz. path loss in case of LOS condition between transmitter and receiver is given by [1]:

$$PL(dB) = 42.64 + 26\log_{10}(d) + 20\log_{10}(f) \quad (5)$$

In case of NLOS condition path loss is:

$$PL(dB) = L_0 + L_{RTS} + L_{msd} \quad (6)$$

Where, L_0 is attenuation in free space and given as:

$$L_0 = 32.45 + 20\log_{10}(d) + 20\log_{10}(f) \quad (7)$$

L_{RTS} is rooftop to street diffraction.

$$L_{RTS} = -16.9 - 10\log_{10}(w) + 10\log_{10}(f) + 20\log_{10}(\Delta H_m) + L_{ori} \quad (8)$$

$\Delta H_m = h_{roof} - h_b$ and L_{ori} is given as follow:

$$L_{ori} = -10 + 0.345\phi \qquad \text{for } 0 < \phi < 35$$
$$= 2.5 + 0.075(\phi - 35) \qquad \text{for } 35 < \phi < 55$$
$$= 4 - 0.114(\phi - 55) \qquad \text{for } 55 < \phi < 90 \quad (9)$$

L_{msd} is multi screen diffraction loss.

$$L_{msd} = l_{bsh} + k_a + k_d\log_{10}(d) + k_f\log_{10}(f) - 9\log_{10}(f) - 9\log_{10}(B) \quad \text{for } L_{msd} > 0$$
$$= 0 \qquad \text{for } L_{msd} < 0 \quad (10)$$

$$l_{bsh} = -18\log_{10}(1 + \Delta h_b) \qquad \text{for } h_b > h_{roof}$$
$$= 0 \qquad h_b \le h_{roof} \quad (11)$$

$$k_a = 54 - 0.8\Delta h_b, \text{ for } h_b \le h_{roof} \text{ and } d \ge 0.5\text{km}$$
$$= 54 - 0.8\Delta h_b(dist/0.5), \text{ for } h_b \le h_{roof} \text{ and } d < 0.5\text{km} \quad (12)$$

$$k_d = 18 \qquad h_b > h_{roof}$$
$$= 18 - 15(\Delta h_b/h_{roof}) \qquad h_b \le h_{roof} \quad (13)$$

$$k_f = -4 + 0.7(f/925 - 1) \qquad \text{for suburban areas}$$
$$= -4 + 1{,}5(f/925 - 1) \qquad \text{for urban areas} \quad (14)$$

where, w is street width in meter and B is building to building distance in meter.

D.) SUI (Standard University Interim) Model

SUI model is used in frequency band of 2.5GHz to 2.7GHz. But their use on higher frequencies is possible by introducing correction factors. SUI models are divided into three types of terrains namely A, B and C. Type A is related with maximum path loss and is also known as urban area. Type C is related with minimum path loss and also known as rural area. Type B is related with suburban area. The basic path loss equation [3] is given by:

$$PL(dB) = A + 10\gamma\log_{10}(d/d_0) + X_f + X_h + S \quad \text{for, } d > d_0 \quad (15)$$

Where, d is distance between transmitter and receiver in km, X_f is correction factor for frequencies above 2GHz, X_r is correction factor for receiving antenna height in meter, S is correction factor for shadowing, its value in urban is 10.6, 9.6 in suburban and 8.2 in rural area.

$$A = 20\log_{10}(4\pi d_0/\lambda) \quad (16)$$

Where, λ is wavelength in meter and d_0 is reference distance of 100 meter. Path loss exponent is given by:

$$\gamma = a - bh_b + (c/h_b) \quad (17)$$

Here h_b is height of transmitter antenna in meter. a, b, c are constants. Value of constants a, b and c is given in table 1 for different terrain

Table 1: Parameter of SUI model [3]

Parameter	A	B	C
a	4.6	4.0	3.6
b	0.0075	0.0065	0.005
c	12.6	17.1	20

Frequency correction factor and correction factor for receiver antenna height are given by:

$$X_f = 6.0\log_{10}(f/2000) \quad (18)$$

$$X_h = -10.8\log_{10}(h_r/2000) \text{ for type A and B}$$
$$X_h = -20.0\log_{10}(h_r/2000) \text{ for type C} \quad (19)$$

Where, f is frequency in MHz and h_r is receiver antenna height in meter.

E.) ECC-33 Model

International Telecommunication Union extended Hata-Okumura model up to 3.5GHz. Such extended model is known as ECC-33 model i.e. Electronic Communication Committee. In such model path loss is given by equation [4]:

$$PL(dB) = A_{fs} + A_{bm} - G_b - G_r \quad (20)$$

Where, A_{fs} is attenuation in free space in dB, A_{bm} is basic median path loss in dB, G_b is gain factor for transmitter antenna height in dBm, G_r is gain factor for receiver antenna height in dBm. These factors are given as follow:

$$A_{fs} = 92.4 + 20\log_{10}(d) + 20\log_{10}(f) \quad (21)$$

$$A_{bm} = 20.41 + 9.83\log_{10}(d) + 7.894\log_{10}(f) + 9.56(\log_{10}(f))^2 \quad (22)$$

$$G_b = \log_{10}(h_b/200)[13.958 + 5.8(\log_{10}(d))^2] \quad (23)$$

$$G_r = [42.57 + 13.7\log_{10}(f)][\log_{10}(h_r) - 0.585] \quad (24)$$

Where, d is distance between transmitter and receiver in km, f is frequency in GHz, h_r is receiver antenna height in meter, h_b is transmitter antenna height in meter.

F.) Received signal Strength (RSS) calculation:

This is power of radio signal received from base station. If received signal strength is below a threshold point then handover process is to be initiated to maintain ongoing communication. Equation used to measure RSS from path loss for various model is given as:

$$RSS = PT + GT + GR - PL - CL \quad (25)$$

Where, RSS is receiver signal strength in dBm, PT is transmitter power in dBm, GR is receiver antenna gain, GT is transmitter antenna gain, and CL is loss factor for cables and connectors.

III. OUR RESULTS AND ANALYSIS

For our simulation, our operating frequency is 3300MHz (3.3GHz) which is licensed frequency band of WiMAX and mostly used in Asian regions. Distance is variable from 250m to 6km. Other parameters taken are suitable for Asian regions and obtained from study of various research papers.

Table 2: values for simulation parameters

Parameter Name	Urban area	Suburban area	Rural area
Transmitter Height	40m	30m	20m
Receiver Height	2m,6m, and10m	2m, 6m, and 10m	2m,6m, and10m
Frequency	3.3GHz	3.3 GHz	3.3GHz
Distance between transmitter and receiver	Varies from 250m-6km	Varies from 250m-6km	Varies from 250m-6km
Shadowing factor	10.6dB	9.6dB	8.2dB
Street width	25m	25m	-------
orientation angle	30 degree	40 degree	Not allowed
Transmitter power	43dBm	43dBm	43dBm
Receiver power	30dBm	30dBm	30dBm

A.) Analysis in urban (High Density Area):

For analysis distance is variable from 250m to 6km. Results are shown in Fig. 1, 2 and 3

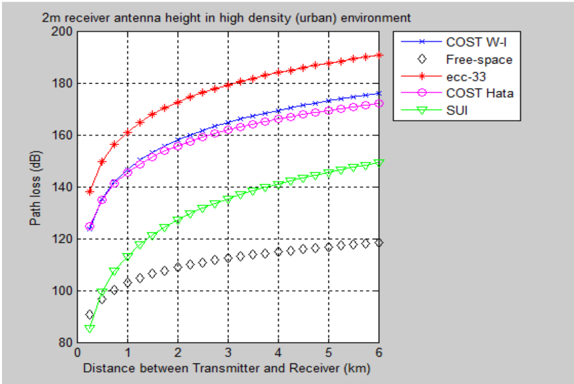


Fig. 1: Simulation of models in urban environment at 2m height of receiver antenna

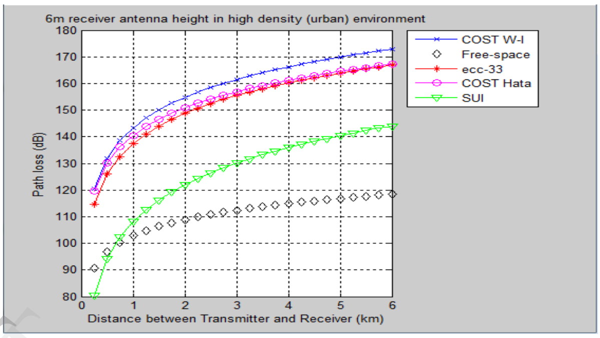


Fig. 2: Simulation of models in urban environment at 6m height of receiver antenna

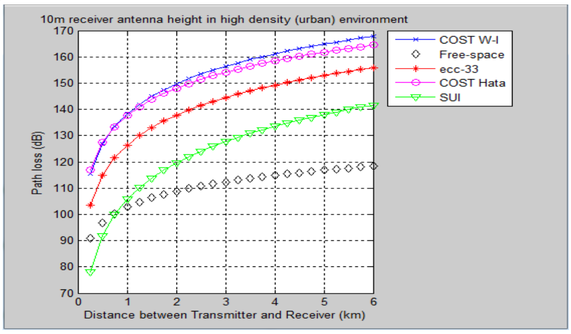
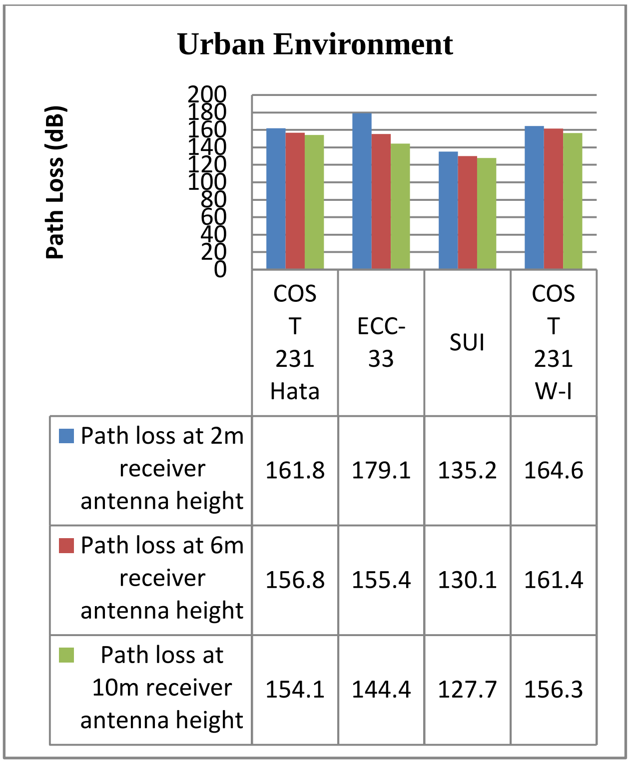


Fig. 3: Simulation of models in urban environment at 10m height of receiver antenna



	COST 231 Hata	ECC-33	SUI	COST 231 W-I
Path loss at 2m receiver antenna height	161.8	179.1	135.2	164.6
Path loss at 6m receiver antenna height	156.8	155.4	130.1	161.4
Path loss at 10m receiver antenna height	154.1	144.4	127.7	156.3

Fig. 4: Analysis of path loss at reference distance of 3km in urban area

Bar chart showing our analysis at reference distance of 3km is shown in Fig. 4. From this we find that SUI model is showing lowest path loss (135.2dB to 127.7dB) with different receiver antenna height. ECC-33 model is showing highest path loss of 179.1dB at 2m receiver antenna height and COST W-I is showing highest path loss 156.3dB at 10m receiver antenna height. SUI is showing lowest variation in path loss values with change in height of receiver antenna and ECC-33 is showing largest variations. COST 231 Hata model is showing moderate path loss value (161.8dB to 154.1dB). Free space model is not analysed here because it is showing same value of path loss in all environment and at all receiver antenna heights.

B.) Analysis in Suburban (medium density) area

For analysis in suburban area we consider same distance and receiver antenna height as in urban area. Results of simulation are shown in Fig. 5, 6 and 7.

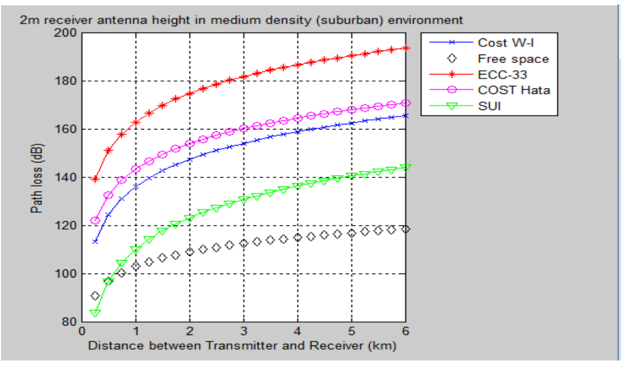


Fig. 5: Simulation of models in suburban area at 2m height of receiver antenna

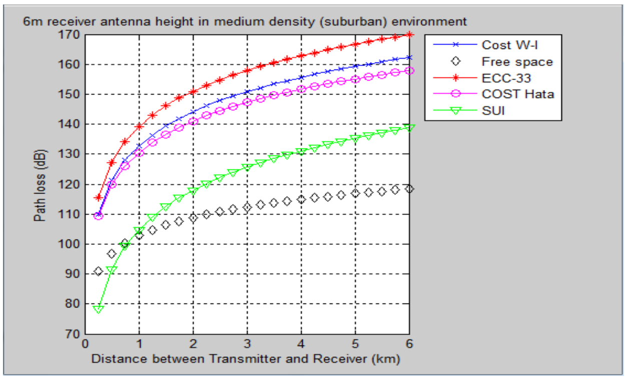


Fig. 6: Simulation of models in suburban area at 6m height of receiver antenna

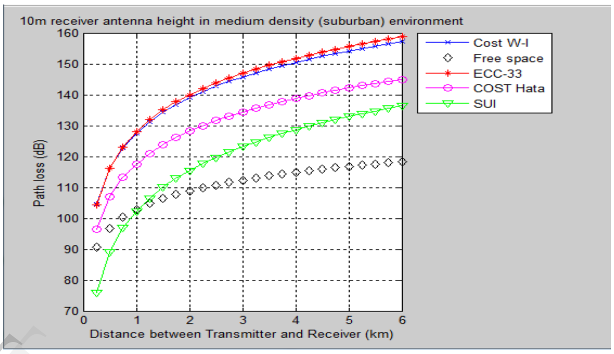
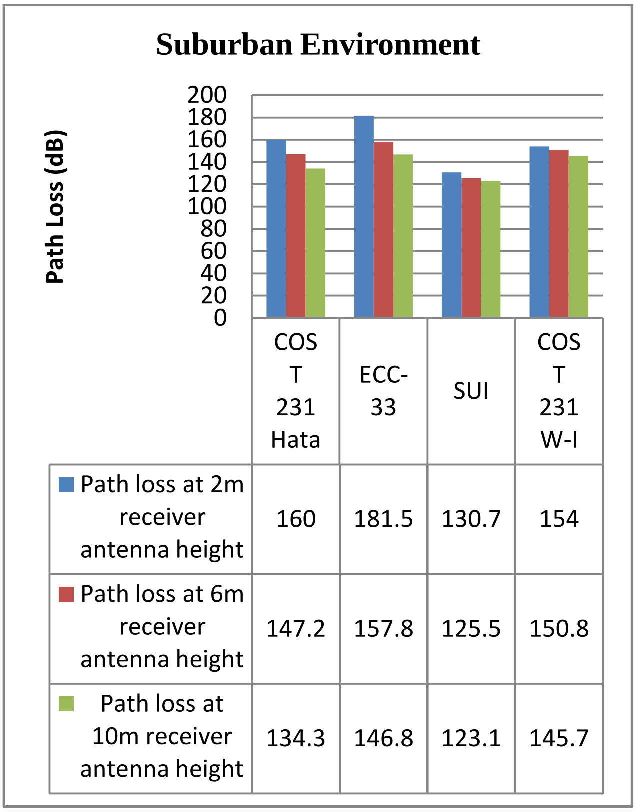


Fig. 7: Simulation of models in suburban area at 10m height of receiver antenna

Bar chart showing our analysis at reference distance of 3km between transmitter and receiver is shown in Fig. 8



	COST 231 Hata	ECC-33	SUI	COST 231 W-I
Path loss at 2m receiver antenna height	160	181.5	130.7	154
Path loss at 6m receiver antenna height	147.2	157.8	125.5	150.8
Path loss at 10m receiver antenna height	134.3	146.8	123.1	145.7

Fig. 8: Analysis of path loss models at reference distance of 3km in suburban area

From our analysis we find that SUI model is showing minimum path loss (130.7dB to 123.1dB). ECC-33 is showing maximum value of path loss (181.5dB to 146.8dB). COST 231 W-I and Hata are showing moderate values of path loss.

C.) Analysis in rural (low density) area

In rural area ECC-33 model is not valid and COST 231 W-I model operates in line-of-sight condition because this model do not have specific parameters for rural areas. Results of simulation are shown in Fig. 9, 10 and 11.

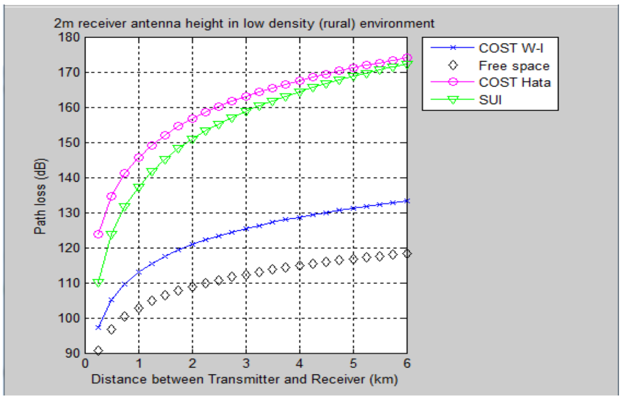


Fig. 9: Simulation of models in rural area at 2m height of receiver antenna

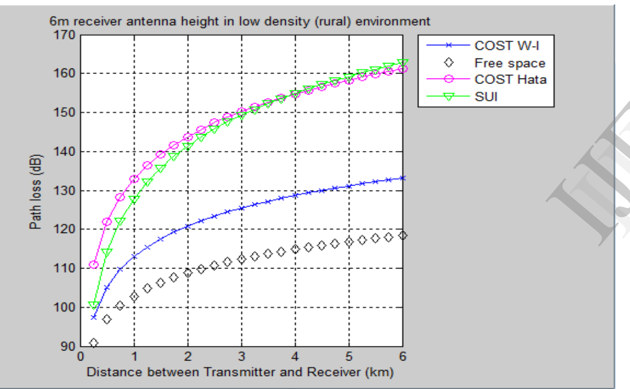


Fig. 10: Simulation of models in rural area at 6m height of receiver antenna

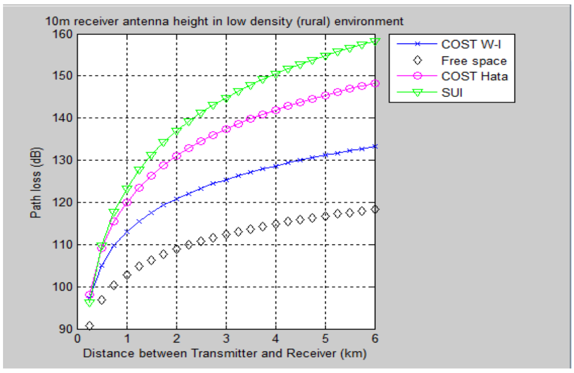


Fig. 11: Simulation of models in rural area at 10m height of receiver antenna

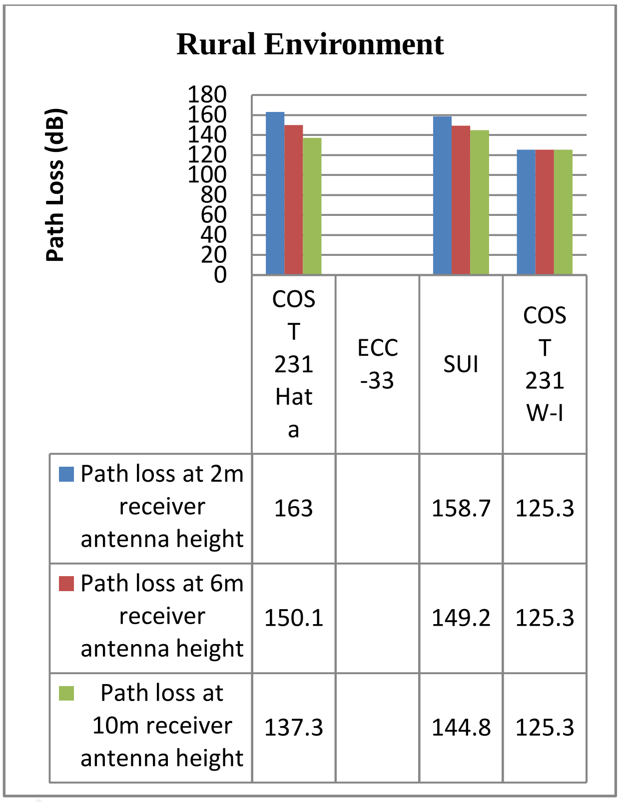


Fig. 12: Analysis of path loss models in rural area at reference distance of 3 km

Bar chart showing our result of analysis is shown in Fig. 12. We find that in rural are SUI model is showing path loss value (158.7dB to 144.8dB). COST 231 W-I model is showing minimum path loss of 125.3dB in line-of-sight condition (minimum as compared to all other models).

D.) Analyzing Handover by calculating Received Signal Strength

Here we are analyzing handover based on RSS calculated from Path Loss value of models taking 6m receiver antenna height and variable distance from 1km to 6km. Threshold from BS is -86dB. Transmitter Antenna gain is 17.5dBi.

Table 3: Parameter RSS

Power of transmitter	43 dBm
Cable and connector loss factor (A)	3.5dB

1.) RSS for Urban Environment

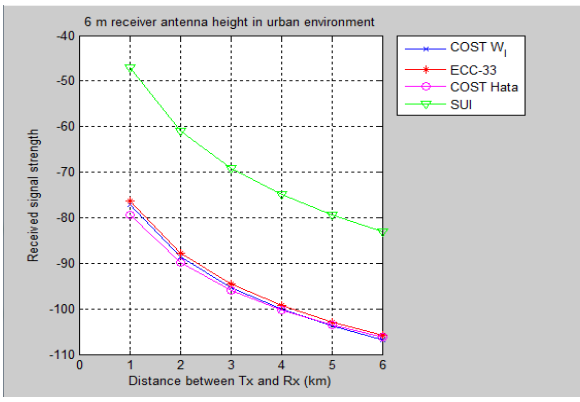


Fig. 13: Simulation of RSS for models in urban Environment

Values for RSS of various models from 1km to 6km are accumulated in Table 4 from this we analyze that that RSS value is highest for SUI (-47.1dBm to -83.0dBm) less than threshold point (-86.0dB) so SUI model is best for spanning greater distance leading to cell of larger size and reducing number of handover. Deciding handover by comparing RSS with threshold will also reduces handover delay.

Table 4: RSS values for path loss models from 1km to 6km in urban area

Distance	RSS forECC-33 (dBm)	COST 231 HATA (dBm)	RSS for SUI (dBm)	RSS for COST 231 W-I (dBm)
1km	-76.3	-79.4	-47.1	-77.2
2km	-87.7	-89.8	-61.0	-88.6
3km	-94.4	-95.8	-69.1	-95.3
4km	-99.1	-100.1	-74.8	-100.1
5km	-102.8	-103.5	-79.3	-103.7
6km	-105.8	-106.2	-83.0	-106.8

2.) RSS for Suburban Environment

Results of simulation for SUI, Cost hata, COST 231 W-I and ECC-33 model for determining Received Signal Strength are shown below in Fig. 14. In this simulation receiver antenna height is taken as fixed and this is 6km.

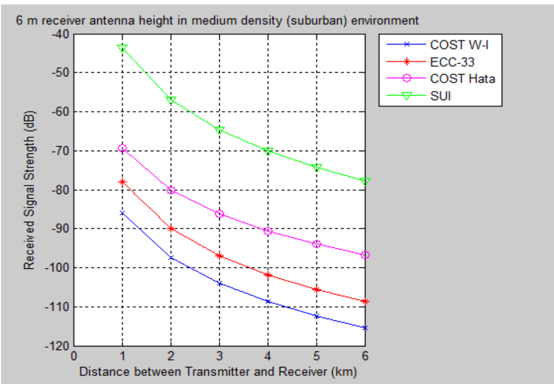


Fig. 14: Simulation of RSS for models in suburban environment

Values for RSS of various models from 1km to 6km are accumulated in Table 5, from this we analyze that that RSS value is highest for SUI (-43.7dBm to -77.7dBm) so SUI model is best for reducing number of handover and leads to efficient performance and COST 231 W-I model have minimum RSS (-115.4dBm) for 6km which is worst for handover.

Table 5: RSS values for path loss models in suburban environment

Distance (km)	RSS for ECC-33 (dBm)	RSS for Cost 231 hata (dBm)	RSS for SUI (dBm)	RSS for COST 231 W-I(dBm)
1km	-78.0	-69.4	-43.7	-85.8
2km	-89.9	-80.0	-56.8	-97.3
3km	-96.8	-86.2	-64.5	-104.0
4km	-101.8	-90.6	-70.0	-108.7
5km	-105.6	-94.0	-74.2	-112.4
6km	-108.7	-96.8	-77.7	-115.4

3.) RSS for Rural Environment

Result of simulation for SUI, Cost hata and COST 231 W-I model for determining RSS are:

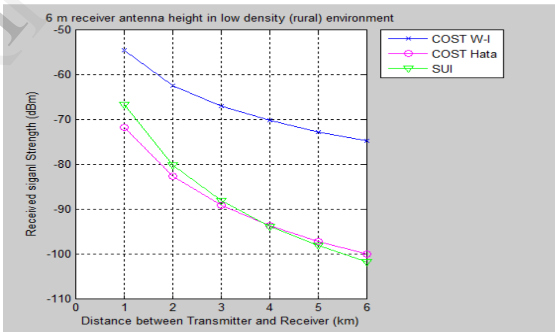


Fig. 15: simulation of RSS for models in rural environment

Values for RSS of various models from 1km to 6km are accumulated in Table 6, from this we analyze that that RSS value is highest for COST 231 W-I (-74.8dBm) greater than threshold point (-86dB).

Table 6: RSS values for path loss models in rural environment

Distance (km)	RSS for COST 231 Hata (dBm)	RSS for SUI (dBm)	RSS for COST 231 W-I (dBm)
1km	-71.8	-66.7	-54.6
2km	-82.7	-80.3	-62.4
3km	-89.1	-88.2	-67.0
4km	-93.7	-93.8	-70.3
5km	-97.2	-98.2	-72.8
6km	-100.1	-101.7	-74.8

IV. CONCLUSIONS

We conclude that path loss value changes with different environments, height of transmitter and receiver antenna and distance between transmitter and receiver. No single model is suitable for all environments. Although SUI model is showing minimum path loss values for Urban and suburban areas but not in rural area reason for this is that we have take height of transmitter 20m in rural and presence of term (c / h_b) in path loss exponent factor increases path loss value in rural area for SUI model. In rural area COST 231 W-I is showing better result. Received signal Strength for SUI model in urban and suburban areas is greater than threshold point up to 6km so this model can leads to cell of larger size by spanning more distance as compared to other models, without reducing RSS below threshold point and thereby reducing number of handover. That will makes handover process efficient.

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