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Suburban Area Path loss Propagation Prediction and Optimisation Using Hata Model at 2375MHz

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Abstract: This paper describes how Cost231 Hata's model is chosen and optimized for suburban outdoor coverage operating in 2375MHz frequency band, Maharashtra, India. This optimized path loss model is based on the empirical measurements collected in the network focusing on the city Ambajogai, MH state. It is developed by comparing the calculated path loss from collected measurements with the well-known path loss models within applicable frequency range of WiMAX system, such as Hata, SUI, ECC 33 and Cost231 W-I models. The Hata model was chosen as a reference for this optimized path loss model development based on the closest path loss exponent and smallest mean error as compared to the measured path loss. This optimized Hata model is implemented in the path loss calculation during the validation process. Thus, this optimized model is successfully improved and would be more reliable to be applied in the Ambajogai. WiMAX system for suburban path loss calculation & open urban path loss calculation in the 2375MHz frequency band.

Key Words: propagation loss prediction, optimisation, Hata model, urban area

I. INTRODUCTION

In wireless communications, the information that is transmitted from one end to another propagates in the form of electromagnetic (EM) wave. All transmitted information incurs path loss as electromagnetic waves propagate from source to destination (due to e.g., reflection, diffraction, and scattering). It has been expressed in the electromagnetic effects such as power attenuation, deep fading. Hence accurate estimation of propagation path loss is a key factor for the good design of WiMAX systems. Propagation path loss models are mathematical tools used by engineers and scientists to plan and optimize wireless network systems. The main goal in the planning phase of the wireless network is to predict the loss of signal strength or coverage in a particular location. the quality of coverage of any wireless network design depends on the accuracy of the propagation model. In order words, the coverage reliability of a wireless network design depends on the accuracy of the propagation model. In the optimization phase, the objective is to make sure the network operates as close as possible to the original design by making sure handoff points are close to prediction; coverage is within design guidelines such as in-door, in-car, and on-street RSS; and co-channel interference is low. Also, in the optimization phase measured data collected from the live network may be used to tune the propagation models utilized in the design phase. the parameters of certain empirical models must be adjusted with reference to the targeted environment in order to achieve minimal error between predicted and measured signal strength [1].

In this paper, two optimised models to predict path loss for WiMAX signals in the 2360-2390MHz based on the COST-231 Hata model [COST Action 231, 1999] will be introduced. The optimised path loss models will be developed based on the received signal strength (RSS) measurements taken in this band in Ambajogai, MH and the path loss estimated by the COST-231 Hata model. The COST-231 Hata model is selected because it showed the best agreement with the measured path loss in terms of path loss exponent, as compared to the SUI model and the ECC 33 path loss model. The performances of these optimised models in estimating the path loss in the 2360-2390MHz band in suburban environment.

II. METHODOLOGY

Several existing path loss models such as Hata's Model [2], Stanford University Interrim (SUI) model [3],Cost 231 Hata Model, ECC33 Model and Cost231 WI Model [6] are chosen for comparison with measurement data. The best existing path loss model with the closest propagation exponent [8], to the measured path loss data will be chosen as a reference for the development of the optimised path loss model. The optimized path loss model will be tested during the validation process by comparing the calculated path loss to the measured path loss WiMAX Network.

A. *Propagation Models*

The existing path loss models are chosen as reference in the development of the optimized path loss model. These existing path loss models are Hata's Model, Cost231 Hata model, SUI, ECC 33 and Cost231 W-I models. These path loss models were developed empirically in the system with similar antenna heights and frequency ranges which are applicable to the WiMAX network in Ambajogai MH.

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1. COST231 Extension to Hata Model

A model that is widely used for predicting path loss in mobile wireless system is the COST-231 Hata model [5, 6]. The COST-231 Hata model is designed to be used in the frequency band from 500 MHz to 2000 MHz. It also contains corrections for urban, suburban and rural (flat) environments. Although its frequency range is outside that of the measurements, its simplicity and the availability of correction factors has seen it widely used for path loss prediction at this frequency band. The basic equation for path loss in dB is [1, 4],

$$PL = 46.3 + 33.9log_{10}(f) - 13.82log_{10}(h_b) - ah_m + \left(44.9 - 6.55log_{10}(h_b)\right)log_{10}d + C_m \quad (1)$$

Where, f is the frequency in MHz, d is the distance between AP and CPE antennas in km, and hb is the AP antenna height above ground level in meters. The parameter cm is defined as 0 dB for suburban or open environments and 3 dB for urban environments. The parameter ah_m is defined for urban environments as [8].

$$ah_m = 3.20\left(log_{10}(11.75h_r)\right)^2 - 4.97 \; for, f > 400\; MHz$$

For suburban or rural (flat) environments,

$$ah_m = (1.1log_{10}f - 0.7)h_r - (2.56log_{10}f - 0.8)$$

Where, hr is the CPE antenna height above ground level. To evaluate the applicability of the COST-231 model for the 2375 MHz band, the model predictions are compared against measurements for suburban environment.

2. Stanford University Interim (SUI) Model

The proposed standards for the frequency bands below 11 GHz contain the channel models developed by Stanford University, namely the SUI models. Frequency band which is used is from 2.5 GHz to 2.7 GHz. Their applicability to the 3.5 GHz frequency band that is in use in the UK has so far not been clearly established [9]. The SUI models are divided into three types of terrains1, namely A, B and C. Type A is associated with maximum path loss and is appropriate for hilly terrain with moderate to heavy foliage densities. Type C is associated with minimum path loss and applies to flat terrain with light tree densities. Type B is characterized with either mostly flat terrains with moderate to heavy tree densities or hilly terrains with light tree densities. The basic path loss equation with correction factors is presented in [7].

$$PL = A + 10log_{10}\left(\frac{d}{d_0}\right) + X_f + X_h + S \quad for\; d > d_0 \quad (2)$$

Where the parameters are, d: Distance between BS and receiving antenna [m], d0: 100 [m], λ: Wavelength [m], $\boldsymbol{X_f}$: Correction for frequency above 2 GHz [MHz], $\boldsymbol{X_h}$: Correction for receiving antenna height [m], s: Correction for shadowing [dB], γ: Path loss exponent. The random variables are taken through a statistical procedure as the path loss exponent γ 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:

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

And the path loss exponent γ is given by:

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

Where, the parameter h_b is the base station antenna height in meters. This is between 10 m and 80 m. The constants a, b, and c depend upon the types of terrain, that are given in Table I. The value of parameter $\gamma = 2$ for free space propagation in an urban area, $3 < \gamma < 5$ for urban NLOS environment, and $\gamma > 5$ for indoor propagation.

The frequency correction factor Xf and the correction for receiver antenna height X_h for the models are expressed in:

$$X_f = 6.0log_{10}\left(\frac{f}{2000}\right) \quad for\; terrain\; type\; A\;\&\; B$$

$$X_f = -10.8log_{10}\left(\frac{h_r}{2000}\right)$$

$$X_h = -20.0log_{10}\left(\frac{h_r}{2000}\right) \quad for\; terrain\; type\; C$$

Where, f is the operating frequency in MHz, and hr is the receiver antenna height in meter. 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.

3. ECC-33 model/hata okumura extended Model

The ECC 33 path loss model, which is developed by Electronic Communication Committee (ECC), is extrapolated from original measurements by Okumura and modified its assumptions so that it more closely represents a fixed wireless access (FWA) system. The path loss model is defined as [5],

$$PL(dB) = A_{fs} + A_{hm} - G_t - G_r$$

Where, A_{fs} is free space attenuation, A_{bm} is basic median path loss, t G is BS height gain factor and r G is received antenna height gain factor. They are individually defined as,

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

$$A_{hm} = 20.4 + 9.83log_{10}(d) + 7.89log_{10}f + 9.56[log_{10}(f)]^2$$

$$G_t = log_{10}\left(\frac{h_b}{200}\right)[13.98 + 5.8(log_{10}(d))^2]$$

For medium city environments,

$$G_r = [42.57 + 13.7log_{10}(f)][log_{10}(h_m) - 0.585]$$

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Table I: The parameter values of different terrain for SUI model

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

The performance analysis is based on the calculation of received signal strength, path loss between the base station and mobile from the propagation model. The GSM based cellular d is distance between base station and mobile (km) hb is BS antenna height in meters and hm is mobile antenna height in meters.

4. COST Walfisch-Ikegami Model

Walfisch-Bertoni method is combined with the Ikegami model [6], to improve path loss estimation through the inclusion of more data. Four factors height of buildings, width of roads, building separation, road orientation with respect to the LOS path are included.The multiple screen diffraction loss *Lmsd* and the rooftop to street diffraction and scatter loss *Lrts* . Thus the path loss *L* in non LOS is defined as

$$L = \begin{cases} L + L_{rts} + L_{msd} & L_{rts} + L_{msd} > 0 \\ L & L_{rts} + L_{msd} < 0 \end{cases}$$

The determination of *Lrts* is based on the principle given in the Ikegami model, but with a different street orientation function .The values of *Lrts* are as follows

$$L_{rts} = -16.9 - 10log_{10}w + 10log_{10}f_{MHz} + 20log_{10}(h - h_m) + L_{ori}$$

Where w, h and *hm* are gap between buildings, height of building and height of mobile stations respectively.

$$L_{ori} = \begin{cases} -10 + 0.354\varphi & 0^0 \le \varphi < 35^0 \\ 2.5 + 0.075(\varphi - 35) & 35^0 \le \varphi < 55^0 \\ 4.0 - 0.114(\varphi - 55)\varphi & 55^0 \le \varphi < 90^0 \end{cases}$$

Where *Lori* is a factor which has been estimated from only a small number of measurements φ, is street orientation angle. The multiple screen diffraction loss was estimated by Walfisch and Bertoni for the case when the base station antenna is above the rooftops i.e. *hb*>*h*. The relevant equations are,

$$L_{msd} = L_{bsh} + k + k_d log_{10} d_{km} + k_f log_{10} f_{MHz} - 9log_{10} b$$

$$L_{bsh} = \begin{cases} -18log_{10}[1 + (h_b - h)] & h_b > h \\ 0 & h_b \le h \end{cases}$$

Where,

$$k_a = \begin{cases} 54 & h_b > h \\ 54 - 0.8(h_b - h) & h_b > h \, and \, d_m \ge 0.5km \\ 54 - 0.8(h_b - h)\dfrac{d}{0.5} & h_b > h \, and \, d_m < 0.5km \end{cases}$$

$$k_d = \begin{cases} 18 & h_b > h \\ 18 - 15\dfrac{(h_b - h)}{h} & h_b > h \end{cases}$$

$$k_f = -4 + \begin{cases} 0.7\left(\frac{f_{MHz}}{925} - 1\right) & formedium\ sized\ cities \\ 1.5\left(\frac{f_{MHz}}{925} - 1\right) & for\ urban \end{cases}$$

The term *ka* represents the increase in path loss when the base station antenna is below rooftop height. The term *kd* and *kf* allow for the dependence of the diffraction loss on range and frequency, respectively.

III. Measurement Configuration

A schematic diagram of the Field measurement set-up is shown in Figure 1. The testing tool used in the measurement was a digital Global positioning System (GARMIN GPS72H) receiver antenna to determine distance (d) from the Base Station (BS). The software comprises a scale, which is calibrated in (dBm). In all the study locations, BS transmitting antenna were dual band with inbuilt features, which enables them to radiate at 2375 MHz for operator A with antenna height of 23.6095m all study access sites. The antennas were sectored 120 degree. An approximate height of 2m and 4m was used as CPE receiver height. The site is situated in latitude 18.72866944 and longitude 76.392369.

IV. Results and Discussion

The path loss estimated by the SUI, COST 231 Hata, ECC33 and COST231 WI models are calculated, and plotted against distance on the same graph as that of the measured path loss.

A. Path loss Model Optimisation

Path loss model optimisation is a process in which a theoretical propagation model is adjusted with the help of measured values obtained from test field data. The aim is to get the predicted field strength as close as possible to the measured field strength. Propagation path loss models optimised for different wireless technologies and environments. The Cost231 Hata model is separated into the three basic elements of an empirical model as shown in eq. (3), (4) & (5).

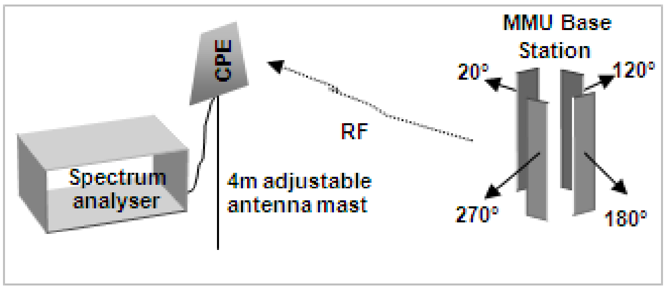

Fig. 1: A set-up Field-test measurement [8]

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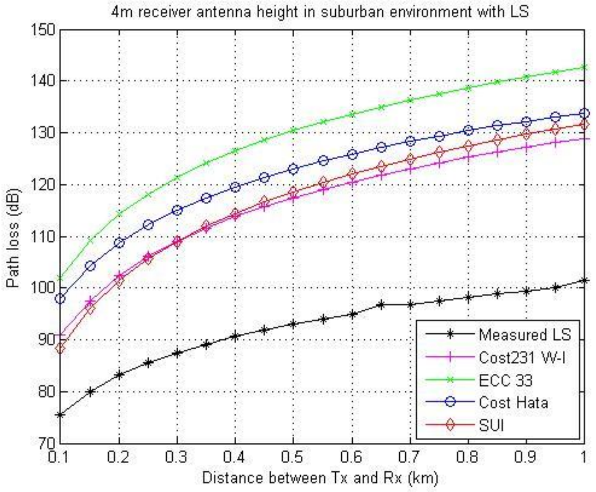

Fig. 2: Comparisons of path loss models with measured path loss in suburban environment

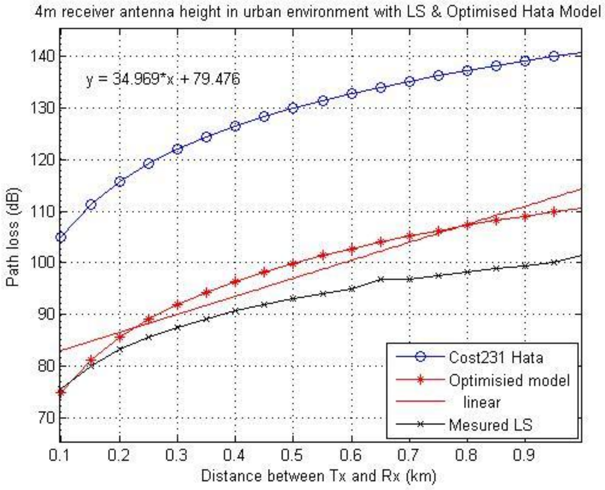

Fig. 3: Optimization for suburban environment

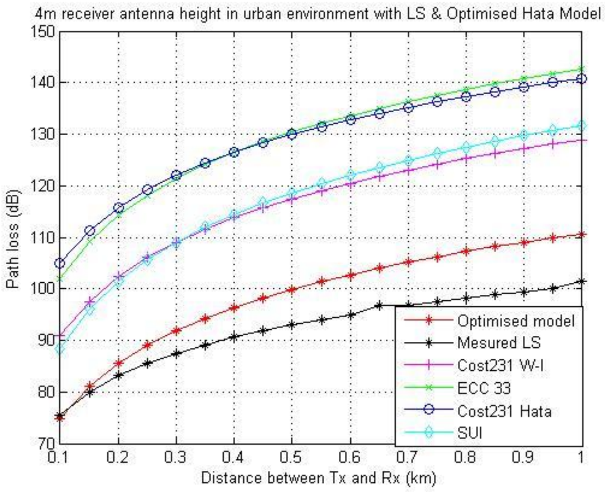

Fig.4: Comparison of Optimized model, Measured and Cost231 Hata path loss for suburban environment.

Table II: NEW INITIAL OFFSET PARAMETER FOR HATA OPTIMIZED MODEL

$E_0 = 46.3 - ah_m + c_m$

E_0 of Cost231 Hata model	"a" from linear line in fig.4	E_{sys}	$E_{0\,new} = a - E_{sys}$
46.3	79.476	55.828	23.648

(3)

$E_{sys} = 33.9log_{10}(f) - 13.82log_{10}(h_b)$

(4)

$\beta_{sys} = (44.9 - 6.55log_{10}(h_b))log_{10}d$

(5)

In order to optimize the proposed model, the condition of a best fit of the theoretical model curve with a given set of experiment data would be met if the function of sum of deviation squares is minimum. The difference between the measured path loss and the Cost231 Hata predicted path loss is plotted in fig. 3 and the new E_0 values found is shown in table II. This new E_0 value substituted into the original Cost231 Hata model equation and new Hata optimized models are presented as shown in eq. (6) For the prediction of path loss in suburban environment i.e. New Optimization Hata model in suburban environment shown in eq. (6)

$$PL_{new} = 23.648 + 33.9log_{10}(f) - 13.82log_{10}(h_b) \\ -ah_m + (44.9 - 6.55log_{10}(h_b))log_{10}d + C_m$$

(6)

The path loss predicted by the Hata optimized models are plotted against measured and Cost231 Hata predicted path losses as shown in fig. 4, this shows that the optimized model is able to predict the path loss with an increased accuracy of 25-40% in the suburban.

V. CONCLUSION

In this paper, the measured path losses in cells are compared with theoretical path loss models: Cost231 Hata, SUI, ECC33 and Cost231 W-I. The measured path loss, when compared with theoretical values from the theoretical models, showed the closest agreement with the path loss predicted by the Hata model in terms of path loss and path loss exponent prediction. Based on this, an optimised Hata model for the prediction of path loss experienced by WiMAX signals in the 2375MHz band in suburban environment of Ambajogai, MH, India is developed in MATLAB. The optimised model showed high accuracy in between 25-40% and is able to predict path loss with smaller path loss and path loss exponent as compared to the Cost231 Hata model.

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BIOGRAPHY

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