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Review of Comparative Analysis of Empirical Propagation model for WiMAX

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Abstract –
The propagation models for path loss may give different results if they are used in different environment other than in which they were designed. In this paper we review of compare the different path loss empirical propagation models with measured field data. For comparative analysis we use the long distance path loss model, Stanford University Interim (SUI) Model, Hata model, Okumura's Model, COST231 Extension to Hata Model and ECC-33 model The field measurement data is taken in urban (high density region), sub urban (medium density region) and rural (low density region) environments at 900 MHz & 1800 MHz frequency with the help of spectrum analyzer. After analyzing the results COST-231 and SUI Model shows the better results in all the three environments particularly in urban and sub urban environments.

***Keywords*— Path loss, Stanford University Interim (SUI) Model, Hata Model, Okumura's Model, Received signal strength.**

I. INTRODUCTION

The path loss propagation models have been an active area of research in recent years Path loss arises when an electromagnetic wave propagates through space from transmitter to receiver. The power of signal is reduced due to path distance, reflection, diffraction, scattering, free-space loss and absorption by the objects of environment. It is also influenced by the different environment (i.e. urban, suburban and rural). Variations of transmitter and receiver antenna heights also produce losses. The losses present in a signal during propagation from base station to receiver may be classical and already exiting. General classification includes three forms of modeling to analyze these losses:

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1. Empirical
2. Statistical
3. Deterministic

In the above models Deterministic models are better to find the propagation path losses, The Statistical models Uses Probability analysis By finding the probability density function. The empirical models uses with Field Measured Data obtained from results of several measurement efforts .this model also gives very accurate results but the main problem with this type of model is computational complexity. The field measurement data was taken in the urban, sub urban and rural environments.

II. PROPAGATION PATH LOSS MODELS

A. Log-distance Path Loss Model

Theoretical and measurement based propagation models indicate that average received signal power decreases logarithmically with distance in radio channels. The expression for path loss in this model is [1]:

$PL(d)$ ά (d/d_0) (1)

$PL(db)-PL(d_0)+10n\log(d/d_0)$ (2)

Where 'n' is path loss exponent
'd' is the T-R separation distance in meters
'd0' is the close-in reference distance in meters.

B. 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 [4]. 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 [2, 3].

$$PL = A + 10\gamma\log_{10}(d/d_0) + X_f + X_h + S \qquad for\ d>d_0$$

Where the parameters are, d: Distance between BS and receiving antenna [m], d0: 100 [m], λ: Wavelength [m] , X_f: Correction for frequency above 2 GHz [MHz], 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:

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

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

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

$X_f = 6.0\log_{10}(f/2000)$ For Terrain type A & B

$X_h = -10.8\log_{10}(h_r/2000)$

$X_h = -20.0\log_{10}(h_r/20000)$ 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.

C. Okumura's Model

One of the most general models for signal prediction in large urban macro cells is Okumura's model [5]. This model is applicable frequency ranges of 150-1920 MHz and over distances of 1-100 Km. Okumura used extensive measurements of base station-to-mobile signal attenuation to develop a set of curves giving median attenuation relative to free space of signal propagation in irregular terrain. The base station heights for these measurements were 30-100 m, the upper end of which is higher than typical base stations today. The path loss formula of Okumura is given by,

$$PL(dB) = L_f + A_{mn}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA}$$

Where, *d* is the distance between transmitter and receiver, *L*50 is the median (50th percentile) value of propagation path loss, *Lf* is free space path loss, *Amu* is the median attenuation in addition to free space path loss across all environments, *G*(*ht*) is the base station antenna height gain factor, *G*(*hr*) is the mobile antenna height gain factor, and *G*AREA is the gain due to the type of environment. The values of *Amu* and *G*AREA are obtained from Okumura's empirical plots [1,5]. Okumura derived empirical formulas for *G*(*ht*) and *G*(*hr*) as,

$$G(h_{te}) = 20\log_{10}\left(\frac{h_{re}}{200}\right), \qquad 30m < h_{re} < 100m$$

$$G(h_{te}) = 10\log_{10}\left(\frac{h_{re}}{3}\right), \qquad h_{re} \le 3m$$

$$G(h_{te}) = 20\log_{10}\left(\frac{h_{re}}{3}\right), \qquad 3m < h_{re} < 10m$$

Correction factors related to terrain are also developed in [5] that improve the model accuracy.

Okumura's model has a 10-14 dB empirical standard deviation between the path loss predicted by the model and the path loss associated with one of the measurements used to develop the model. Okumura's model is wholly based on measured data and doesn't provide any analytical explanation. The major disadvantage with the model is its slow response to rapid changes in the terrain; therefore the model is fairly good in urban and suburban area, but not good in rural area.

D. *Hata Model*

The Hata model [6] is an empirical formulation of the graphical path loss data provided by Okumura and is valid over roughly the same range of frequencies, 150-1500 MHz. This empirical model simplifies calculation of path loss since it is a closed-form formula and is not based on empirical curves for the different parameters. The standard formula for median path loss in urban areas under the Hata model is,

$$PL_{50,urban}\ (dB) = 69.55+26.16\ \log_{10}(f_e)-13.82\ \log_{10}(h)-a(h)+(44.9-6.55\ \log_{10}(h))\ \log_{10}(d).$$

The parameters in this model are the same as under the Okumura model, and *a*(*hre*) is a correction factor for the mobile antenna height based on the size of the coverage area. For small to medium sized cities, this factor is given by [1,6]:

$$a(h_r) = (1.1\log_{10}(f_e)-0.7)h_r - (1.56\log_{10}(f_e) -0.8)dB$$

and for larger cities at frequencies f_e > 300 MHz by,

$$a(h_r) = 3.2(\log_{10}(11.75hr)^2-4.97\ dB.$$

Corrections to the urban model are made for suburban and rural propagation, so that these models are, respectively,

$$PL_{50,\ suburban}\ (dB)= PL_{50,urvan}(dB) - 2[\log_{10}(f/28)]^2-5.4$$

$$PL_{50,rural}\ (dB = PL_{50,urban}(dB) - 4.78[\log_{10}(f_e)^2] +18.33\log_{10}(f_e) – K$$

Where *K* ranges from 35.94 (countryside) to 40.94 (desert). Hata's model does not provide for any path specific correction factors, as is available in the Okumura model. The Hata model well-approximates the Okumura model for distances *d* > 1 Km. Thus, it is a good model for first generation cellular systems, but does not model propagation well in current cellular systems with smaller cell sizes and higher frequencies. Indoor environments are also not captured with the Hata model.

E. *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 [4,7]. 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],

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

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 metres. 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].

$$ah_m= 3.20(\log_{10}(11.75hr))^2 -4.97,\ \text{for}\ f > 400\ MHz$$

for suburban or rural (flat) environments,

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

where, *hr* is the CPE antenna height above ground level. Observation of above two equations reveals that the path loss exponent of the predictions made by COST-231 Hata model is given by,

$$ncost =(44.9 - 6.55\log10\ (hb\ ))/ 10$$

To evaluate the applicability of the COST-231 model for the 3.5 GHz band, the model predictions are compared against measurements for three different environments namely, rural (flat), suburban and urban.

F. *ECC-33 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 [4],

$$PL(dB) = A_{fs} +A_{bm} – G_t – G_r$$

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

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

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

$$G_t=\log(h_b/200)[13.98+5.8(\log(d))^2]$$

for medium city environments,

$$G_r=[42.57+13.7\log(f)][\log(h_m)-0.585]$$

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.

III. COMPARSION WITH MEASUREMENTS

Field measurement data was taken in the urban (high density region means market area, Sub urban (medium density region means colonies and Rural (low density means in a villages using spectrum analyzer. The power from the transmitter taken is 5KW.The close-in reference distance taken is 1KW.Measurements were taken in regular intervals between 1KW and 5KW. By observing the practical received power strength we got a conclusion that the path loss is less in the rural areas than in sub urban and urban areas. That means the path loss is more in the case of urban environment.

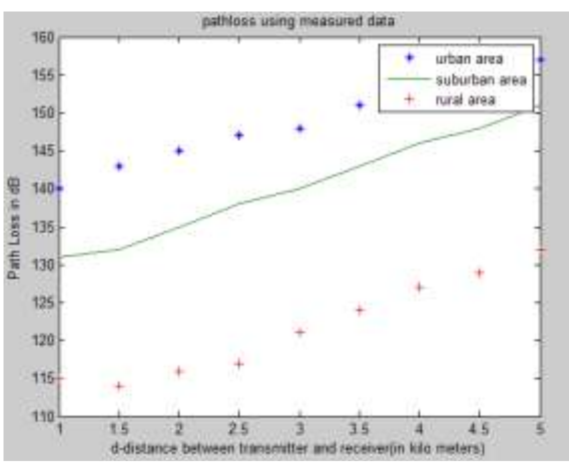

Fig.1 Measured path loss in different environment

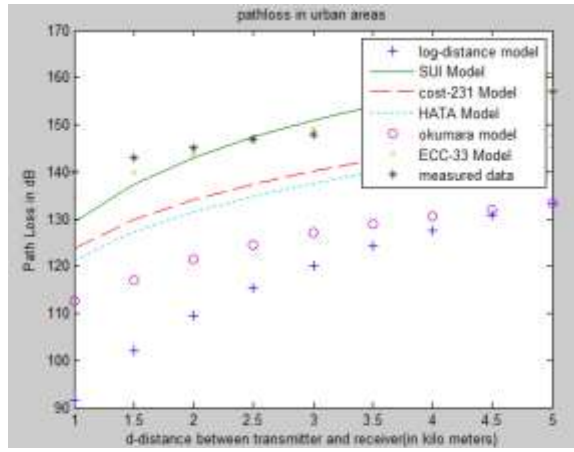

Fig.2 Comparison of path loss models with measurements from an urban environment

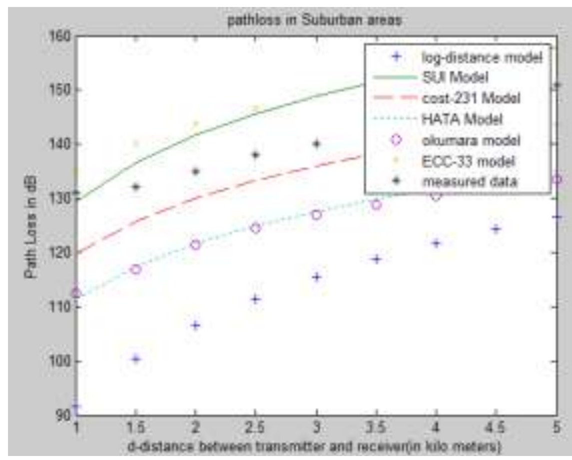

Fig.3 Comparison of path loss models with measurements from a suburban environment

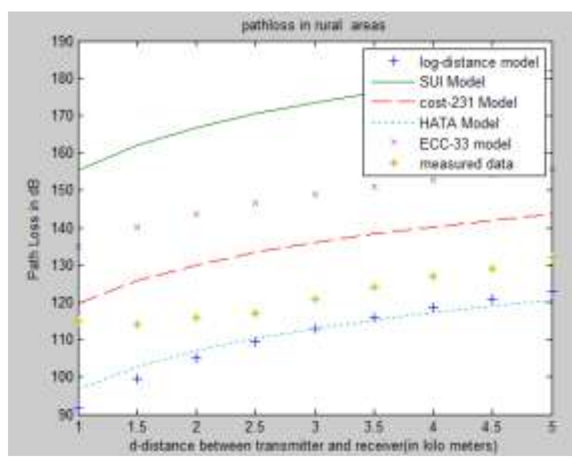

Fig.4 Comparison of path loss models with measurements from a rural environment

IV. CONCLUSION

Here we discussed different models and calculated path loss in three different environments (urban, suburban and rural) using MATLAB Software. The obtained path losses are graphically plotted for the better conclusion using the same software. By observing the graphical representation we concluded that ECC-33 and SUI models are giving the best results in urban area. ECC-33, SUI and COST-231 models are showing better results in sub urban area. HATA and Log-distance path loss models are also giving better results in rural areas. Okumara model is showing better results in urban and sub urban environments.

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