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Performance and Sensitivity Analysis of Path Loss Models for WiMAX Signals

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Abstract

The paper depicts investigation related to path loss estimation and overall performance of both theoretical and experimental propagation models. Performance of propagation models namely, SUI, Okumara-Hata and COST-231 has been analyzed and compared with the experimental results obtained for frequency range of 2360-2390 MHz of WiMAX signals in different environments. The performance analysis of these models reveals that COST 231-Hata Model gives closest approximation to experimental data. Thereafter, sensitivity analysis of various parameters i.e., base station height, receiver antenna height, correction factor was done to demonstrate which parameter can be modified for optimization of COST 231-Hata Model.

Keywords Path Loss; WiMAX; Propagation models; Sensitivity.

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1. Introduction

In India, the Government has taken initiative to cover both rural and urban area with broadband services [1]. Consequently, communication sector is witnessing lots of activity. WiMAX signals are integral part of broadband services, mobile entertainment and voice over IP (VoIP) services [3].

It has been observed that when signal propagates through a environment, its strength decreases. This decrease in strength of signal is known as path loss. There are many factors which cause path loss like free space absorption, diffraction and multipath signal losses.

The path loss information is vital component to achieve perfect reception, proper coverage and improved performance of communication system. Several models have been developed to predict path loss; some well known models are Hata model, SUI model, and COST 231-Hata model.

In this paper a short introduction of the propagation models is presented. Their performance is compared with field data of WiMAX signals in 2360-2390 MHz band. Moreover, sensitivity analysis of these models has been done with respect to base station height. This sensitivity study conveys information regarding dependence of path loss, predicted by various models on base station height and distance of reception of signals.

2. Description of propagation model

Propagation models have been active area of research. Models are being developed and analyzed for both long distance and short distance communication; operating under different condition (like indoor, outdoor, urban, suburban and rural). The long distance models encapsulate various parameters like base station height, receiver antenna height, operating frequency, terrain roughness and environmental conditions. Some of the significant propagation models are:

2.1. *Okumura- Hata model*

Basically, this empirical model has been framed by Okumura, a Japanese for urban areas (big city and small city); and with some correction factors it could be extended to suburban and rural areas[2]. For urban areas the standard median path loss equation is given by-

$$L_{(urban)}(dB) = 69.55+26.16\log(f_c)-13.82\log(h_r)-a(h_r) +(44.9-\log(h_t))\log d \quad (1)$$

For suburban area, it is expressed as

$$L_{(suburban)}(dB) = L_{(urban)}-2[\log(f_c/28)]^2-5.4 \quad (2)$$

Finally, for open rural area, it is modified as

$$L_{(open)}(dB) = L_{(urban)}-4.78(\log(f_c))^2+18.33\log(f_c)-K \quad (3)$$

With K ranges from 35.94(country side) and 40.94(desert)

The correction factor, $(a(h_r))$, in Equation (1), differs as a function of the size of the coverage area in urban.

For small city, it is

$$a(h_r)= (1.1\log(f_c) - 0.7)h_r - (1.56\log f_c - 0.8)dB \quad (4)$$

For Big city, it is

$$a(h_r) = 8.29(\log 1.54h_r)^2 - 1.1dB \quad \text{for} \quad f_c < 300MHz \quad (5a)$$

$$a(h_r) = 3.2(\log 11.75h_r)^2 - 4.97dB \quad \text{for} \quad f_c > 300MHz \quad (5b)$$

In the above equations:

f_c = carrier frequency (MHz)

d = distance between base station and receiver (km)

h_b = base station antenna height (m)

h_m = receiver antenna height (m)

The range of parameters for the Hata model is:

$150 \le f_c \le 1500$ MHz

$30 \le h_b \le 200$ m

$1 \le h_r \le 10$ m

$1 \le d \le 20$ km

The Hata's model well-approximates the Okumura model for distance d >1Km, but does not model propagation well in current cellular systems with smaller cell sizes and higher frequencies [2].

2.2. *COST 231-Hata model*

A model that is used for all type of environment for path loss prediction in mobile wireless system is the COST-231Hata model, amendment done by European Council[4] based on the Hata model. The COST 231 model works accurate for carrier frequencies up to 2000MHz. Its empirical formula is:

$$PL(dB) = 46.3- (44.9-6.55\log(h_b))\log d + 33.9\log f - ah_r - 13.82\log h_b - c \quad (6)$$

The Equation consists of three basic elements like in any other empirical propagation models [3]. The entire equation can be grouped into the initial offset parameter, E_0, the initial system design parameter, E_{sys}, and the slope of the model curve, β_{sys}.

Where, this parameter modeled as:

$E_0 = 46.3 - ah_r - c$

$E_{sys} = 33.9\log (f) - 13.82\log (h_b)$

$B_{sys} = (44.9-6.55\log (h_b)) \log d$

From the equation (6), in which correction factor [5], ah_r

$$ah_r = 1.1(\log f- 0.7)h_r - (1.56\log f -0.8) \quad \text{for suburban and rural}$$

$$ah_r = 3.20(\log(11.75h_r))^2-4.97 \quad \text{for urban}$$

$$C = \begin{cases} -3 & \text{Big City} \\ 0 & \text{City} \\ 12.28 & \text{Suburban} \\ 22.52 & \text{Countryside} \end{cases}$$

2.3. *SUI-Model*

SUI is another path loss model developed by Institute of Electronics &Electrical Engineering (IEEE) working group in year 1995. SUI model take into account of three different terrains namely terrain A, Terrain B and Terrain C. Terrain A is associated with hilly areas. Terrain A is associated with maximum path loss depicting urban condition. Terrain B is for hilly terrains with Suburban condition and terrain C is for flat terrain associated with minimum path loss [3], in this paper we have only considered terrain A and terrain B. The SUI model is given by:

$$PL(dB)=A+10\gamma\log_{10}(d/d_0)+Xf+Xh$$

Where d_0 = 100m, d is distance between base station and antenna receiver.

The value of SUI model is typically between 8.2 dB and 10.6 dB and used to account for tree and cluster shadowing. The path loss exponent γ is calculated from constant in Table.1.

$$\gamma = a - b*h_b + c/h_b$$

Table 1. Terrain constants

Terrain	Equivalent Environment	A	b	c
A	Urban	4.6	0.0075	12.6
B	Suburban	4.0	0.0065	17.1

3. Simulation of comparative Performances

The performance of various path loss models was compared with experimental values [3]. Two different environments were chosen namely urban and suburban. In each environment, two scenarios were considered one having receiving antenna height of 2m and other having height of 4m**.**

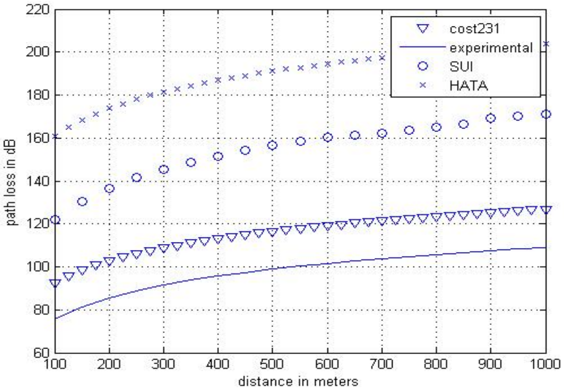

Fig. 1. Performance of path loss models in urban environment with receiving antenna height 2m

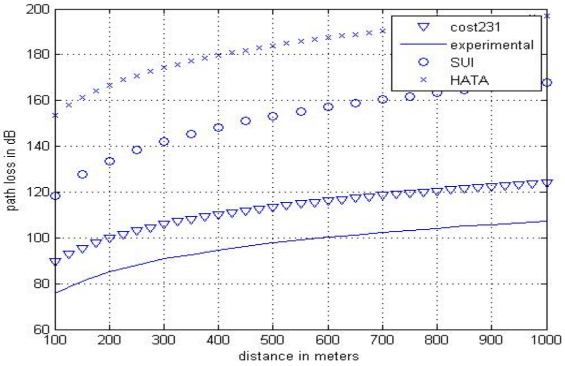

Fig. 2. Performance of path loss models in urban environment with receiving antenna height 4m

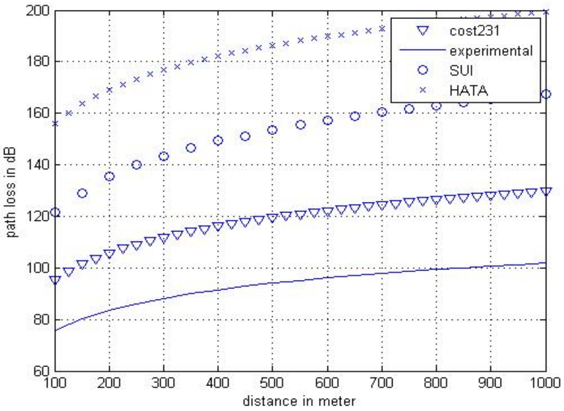

Fig. 3. Performance of path loss model in suburban environment with receiver antenna height 2m

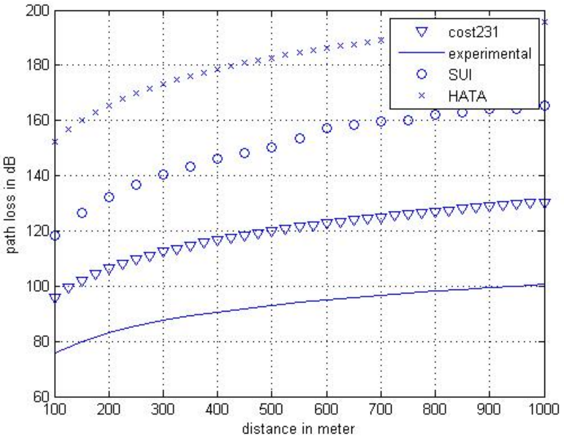

Fig. 4. Performance of path loss model in suburban environment with receiver antenna height 4m