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Comparative Analysis of Different Parameters in Propagation Model for Mobile Communication System

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Abstract- Nowadays the wireless technology becomes popular and receives growing acceptance as a Broadband Wireless Access (BWA) system. Wireless system has potential success in its line-of-sight (LOS) and non line-of-sight (NLOS) conditions which operating with different frequency. Estimation of path loss is very important in initial deployment of wireless network and cell planning. Numerous path loss (PL) models (e.g. Okumura Model, Hata Model) are available to predict the propagation loss, but they are inclined to be limited to the lower frequency bands. Radio propagation is essential for emerging technologies with appropriate design deployment and management strategies for any wireless network. It is site specific and can vary significantly depending on terrain, frequency of operation, velocity of mobile terminal, interface sources and other dynamic factor. Accurate characterization of radio channel through key parameters and a mathematical model is important for predicting signal coverage, achievable data rates, specific performance attributes of alternative signaling and reception schemes. Empirical path loss models for macro cells such as free path loss, Hata Okumura, COST 231 Hata and ECC 33 models are analyzed and compared. The received signal strength is calculated with respect to distance to determine the model that can be adopted to minimize the number of handoffs and avoid ping pong effect. This paper proposes a comparison study of different propagation model such as Okumara-Hata model, COST 231 Hata model, ECC-33 to calculate path loss for highway and urban between Bhubaneswar and Cuttack. Comparative study with real time measurement obtained from Bharat Sanchar Nigam Limited (BSNL) a GSM based wireless networks for Bhubaneswar and Cuttack has been implemented. A suitable empirical model for different environments is to be proposed. Also calculate received signal strength for each environment under all three models and calculate the probability for each case.

***Keywords*:** Cellular mobile, Handoff, Path loss, Ping Pong, Received signal strength.

I. INTRODUCTION

Wireless communication is the fastest growing segment of the wireless industry. As such, it has captured the attention of the media and imagination of the public. The vision of the wireless network communications supporting information exchange between people or devices is the communications frontier of the next few decades and much of it already exists in some form. However, many technical challenges remain in designing of wireless networks that deliver the performance necessary to support emerging applications. This thesis analyses the comparison of three different models with calculating path loss for urban and highway. In addition, calculate the received signal strength (RSS) of base station with noise and without noise for the same area. We approach this problem by doing comparative study of different types of path loss models. And using these models we can measure the RSS which helps to deciding the handover. The basic characterization of the propagation of the wireless channel can be described as large-scale and small-scale fading. Large-scale fading deals with spatial characteristics of the channels. Basic propagation models indicate that average received signal strength (RSS) power decreases logarithmically with distance.

II. PATH LOSS

The reduction in power density of an electromagnetic wave is called Path loss (or path attenuation) as it propagates through space. Path loss is a major component in the analysis and design of the link budget of a telecommunication system. This term path loss is commonly used in wireless communications and signal propagation. Path loss may be due to many effects, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss, and absorption [1] [2]. Path loss is also influenced by terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, and the height and location of antennas [3].

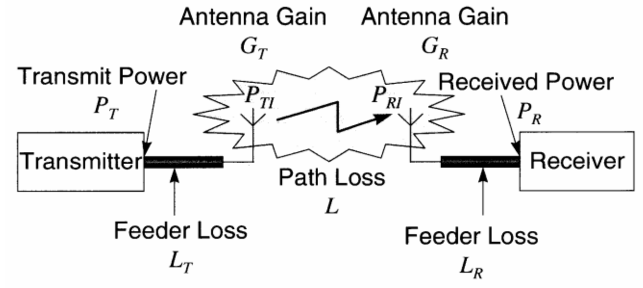

Figure 1 Concept of path loss

III. PATH LOSS MODELS

A. Free Space Path Loss Model (FSPL):

Path loss in free space defines how much strength of the signal is lost during propagation from transmitter to receiver [4]. FSPL is diverse on frequency and distance. The calculation is done by using the following equation:

The free space path loss

$$PL(db) = Gt - Gr + 32.44 + 20\log(d) + 20\log(f) \quad (1)$$

Where,

Gt is transmitted antenna gain in dBm

Gr is received antenna gain in dBm

d is T-R separation in Km.

f is frequency in [MHz].

B. Hata-Okumura Model:

The Okumura model is used for Urban Areas is a Radio propagation model that is used for signal prediction [4]. The frequency coverage of this model is in the range of 200 MHz to 1900 MHz and distances of 1 Km to 100 Km. It can be applicable for base station effective antenna heights (ht) ranging from 30 m to 1000 m. The Okumura model is a well known classical empirical model to measure the radio signal strength in build up areas. This model is perfect for using in the cities having dense and tall structure.The Hata model is an empirical formulation of the graphical path-loss data provided by the Okumura and is valid over roughly the same range of frequencies, 150-1500MHz. This empirical formula simplifies the calculation of path loss because it is closed form formula and it is not based on empirical curves for the different parameters. The Okumara Hata model is the combination of both the above models.

The standard formula for empirical path loss [dB] in urban areas under the Okumara Hata model is given by:

$$PL(db) = A + B\ log(d) \quad (2)$$

Where,

d is distance in Km.

A is fixed loss depends on frequency *f*.

These parameters are given by empirical formula.

$$A = 69.55 + 26.16\ log(f) - 13.82\log(h_b) - a(h_m) \quad (3)$$

$$B = 44.9 - 6.55\log(h_b) \quad (4)$$

Where,

f is frequency measured in MHz

hb is height of base station antenna in meters.

hm is height of mobile station antenna in meters.

a (hm) is correlation factor in dBm.

For effective mobile antenna height a (hm) is given by

$$a(hm) = [1.1\log(f) - 0.7]hm - [1.56\log(f) - 0.8] \quad (5)$$

The path loss model for highway is given by

For without noise factor

$$PL(db) = PL(db)urban - 2\left[\log\left(\frac{f}{28}\right)\right]^2 - 5.4 \quad (6)$$

For with noise factor

$$PL(db) = PL(db)urban - 2[\log(\frac{f}{28})]^2 \quad (7)$$

C. COST-231 Hata Model:

Hata model is used for the frequency range of 150 MHz to 1500 MHz to predict the median path loss for the distance d from transmitter to receiver antenna up to 20 km, and transmitter antenna height is considered 30 m to 200 m and receiver antenna height is 1 m to 10 m [5]. To predict the path loss in the frequency range 1500 MHz to 2000 [MHz], COST 231 Hata model is initiated as an extension of Hata model. To extend Hata-Okumura- model for personal communication system (PCS) applications operating at 1800 to 2000 MHz, the European Co-operative for Scientific and Technical Research (COST) came up with COST-231 model. This model is derived from Hata model and depends upon four parameters for prediction of propagation loss: frequency, height of received antenna, height of base station and distance between base station and received antenna. It is used to calculate path loss in three different environments like urban, suburban and rural (flat). This model provides simple and easy ways to calculate the path loss. Although our working frequency range (3.5 GHz) is outside of its measurement range, its simplicity and correction factors still allowed to predict the path loss in this higher frequency range.

The standard formula to calculate path loss in urban areas under COST-231 Hata model is given by

$$PL(db) = 46.33 + 33.9\log(f) - 13.82\log(h_b) - a(h_m) + [44.9 - 6.55\log(h_b)]\log(d) \quad (8)$$

Where

$$a(hm) = [1.1\log(f) - 0.7]hm - [1.56\log(f) - 0.8] \quad (9)$$

The path loss model for highway under COST-231 Hata is same as for Hata-Okumara model that is given by

For without noise factor

$$PL(db) = PL(db)urban - 2\left[\log\left(\frac{f}{28}\right)\right]^2 - 5.4 \quad (10)$$

For with noise factor

$$PL(db) = PL(db)urban - 2\left[\log\left(\frac{f}{28}\right)\right]^2 \quad (11)$$

D. Hata-Okumura Extended Model or ECC-33 Model:

The ECC 33 path loss model is developed by Electronic Communication Committee (ECC), which is extrapolated from original measurements by Okumura and modified its assumptions so that it more closely represents a fixed wireless access (FWA) system [4]. The most extensively used empirical propagation model is the Hata-Okumura model, which is a well-established model for the Ultra High Frequency (UHF) band. The original Okumura model doesnot provide any data greater than 3 GHz. Based on prior knowledge of Okumura model an extrapolated method is applied to predict the model for higher frequency greater than 3 GHz. The tentatively proposed propagation model of Hata-

Okumura model with report is referred to as ECC-33 model. In this model path loss is given by

$$PL(db) = A_{FS} + A_{bm} - G_t - G_r \tag{12}$$

Where

Afs is free space attenuation

Abm is basic medium path loss.

Gt is BS height gain factor.

Gr is Received antenna height gain factor.

$$A_{fs} = 92.4 + 20\log(d) + \log(f) \tag{13}$$

$$A_{bm} = 20.41 + 9.83\log(d) + 7.894\log(f) + 9.56\ \log(f)^2 \tag{14}$$

$$G_t = \log\left(\frac{h_b}{200}\right)[13.958 + \{5.8\log(d)\}]^2 \tag{15}$$

$$G_r = [42.57 + 13.7\log(f)][log(h_m) - 0.585] \tag{16}$$

Where, f is frequency in GHz.

IV. COMPARISON BETWEEN OKUMARA HATA MODEL, COST-231 HATA MODEL AND ECC-33 MODEL

Path loss is the reduction in power of an electromagnetic wave as it propagates through space [6]. It is a major component in analysis and design of link budget of a communication system. It depends on frequency, antenna height, receive terminal location relative to obstacles and reflectors, and link distance, among many other factors. Macro cells are generally large, providing a coverage range in kilometers and used for outdoor communication. Several empirical path loss models have been determined for macro cells. Among numerous propagation models, the following are the most significant ones, providing the foundation of mobile communication services [7].

The path loss empirical models are

i. Hata Okumura model
ii. COST 231 model
iii. ECC 33 model

These prediction models are based on extensive experimental data and statistical analysis, which enable us to compute the received signal level in a given propagation medium [8] [9]. The usage and accuracy of these prediction models depends on the propagation environment. In our thesis, we analyze three different models which have been proposed by the researchers at different operating frequency up to 3 GHz. We also choose our parameters for best fitted to the Orissa environment. In this chapter we consider free space path loss model which is most commonly used idealistic model.

V. RECEIVED SIGNAL STRENGTH IN MOBILE COMMUNICATION

Received signal strength is a strength which is used to measure the power between the received radio signals [10]. For each base station there is a threshold point below which connection break with active base station. Therefore the signal strength must be greater than threshold point to maintain the connection with active BS. The signal gets weaker as mobile moves far away from active base station and gets stronger signal towards new base station as it move closer. There is an option named Handoff if RSS of active base station decreases below threshold level to maintain the connection. Path loss is an important factor in handoff. The RSS can be calculated with different path loss models like Hata-Okumara, COST-231 etc [11].

The received signal strength for Okumara Hata model, COST-231 Hata model and ECC-33 model are calculated as

$$P_r = P_t + G_t + G_r - PL - A \tag{17}$$

Where,

Pr is received signal strength in dBm

Pt is transmitted power in dBm.

Gt is transmitted antenna gain in dBm

Gr is received antenna gain in dBm

PL is total path loss in dBm

A is connector and cable loss in dBm

With existing draft, the formula for highway area under ECC-33 model not defined. For this model, only urban path loss can be calculated [12].

VI. PROBABILITY OF HANDOVER

As distance increases between mobile station and base station, the probability of handover increases [13]. When mobile present at centre of base station probability of handover is very less but as mobile user move towards the edge of base station received signal strength decreases and probability of handover increases [14]. At the edge of base station the received signal strength goes down below the threshold value and probability of handover becomes maximum, at that point handover take place otherwise connection lost.

$$Prob\ of\ handover = \frac{Tinit+Savg}{Tinit+Tmin} \tag{18}$$

Where,

Tinit: initial threshold point at which initial handoff process starts to find out target base station with suitable parameters.

Timin: it is minimum threshold point at which execution phase of handoff start and below this point connection breaks with current base station or delay produces if handoff execution is completed and packets lost.

VII. RESULT AND CONCLUSION

The results shows the path loss for urban and highway area under the three path loss models. For computation purpose, parameter, operating frequency: 300 MHz, distance between transmitter and receiver antenna height: one to seven meter, transmitter antenna height: 150 m and receiver antenna height: 10 m have been considered. Results show the comparison between Okumara Hata model, COST-231 Hata model and ECC-33 model for urban and highway area of Cuttack and Bhubaneswar, also compare the received signal strength and probability of handover for the same three models and for the same area. The result shows that modified suburban model for highway using Hata- Okumura and COST 231 model is closer to the observed received signal strength and predicted to be suitable model for highway received signal strength calculation. With this RSS for constant threshold, probability of handover have been calculated and compared results for Hata-Okumara, COST-231 Hata and Ecc-33 models. The proposed work concluded that in all of three models the Hata-Okumara model and COST-231 Hata model are more preferable than ECC-33 model and gives very close values to experimental values.

Table1 Simulation parameters

Parameter	*Value*
Base station transmitter power	43 dBm
Mobile transmitter power	30dBm
Base station antenna height	35m
Mobile antenna height	1.5m
Transmitter antenna gain	17.5dB
Threshold level for mobile	-102dBm
Threshold level for base station	-110dBm
Frequency	900 MHz
Connector loss	2dB
Cable loss	1.5dB
Duplexer loss	1.5dB
Maximum uplink loss	167.15dB

A. Path loss for Various Method:

The path loss of various models has been calculated and presented in table 2 for urban area.

Table 2: Path loss for various models (dB)

Distance	*Hata –Okumara*	*COST -231 Hata*	*ECC -31*
1	125.4388	125.123	119.444
2	135.9055	135.59	134.8942
3	142.0311	141.7212	144.2851
4	146.3772	146.0674	151.1061
5	149.7484	149.4385	156.4873
6	152.5028	152.193	160.9426
7	154.8316	154.5218	164.7507

B. Graphical Result for Path Loss:

Figure 2(a) shows the comparison results of path loss for various models. The allowable uplink and downlink loss for base station transceiver are 167.15dB and 167.61dB. The number of handoffs per call is related to cell size, if cell size is smaller number of handoff comes maximum and result shows that path loss model which cover maximum distance minimizes the number of handoff. The path loss calculation using Hata- Okumura and COST-231 model are less than the threshold value up to 13 and ECC-33 model exceed the threshold value at 3. Therefore these two models except ECC-31 are more preferable. Hence, Okumara-Hata model and COST-231 Hata model are better option other than ECC-31.
Figure 2(b) shows the comparison of highway using Hata-Okumara, COST-231 Hata models. As distance increases, Hata Okumara model has greater path loss as compared to COST. Therefore COST model is better option than Hata for highway environment to calculate path loss.

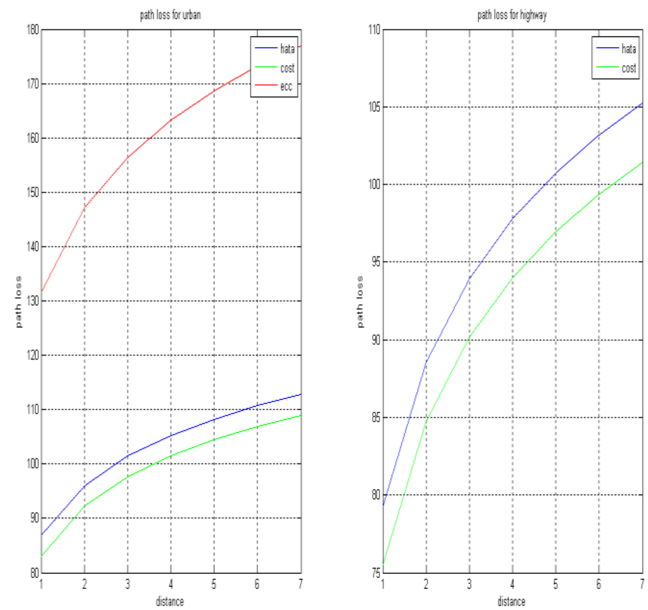

Figure 2 Path loss comparisons for (a) urban area and (b) highway

C. Received Signal Strength for Urban:

Table 3: Received Signal Strength for Urban (dB)

Distance	*Hata- Okumara*	*COST 231 Hata*	*ECC 31*
1	-35.5147	-35.456	-60.1828
2	-44.438	-44.38	-75.331
3	-52.905	-52.846	-87.792
4	-55.293	-53.234	-91.172
5	-54.342	-54.283	-94.632
6	-53.026	-52.967	-95.345
7	-60.429	-60.37	-104.505

Table 3 shows calculated received signal strength for various models that have been used in proposed work like Okumara-Hata, COST-231 Hata and ECC-33 model in urban area.

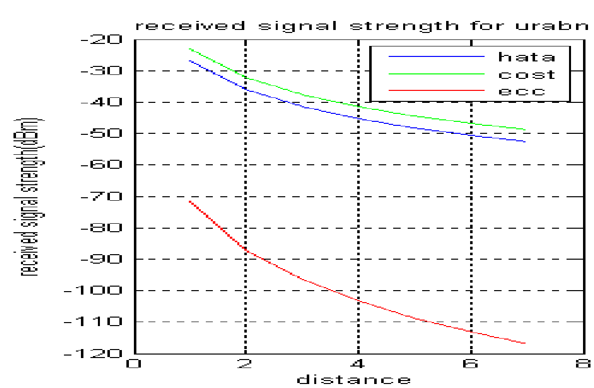

Figure 3 RSS for urban (dB)

Figure 3 shows the comparison in urban area for three considered models. Result shows that ECC-31 model at 4Km distance is slightly greater than threshold value which is -102 dB. And other two models show less value than threshold value. Therefore Hata Okumara model and COST-231 model are preferable for maximum coverage area and helps to reduce the number of handoff as compared to ECC-33 model.

The general area around highway could be suburban because of location. Received signal strength is also a major parameter to measure for highway. Table 5.4 shows RSS for Hata and COST-231 Hata model with experimental values.

Table 4: RSS for Highway

istance	*Hata –Okumara*	*COS -231 Hata*	*Experimental values*
1	-25.572	-25.513	-25
2	-34.496	-34.437	-34
3	-42.962	-42.903	-42
4	-43.35	-43.291	-43
5	-44.399	-44.34	-44
6	-43.083	-43.024	-43
7	-50.487	-50.428	-50

D. Graphical Representation for Highway:

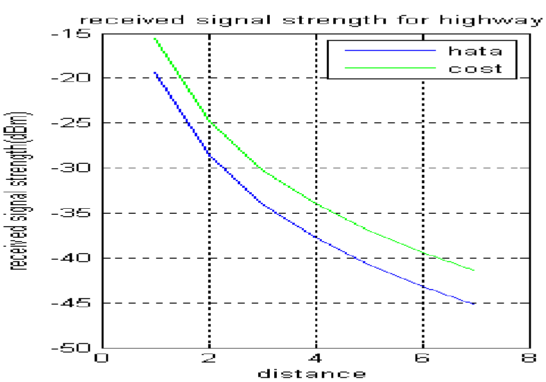

Figure 4: RSS for Highway

Figure 4 Show RSS for highway have been calculated. Received signal strength for COST 231 and Hata- Okumura models are calculated and compared with experimental value as shown in table 5.4. The modified COST 231, Hata-Okumura suburban models for highway are matches with the experimental values.

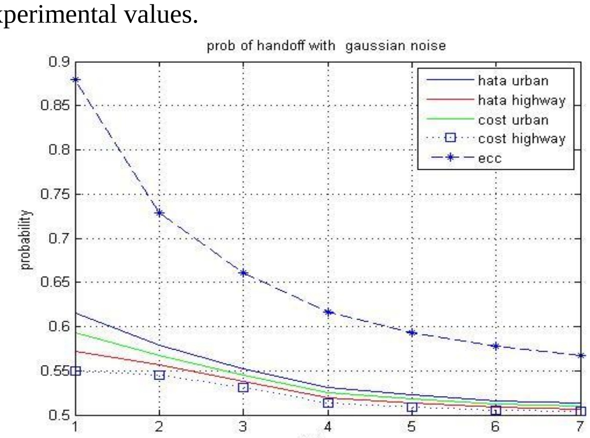

Figure 5 Comparison between probabilities of handoff for different models with Gaussian noise

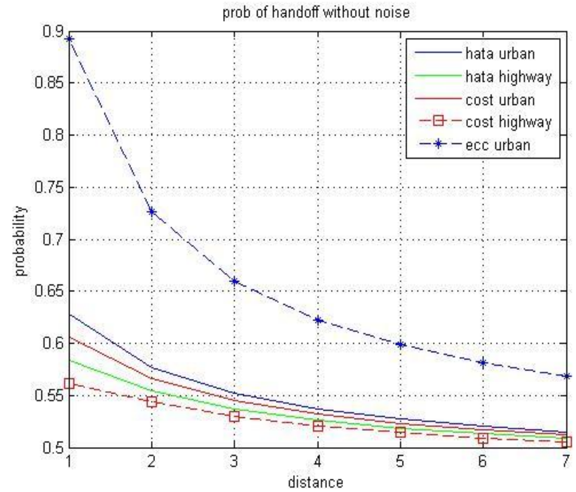

Figure 6 Comparison between probabilities of handoff for different models with Gaussian noise

Result shows the highest probability as compared to Hata-Okumara and COST-231 models for same parameters. Therefore, Hata-Okumara and COST-231 models are the better option as compared to ECC-33 model.

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