Comparative Analysis of CDMA Based Wireless Communication under Radio Propagation Environment

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Abstract

Knowledge of the propagation characteristics of a mobile radio channel is essential to the understanding and design of a cellular system [1]. An appropriate propagation model is required when estimating the link budget or designing a Code Division Multiple Access (CDMA) system [2]. This paper deals with comparative parametric analysis for propagation path loss considering macro cell region using different models and contains comparative study with real measurement obtained from Pacific Bangladesh Telecom Limited (PBTL), a CDMA based wireless network for city Dhaka, Bangladesh.

1. Introduction.

The pioneering of CDMA in cellular radio is due to Qualcomm Inc. Starting in the late 1980s, Qualcomm embarked on a series of experiments that culminated in demonstrating that CDMA had the potential to provide an efficient radio interface for use in cellular networks. By July 1993, Qualcomm proposals were adopted by the Telecommunications Industry Association as Interim Standard 95 (IS-95) [3].

Wireless cellular communication is witnessing a rapid growth in markets, technology, and range of services. A major current thrust for cellular communication systems is improved economics through enhanced coverage early in the life cycle of a network and high spectrum efficiency later in the life cycle. An attractive approach for economical, spectrally efficient, and high quality digital cellular and personal communication services (PCS) is the use of spread spectrum modulation with code division multiple access (CDMA) technology [4].

In a cellular system reusing each frequency at several regions of service area increases the capacity. Also cell splitting, sectoring and micro cell zone approaches are used to expand the capacity of cellular system. Consideration must be taken into account to keep the interference at acceptable limit.

Macro cells correspond to cells where the base station is placed on top of tall buildings or towers and transmits enough power to cover several miles. The physical propagation environment in macro cells is characterized by near-ground irregularities (buildings, terrains, etc). The propagation path length can be up to several miles. Macro cells can be classified into different channel types: urban, suburban, and rural. One of the most significant issues of interference into microwave systems is a line of sight situation [5]. The most common occurrence of this will be from a subscriber unit located in a high-rise building or on a balcony. In this case, path loss figures approaching free space loss may be experienced between the subscriber unit and microwave antennas. It is possible for this situation that the subscriber unit's interfering signal will be stronger than the aggregated powers of many base station transmissions at the microwave receiver. In urban environments, the probability of an elevated subscriber unit is greater. Thus, the impact of the subscriber unit interference sources on the microwave receiver will be more substantial than in residential areas. The performance of wireless systems is affected by a number of propagation phenomena [6]:

1) Path-loss variation versus distance;
2) Random slow shadowing;
3) Random multipath fading;
4) Inter-Symbol Interference (ISI), co-channel interference as well as multiuser interference;
5) Background noise.

2. Propagation path Loss

A measure of interest in radio propagation is the path loss, which is defined as the ratio between the received power *Pr* and the transmitted power *Pt*

$$L_d = \frac{P_r}{P_t}$$

Propagation models are used to determine how many cell sites are required to provide the coverage requirement for the networks. Initial network design typically is engineered for coverage. Later on network growth is based on capacity. The propagation model helps to determine where the cell sites should be located to achieve an optimal position in the network. If the propagation model used is not effective in placing cell sites correctly, the probability of incorrectly deploying a cell sites into the network is high. The propagation model is also used in other system performance aspects including handover optimization, power level adjustments and antenna placements [6]. Predictions of signal strength and propagation coverage area are vital aspects in the design of wireless communication systems. There are several methods for finding the propagation loss as follows:

- Hata-Okumura
- Walfisch-Ikegami
- Bullington
- Elgi
- Epstien-Peterson
- Longley-rice

Propagation models can de described to two distant classes: deterministic and stochastic. The deterministic model is useful when multipath is caused by a large number of paths between the transmitter and receiver. Phenomena like multipath propagation, reflection, diffraction and shadowing have a significant influence on the received power. So the propagation models should consider these phenomena to obtain accurate results. In the present study we have considered following models for Dhaka city, Bangladesh.

2.1 Hata-okumura propagation model

Among the many technical reports that are concerned with propagation prediction methods for mobile radio, Okumura's [7] report is believed to be the most comprehensive one. In his report, many useful curves to predict a median value of the received signal strength are presented based on the data collected in the Tokyo area. The Tokyo urban area was then used as a basic predictor for urban areas. The correction factors for suburban and open areas are determined based on the transmit frequency. Based on Okumura's prediction curves, empirical formulae for the median path loss, *Lp*, between two isotropic antennae were obtained by Hata and are known as the Hata Empirical Formulae for Path Loss [8]. The Hata propagation formulae are used with the link budget calculation to translate a path loss value to a forward link cell radius and a reverse link cell radius.

Hata model illustrate a slightly more complicated path loss model that's a function of parameters such as frequency, frequency range, heights of transmitter and receiver, and building density. The Hata model is based on extensive empirical measurements taken in urban environments. In its decibel form, the generalized model can be written as

$$L_p = -K_1 - K_2 \log(f) + 13.82\log(h_b) + a(h_m) - [44.9 - 6.55 log(h_b)]\log(d) - K_0 \quad \text{..........................(1.1)}$$

Where

f is the carrier frequency (in megahertz),
h_b is the antenna height (in meters) of the base station,
h_m is the mobile antenna height (in meters),
d is the distance (in kilometers) between the base station and the mobile user.

For these parameters, there are only certain ranges in which the model is valid; that is, h_b should only be between 30m to 200m, h_m should be between 1m to 10m, and d should be between 1 km to 20 km. Note that the slope of equation (1.1) is $-[44.9 - 6.55 log(h_b)]$ dB/decade.

The terms $a(h_m)$ and K_o are used to account for whether the propagation takes place in an "urban" or a "dense urban" environment. In particular,

$a(h_m) = [1.1 \log(f) - 0.7]\, h_m - [1.56 \log(f) - 0.8]$ for "urban" or

$a(h_m) = 3.2[\log(11.75 h_m)]^2 - 4.97$ for "dense urban" and

K_0=0 for "urban", or

K_0=3dB for "denseurban"

The term K1 and the factor K 2 are used to account for the frequency ranges. Specifically,

K_1=69.55 for frequency range $150 \le f \le 1000$ MHz, or
K_1=46.3 for frequency range $1500 \le f \ge 2000$ MHz
And
K_2=26.16 for frequency range $150 \le f \le 1000$ MHz, or
K_2=33.9 for frequency range $1500 \le f \ge 2000$ MHz

According to Hata model the path loss is expressed as,

P_L=69.55+26.16log (f)-13.82log h_b-(1.1 log f-0.7)h_m+(1.56 log(f)-0.8)+(44.9-6.55log h_b)logd ....(1.2)

Modification for suburban city

P_{LM}= P_L(Urban)-2[log (f/28)]^2-5.4 ....(1.3)

2.2 Walfisch-Ikegami propagation model

This empirical model is a combination of the models from J. Walfisch and F. Ikegami. It was further developed by the COST 231 project. It is now called Empirical COST-Walfisch-Ikegami Model [9]. The model considers the buildings in the vertical plane between the transmitter and the receiver. The accuracy of this empirical model is quite high because in urban environments especially the propagation over the rooftops (multiple diffractions) is the most dominant part. If the scenario is analyzed individually for each receiver pixel (parameters of building data are determined depending on the actual buildings between Tx and Rx) the accuracy is high - only wave guiding effects due to multiple reflections are not considered. The main parameters of the model are:

- Frequency f (800...2000 MHz)
- Height of the transmitter h_{TX} (4...50 m)
- Height of the receiver h_{RX} (1...3 m)
- Distance d between transmitter and receiver (20...5000 m)

Parameters depending on the buildings in the vertical plane between transmitter and receiver:

- Mean value of building heights h_{ROOF}
- Mean value of widths of streets w
- Mean value of building separation b

The model distinguishes between two situations, the "line of sight" (LOS) and the "none line of sight" (NLOS) situation.

LOS situation:
For the LOS-case the prediction is very easy, as only one equation with two parameters is necessary.
L_0=32.44+20logf+20logd
This LOS equation is similar to the free space loss equation. It was modified after evaluating measurements in European cities. If the distance is d = 20 m, the loss is almost equal to the free space loss at the same distance.
NLOS situation:
The NLOS equations are more complicated. The loss in the NLOS case is the sum of the free space loss L_0, the multiple screen diffraction loss L_{msd} and the rooftop-to-street diffraction loss L_{rts}:

$$L_p = \begin{cases} L_0 + L_{rts} + L_{msd} & when L_{rts} + L_{msd} > 0 \\ L_0 & when L_{rts} + L_{msd} \leq 0 \end{cases}$$

The free space loss:
L_0=32.44+20logf+20logd

..........................(1.4)

The rooftop-to-street diffraction loss term l_{rts} determines the loss that occurs on the wave coupling into the street where the receiver is located. The origin of this loss comes from the Ikegami model, but COST 231 has extended this equation (1.4).
L_{rts}= - 16.9 – 10logw+10logf+20log h_{roof} – h_{RX}+L_{ori}

With

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

The width of the roads w, the rooftop height h_{ROOF}, the receiver height h_{RX} and the road orientation φ are the parameters in this equation. The orientation loss $_{Lori}$ is an empirical correction term obtained from the calibration with measurements.
An approximation for the multi-screen diffraction loss was published by Walfisch and Bartoni. COST 231 modified this approximation to be used also for base station antenna heights below rooftop level. The building heights h_{ROOF} and the building separation b are taken into account additionally:

L_{msd}=L_{bsh}+K_a+$K_d$logd+K_f logf – 9logb

With

$$L_{bsh} = \begin{cases} -18(1 + h_{TX} - h_{roof}) & when h_{TX} > h_{roof} \\ 0 & h_{TX} < h_{roof} \end{cases}$$

$$K_a = \begin{cases} 54 & when \quad h_{TX} > h_{roof} \\ 54 - 0.8(h_{TX} - h_{roof}) & when \quad d \geq 0.5Km and h_{TX} \leq h_{roof} \\ 54 - 0.5(h_{TX} - h_{roof}) & when d/0.5, d < 0.5Km and h_{TX} \leq h_{roof} \end{cases}$$

$$K_d = \begin{cases} 18 & h_{TX} > h_{roof} \\ 18 - 15(h_{TX} - h_{roof})/(h_{roof} - h_{RX}) & h_{TX} < h_{roof} \end{cases}$$

$$K_d = -4 + \begin{cases} 0.7(f/925 - 1) & \text{suburban centers} \\ 1.5(f/925 - 1) & \text{for metropolitan centers} \end{cases}$$

The factors k_d and k_f control the dependence of the multi-screen diffraction loss versus the distance and the radio frequency. The factor k_a indicates the increase of the path loss for base stations below the rooftop.

The final expression of Path loss using Walfisch-Ikegami model for pathloss calculation becomes:

$$L_p=32.4+20\log(d)+20\log(f)-16.9-10\log(w)+10\log(f)+20\log(h_{roof}-h_{rx})-9.646-18(1+(h_{tx}-h_{roof}))+(h_{tx}-h_{roof})+54+18\log(d)-[4+0.7(f/925-1)]\log(f)-9\log(b) \quad \text{.................(1.5)}$$

3. Simulations and results

The parameters for the city Dhaka, Bangladesh for it's CDMA based system has been taken from the Pacific Bangladesh Telecom Ltd (PBTL). It is single cell, three sectors, 35-channel/sector system considering 30% handoff rate. These parameters were used to evaluate the path loss for the signal [10, 11].
The propagation model can be used to calculate the amount of signal received by a mobile. The calculation is performed based on a BTS antenna of ANDREW (Model no CTSD08 – 06516 – 0D).
Let,

BTS transmitter power P_T=500 W= 57 dBm	BTS antenna height =h_b=30 m
MS P_X power P_T=23 dBm	MS antenna height =h_m=1.5 m
T_X antenna gain G_T=17 dBi	MS R_X sensitivity = -106 dBm
MS Antenna Gain G_R= 0	BTS R_X sensitivity = - 121 dBm
Down link transmit frequency= 869 – 894 MHz	D= distance from BTS to MS
Up link transmit frequency =824 – 894 MHz	P_R= Received power
P_L= Path loss	

UP link (MS to BTS), received power is shown in table 1

Table 1: MS to BTS received power

D(km)	P_L(dB)	P_T(dBm)	G_T(dB)	G_R(dB)	$P_R=P_T+G_T+G_R-P_L$(dB)	Minimum allowable received power at BTS in CDMA
1.65	133.06	33	17	0	-93.06	-121 dBm
2	136.006	23	17	0	-96	
2.5	139.42	23	17	0	-96.42	
3.0	142.20	23	17	0	-102.2	

Down link (BTS to MS), received power is shown in table 2

Table 2: BTS to MS received power

D(km)	P_L(dB)	P_T(dBm)	G_T(dB)	G_R(dB)	$P_R=P_T+G_T+G_R-P_L$(dB)	Minimum requirement of CDMA at MS
1.65	133.665	57	17	0	-59.66	-63 to -106 dBm
2	136.6	57	17	0	-62.6	
2.5	140.02	57	17	0	-66.02	
3.0	142.81	57	17	0	-68.81	

Table 3: Comparison of Hata's Model, Walfisch's Model with practical value

Distance (Km)	Path loss (dB)			
	Hata Model	Modified Hata Model	Walfisch's Model	Practical value
1	197.83	169.55	134.20	------
2	207.00	178.73	149.61	132.5
3	213.51	185.23	160.54	136.6
4	218.56	190.28	169.02	140.02
5	222.68	194.41	175.95	142.81

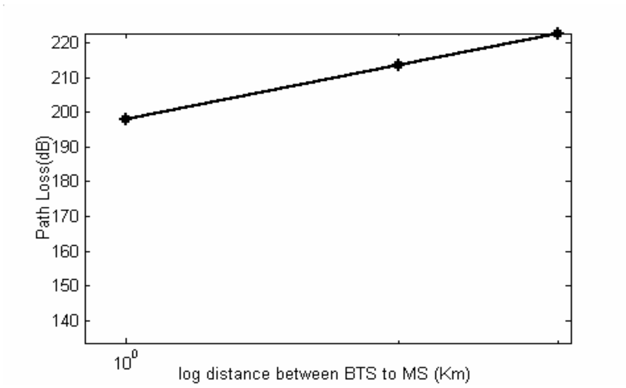

Figure 1: Path loss Vs log of distance for Hata-Okumura model

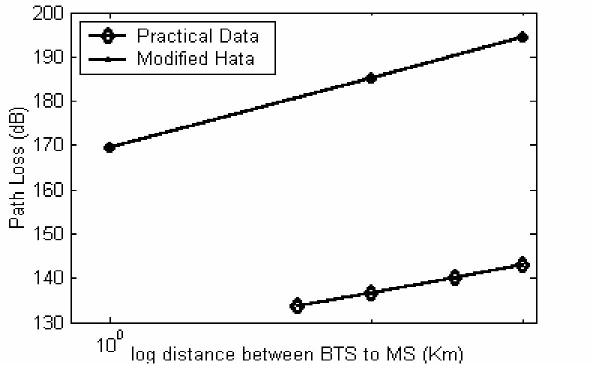

Figure 2: Path loss comparison between Modified Hata model and Practical data

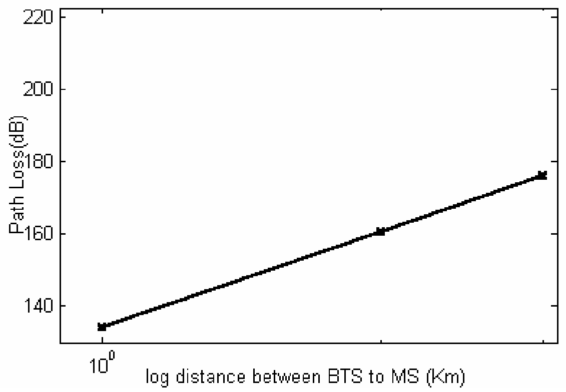

Figure 3: Path loss Vs log of distance for Walfisch-Ikegami model

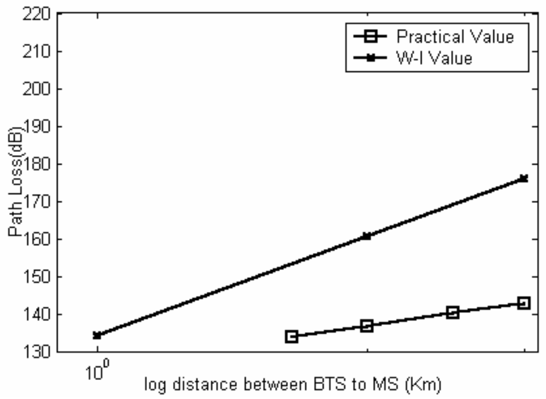

Figure 4: Path loss comparison between Walfisch-Ikegami model and Practical data

Figure 1 shows the variation in path loss as the distance in logarithmic form is varied. The correction factor was also calculated using equation (1.3) for varying path loss of (P_{LM}) for the carrier frequency (824 MHz). The values of the correction factor are as follows:

- P_{LM}=169.55 dB at P_L=197.83 dB
- P_{LM}=178.73 dB at P_L= 207.00 dB
- P_{LM}=185.23 dB at P_L= 213.51 dB
- P_{LM}=190.28 dB at P_L=218.56 dB
- P_{LM}= 194.41dB at P_L=222.68 dB

Modified Hata value vs practical data of path loss have been shown in figure 2. Similarly, path losses were calculated using Walfisch-Ikagami Model for the Dhaka city using parameters as obtained from Pacific Bangladesh Telecom Limited (PBTL).

Table 1 and 2 shows that the path loss were found to be increase as the distance is increased from 1 to 3 Km.

A comparison of path loss using Modified Hata and Walfisch-Ikegami models for their standard value with real measurement is shown in figure 2 and figure 4 respectively. The result for Dhaka city are on the line of result of above models as given in the above comparison table 3. The results are closer to Walfisch's Model as compared to Hata Model's. So in order to maximize the spectral efficiency of a cellular system, it is advisable to use Walfisch's Model with appropriate factor as computed in the present study. The computation time for Walfisch's Model is a bit long as it depends upon several variable however terrain profiles has been neglected.

4. Conclusion

Different path loss sources (statistical, deterministic, real world) may be used by the simulator to aid in defining the CDMA coverage area. Each path loss type has its benefits and disadvantages. While Hata, Power Law and Micro Cell models do not consider terrain variation, they do allow for simulation in areas where digitized terrain or overlay databases do not exist. Deterministic propagation models incorporate terrain variation, antenna data, overlay (clutter) data, etc. in an attempt to model actual installations. This predictive modeling can be performed for a large area. Measured street data incorporates terrain variation and actual installed antennas, but is limited in the area covered. A LogNormal-fading overlay can also be included to account for the effects of shadowing on the system being modeled. The present study has presented the comparative parametric analysis of different path loss models for CDMA based mobile communication. The study has impact on the design of radio frequency planning of CDMA based system.

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